World Sustainability Series

Walter Leal Filho
Fernanda Frankenberger
Patricia Iglecias
Roberta Consentino Kronka Mülfarth
*Editors*

# Towards Green Campus Operations

## Energy, Climate and Sustainable Development Initiatives at Universities

Springer

# World Sustainability Series

**Series editor**

Due to its scope and nature, sustainable development is a matter which is very interdisciplinary, and draws from knowledge and inputs from the social sciences and environmental sciences on the one hand, but also from physical sciences and arts on the other. As such, there is a perceived need to foster integrative approaches, whereby the combination of inputs from various fields may contribute to a better understanding of what sustainability is, and means to people. But despite the need for and the relevance of integrative approaches towards sustainable development, there is a paucity of literature which address matters related to sustainability in an integrated way.

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Editors

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## Energy, Climate and Sustainable Development Initiatives at Universities

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*Editors*
Walter Leal Filho
FTZ-ALS
HAW Hamburg
Hamburg
Germany

Fernanda Frankenberger
Business School
PUCPR
Curitiba, Paraná
Brazil

and

Universidade Positivo
Curitiba, Paraná
Brazil

Patricia Iglecias
USP
São Paulo
Brazil

Roberta Consentino Kronka Mülfarth
USP
São Paulo
Brazil

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# Preface

It is widely known that matters related to sustainable development, albeit global in nature, are best handled at the local level. This line of thinking is particularly true to the higher education context, where the design and implementation of sustainability initiatives on campuses can demonstrate how a given university translates the principles of sustainable development into practice, at the institutional level.

Yet, despite the perceived need to discuss approaches and methods to make university campuses more sustainable, there is a paucity of specific events where a dialogue among sustainability academics and practitioners concerned with (a) research, projects (b) teaching and (c) planning and infrastructure leading to campus greening takes place, so as to allow a transdisciplinary and cross-sectoral exchange of ideas and experiences on the issues, matters and problems at hand. It is against this background that the book "**Towards Green Campus Operations: Energy, Climate and Sustainable Development Initiatives at Universities**" has been prepared.

It is one of the outcomes of the **"First Symposium on Sustainability in University Campuses" (SSUC-2017)** organised by the University of São Paulo in Brazil, Manchester Metropolitan University in UK, the Research and Transfer Centre "Applications of Life Sciences" of the Hamburg University of Applied Sciences in Germany and the Inter-University Sustainable Development Research Programme (IUSDRP).

This book showcases examples of campus-based research and teaching projects, regenerative campus design, low-carbon and zero carbon buildings, waste prevention and resilient transport among others. It also demonstrates the role of campuses as platforms for transformative social learning and research and explores the means via which university campuses can be made more sustainable.

The aims of this publication are as follows:

i. To provide universities all around the world with an opportunity to obtain information on campus greening and sustainable campus development initiatives from around the world;

ii. To document and promote information, ideas and experiences acquired in the execution of research, teaching and projects on campus greening and design, especially successful initiatives and good practice;
iii. To introduce methodological approaches and projects which aim to integrate the topic of sustainable development in campus design and operations.

This book entails contributions from researchers and practitioners in the field of campus greening and sustainable development in the widest sense, from business and economics to arts, administration and environment.

Thanks to its nature, this publication is expected to contribute to the further development of this fast-growing field. We thank the authors for sharing their knowledge and know-how, and the many reviewers who have assisted with the peer review of the papers. We hope this book will further support the development of more sustainable campuses around the world.

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|---|---|
| Hamburg, Germany | Walter Leal Filho |
| Curitiba, Brazil | Fernanda Frankenberger |
| São Paulo, Brazil | Patricia Iglecias |
| São Paulo, Brazil | Roberta Consentino Kronka Mülfarth |
| Spring 2018 | |

# Contents

# Part I
# Concepts and Reflexions on Campus Greening

# Space, Like Time, Is Money: Evaluating Space Utilisation in Saudi Arabian Universities

**Naif Alghamdi**

**Abstract** The demand for tertiary education in the Kingdom of Saudi Arabia has been increasing. As a result, the Kingdom is expanding its higher education sector, through which twenty public universities were established. The establishment of these institutions has led to the building of campuses in order to provide enough space for teaching, learning, training, and research. However, the United Nations long-term projections of the Kingdom forecast that there will be a sharp decline in the youth population. The consequences of these projections pose a problem to long-term strategic planning for space at university campuses. To ensure a match between supply and demand for space, this paper investigates the provision and utilisation of space in Saudi Arabian university campuses. Operating the physical plant sustainably by identifying and eliminating underutilised space not only saves energy and funds, but also improves the student and staff satisfaction by creating a good balance between space needs and space provision. The ultimate aim of this paper is to highlight how space use is measured, what the utilisation rate of existing premises is, and how space can be effectively and efficiently operated. Data was collected through two instruments: the first and predominant instrument was the examination of the space utilisation of five college buildings in five different universities; four buildings were from recently founded universities, while one building was from a well-established university. The second instrument employed was a questionnaire in which one thousand two hundred and ninety users including students, faculty members, and supporting staff were asked about their experience of space use. Findings show that almost all spaces in college buildings, in both new and old institutions, were not utilised as they should be. The paper ends with some recommendations to improve space planning and to optimise space use.

**Keywords** Space utilisation · University campus · Space planning
Facility management · Saudi Arabia

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N. Alghamdi (✉)
Department of Architecture and Building Sciences,
College of Architecture and Planning, King Saud University,
P.O. Box 230670, Riyadh 11321, Saudi Arabia
e-mail: naag@ksu.edu.sa



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## 1 Introduction

The institution's physical structure is 'one of its most valuable assets' (HEFCE 2000, 01). The real estate owned by universities can be described as the most expensive asset (Abdullah et al. 2012). It is widely observed that higher education institution buildings 'are becoming an under-utilised asset' (Shabha 2004, 81). A poor ratio of utilising space dictates the costs of cleaning, maintaining, cooling, heating, and so on (Williams and Worthington 1986). They added that '[a] large number of buildings seem to be designed for the benefit of the passerby, the investor, the builder—anyone but the occupier, the user of space' (Williams and Worthington 1986, 07). This indicates the significance of space planning in general and in university campuses in particular.

Identifying and eliminating vacant spaces can save money and energy. The significance of operating space efficiently is certainly not new. Knapp et al. (2009) believe that what is less widely understood is how difficult it can be to precisely measure space utilisation. They highlight the fact that '[there] is often a significant difference between how much vacancy real estate executives think they have and how much they actually have in their portfolios' (Knapp et al. 2009, 238). The way in which space is utilised will have a major influence on efficiency and cost (Williams and Harris 1988). This shows the importance of understanding how space can be measured and how it can be managed. The UK National Audit Office (NAO 1996, 01) succinctly stated that:

> Space, like time, is money. If your institution is typical, the provision, servicing and maintenance of accommodation is the second largest cost it has to bear. Without efficient space management, the resources tied up in your institution's estate are not used to best effect. Reducing estates costs by using space more efficiently can release funds for other important activities.

The amount of resources needed to provide and operate space in higher education has drawn attention to both space provision and space utilisation. As a developing country, Saudi Arabia is spending massively in education, health, infrastructure, among others. Special focus is given to its higher education sector, through which new universities have been recently established. A considerable investment in university campuses is intended to meet accommodation demands for ever increasing student population. Space provision has become a necessity in the majority of public universities in Saudi Arabia. Space planning and space management are vitally important in order to achieve a balance between the supply and demand. 'What we need versus what we have determines the mismatch between current supply and current demand, [while] what we might need in the future versus what we have now determine the mismatch between future demand and current supply' (De Jonge et al. 2009, 36). Building new university campuses in the Kingdom is undertaken in phases. Nonetheless, the scale, size, and speed of constructing new college buildings in the country raise concerns about not only the utilisation of the existing stock of premises, but also the feasibility of the newer ones.

There is an urgent need to address the issues of space planning and space management in Saudi Arabia in order for university campuses to be more environmentally, economically, and socially sustainable. Therefore, the purpose of this paper is to explore the provision and utilisation of space in Saudi Arabian university campuses. The ultimate aims of this research are to highlight how space use is measured, show the utilisation rates of existing premises, and underline how space can be operated effectively and efficiently.

Surprisingly, little attention has been paid to space utilisation in the literature. Conducting a space utilisation study was described as 'difficult due to the lack of research in this area' (Abdullah et al. 2012, 932). The central reason for this difficulty is that utilisation surveys are expensive. They require considerable resources, given the number of staff involved, the number of rooms surveyed, and the length of observation time (NAO 1996). Another reason is that 'some have argued that the amount of space per student or per member of staff is a more useful space management performance indicator than space utilisation rates' (SMG 2006, 06). Having said that, there has been no single study that explores space utilisation in Saudi Arabian campuses. As a result, this research makes a major scientific contribution to research on space utilisation by providing data on how space is being utilised and hence helping to inform policy- and decision-makers about the type and amount of space required.

This research paper has some limitations. Although Saudi Arabia has 28 public universities, this research project selected only five university campuses as case studies. This choice was purely based on the availability of information and also permission to access these premises. The research is unable to include all college buildings in the five selected university campuses. Instead, only five buildings were chosen. Yet, in every college building, not all rooms were included in the survey. Only 30 rooms were surveyed in each building. These rooms, according to the scheduled activities and the planned group sizes, were the busiest rooms in the building. Therefore, the result of this research cannot be used for generalisation. However, what matters is that this research provides in-depth analysis to better understand the issues of space utilisation and planning in Saudi Arabian campuses. Flyvbjerg (2006, 227) '[a] purely descriptive, phenomenological case study without any attempt to generalise can certainly be of value in this process and has often helped cut a path toward scientific innovation.' Another limitation is that it is beyond the scope of this study to examine all types of space in college buildings. The main focus was on the teaching rooms, which include classrooms, science laboratories, studios, and computer rooms, given that most higher education institutions collect data mainly for teaching space (SMG 2006, 07). Rooms that are excluded from the survey include technology laboratories, libraries, offices, meeting rooms, exhibition areas, conference rooms, theatres/auditoriums, staff rooms, and leisure rooms.

The overall structure of this paper takes the form of six sections. The first part, the introduction, begins by underlining the importance of space utilisation study, presenting background information about the use of space and its implications. It also emphasises the societal and scientific problems of the research. Section two gives a brief overview of the higher education system in Saudi Arabia, some recent developments of university campuses, and the projection of youth population in the Kingdom. Section three analyses space utilisation literature through which definitions and measurements are presented. Section four reports the research methodology in which data collection techniques are explained. Section five comprises of discussion of the results of the survey. The last section presents the findings of the research and some recommendations.

## 2 Higher Education in Saudi Arabia

### *2.1 Higher Education System in Saudi Arabia*

The Kingdom of Saudi Arabia has adopted a long-term strategic plan for its Higher Education (Ministry of Education 2011). The strategic plan, the so-called 'The Horizon', aims to build a knowledge society by investing in human resources through both general education and higher education. Additionally, it aims to be a major driver for transforming the Saudi Arabian economy from dependency on oil revenues to diverse resources and manufacturing. The plan's three strategic dimensions are quality, expansion, and diversity. It is believed that through these dimensions, higher education can advance the country efforts in achieving a 'knowledge society'. The plan identifies eight main areas to focus on, one of which is the infrastructure. The physical settings, such as buildings and other facilities, include both the planning for the transformation of existing university campuses as well as the construction of new campuses in both public and private higher education institutions.

To implement the abovementioned strategic plan, the government of Saudi Arabia is currently investing heavily in the education sector with a special focus on the higher education sector. In 2016, almost a quarter of the national budget was spent on education and training sector.

Furthermore, when comparing higher education in Saudi Arabia with other nations, the Kingdom's system is relatively young. Only four universities are over 50 years old. For almost four decades (1960–2000), the Kingdom was known to have just eight universities, established between 1957 and 1998. Today, however, it has 28 public universities, in which the majority of universities were established between 2003 and 2014. The recently founded universities were in fact satellite or branch campuses of those eight well-established Saudi universities, which in recent years became independent universities. This in turn means that 70% of public universities have been established in the last decade. These 28 public universities are funded directly by the Saudi Ministry of Education. These public universities tend to be comprehensive; providing a wide range of disciplines. These universities serve 1,323,692 students (Ministry of Education 2015). Furthermore, there are other higher education institutions that are managed and funded by other ministries and government agencies. These institutions focus on some technical, industrial, medical, and administrative aspects, offering higher education to 125,279 students in the country.

Moreover, private higher education in the Kingdom is expanding rapidly. Currently, the country has 11 private universities and 18 private colleges, covering a whole range of areas including medical, administrative, scientific, and technological subjects. There are over 78,798 students in private universities and colleges in Saudi Arabia (Ministry of Education 2015).

According to the Ministry's Statistic Centre, there were in total 1,527,769 students, 76,985 faculty members, and 77,130 administrative and technical staff in higher education institutions, both public and private (Ministry of Education 2015).

Other characteristics of the higher education system in the Kingdom are: centralised system of control, gender segregation, funded by the state, free for all citizens at all levels, so citizens do not pay to study, instead they are paid (Smith and Aboummoh 2013).

## *2.2 University Campuses in Saudi Arabia: A General Overview*

With this in mind, the boom has led to the construction of 20 new campuses in different parts of the kingdom. Phase one—which includes constructing community colleges, science colleges, medical colleges, engineering colleges, and some housing units for both students and academic staff—is expected to be completed by 2017. These campuses are located in cities that have had no prior history of hosting such institutions. Thus, their impact can be clearly ascertained, to the extent that it is safe to conclude that their construction has added value to these cities and even to the wider province. The new universities cost more than €16 billion in total. The capacity of new campuses ranges between 10,000 and 90,000 students each. According to the Saudi Ministry of Education (2015), the enrolled students in 2015 were 1,323,692 students; 1,252,634 Saudis (94%) and only 71,058 non-Saudis (6%). Around 350,000 new students (freshmen) are expected to be enrolled in public universities each year. The total capacity of the 20 new campuses will be more than 800,000 students, increasing accessibility of higher education learning to a total of almost two million students once these new campuses are fully operational. The total area of campus land is more than 112 million square meters (11 thousand hectares). This massive city-like area allows for flexibility and future expansions. It has to be said that the majority of the 20 new universities have male campus and female campus within the university campus boundaries. These campuses also include medical cities, research cities, sport cities, housing for students and staff, investment areas (endowments), future expansion zones, and other service areas. Such rapid expansion has the propensity to hinder a more sustainable future.

## 2.3 Saudi Arabia's Youth Population

Figure 1 shows that the projections of the youth population in Saudi Arabia aged between 15 and 24. The data is based on the United Nations (2015) projections of the Saudi youth population. It should be highlighted that the important segment for this study is the group aged between 19 and 24, where youth are expected to be at the university having completed their high school. The graph displays that in the short-term, there will be an increase of the youth population. It is also projected that this particular segment of the Saudi society will continue to increase and reach its peak in 2035. In the long-term, however, a sharp continuous declining of the youth population can be clearly noticed. This raises a concern about the long-term planning for space management and the feasibility of such large university campuses.

Looking closely at this graph, especially at the statistics of the year 2015, it can be said that of the 4.5 million youth population, 1.5 million were studying in higher education institutions in Saudi Arabia. This means that around one-third of the youth population was enrolled in the Kingdom's colleges and universities. Moving forward, it can be seen that there will be a sharp increase until the year 2035 with the peak reaching about 5.7 million. If one-third attends universities, then the expected number would be around 1.9 million students in the years 2030–2035. This should not automatically mean an increase in the space provision at university campuses. That is because there will be a huge drop in the youth population from its peak of 5.7 million to 5 and then 4 million in 2040 and 2045, respectively. The projection indicates that the youth population might remain flat at around 4 million, which means about 1.3 million students in higher education system if the admission's level stays as it is now. This data should be taken into account when planning for physical space in university campuses. In order to avoid over-provision of space, there is a need to audit space at the national level, given that the latter does not exist yet in the Kingdom of Saudi Arabia. The drop in the number of students is a major issue facing many countries around the world, including Japan (TJTN 2016), Russia (UWN 2015), and the United States of America (IHED 2015). The only reservation about the United Nations (2015) projections for the Saudi youth

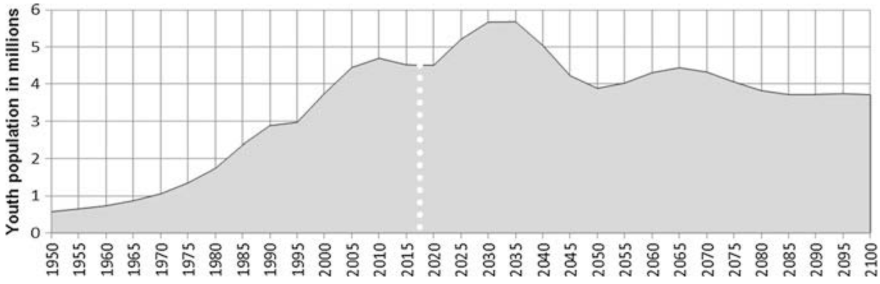



**Fig. 1** Saudi Arabia's youth population in millions

population is that it is merely a prediction. With this in mind, planners should make scenarios in which youth population might be far less or maybe far more than projected and build upon these scenarios by taking into consideration other alternatives.

## 3 Space Utilisation: An Analytical Review

This section aims to systematically review the concept of space utilisation by providing some key definitions as well as outlining some theories and practice in order to understand the idea behind space utilisation.

### *3.1 Key Definitions*

In one of its early reports, Space Management Group in the United Kingdom (SMG 2006, 03) has concisely defined space utilisation key terms as:

- Space utilisation is 'a measure of whether and how space is being used'.
- Frequency rate 'measures the proportion of time that space is used compared to its availability'.
- Occupancy rate 'measures how full the space is compared to its capacity'.
- Space utilisation rate is 'a function of a frequency rate and an occupancy rate'.

### *3.2 The Importance of Space Utilisation Studies*

The SMG (2006, 11) emphasises that the survey of UK Higher Education Space Management Project 'found that utilisation rates were the most frequently cited indicator' for measuring the performance of managing space.

Additionally, there are a number of benefits results from conducting space utilisation studies. Russell and Doi (1957, 02) pointed out that there are two compelling reasons why universities should make space utilisation studies:

- Knowledge of the degree and kind of use made of the physical plant is a condition of good management. The physical plant of a typical college or university represents a large investment of financial resources. It is costly to build, costly to maintain in good repair, and costly to heat, light, clean, and attend to. Thus, any addition to the physical plant should be made only after careful study.
- A second compelling reason for plant utilisation studies is the prospect of large enrolment increases, dramatized by the now familiar phrase "the impending tidal

wave of students." The plant facilities hosting greater student numbers will have to provide more efficient utilisation of space.

The strategic role of space utilisation studies was highlighted by the SMG (2006, 03) indicating that these studies assist universities to 'assess what size of estate is affordable' by providing 'information on how space is being used and help to inform decisions about the type and scale of facilities needed.' Such information can be directly used to reduce the energy consumption of building systems such as lighting, HVAC, IT, and other plugged-in devices including computers, printers, desk lamps, coffee makers…etc. (Garg and Bansal 2000). For example, good occupancy detection and control for lighting systems and for HVAC result in energy savings of 50% (Harle and Hopper 2008) and 20% (Erickson and Cerpa 2010), respectively.

The technical role of such studies was summarised by the National Audit Office in the United Kingdom (NAO 1996, 01) as:

- Measure how intensively accommodation is being used, both in terms of levels of occupancy and frequency of use.
- Reveal whether scheduled activities are actually taking place.
- Track changes in demand over a period of years.
- Identify surplus and shortfalls and areas of poorperformance, which could be remodelled or disposed of.
- Provide data for reviewing space management policies.

### 3.3 Historical Development of Space Utilisation Studies

Historically, the first work on space utilisation in higher education institutions was initiated in the United States by the University of Iowa in 1916 (Sharma 1991). In 1957, Russell and Doi have published a comprehensive document titled 'Manual for studies of space utilization in colleges and universities', which was seen by many as the first extensive research on how space in universities can be measured (Tjomsland 1959).

Kenny (1977) believes that space utilisation studies began to gain momentum in the United Kingdom in the late 1960s, when higher education institutions came under huge pressure to take in more students. The National Audit Office (NAO) was established in 1996 to manage the space provision and utilisation in British colleges and universities.

In Australia, Sharma (1982) is believed to be the first to undertake space utilisation survey in the Australian higher education institutions. Since 1978, the then Tertiary Education Commission began a yearly gathering of space utilisation data from the Australian Colleges (Sharma 1991). Another early attempt to advance space utilisation studies in Australia was carried out by Lagunzad (1990) in which it was indicated that a great effort is needed to institutionalise such studies in higher education institutions.

Scanning the literature of space utilisation shows that there are a number of publications coming from Malaysia. Authors such as Abdullah et al. (2012), Kasim et al. (2012), and Abdullah et al. (2012), have all provided some insightful practice and performance of space utilisation in Malaysia.

### 3.4 The Challenges in Optimising Space Utilisation

There are a number of factors influencing the optimal use of space. The SMG (2006, 13) sums them up in eight factors:

- Poor condition and functional suitability.
- Poor environmental quality.
- Split sites.
- Specialist spaces and equipment that have a limited range of uses.
- Accessibility and health and safety restrictions on space.
- Availability of audio-visual equipment and the layout of rooms.
- The difference between predicted and surveyed rates of utilisation.
- Other factors include teaching and learning trends, whether or not detailed information is available on what space is needed, and the nature of the estate in terms of its fitness for purpose and versatility.

### 3.5 How to Measure Space Utilisation Level

There are a number of aspects to bear in mind when conducting data collection for space utilisation rate. There are two methods of calculating the utilisation rate:

- First is by calculating the planned utilisation which is based on the assumption of how the space will be used. For example, using data from the timetables in existing buildings or the projected level of use in new buildings.
- Second is by calculating how the space is actually being used. For instance, using data based on observation (manually counting).

Some colleges and universities collect data using both methods: planned and actual use of space. There is, however, a difference between predicted and surveyed rates. The predicted or timetabled rates tend to be higher than the actual use of space with about 15% (SMG 2006, 10).

Furthermore, some institutions have used other ways to collect space utilisation data. Swipe card and webcams are cases in point. Yet, these tools have pros and cons. The main advantage is that it reduces the time required to collect data.

However, the swipe card does not provide reliable data about how many people are actually using the space. In both cases (Swipe card and webcams) 'data obtained would still need to be entered into the analysis software' (SMG 2006, 23). More advanced technologies are being used to monitor the utilisation of space in university campuses worldwide. Examples of such as technologies include Bluetooth, Wi-Fi, Passive Infrared and Ultrasonic Motion Sensors, and PC Login (Von Neida et al. 2001; Dodier et al. 2006; Melfi et al. 2011; Christensen et al. 2014). Valks et al. (2016) have investigated using such technologies in 14 Dutch public universities and concluded that using Wi-Fi to measure utilisation in university campuses is the most suitable tool, given that it uses already existing IT infrastructure and hence cheaper compared with other technologies. It is also flexible and hence easy to change, and it is applicable for many users on campus.

Higher education institutions focus more on the teaching rooms, given that 'the general purpose teaching space is the most common type of space to be surveyed' (SMG 2006, 07). Other rooms that are less surveyed include science and technology laboratories, libraries, offices for both academic and staff, meeting rooms, exhibition areas, conference rooms, theatres/auditoriums, staff rooms, and leisure rooms.

According to the SMG (2006, 07), comparing results of utilisation between institutions is difficult. This is because there are many issues to take into account including 'the types of rooms surveyed, the hours covered, the basis on which capacities are calculated, and whether reports are provided on the basis of a planned use of space or observations of how space is being used.'

The NAO (1996, 20) indicates that '[the] survey represents a snap shot view of the use of the estate at a particular time. The standard calculation of utilisation is

$$\frac{\%\,\text{frequency} \times \%\,\text{occupancy}}{100} = \text{space utilisation rate}$$

- Frequency is the number of hours a room is in use as a proportion of total availability (the timetabled week).
- Occupancy is the average group size as a proportion of total capacity for the hours the room is in use.

It is important to highlight that some higher education institutions do not collect data on occupancy rates; instead they focus on merely the frequency levels. The SMG (2006, 08) shows that this is 'often on the on the grounds that they have much greater control over the frequency with which rooms are used, whereas occupancy rates are highly dependent on whether students and other users choose to attend.'

Timing is crucial when collecting data for the utilisation study. The utilisation rate will be greatly influenced by the chosen timeslots. 'Results will differ if average utilisation levels are calculated over a 9.00 am–5.00 pm period or between 8.00 am to 8.00 pm' (NAO 1996, 21). Undertaking the survey over a period of time may result in a better overview of the utilisation level. 'One Welsh institution carried out a survey over five weeks taking a different day each week in order to minimise the possibility that staff would argue that the selected week was not typical' (NAO 1996, 21). The main objective should be to:

- assess the space at 'a time of peak load',
- assess 'four to six weeks' after the semester starts, and
- 'avoid seasonal factors such as reading weeks, examination weeks, or field trips' (NAO 1996, 21).

### *3.6 The Targeted Rate of Space Utilisation*

The Polytechnics and Colleges Funding Council (PCFC) in the UK suggests a figure of 64% (80% frequency and 80% occupancy), which many believed to be significantly higher than any figure in practice (NAO 1996, 21). They added that '[even] 50% (70% frequency and 70% occupancy) may prove very challenging. The Higher Education Funding Council for England (HEFCE 2000, 37) grades space utilisation levels 'as follows:

- Good is equal to or greater than 35% utilisation rate.
- Fair is 25–35% utilisation rate.
- Poor is equal to or less than 25% utilisation rate'.

Regardless, all higher education institutions 'must set their own target rate in relation to their individual problems of bad fit. The target rate should improve each year' (NAO 1996, 21).

## 4 Research Methodology

This section explains the approach used in this research through highlighting (i) how the data was collected, (ii) what type of space surveyed, (iii) how the space rate is calculated, and (iv) when the survey was carried out.

Two techniques were employed in order to collect data to explore the utilisation level in public university campuses in Saudi Arabia. The primary technique was the examination of the space usage of five college buildings in five different universities. The second instrument employed was a questionnaire in which almost 2000 users including students, faculty members, and supporting staff were asked about their experience of space use in their college buildings.

Given that the majority of higher education institutions tend to focus on the general purpose teaching space, this research has followed suit. Therefore, this paper concentrates on general teaching rooms which include mainly classrooms, few teaching laboratories, studios, and computer rooms. Other rooms such as specialist teaching space (theatres/auditoriums), research areas (research laboratories), offices (for both academic and staff), and support space (libraries, meeting rooms, exhibition areas, conference rooms, staff rooms, and leisure rooms) are not included in this study.

As for how space utilisation rate is calculated, this research uses the scheduled activities and the planned group sizes to calculate the predicted utilisation rates. This means that this study uses data from the timetables of the five existing college buildings in order to assume how teaching space is used. Digital copies of the timetables have been requested from the Registration Departments at each college. Microsoft Excel program was used for data entry and analysis.

The research collected its data during the second semester of the academic year 2015–2016 and hence the results of this research represent the utilisation rates of this period. This research uses the standard working hours of 40 per week for its analysis (eight hours a day; 09:00–17:00). However, since universities in Saudi Arabia have different timetables, and hence no ‘typical day’, a comparison between different working hours per day and their impact on the utilisation rates has been carried out to identify the utilisation levels in every case. Note that the working week in Saudi Arabia starts on Sunday and ends on Thursday.

Therefore, the sample in this research consists of five college buildings from five different universities; four buildings were from recently founded universities, while one building was from a well-established university. Table 1 illustrates the five cases and some basic information for each case. The choice of these five cases was purely based on the availability of information and also permission to access these premises. These cases are:

**1**st **Case** College of Languages and Translation at King Saud University (KSU) that founded in 1957, and is in the centre of the country (Note 1).

**2**nd **Case** College of Science at University of Hail (UofH) that founded in 2005, and is in the north of the country (Note 2).

**3**rd **Case** College of Engineering at University of Najran (UofN) that founded in 2006 and is in the south of the country (Note 3).

**4**th **Case** College of Science and Humanities at Prince Sattam bin Abdulaziz University (PSAU) that founded in 2006, and is in the centre of the country (Note 4).

**5**th **Case** Community College at University of Hafr Albatin (UHB) that founded in 2006 and is in the east of the country (Note 5).

* More information about these college buildings can be found in Note 6.

In order to assess the space at ‘a time of peak load’, 30 of the busiest rooms were selected in each college building. These rooms were selected based on their high frequency and occupancy rates. The total number of rooms analysed in this research were 150 rooms.

**Table 1** The research sample

| 1st case | 2nd case | 3rd case | 4th case | 5th case |
|---|---|---|---|---|
|  |  |  |  |  |
| College of Languages and Translation | College of Science | College of Engineering | College of Science and Humanities | Community College |
| King Saud University | University of Hail | University of Najran | Prince Sattam bin Abdulaziz University | University of Hafr Albatin |
| (KSU) | (UofH) | (UofN) | (PSAU) | (UHB) |
| City of Riyadh | City of Hail | City of Najran | City of Alkharj | City of Hafr Albatin |
| Central part of Saudi Arabia | North part of Saudi Arabia | South part of Saudi Arabia | Central part of Saudi Arabia | East part of Saudi Arabia |

# 5 Results and Discussion

This section presents and describes the results of the analysis of exploring space utilisation of five college buildings from different universities in Saudi Arabia. It shows the rates of utilisation, frequency, and occupancy of 150 rooms. It highlights the frequency rates per timeslot, the occupancy rates per timeslot, and the room requirement. Finally, this section gives an overview of space utilisation and user satisfaction (students, academics, and supporting staff) and how flexible are users with working hours.

## *5.1 Frequency, Occupancy, and Utilisation Rates*

Figure 2 displays the frequency, occupancy, and utilisation rates of the five college buildings. The figure shows each college individually, in which there were two colleges with very poor utilisation rates (UofN 7% and UHB 7%), two colleges with fair level of utilisation (KSU 25% and UofH 32%), and one college with good rate of utilisation (PSAU 36%). The poor utilisation rates are caused by very low frequency and occupancy rates. It has to be highlighted though that these rates represent the 30 busiest rooms in each college building. Therefore, this indicates a serious utilisation issue, given that the predicted or timetabled rates tend to be higher than the actual use of space.

This paper uses the standard working hours of 40 per week for its main analysis (eight hours a day; 09:00–17:00). Table 2 shows the frequency, occupancy, and space utilisation rates of all college buildings combined when working hours are between 09:00 and 17:00 (8 h per day–40 h per week). It illustrates that the average rate of utilisation of all college buildings is poor (22%).

However, given that every institution has different timetables (no fixed working hours per day), a comparison between different working hours per day and their impact on the utilisation rates was carried out to identify the utilisation levels in every case. Tables 3 and 4 present the frequency, occupancy, and space utilisation rates of all college buildings combined when working hours are between 08:00 and

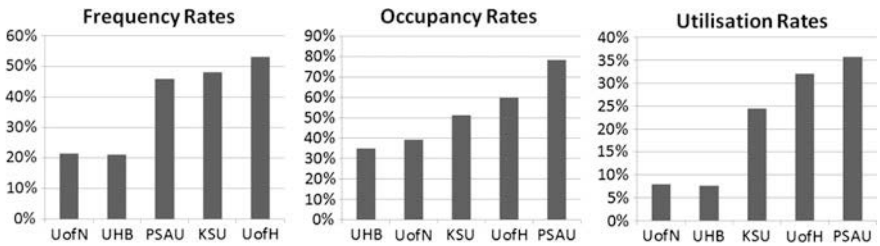



**Fig. 2** Frequency, occupancy, and utilisation rates of the five college buildings

**Table 2** Frequency, occupancy, and space utilisation rates of all college buildings combined when working hours are between 09:00 and 17:00 (8 h per day–40 h per week)

| | Frequency (%) | Occupancy (%) | Utilisation (%) |
|---|---|---|---|
| Average rates of recently founded colleges | 35 | 53 | 21 |
| Average rates of old college | 48 | 51 | 24 |
| Average rates of all | 38 | 53 | 22 |

**Table 3** Frequency, occupancy, and space utilisation rates of all college buildings combined when working hours are between 08:00 and 17:00 (9 h per day–45 h per week)

| | Frequency (%) | Occupancy (%) | Utilisation (%) |
|---|---|---|---|
| Average rates of recently founded colleges | 37 | 53 | 22 |
| Average rates of old college | 50 | 53 | 27 |
| Average rates of all | 39 | 53 | 23 |

**Table 4** Frequency, occupancy, and space utilisation rates of all college buildings combined when working hours are between 08:00 and 20:00 (12 h per day–60 h per week)

| | Frequency (%) | Occupancy (%) | Utilisation (%) |
|---|---|---|---|
| Average rates of recently founded colleges | 26 | 52 | 15 |
| Average rates of old college | 35 | 53 | 19 |
| Average rates of all | 28 | 52 | 16 |

17:00 (9 h per day–45 h per week) and when working hours are between 08:00 and 20:00 (12 h per day–60 h per week). In all seniors, the utilisation rates are very low, except in the old college where working hours are 45 per week. These poor utilisation rates are alarmingly low, since the analysed rooms were supposed to be the busiest in each building.

Another serious issue is the space area per an equivalent full-time student unit (EFTSU). The analysis of space per user in the five college buildings (see Notes 1, 2, 3, 4, and 5) shows that the average area per student is 1.8 $m^2$ per student. This excludes specialised teaching rooms such as science laboratories, computer rooms, and studios, which all have different size requirements. The standard for general teaching room suggests 1.0 $m^2$ per workplace (UGC 1987). Therefore, space planning has to be addressed, given that the average area of teaching space in Saudi Arabia tends to be higher than the norm.

The space planning issue, abovementioned, has led to a mismatch between the planned capacity and the scheduled capacity. The planned capacity is what the designers/architects have suggested for each space, whereas the scheduled capacity is what the college registrars have actually scheduled in each space (the scheduled group size). The average difference between the available capacity and the scheduled capacity is 5.2 people. This demonstrates another issue concerning the facility management particularly in the teaching space allocation in college buildings. It has to be highlighted that there is a difference between the scheduled capacity and the actual attendees (or the real-time use). The latter provides very accurate occupancy rate and hence utilisation rate.

Further facility management issue discovered is the allocation of teaching rooms per department per subject. The analysis shows that only 44% of the total 150 rooms surveyed were commonly used by different departments for different subjects. To increase the utilisation rate of teaching space and counteract the 'territorial culture', more rooms should be accessible to all departments. This can be achieved when classrooms are managed centrally in order to maximise the frequency in using the space.

## 5.2 The Frequency Rate Per Timeslot

The frequency rate per timeslot indicates the number of times the room is being used during the day. Table 5 shows a heat map that represents how the frequency rates of 150 rooms surveyed differ during the week. The highest frequency rates were coloured with dark green, whereas the lowest frequency rates were coloured with dark red. The last column shows the average frequency rate per day. It indicates that the busiest days in all college buildings were Sundays. Tuesdays were not too far behind Sundays. By contrast, Thursdays had the lowest average frequency rate.

The table also shows that in general, morning timeslots were busier than the afternoon timeslots. The timeslot 10:00–11:00 had the highest frequency rates in almost all days. However, the timeslot 12:00–13:00 was the least, given that in most universities this is the lunch hour. At large, the last timeslots of the days were less busy.

Figure 3 is another representation of how the frequency rate changes during the weeks of the semester. It represents the fluctuation of the frequency rates identifying the peaks and troughs patterns. This shows how the use of teaching rooms

**Table 5** A heat map representing the frequency rates of 150 rooms surveyed

| | 09:00 to 10:00 | 10:00 to 11:00 | 11:00 to 12:00 | 12:00 to 13:00 | 13:00 to 14:00 | 14:00 to 15:00 | 15:00 to 16:00 | 16:00 to 17:00 | | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sunday** | 55% | 61% | 64% | 16% | 41% | 35% | 31% | 24% | | 41% |
| **Monday** | 51% | 61% | 53% | 16% | 37% | 38% | 31% | 23% | | 39% |
| **Tuesday** | 55% | 63% | 53% | 16% | 42% | 38% | 31% | 22% | | 40% |
| **Wednesday** | 47% | 55% | 47% | 19% | 41% | 40% | 29% | 23% | | 38% |
| **Thursday** | 52% | 49% | 40% | 12% | 39% | 30% | 21% | 15% | | 32% |

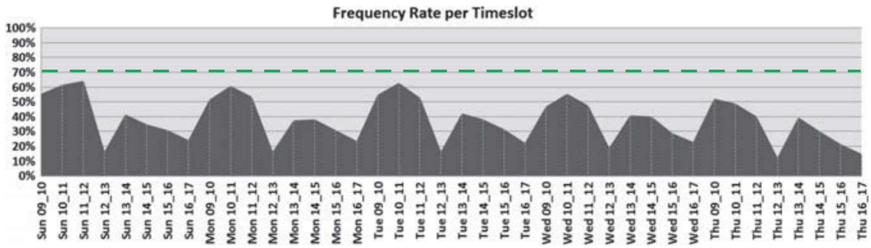



**Fig. 3** The frequency rate per timeslot

changes throughout the semester. The ideal situation would be a complete flat line (represented in dark green line), which means that almost every room in the college building is being used for the same amount of time during the semester. These peaks and troughs result in having to supply more rooms than what is actually needed.

### *5.3 The Occupancy Rate Per Timeslot*

The occupancy rate per timeslot indicates the size of the group to be occupying a room during the day timeslots. Table 6 displays a heat map that shows how the occupancy rates of rooms surveyed vary during the week. The highest occupancy rates were coloured with dark green, while the lowest occupancy rates were coloured with dark red. The last column demonstrates the average occupancy rate per day. It shows that Sundays were the busiest days in all five college buildings, followed by Wednesdays, 49 and 45% respectively. In contrast, Tuesdays had the lowest average occupancy rate with 45%.

Table 6 also presents that generally, the size of the student groups in the morning timeslots were bigger than in the afternoon timeslots. The timeslot 09:00–10:00 had the highest occupancy rates in almost all days. Nonetheless, the timeslot 16:00–17:00 had the lowest occupancy rates.

**Table 6** A heat map representing the occupancy rates of 150 rooms surveyed

| | 09:00 to 10:00 | 10:00 to 11:00 | 11:00 to 12:00 | 12:00 to 13:00 | 13:00 to 14:00 | 14:00 to 15:00 | 15:00 to 16:00 | 16:00 to 17:00 | | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sunday** | 55% | 51% | 51% | 59% | 48% | 44% | 45% | 37% | | 49% |
| **Monday** | 57% | 52% | 54% | 43% | 46% | 43% | 41% | 34% | | 46% |
| **Tuesday** | 52% | 50% | 52% | 53% | 45% | 45% | 37% | 28% | | 45% |
| **Wednesday** | 58% | 55% | 52% | 49% | 44% | 39% | 43% | 37% | | 47% |
| **Thursday** | 53% | 55% | 55% | 56% | 44% | 40% | 35% | 33% | | 46% |

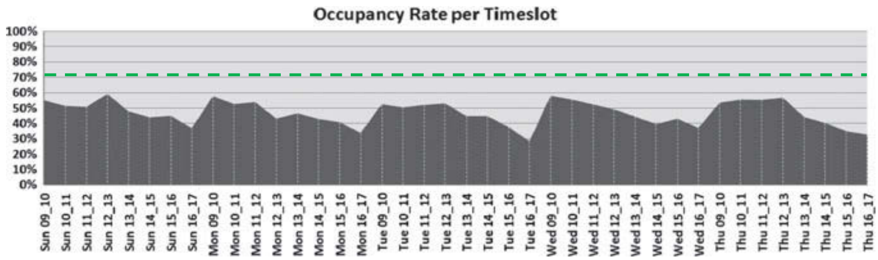



**Fig. 4** The occupancy rate per timeslot

Figure 4 is another demonstration of how the occupancy rate changes throughout the weeks of the semester. It shows the flux of the occupancy rates which identifies the highs and lows patterns. This shows how the size of the group changes during the course of the semester. The ideal situation would be a complete flat line (represented in dark green line), where the average rate of occupancy is around 70% or above.

## 5.4 *Room Requirement*

This represents how many rooms of certain capacities that the institution actually needs, presuming ideal situations with optimal space utilisation rate. Table 7 illustrates the capacity band (number of students), room requirement (how many rooms are used by each band), currently available (how many rooms are actually available), and difference (how the room requirement compares to what is currently

**Table 7** Room requirement

| No. | Capacity band | Room requirement | Currently available | Difference |
|---|---|---|---|---|
| 01 | 01–10 | 19.075 | 0 | −19.075 |
| 02 | 11–20 | 15.45 | 14 | −1.45 |
| 03 | 21–30 | 10.175 | 34 | 23.825 |
| 04 | 31–40 | 9.25 | 62 | 52.75 |
| 05 | 41–50 | 2.45 | 21 | 18.55 |
| 06 | 51–60 | 0.325 | 4 | 3.675 |
| 07 | 61–70 | 0.1 | 11 | 10.9 |
| 08 | 71–80 | 0 | 0 | 0 |
| 09 | 81–90 | 0 | 4 | 4 |
| 10 | 91–100 | 0 | 0 | 0 |
| 11 | >100 | 0 | 0 | 0 |

available for each group size). The ‘difference’ column, in other words, explains the difference between the supply and the current need.

It can be clearly noticed that there is a large oversupply of middle and big sized rooms. For example, in the surveyed five college buildings, there are 11 rooms with capacities of 60–70 students which have very few reservations. The same is true for rooms with capacities of 20–30, 30–40, 40–50, and 50–60 students. In contrast, small sized rooms were noticeably undersupplied. The table also shows that there was no room available that suited a small capacity of one to ten students. This indicates that most of the rooms in these colleges were either middle sized or large. The absence of small sized rooms means that small groups of students have no option but to use middle sized rooms or large rooms. Consequently, space is wasted and vacancy rate increases due to poor planning. This leads to a huge energy bill to pay in order to operate and maintain these middle sized and large underutilised spaces.

### 5.5 Space Utilisation and User Satisfaction

Finding the balance between satisfaction and high utilisation rate in college buildings is challenging. SMG (2006, 06) stated that ‘[high] rates of utilisation do not necessarily mean that space is being managed effectively. Staff and students may complain about lack of space, overcrowding, and the adverse effect on academic activity, recruitment, and retention.’ Therefore, given the importance of user satisfaction in college buildings, a questionnaire was distributed with the purpose of exploring:

(a) The level of feeling experienced about the utilisation in these five college buildings, and
(b) The extent to which users are flexible with the working hours particularly in the evening.

In the questionnaire, there were three targeted groups: students, academics, and supporting staff. Table 8 presents the number and percentage of participants per university. The total number of respondents was 1290; consisting of 1038 students (80%), 148 academics (12%), and 104 supporting staff (8%). Large contributions came from KSU, UofH, and KSAU, whereas fewer respondents came from UofN and HAU.

A core issue raised in the questionnaire was the size of rooms in their college buildings compared to the number of students. Figure 5 reveals that over a quarter of participants claimed that their classrooms are either very congested (9%) or crowded (19%).

On the other hand, 15% of the 1290 participants indicated that there are plenty of seats available in their teaching rooms, while 24% of them pointed out that their

**Table 8** Number and percentage of participants per university

| No. | Name of the institution (code) | User category | | | Total |
|---|---|---|---|---|---|
| | | Students | Academics | Supporting staff | |
| 01 | King Saud (KSU) | 307 | 17 | 11 | 335 |
| 02 | Hail (UofH) | 272 | 37 | 18 | 327 |
| 03 | Najran (NofU) | 94 | 25 | 26 | 145 |
| 04 | Prince Sattam bin Abdulaziz University (PSAU) | 258 | 36 | 7 | 301 |
| 05 | Hafr Albatin (HAU) | 107 | 33 | 42 | 182 |
| | Total | 1038 (80%) | 148 (12%) | 104 (8%) | 1290 (100%) |

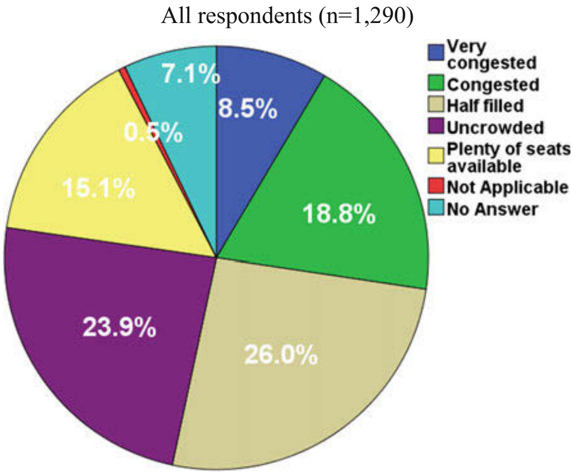



**Fig. 5** Assessing the size of classrooms compared to the number of students

teaching rooms are not crowded. Over a quarter of respondents stated that their teaching rooms are half filled. When combining all these percentages (15, 24, and 26%), the result indicates that 65% of teaching rooms in the five college buildings were half filled or have plenty of seats available.

Another question asked was about the satisfaction of users about the overall size of teaching rooms in their college buildings. Figure 6 exhibits that more than a half of the 1290 participants were pleased with the overall size of teaching rooms in their college buildings, either very satisfied (16%) or satisfied with the size (39%).

Nevertheless, nearly 17% of respondents indicated their dissatisfaction, with 7% of respondents stating that they were very dissatisfied about the size of classrooms.

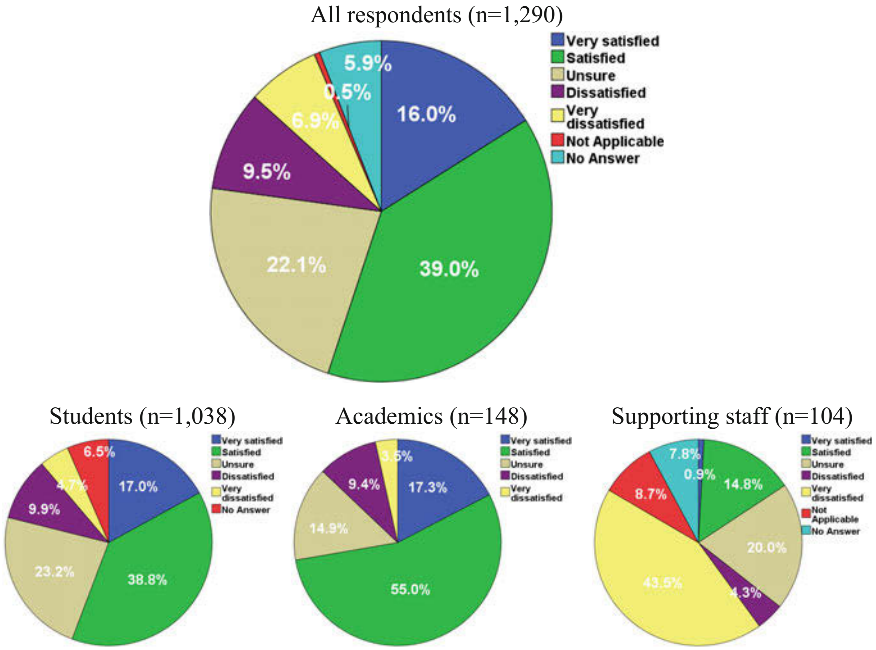



**Fig. 6** Measuring user satisfaction about the overall size of classrooms

The following two questions explored how the users are flexible with the working hours particularly in the evening. Figure 7 shows how many respondents that are prepared to come to the university in the evening period (between 17:00 and 21:00). Overall, only a quarter of participants are prepared to attend lectures in the evening session.

However, when looking at the three groups, it can be seen that they vary in their preference. Over a half of the academics indicated their willingness to work in the evening period. This is advantageous when thinking about optimising the utilisation of college buildings. Around a quarter of students and supporting staff favour the evening classes instead of the morning session.

The following chart, Fig. 8, shows the amount of people who actually prefer to come to the university in the evening session (between 17:00 and 21:00) rather than the daytime working hours (between 09:00 and 17:00). The analysis result shows that only 12% prefer to go to the university in the evening. Even with this small percentage, the utilisation of the building can be optimised. It is noticeable that around a quarter of the 1290 respondents did not answer this question. The 12% is promising, but had the 22% of participants answered this question, the percentage might have increased even further.

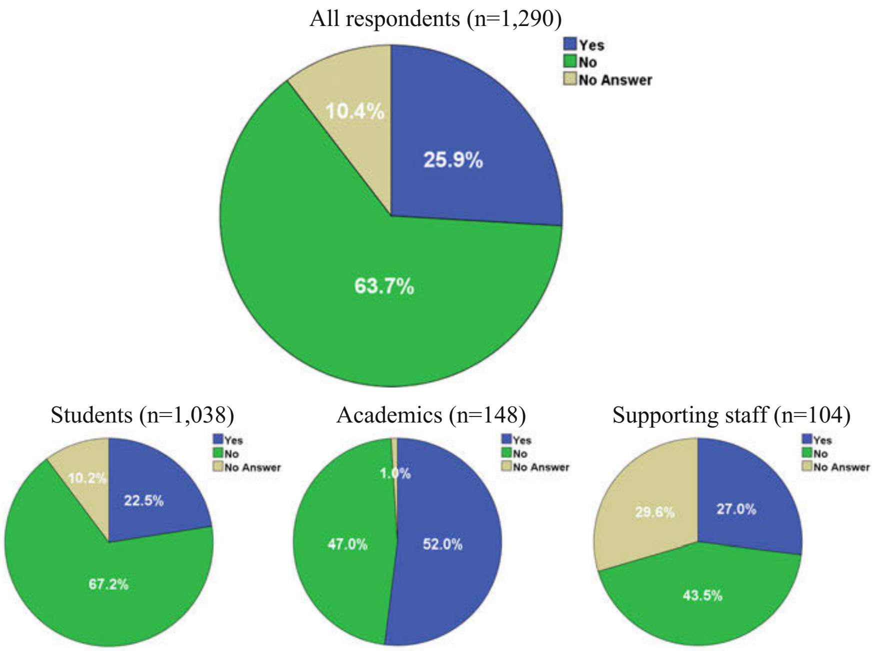



**Fig. 7** Users willingness to come to the university in the evening

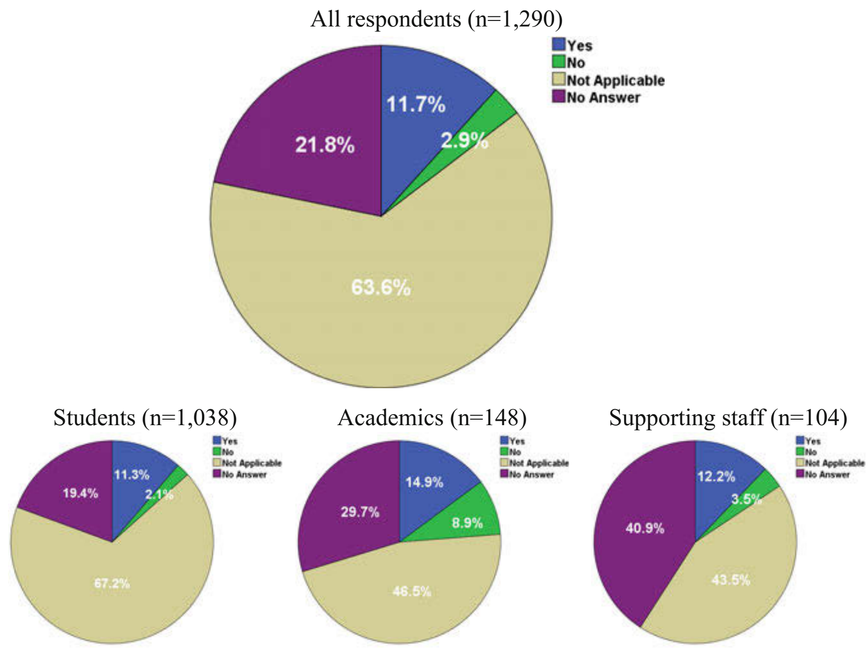



**Fig. 8** Prefer to attend university in the evening

## 6 Conclusion and Recommendations

In an effort for sustainability policies to occupy a more prominent place in university campuses in Saudi Arabia and elsewhere, the aims of the present research were to (i) highlight how space use is measured, (ii) examine what the utilisation rate of existing premises is, and (iii) explore how space can be efficiently operated. This paper has analysed two important issues in Saudi Arabian campuses; space provision and space utilisation in relation to the projections of youth population in the Kingdom.

The first major result to emerge from this study is that it has identified a short-term increase in the Saudi youth population. However, this should not lead to an increase in space provision in university campuses, given that long-term forecasts predict a sharp drop in the Saudi youth population. The investigation has indicated that there is a lack of strategic planning of space in higher education institutions at the national level, which led to massive construction of facilities across the country. Understanding the dynamic of the supply and demand of space in university campuses would result in more sustainable space provision and utilisation. Therefore, in order to avoid over-provision of space in colleges and universities, space management is urgently needed to address this issue. Such management would effectively and efficiently control the supply and demand of space in all public institutions, saving energy and money. To do so, there are two steps to be taken: First, a regulatory body that manages space in campuses has to be established. Second, the proposed ‘space management tool’ (see Note 7) should be used to audit and therefore manage space. The tool highlights important information to be collected in order to develop baseline data to help the decision-making process for space provision and utilisation.

The second major finding was that the existing stock of premises is not utilised as they should be. The average space utilisation rate of college buildings in recently founded universities was 21%, while 24% in older universities. The overall utilisation rate was 22%, which is astonishingly low given that this result was based on (a) analysing the 150 busiest rooms in five college buildings and (b) analysing the planned utilisation (timetable). Had this study measured how space is actually being used (the real-time use), the space utilisation rate would have been even lower, since the difference between the predicted and surveyed rates is 15% (SMG 2006, 10). Furthermore, the low overall utilisation rate was confirmed by the result of the questionnaire in which the 1290 participants indicated that 65% of teaching rooms in the five college buildings were half filled or have plenty of seats available.

Other significant findings to emerge from this study were related to space planning. The research has shown that the average area of general classrooms is almost 2 $m^2$ per student. This excludes specialised teaching rooms such as science laboratories, computer rooms, workshops and studios, which all have different size requirement. The standard for general teaching room suggests 1.0 $m^2$ per workplace (UGC 1987). Therefore, space planning has to be addressed, given that the average area of teaching space in Saudi Arabia tends to be higher than the norm.

This study has also found that there are a number of facility management issues. These issues can be summed up into two points:

- The allocation of teaching rooms per department per subject. The analysis shows that only 44% of the total 150 rooms surveyed were commonly used by many departments for many subjects. To increase the utilisation rate of teaching space, more rooms should be accessible by all departments, despite the challenge of the 'territorial culture'. This can be achieved when classrooms are managed centrally.
- The difference between the supply and the current need. The results have shown that there is a large oversupply of middle and big sized rooms, whereas small sized rooms were noticeably undersupplied. This indicates that most of the rooms in these colleges were either middle sized or big. This result was supported by the findings from the questionnaire in which more than a half of the 1290 participants were pleased with the overall size of teaching rooms in their college buildings, either very satisfied (16%) or satisfied with the size (39%). The absence of small sized rooms means that small groups of students have no option but to use middle sized rooms or big rooms. Consequently, space is wasted and vacancy rate increases due to poor planning that has not offered a variety of space sizes which is actually required. This leads to a huge energy bill to pay in order to operate and maintain these middle sized and big underutilised spaces.

The contribution of this study has been to provide useful information on how space is being used in some Saudi Arabian university campuses which helps decision-makers formulate evidence-based policies for space provision and utilisation. This is important because in general, every single square meter requires planning, designing, constructing, furnishing, operating, maintaining, and renovating (life cycle). The empirical findings in this study offer a clear understanding of how the physical plant of universities is being operated. Such understanding assists in making the most effective use of resources. Otherwise, such resources, which are consumed by underutilised space, can be better channelled elsewhere. Although undertaking space utilisation study needs considerable resources – given the number of staff involved, the number of rooms surveyed, and the length of observation time (NAO 1996)—there is a lot to gain from it. Therefore, it is worth doing, since its strategic role has a significant contribution in managing space at university campuses.

In order to improve the utilisation of general teaching spaces, there are a number of strategies that can be employed. Sharma (1991, 04) recommended the following policies:

- 'Increasing after hour's space usage.
- Annual review of space utilisation.
- Promoting off-campus studies.
- Analysing request for specialist space in terms of the department's utilisation of existing space and rejecting requests where low usages of similar facilities exist.

- Retaining central control of general purpose teaching spaces.
- Spreading classes as evenly as possible throughout the week.
- Consolidating of small classes.
- Encouraging students to use under-utilised teaching spaces for private study during times when the rooms are vacant.
- Encouraging extracurricular community activities on campus.
- Spreading load to evening sessions for part-time students. [According to the questionnaire, a quarter of participants are prepared to attend lectures in the evening (between 17:00 and 21:00). Over one half of the academics indicate their willingness to do so in comparison to around a quarter of students and supporting staff. Additionally, about 12% of participants were not only willing to come to the evening classes, but rather they favour them instead of the morning sessions.]
- Conversion of specialised space which is under-utilised to other space types which are in demand.'

The limitations of current study can be summarised as following:

- Although Saudi Arabia has 28 public universities, this research project selected only five university campuses as case studies. Furthermore, the research is unable to include all college buildings in these five selected university campuses. Instead, only five buildings were chosen. Yet, in every college building, not all rooms were included in the survey. Only 30 rooms were surveyed in each building. Therefore, the result of this research cannot be used for generalisation. However, what matters is that this research provides in depth analysis to better understand the issue of space utilisation in Saudi Arabian campuses. Flyvbjerg (2006, 227) '[a] purely descriptive, phenomenological case study without any attempt to generalize can certainly be of value in this process and has often helped cut a path toward scientific innovation.' Future work needs to be undertaken to cover more campuses, college buildings, and spaces so that the research sample can be representative and therefore results can be fairly generalisable.
- Another limitation is that it is beyond the scope of this study to examine all types of space in college buildings. The main focus was on the teaching rooms, which include classrooms, science laboratories, studios, and computer rooms, given that most higher education institutions collect data mainly for teaching space (SMG 2006, 07). Rooms that are excluded from the survey include technology laboratories, libraries, offices, meeting rooms, exhibition areas, conference rooms, theatres/auditoriums, staff rooms, and leisure rooms. More research is required to determine the utilisation of other spaces than just the teaching rooms. Special teaching space (theatres/auditoriums), research areas (research laboratories), offices (for both academic and staff), and support space (libraries, meeting rooms, exhibition areas, conference rooms, staff rooms, and leisure rooms) are all cases in point.

Note 1: The data gathered to measure space utilisation rate for College of Languages and Translation, King Saud University (KSU), (The 2nd Semester of the Academic Year 2015–2016).

| NO. | Department | Space Code | Space Type | Planned capacity | Planned space/user | Space Size (m2) | Space Per User | Current Capacity | Count | Sum | Frequency % | Occupancy % | Utilisation % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Common | G050 | Lecture | 25 | 1.7 | 42 | 1.4 | 30 | 16 | 424 | 40% | 88% | **35%** |
| 2 | French | G004 | Lecture | 70 | 1.3 | 91 | 1.8 | 50 | 23 | 671 | 58% | 58% | **34%** |
| 3 | Spanish | G024 | Lecture | 70 | 1.3 | 91 | 2.6 | 35 | 21 | 395 | 53% | 54% | **28%** |
| 4 | French | G073 | Computer lab | 33 | 2.6 | 85 | 1.7 | 50 | 21 | 491 | 53% | 47% | **25%** |
| 5 | Common | 1014 | Lecture | 70 | 1.3 | 90 | 2.0 | 44 | 26 | 672 | 65% | 59% | **38%** |
| 6 | Common | 1001 | Lecture | 42 | 1.6 | 68 | 1.9 | 35 | 21 | 541 | 53% | 74% | **39%** |
| 7 | French | 1003 | Lecture | 40 | 1.5 | 60 | 1.7 | 35 | 24 | 391 | 60% | 47% | **28%** |
| 8 | Common | 1012 | Lecture | 70 | 1.3 | 91 | 2.6 | 35 | 26 | 672 | 65% | 74% | **48%** |
| 9 | Common | 1013 | Lecture | 70 | 1.3 | 91 | 2.6 | 35 | 26 | 581 | 65% | 64% | **42%** |
| 10 | Common | 1014 | Lecture | 70 | 1.3 | 91 | 2.1 | 44 | 26 | 672 | 65% | 59% | **38%** |
| 11 | Common | 1004 | Lecture | 70 | 1.3 | 91 | 2.3 | 40 | 20 | 493 | 50% | 62% | **31%** |
| 12 | Common | 1006 | Lecture | 25 | 1.7 | 42 | 1.7 | 25 | 16 | 104 | 40% | 26% | **10%** |
| 13 | English | 1008 | Lecture | 35 | 1.5 | 51 | 1.7 | 30 | 17 | 278 | 43% | 55% | **23%** |
| 14 | Spanish | 1009 | Lecture | 25 | 1.7 | 42 | 1.4 | 30 | 15 | 99 | 38% | 22% | **8%** |
| 15 | Spanish | 1011 | Lecture | 25 | 1.7 | 42 | 1.4 | 30 | 15 | 124 | 38% | 28% | **10%** |
| 16 | Common | 1015 | Lecture | 25 | 1.7 | 42 | 1.4 | 30 | 14 | 94 | 35% | 22% | **8%** |
| 17 | Common | 1016 | Lecture | 25 | 1.7 | 42 | 1.4 | 30 | 17 | 86 | 43% | 17% | **7%** |
| 18 | Common | 1017 | Lecture | 36 | 1.4 | 51 | 1.7 | 30 | 27 | 299 | 68% | 37% | **25%** |
| 19 | Common | 1018 | Lecture | 20 | 1.7 | 33 | 1.7 | 20 | 7 | 55 | 18% | 39% | **7%** |
| 20 | Common | 1019 | Lecture | 16 | 1.6 | 26 | 1.6 | 16 | 16 | 58 | 40% | 23% | **9%** |
| 21 | Common | 1033 | Lecture | 25 | 1.7 | 42 | 1.4 | 30 | 12 | 282 | 30% | 78% | **24%** |
| 22 | Common | 1070 | Lecture | 35 | 1.5 | 51 | 1.7 | 30 | 11 | 334 | 28% | 101% | **28%** |
| 23 | Common | 1074 | Lecture | 35 | 1.5 | 51 | 1.7 | 30 | 16 | 543 | 40% | 113% | **45%** |
| 24 | Hebrew | G002 | Lecture | 25 | 1.7 | 42 | 1.7 | 25 | 24 | 141 | 60% | 24% | **14%** |
| 25 | Hebrew | G003 | Lecture | 35 | 1.5 | 51 | 1.7 | 30 | 25 | 360 | 63% | 48% | **30%** |
| 26 | Persian | G005 | Lecture | 35 | 1.5 | 51 | 1.7 | 30 | 27 | 175 | 68% | 22% | **15%** |
| 27 | Spanish | G024 | Lecture | 70 | 1.3 | 91 | 2.6 | 35 | 22 | 424 | 55% | 55% | **30%** |
| 28 | French | G025 | Lecture | 70 | 1.3 | 91 | 1.8 | 50 | 22 | 480 | 55% | 44% | **24%** |
| 29 | English | G035 | Lecture | 35 | 1.5 | 51 | 1.5 | 35 | 12 | 172 | 30% | 41% | **12%** |
| 30 | Russian | G055 | Lecture | 25 | 1.7 | 42 | 1.4 | 30 | 12 | 220 | 30% | 61% | **18%** |

| NO. | Sunday | | | | | | | | Monday | | | | | | | | Tuesday | | | | | | | | Wednesday | | | | | | | | Thursday | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | 0 | 24 | 24 | 0 | 0 | 0 | 21 | 21 | 31 | 24 | 24 | 0 | 39 | 39 | 29 | 29 | 0 | 19 | 19 | 0 | 0 | 0 | 0 | 0 | 34 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 8 | 8 | 0 | 23 | 23 | 0 | 0 | 51 | 51 | 51 | 0 | 25 | 25 | 0 | 0 | 0 | 33 | 33 | 0 | 19 | 19 | 0 | 0 | 49 | 50 | 50 | 0 | 18 | 18 | 8 | 8 | 50 | 33 | 0 | 0 | 18 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 9 | 9 | 9 | 9 | 32 | 32 | 32 | 0 | 11 | 11 | 0 | 0 | 29 | 29 | 0 | 0 | 9 | 9 | 9 | 9 | 32 | 32 | 32 | 0 | 11 | 11 | 0 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 50 | 51 | 51 | 0 | 0 | 0 | 29 | 29 | 21 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 19 | 0 | 0 | 0 | 23 | 23 | 12 | 27 | 27 | 0 | 21 | 21 | 14 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 16 |
| 5 | 31 | 31 | 31 | 0 | 0 | 0 | 21 | 0 | 43 | 46 | 46 | 0 | 21 | 21 | 2 | 2 | 46 | 43 | 43 | 0 | 0 | 0 | 21 | 21 | 0 | 43 | 0 | 0 | 3 | 3 | 0 | 21 | 29 | 46 | 0 | 0 | 5 | 5 | 24 | 24 |
| 6 | 22 | 36 | 36 | 0 | 21 | 21 | 30 | 0 | 29 | 31 | 31 | 0 | 0 | 0 | 0 | 0 | 29 | 28 | 28 | 0 | 9 | 9 | 0 | 0 | 0 | 28 | 0 | 0 | 30 | 30 | 0 | 0 | 30 | 29 | 0 | 0 | 17 | 17 | 0 | 0 |
| 7 | 0 | 18 | 18 | 0 | 14 | 14 | 1 | 1 | 22 | 31 | 31 | 0 | 16 | 16 | 0 | 0 | 17 | 0 | 18 | 0 | 13 | 13 | 0 | 0 | 32 | 0 | 0 | 0 | 20 | 20 | 0 | 0 | 0 | 18 | 18 | 0 | 18 | 18 | 2 | 2 |
| 8 | 30 | 36 | 36 | 0 | 23 | 23 | 0 | 27 | 32 | 24 | 24 | 0 | 31 | 31 | 27 | 27 | 27 | 26 | 26 | 0 | 0 | 0 | 2 | 2 | 0 | 26 | 0 | 0 | 27 | 27 | 27 | 0 | 22 | 27 | 0 | 0 | 31 | 31 | 0 | 0 |
| 9 | 30 | 15 | 15 | 0 | 9 | 9 | 13 | 0 | 30 | 28 | 28 | 0 | 18 | 18 | 22 | 22 | 29 | 31 | 31 | 0 | 29 | 29 | 13 | 13 | 0 | 31 | 0 | 0 | 0 | 0 | 0 | 18 | 29 | 29 | 0 | 0 | 0 | 0 | 21 | 21 |
| 10 | 31 | 31 | 31 | 0 | 0 | 0 | 21 | 0 | 43 | 46 | 46 | 0 | 21 | 21 | 2 | 2 | 46 | 43 | 43 | 0 | 0 | 0 | 21 | 21 | 0 | 43 | 0 | 0 | 3 | 3 | 0 | 21 | 29 | 46 | 0 | 0 | 5 | 5 | 24 | 24 |
| 11 | 45 | 21 | 21 | 0 | 0 | 0 | 0 | 28 | 35 | 38 | 38 | 0 | 18 | 18 | 8 | 8 | 0 | 0 | 0 | 0 | 30 | 30 | 0 | 0 | 22 | 17 | 17 | 0 | 28 | 28 | 8 | 0 | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 4 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 21 | 21 | 0 | 2 | 2 | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 4 | 4 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 4 | 4 | 0 | 0 | 0 | 28 | 0 | 6 | 3 | 3 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 1 | 1 | 0 | 28 | 28 | 0 | 0 | 0 | 46 | 46 | 0 | 27 | 27 | 0 | 0 |
| 14 | 9 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 | 0 | 2 | 2 | 0 | 0 |
| 15 | 0 | 8 | 8 | 0 | 11 | 11 | 0 | 0 | 6 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 12 | 12 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 13 | 13 | 0 | 0 | 0 | 0 | 7 | 7 | 0 | 0 |
| 16 | 4 | 5 | 5 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 8 | 8 | 0 | 0 | 8 | 4 | 4 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 13 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 2 | 0 | 0 | 4 | 0 | 0 | 0 | 9 | 9 | 0 | 0 | 23 | 7 | 7 | 0 | 1 | 1 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 1 | 18 | 18 | 0 | 0 | 11 | 11 | 0 | 12 | 10 | 10 | 0 | 15 | 15 | 12 | 12 | 2 | 26 | 26 | 0 | 0 | 0 | 12 | 12 | 2 | 0 | 10 | 0 | 13 | 13 | 0 | 0 | 13 | 10 | 10 | 0 | 2 | 1 | 2 | 0 |
| 19 | 7 | 9 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 3 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 0 | 4 | 4 | 0 | 0 | 0 | 4 | 4 | 3 | 3 | 0 | 0 | 0 | 0 | 4 | 4 |
| 21 | 28 | 23 | 23 | 0 | 34 | 34 | 0 | 0 | 29 | 17 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 14 | 14 | 0 | 0 | 0 | 0 | 0 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 33 | 30 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 36 | 0 | 0 | 0 | 0 | 0 | 30 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 36 | 0 | 0 | 0 | 0 | 0 |
| 23 | 30 | 31 | 31 | 0 | 33 | 33 | 0 | 0 | 0 | 31 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 38 | 38 | 0 | 33 | 0 | 0 | 0 | 31 | 31 | 0 | 0 | 38 | 38 | 0 | 0 | 0 | 0 | 38 | 0 | 38 | 0 | 0 | 0 |
| 24 | 0 | 6 | 6 | 0 | 4 | 4 | 0 | 0 | 0 | 9 | 9 | 0 | 3 | 3 | 5 | 10 | 9 | 7 | 7 | 0 | 5 | 5 | 3 | 0 | 7 | 3 | 3 | 0 | 10 | 10 | 0 | 0 | 6 | 0 | 3 | 0 | 4 | 0 | 0 | 0 |
| 25 | 26 | 23 | 23 | 0 | 3 | 3 | 4 | 4 | 25 | 27 | 27 | 0 | 3 | 0 | 3 | 3 | 26 | 27 | 27 | 0 | 4 | 4 | 0 | 0 | 25 | 23 | 23 | 0 | 3 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 | 0 | 0 |
| 26 | 11 | 3 | 3 | 0 | 0 | 0 | 16 | 16 | 0 | 0 | 0 | 0 | 5 | 5 | 9 | 9 | 1 | 1 | 1 | 0 | 5 | 5 | 7 | 9 | 7 | 0 | 0 | 0 | 5 | 5 | 7 | 7 | 0 | 6 | 6 | 0 | 6 | 6 | 7 | 7 |
| 27 | 0 | 0 | 0 | 0 | 9 | 9 | 9 | 9 | 32 | 32 | 32 | 0 | 11 | 11 | 0 | 0 | 29 | 29 | 29 | 0 | 9 | 9 | 9 | 9 | 32 | 32 | 32 | 0 | 11 | 11 | 0 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 41 | 45 | 45 | 0 | 1 | 1 | 0 | 0 | 46 | 44 | 44 | 0 | 2 | 2 | 4 | 4 | 0 | 9 | 9 | 0 | 0 | 0 | 2 | 2 | 43 | 45 | 45 | 0 | 1 | 1 | 0 | 0 | 44 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 0 | 0 | 0 | 2 | 2 | 0 | 12 | 12 | 0 | 0 | 0 | 17 | 17 | 0 | 13 | 13 | 17 | 0 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 24 | 24 | 24 | 0 | 0 | 0 | 0 | 0 | 18 | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 24 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 18 | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Note 2: The data gathered to measure space utilisation rate for College of Science, University of Hail (UofH), (The 2nd Semester of the Academic Year 2015–2016).

| NO. | Department | Space Code | Space Type | Planned capacity | Planned space/user | Space Size (m2) | Space Per User | Current Capacity | Count | Sum | Frequency % | Occupancy % | Utilisation % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | Biology | F112 | Lecture | 35 | 1.2 | 43 | 1.2 | 35 | 14 | 330 | 35% | 67% | **24%** |
| 32 | Chemistry | F080 | Lecture | 35 | 1.2 | 43 | 1.0 | 41 | 26 | 377 | 65% | 35% | **23%** |
| 33 | Mathletics | F072 | Lecture | 35 | 1.2 | 41 | 1.0 | 40 | 15 | 301 | 38% | 50% | **19%** |
| 34 | Physics | S057 | Lecture | 45 | 2.3 | 103 | 2.9 | 35 | 26 | 601 | 65% | 66% | **43%** |
| 35 | English | F051 | Lecture | 25 | 1.3 | 32 | 0.8 | 40 | 24 | 333 | 60% | 35% | **21%** |
| 36 | Physics | F097 | Lecture | 35 | 1.2 | 43 | 1.1 | 40 | 21 | 274 | 53% | 33% | **17%** |
| 37 | Tourism | F063 | Lecture | 84 | 1.5 | 122 | 3.5 | 35 | 20 | 628 | 50% | 90% | **45%** |
| 38 | Archaeology | F055 | Lecture | 25 | 1.3 | 32 | 1.3 | 25 | 15 | 166 | 38% | 44% | **17%** |
| 39 | Tourism | F062 | Lecture | 35 | 1.2 | 43 | 1.7 | 25 | 12 | 198 | 30% | 66% | **20%** |
| 40 | English | S060 | Lecture | 25 | 2.7 | 67 | 2.2 | 30 | 18 | 407 | 45% | 75% | **34%** |
| 41 | Common | F052 | Lecture | 25 | 1.3 | 32 | 0.8 | 40 | 20 | 419 | 50% | 52% | **26%** |
| 42 | Common | F061 | Lecture | 35 | 1.2 | 43 | 1.2 | 35 | 18 | 159 | 45% | 25% | **11%** |
| 43 | Common | F066 | Lecture | 35 | 1.3 | 44 | 1.3 | 35 | 23 | 199 | 58% | 25% | **14%** |
| 44 | Common | F071 | Lecture | 25 | 1.3 | 32 | 1.3 | 25 | 25 | 262 | 63% | 42% | **26%** |
| 45 | Common | F090 | Lecture | 35 | 1.1 | 40 | 1.3 | 30 | 23 | 180 | 58% | 26% | **15%** |
| 46 | Common | F091 | Lecture | 40 | 1.6 | 65 | 1.6 | 40 | 23 | 538 | 58% | 58% | **34%** |
| 47 | Common | F098 | Lecture | 35 | 1.2 | 43 | 1.7 | 25 | 20 | 217 | 50% | 43% | **22%** |
| 48 | Common | F100 | Lecture | 45 | 1.8 | 82 | 2.1 | 40 | 18 | 528 | 45% | 73% | **33%** |
| 49 | Common | F128 | Lecture | 45 | 1.5 | 69 | 1.7 | 40 | 17 | 547 | 43% | 80% | **34%** |
| 50 | Common | F131 | Lecture | 60 | 1.7 | 102 | 2.3 | 45 | 11 | 281 | 28% | 57% | **16%** |
| 51 | Physics | G061 | Lab | 20 | 4.7 | 94 | 4.7 | 20 | 37 | 546 | 93% | 74% | **68%** |
| 52 | Physics | G067 | Lab | 20 | 4.7 | 93 | 4.7 | 20 | 32 | 544 | 80% | 85% | **68%** |
| 53 | Physics | G068 | Lab | 15 | 4.4 | 66 | 4.4 | 15 | 33 | 533 | 83% | 108% | **89%** |
| 54 | Chemistry | G086 | Lab | 20 | 4.4 | 87 | 4.4 | 20 | 19 | 336 | 48% | 88% | **42%** |
| 55 | Chemistry | G087 | Lab | 25 | 3.8 | 94 | 3.8 | 25 | 24 | 316 | 60% | 53% | **32%** |
| 56 | Chemistry | G092 | Lab | 25 | 3.8 | 94 | 3.8 | 25 | 26 | 391 | 65% | 60% | **39%** |
| 57 | Common | S054 | Lecture | 45 | 2.4 | 109 | 2.7 | 40 | 20 | 697 | 50% | 87% | **44%** |
| 58 | Common | S058 | Lecture | 25 | 2.0 | 50 | 1.3 | 40 | 14 | 466 | 35% | 83% | **29%** |
| 59 | Common | S059 | Lecture | 60 | 3.3 | 198 | 5.0 | 40 | 20 | 402 | 50% | 50% | **25%** |
| 60 | Common | S061 | Lecture | 45 | 3.5 | 159 | 4.0 | 40 | 22 | 528 | 55% | 60% | **33%** |

| NO. | Sunday | | | | | | | | Monday | | | | | | | | Tuesday | | | | | | | | Wednesday | | | | | | | | Thursday | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 31 | 36 | 30 | 34 | 0 | 0 | 0 | 0 | 18 | 36 | 30 | 34 | 8 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 30 | 34 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 39 | 7 | 7 | 30 | 30 | 12 | 12 | 0 | 39 | 5 | 5 | 0 | 0 | 0 | 5 | 5 | 0 | 12 | 12 | 9 | 0 | 7 | 0 | 6 | 39 | 3 | 3 | 0 | 18 | 18 | 0 | 4 | 39 | 0 | 0 | 5 | 6 | 0 | 0 | 0 |
| 33 | 0 | 37 | 0 | 0 | 0 | 21 | 21 | 2 | 0 | 37 | 0 | 11 | 0 | 0 | 0 | 5 | 6 | 21 | 21 | 0 | 20 | 0 | 23 | 2 | 0 | 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 37 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 35 | 0 | 0 | 0 | 0 | 38 | 38 | 3 | 35 | 11 | 11 | 0 | 47 | 47 | 0 | 0 | 18 | 18 | 5 | 0 | 23 | 23 | 2 | 3 | 35 | 27 | 27 | 30 | 30 | 0 | 0 | 0 | 40 | 23 | 0 | 0 | 7 | 7 | 18 | 0 |
| 35 | 0 | 6 | 3 | 31 | 0 | 0 | 22 | 0 | 20 | 7 | 0 | 2 | 2 | 6 | 0 | 0 | 12 | 6 | 3 | 21 | 21 | 0 | 0 | 0 | 37 | 33 | 33 | 2 | 2 | 0 | 14 | 10 | 31 | 6 | 3 | 0 | 0 | 0 | 0 | 0 |
| 36 | 37 | 10 | 10 | 3 | 5 | 5 | 0 | 0 | 37 | 17 | 17 | 14 | 14 | 0 | 0 | 0 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 37 | 5 | 5 | 17 | 0 | 0 | 0 | 0 | 0 | 5 | 14 | 0 | 8 | 8 | 0 | 0 |
| 37 | 31 | 30 | 0 | 39 | 0 | 0 | 0 | 0 | 33 | 0 | 0 | 32 | 32 | 33 | 33 | 0 | 31 | 30 | 0 | 39 | 0 | 0 | 0 | 0 | 2 | 33 | 33 | 32 | 32 | 0 | 33 | 0 | 31 | 30 | 0 | 39 | 0 | 0 | 0 | 0 |
| 38 | 5 | 43 | 31 | 0 | 0 | 9 | 0 | 0 | 27 | 0 | 6 | 6 | 1 | 0 | 0 | 6 | 5 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 6 | 6 | 1 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | 10 | 0 | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 9 | 0 | 3 | 0 | 0 | 10 | 0 | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 9 | 0 | 3 | 0 | 0 | 10 | 0 | 36 | 0 | 0 | 0 | 0 | 0 |
| 40 | 0 | 19 | 19 | 20 | 20 | 0 | 0 | 0 | 0 | 34 | 34 | 0 | 0 | 2 | 0 | 0 | 49 | 19 | 19 | 20 | 20 | 0 | 0 | 0 | 4 | 34 | 34 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 29 | 0 | 0 |
| 41 | 0 | 33 | 6 | 6 | 6 | 0 | 0 | 10 | 14 | 8 | 0 | 0 | 18 | 18 | 0 | 0 | 0 | 29 | 29 | 0 | 0 | 0 | 0 | 10 | 0 | 8 | 0 | 43 | 43 | 31 | 31 | 0 | 0 | 33 | 33 | 0 | 0 | 0 | 0 | 10 |
| 42 | 0 | 16 | 10 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 10 | 10 | 9 | 1 | 0 | 0 | 0 | 16 | 10 | 0 | 0 | 1 | 0 | 0 | 0 | 18 | 10 | 10 | 9 | 1 | 0 | 0 | 0 | 16 | 10 | 0 | 0 | 1 | 0 | 0 |
| 43 | 7 | 0 | 2 | 5 | 5 | 0 | 0 | 0 | 0 | 18 | 18 | 0 | 0 | 3 | 3 | 5 | 7 | 2 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 0 | 0 | 3 | 3 | 5 | 7 | 0 | 2 | 5 | 5 | 28 | 28 | 0 |
| 44 | 6 | 13 | 5 | 10 | 5 | 0 | 0 | 0 | 0 | 0 | 17 | 28 | 11 | 3 | 0 | 0 | 6 | 13 | 5 | 10 | 5 | 0 | 0 | 0 | 0 | 0 | 17 | 28 | 11 | 3 | 0 | 0 | 6 | 13 | 0 | 7 | 7 | 7 | 13 | 13 |
| 45 | 7 | 0 | 20 | 0 | 12 | 12 | 3 | 3 | 2 | 0 | 20 | 3 | 0 | 3 | 3 | 0 | 7 | 9 | 9 | 5 | 5 | 0 | 0 | 0 | 2 | 0 | 20 | 0 | 2 | 2 | 0 | 0 | 7 | 12 | 12 | 0 | 0 | 0 | 0 | 0 |
| 46 | 0 | 5 | 5 | 0 | 0 | 31 | 31 | 0 | 34 | 27 | 27 | 1 | 1 | 18 | 18 | 0 | 0 | 31 | 31 | 0 | 0 | 37 | 37 | 0 | 14 | 18 | 18 | 0 | 0 | 34 | 34 | 0 | 24 | 31 | 31 | 0 | 0 | 0 | 0 | 0 |
| 47 | 0 | 14 | 14 | 0 | 10 | 10 | 0 | 0 | 4 | 1 | 0 | 5 | 5 | 12 | 12 | 0 | 0 | 11 | 11 | 0 | 4 | 22 | 22 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 10 | 0 | 17 | 17 | 0 | 0 | 0 |
| 48 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 15 | 47 | 47 | 37 | 37 | 0 | 34 | 0 | 0 | 0 | 0 | 34 | 34 | 33 | 33 | 0 | 37 | 0 | 0 | 15 | 15 | 0 | 0 | 0 | 34 | 33 | 33 | 0 | 0 | 0 | 0 | 0 |
| 49 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 44 | 44 | 0 | 0 | 0 | 40 | 0 | 0 | 24 | 24 | 0 | 0 | 0 | 44 | 30 | 0 | 47 | 47 | 0 | 0 | 0 | 16 | 36 | 36 | 40 | 40 | 0 | 0 | 0 |
| 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 44 | 0 | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 34 | 0 | 0 | 7 | 13 | 13 | 0 | 44 | 44 | 0 | 0 |
| 51 | 15 | 15 | 17 | 17 | 17 | 19 | 19 | 19 | 14 | 14 | 0 | 0 | 0 | 16 | 16 | 16 | 16 | 16 | 14 | 14 | 14 | 14 | 14 | 14 | 18 | 18 | 12 | 12 | 12 | 11 | 11 | 11 | 18 | 18 | 12 | 12 | 12 | 13 | 13 | 13 |
| 52 | 15 | 15 | 21 | 21 | 21 | 20 | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 15 | 15 | 15 | 16 | 16 | 18 | 18 | 18 | 15 | 15 | 15 | 18 | 18 | 15 | 15 | 15 | 17 | 17 | 17 | 19 | 19 | 0 | 0 | 0 | 15 | 15 | 15 |
| 53 | 15 | 15 | 17 | 17 | 17 | 14 | 14 | 14 | 0 | 0 | 15 | 15 | 15 | 20 | 20 | 20 | 0 | 0 | 20 | 20 | 20 | 12 | 12 | 12 | 19 | 19 | 17 | 17 | 17 | 0 | 0 | 0 | 18 | 18 | 14 | 14 | 14 | 14 | 14 | 14 |
| 54 | 0 | 0 | 26 | 26 | 26 | 0 | 22 | 22 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 16 | 0 | 0 | 20 | 20 | 20 | 0 | 12 | 12 | 0 | 0 | 20 | 20 | 20 | 0 | 16 | 16 |
| 55 | 3 | 3 | 10 | 10 | 0 | 19 | 19 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 7 | 7 | 0 | 2 | 0 | 21 | 21 | 21 | 0 | 0 | 0 | 0 | 0 | 19 | 19 | 19 | 10 | 0 | 20 | 20 | 20 | 5 | 5 | 5 |
| 56 | 0 | 0 | 20 | 20 | 20 | 0 | 3 | 3 | 20 | 20 | 3 | 3 | 3 | 21 | 21 | 21 | 0 | 0 | 0 | 0 | 0 | 24 | 24 | 24 | 8 | 8 | 0 | 14 | 14 | 14 | 19 | 19 | 0 | 0 | 15 | 15 | 15 | 0 | 0 | 0 |
| 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 37 | 0 | 0 | 0 | 40 | 40 | 39 | 0 | 33 | 64 | 0 | 32 | 32 | 63 | 31 | 13 | 39 | 40 | 0 | 0 | 0 | 0 | 37 | 0 | 2 | 31 | 31 | 31 | 31 | 31 | 0 | 0 |
| 58 | 0 | 39 | 39 | 46 | 46 | 0 | 0 | 12 | 55 | 0 | 0 | 41 | 41 | 0 | 0 | 0 | 52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 38 | 38 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 59 | 0 | 0 | 14 | 46 | 0 | 0 | 0 | 0 | 8 | 8 | 15 | 15 | 30 | 30 | 41 | 0 | 0 | 7 | 14 | 46 | 0 | 0 | 30 | 0 | 8 | 8 | 15 | 15 | 0 | 11 | 11 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 37 | 37 | 25 | 25 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 20 | 20 | 0 | 0 | 41 | 47 | 0 | 25 | 25 | 37 | 38 | 38 | 11 | 20 | 0 | 0 | 18 | 18 | 0 | 0 |

Note 3: The data gathered to measure space utilisation rate for College of Engineering, University of Najran (UofN), (The 2nd Semester of the Academic Year 2015–2016).

| NO. | Department | Space Code | Space Type | Planned capacity | Planned space/user | Space Size (m2) | Space Per User | Current Capacity | Count | Sum | Frequency % | Occupancy % | Utilisation % | Sunday | | | | | | | | Monday | | | | | | | | Tuesday | | | | | | | | Wednesday | | | | | | | | Thursday | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 61 | Civil | CE212 | Lecture | 32 | 1.3 | 43 | 1.4 | 30 | 8 | 114 | 20% | 48% | **10%** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 0 | 0 | 0 | 0 | 19 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 0 | 0 | 0 | 0 | 17 | 17 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| 62 | Civil | CE214 | Lecture | 32 | 1.7 | 53 | 1.3 | 40 | 12 | 162 | 30% | 34% | **10%** | 0 | 16 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 17 | 17 | 0 | 16 | 0 | 0 | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 |
| 63 | Civil | CE206 | Lecture | 29 | 1.1 | 31 | 1.0 | 30 | 8 | 156 | 20% | 65% | **13%** | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 26 | 26 | 0 | 0 | 13 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 64 | Civil | CE213 | Lecture | 31 | 1.4 | 44.7 | 1.5 | 30 | 10 | 98 | 25% | 33% | **8%** | 0 | 9 | 9 | 0 | 17 | 17 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 65 | Civil | CE225 | Studio | 60 | 1.9 | 111 | 1.9 | 60 | 5 | 209 | 13% | 70% | **9%** | 0 | 0 | 0 | 0 | 61 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 61 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 66 | Electrical | EE216 | Lecture | 36 | 1.5 | 53 | 2.1 | 25 | 8 | 109 | 20% | 55% | **11%** | 24 | 14 | 14 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 | 0 |
| 67 | Electrical | EE212 | Lecture | 32 | 1.3 | 43 | 1.7 | 25 | 13 | 172 | 33% | 53% | **17%** | 19 | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 0 | 17 | 17 | 10 | 10 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 17 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 68 | Electrical | EE211 | Lecture | 32 | 1.3 | 43 | 1.7 | 25 | 8 | 65 | 20% | 33% | **7%** | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 15 | 13 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 69 | Architecture | ARE221 | Lecture | 42 | 1.3 | 56 | 1.9 | 30 | 10 | 126 | 25% | 42% | **11%** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 12 | 0 | 0 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 12 | 13 | 13 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 | Electrical | EE213 | Lecture | 32 | 1.6 | 52 | 2.1 | 25 | 9 | 113 | 23% | 50% | **11%** | 9 | 17 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 71 | Architecture | ARE203 | Lecture | 20 | 1.7 | 33 | 1.7 | 20 | 9 | 51 | 23% | 28% | **6%** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 7 | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 72 | Civil | CE216 | Lecture | 36 | 1.5 | 53 | 1.8 | 30 | 12 | 22 | 30% | 6% | **2%** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 73 | Civil | CE211 | Lecture | 32 | 1.3 | 43 | 1.4 | 30 | 11 | 61 | 28% | 18% | **5%** | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 18 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 0 |
| 74 | Civil | CE209 | Lab | 30 | 2.9 | 86 | 2.9 | 30 | 3 | 66 | 8% | 73% | **6%** | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 75 | Civil | CE204 | Lecture | 29 | 1.1 | 31 | 1.0 | 30 | 8 | 144 | 20% | 60% | **12%** | 0 | 0 | 0 | 0 | 13 | 13 | 23 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 13 | 23 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 76 | Civil | CE202 | Lecture | 29 | 1.1 | 32 | 1.1 | 30 | 6 | 84 | 15% | 47% | **7%** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 14 | 14 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 77 | Civil | CE205 | Lecture | 30 | 1.0 | 31 | 1.0 | 30 | 4 | 20 | 10% | 17% | **2%** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 78 | Electrical | EE201 | Studio | 70 | 1.6 | 110 | 1.8 | 60 | 5 | 175 | 13% | 58% | **7%** | 0 | 0 | 0 | 0 | 35 | 35 | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 79 | Architecture | ARE228 | Studio | 90 | 3.8 | 342 | 5.7 | 60 | 5 | 147 | 13% | 49% | **6%** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 18 | 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 37 | 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 | Civil | CE201 | Studio | 70 | 1.6 | 110 | 1.8 | 60 | 8 | 259 | 20% | 54% | **11%** | 0 | 41 | 14 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 41 | 41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 36 | 36 | 0 | 0 | 0 | 0 |
| 81 | Electrical | EE225 | Lecture | 32 | 1.7 | 53 | 1.8 | 30 | 2 | 20 | 5% | 33% | **2%** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 82 | Electrical | EE218 | Lecture | 36 | 1.4 | 51 | 2.0 | 25 | 10 | 102 | 25% | 41% | **10%** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 6 | 6 |
| 83 | Architecture | ARE201 | Studio | 32 | 3.4 | 109 | 3.6 | 30 | 13 | 195 | 33% | 50% | **16%** | 15 | 15 | 15 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 18 | 0 | 0 | 15 | 15 | 15 | 15 | 0 | 13 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 84 | Architecture | ARE214 | Lecture | 30 | 1.4 | 41 | 1.4 | 30 | 9 | 72 | 23% | 27% | **6%** | 8 | 8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 85 | Architecture | ARE213 | Lecture | 36 | 1.6 | 56 | 1.9 | 30 | 14 | 86 | 35% | 20% | **7%** | 0 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 0 | 0 | 4 | 4 | 4 | 0 | 0 | 0 | 7 | 7 | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 86 | Architecture | ARE222 | Lecture | 42 | 1.3 | 56 | 1.9 | 30 | 12 | 78 | 30% | 22% | **7%** | 0 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 87 | Architecture | ARE207 | Computer lab | 30 | 2.9 | 86 | 2.9 | 30 | 8 | 84 | 20% | 35% | **7%** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 9 | 9 | 9 | 0 | 0 | 0 | 0 | 12 | 12 | 12 | 12 |
| 88 | Architecture | ARE212 | Lecture | 36 | 1.5 | 54 | 1.8 | 30 | 7 | 28 | 18% | 13% | **2%** | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 4 | 4 | 0 | 0 | 0 |
| 89 | Architecture | ARE210 | Lecture | 36 | 1.4 | 52 | 1.7 | 30 | 16 | 113 | 40% | 24% | **9%** | 7 | 7 | 7 | 0 | 15 | 15 | 15 | 0 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 7 | 7 | 7 | 0 | 6 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 | Architecture | ARE220 | Lecture | 20 | 1.4 | 27 | 0.9 | 30 | 4 | 24 | 10% | 20% | **2%** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Note 4: The data gathered to measure space utilisation rate for College of Science and Humanities, Prince Sattam bin Abdulaziz University (PSAU), (The 2nd Semester of the Academic Year 2015–2016).

| NO. | Department | Space Code | Space Type | Planned capacity | Planned space/user | Space Size (m2) | Space Per User | Current Capacity | Count | Sum | Frequency % | Occupancy % | Utilisation % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 91 | Common | 2M1 | Lecture | 45 | 1.5 | 69 | 1.7 | 40 | 18 | 645 | 45% | 90% | **40%** |
| 92 | Common | 2B9 | Lecture | 84 | 1.5 | 122 | 4.1 | 30 | 14 | 395 | 35% | 94% | **33%** |
| 93 | Common | 2B4 | Lecture | 35 | 1.1 | 40 | 1.3 | 30 | 20 | 560 | 50% | 93% | **47%** |
| 94 | Common | 2C1 | Lecture | 25 | 1.2 | 31 | 1.0 | 30 | 23 | 327 | 58% | 47% | **27%** |
| 95 | Common | 2D4 | Lecture | 25 | 1.3 | 32 | 1.1 | 30 | 27 | 416 | 68% | 51% | **35%** |
| 96 | Common | 2W4 | Lecture | 45 | 2.1 | 95 | 3.2 | 30 | 13 | 438 | 33% | 112% | **37%** |
| 97 | Common | 2M5 | Lecture | 35 | 1.3 | 44 | 1.5 | 30 | 14 | 345 | 35% | 82% | **29%** |
| 98 | Common | 2B5 | Lecture | 40 | 1.6 | 65 | 2.2 | 30 | 16 | 277 | 40% | 58% | **23%** |
| 99 | Common | 2B2 | Lecture | 25 | 1.3 | 32 | 1.1 | 30 | 15 | 283 | 38% | 63% | **24%** |
| 100 | Common | B10 | Lecture | 45 | 1.8 | 82 | 2.7 | 30 | 17 | 607 | 43% | 119% | **51%** |
| 101 | English | 2B1 | Lecture | 25 | 1.0 | 26 | 0.9 | 30 | 15 | 458 | 38% | 102% | **38%** |
| 102 | Common | 2B3 | Lecture | 35 | 1.2 | 41 | 1.4 | 30 | 16 | 305 | 40% | 64% | **25%** |
| 103 | Common | 2B6 | Lecture | 50 | 1.7 | 84 | 1.7 | 50 | 17 | 606 | 43% | 71% | **30%** |
| 104 | English | 2B8 | Lecture | 35 | 1.2 | 43 | 1.4 | 30 | 14 | 406 | 35% | 97% | **34%** |
| 105 | Mathematics | 2C3 | Lecture | 35 | 1.2 | 41 | 1.4 | 30 | 4 | 68 | 10% | 57% | **6%** |
| 106 | Mathematics | 2C4 | Lecture | 35 | 1.1 | 40 | 1.3 | 30 | 25 | 331 | 63% | 44% | **28%** |
| 107 | Mathematics | 2C7 | Lecture | 35 | 1.2 | 43 | 1.4 | 30 | 17 | 508 | 43% | 100% | **42%** |
| 108 | Common | 2D1 | Lecture | 25 | 1.2 | 31 | 1.0 | 30 | 14 | 352 | 35% | 84% | **29%** |
| 109 | Common | 2D10 | Lecture | 35 | 1.3 | 44 | 1.5 | 30 | 18 | 404 | 45% | 75% | **34%** |
| 110 | Common | 2D11 | Lecture | 35 | 1.2 | 43 | 1.4 | 30 | 18 | 196 | 45% | 36% | **16%** |
| 111 | Physics | 2D5 | Lecture | 25 | 1.3 | 32 | 1.1 | 30 | 16 | 194 | 40% | 40% | **16%** |
| 112 | Common | 2D8 | Lecture | 35 | 1.2 | 43 | 1.4 | 30 | 18 | 402 | 45% | 74% | **34%** |
| 113 | Common | 2D9 | Lecture | 84 | 1.5 | 122 | 4.1 | 30 | 19 | 408 | 48% | 72% | **34%** |
| 114 | Common | 2M7 | Lecture | 35 | 1.3 | 44 | 1.1 | 40 | 23 | 622 | 58% | 68% | **39%** |
| 115 | Common | 2W1 | Lecture | 45 | 2.4 | 108 | 2.7 | 40 | 21 | 660 | 53% | 79% | **41%** |
| 116 | Common | 2W2 | Lecture | 45 | 2.3 | 103 | 2.6 | 40 | 21 | 638 | 53% | 76% | **40%** |
| 117 | Common | 3W1 | Lecture | 45 | 2.4 | 109 | 2.7 | 40 | 28 | 1136 | 70% | 101% | **71%** |
| 118 | Common | 3W2 | Lecture | 35 | 2.1 | 73 | 2.4 | 30 | 20 | 733 | 50% | 122% | **61%** |
| 119 | Common | 3W3 | Lecture | 35 | 2.1 | 73 | 2.4 | 30 | 25 | 805 | 63% | 107% | **67%** |
| 120 | Common | 3W4 | Lecture | 45 | 2.3 | 104 | 2.6 | 40 | 24 | 674 | 60% | 70% | **42%** |

| NO. | Sunday | | | | | | | | Monday | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 91 | 0 | 34 | 34 | 33 | 39 | 39 | 29 | 29 | 0 | 39 | 39 | 0 | 38 | 38 | 38 | 0 |
| 92 | 25 | 27 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 22 | 0 | 0 | 0 | 0 | 0 |
| 93 | 35 | 33 | 31 | 0 | 0 | 0 | 0 | 0 | 28 | 24 | 24 | 0 | 21 | 21 | 0 | 0 |
| 94 | 28 | 18 | 8 | 0 | 11 | 0 | 0 | 3 | 16 | 18 | 18 | 0 | 0 | 0 | 8 | 8 |
| 95 | 28 | 18 | 8 | 0 | 11 | 0 | 0 | 3 | 16 | 18 | 18 | 0 | 25 | 25 | 0 | 15 |
| 96 | 0 | 15 | 0 | 0 | 0 | 42 | 0 | 0 | 31 | 34 | 34 | 0 | 0 | 0 | 0 | 0 |
| 97 | 7 | 31 | 31 | 0 | 0 | 0 | 38 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 98 | 22 | 9 | 13 | 0 | 20 | 13 | 0 | 0 | 24 | 20 | 20 | 0 | 0 | 0 | 0 | 0 |
| 99 | 25 | 0 | 16 | 0 | 23 | 0 | 0 | 0 | 11 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 100 | 35 | 35 | 34 | 0 | 0 | 0 | 0 | 0 | 35 | 35 | 30 | 0 | 0 | 0 | 51 | 51 |
| 101 | 35 | 33 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 0 |
| 102 | 25 | 0 | 16 | 0 | 23 | 0 | 0 | 0 | 11 | 16 | 0 | 0 | 0 | 0 | 0 | 0 |
| 103 | 32 | 43 | 38 | 0 | 0 | 0 | 0 | 0 | 32 | 43 | 38 | 0 | 0 | 0 | 0 | 0 |
| 104 | 31 | 27 | 34 | 0 | 26 | 0 | 0 | 0 | 0 | 26 | 26 | 0 | 0 | 0 | 0 | 0 |
| 105 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 106 | 6 | 8 | 16 | 0 | 0 | 15 | 20 | 0 | 12 | 8 | 8 | 0 | 0 | 0 | 15 | 15 |
| 107 | 32 | 23 | 29 | 0 | 0 | 0 | 0 | 0 | 32 | 29 | 29 | 0 | 0 | 0 | 0 | 0 |
| 108 | 27 | 24 | 0 | 0 | 27 | 0 | 0 | 0 | 24 | 27 | 27 | 0 | 0 | 0 | 0 | 0 |
| 109 | 20 | 0 | 17 | 0 | 37 | 0 | 0 | 0 | 0 | 17 | 17 | 0 | 0 | 0 | 15 | 15 |
| 110 | 9 | 14 | 0 | 0 | 10 | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 14 | 14 | 0 | 0 |
| 111 | 16 | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 16 | 16 | 0 | 0 | 0 | 0 | 0 |
| 112 | 24 | 18 | 29 | 0 | 10 | 0 | 18 | 18 | 29 | 0 | 0 | 0 | 28 | 28 | 0 | 0 |
| 113 | 18 | 25 | 24 | 0 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 25 | 0 | 0 |
| 114 | 34 | 31 | 31 | 0 | 26 | 26 | 26 | 0 | 0 | 22 | 22 | 0 | 36 | 36 | 36 | 0 |
| 115 | 16 | 29 | 37 | 0 | 34 | 34 | 0 | 0 | 33 | 40 | 28 | 0 | 0 | 0 | 0 | 0 |
| 116 | 0 | 30 | 30 | 0 | 38 | 38 | 29 | 29 | 30 | 23 | 20 | 0 | 0 | 0 | 0 | 0 |
| 117 | 34 | 34 | 42 | 34 | 38 | 38 | 0 | 0 | 46 | 46 | 42 | 0 | 50 | 40 | 0 | 0 |
| 118 | 43 | 36 | 35 | 0 | 0 | 42 | 0 | 0 | 40 | 30 | 24 | 0 | 39 | 39 | 0 | 0 |
| 119 | 42 | 0 | 25 | 0 | 35 | 29 | 29 | 0 | 24 | 28 | 41 | 0 | 42 | 39 | 18 | 0 |
| 120 | 26 | 0 | 31 | 0 | 34 | 0 | 0 | 0 | 29 | 27 | 27 | 0 | 28 | 22 | 22 | 0 |

| NO. | Tuesday | | | | | | | | Wednesday | | | | | | | | Thursday | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 91 | 0 | 32 | 32 | 33 | 43 | 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 0 | 0 | 0 | 0 |
| 92 | 31 | 27 | 30 | 0 | 0 | 0 | 0 | 0 | 25 | 31 | 31 | 0 | 0 | 0 | 0 | 0 | 32 | 32 | 30 | 0 | 0 | 0 | 0 | 0 |
| 93 | 35 | 33 | 31 | 0 | 0 | 0 | 0 | 0 | 28 | 24 | 24 | 0 | 32 | 32 | 0 | 5 | 35 | 33 | 31 | 0 | 0 | 0 | 0 | 0 |
| 94 | 28 | 18 | 8 | 0 | 11 | 0 | 0 | 3 | 28 | 0 | 0 | 0 | 0 | 0 | 14 | 8 | 28 | 18 | 8 | 0 | 11 | 0 | 0 | 8 |
| 95 | 28 | 28 | 18 | 8 | 0 | 11 | 5 | 0 | 28 | 0 | 0 | 0 | 0 | 5 | 14 | 8 | 28 | 18 | 8 | 0 | 11 | 0 | 5 | 8 |
| 96 | 31 | 0 | 0 | 0 | 0 | 42 | 0 | 0 | 31 | 34 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 34 | 0 | 0 | 42 | 0 | 0 |
| 97 | 7 | 31 | 31 | 0 | 0 | 0 | 38 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 31 | 31 | 0 | 0 | 0 | 38 | 0 |
| 98 | 22 | 9 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 16 | 0 | 0 | 0 | 0 | 0 | 22 | 25 | 13 | 0 | 0 | 0 | 0 | 0 |
| 99 | 25 | 0 | 0 | 0 | 23 | 0 | 0 | 0 | 20 | 22 | 22 | 0 | 11 | 11 | 0 | 0 | 25 | 16 | 0 | 0 | 23 | 0 | 0 | 0 |
| 100 | 35 | 35 | 34 | 0 | 0 | 0 | 0 | 0 | 33 | 30 | 30 | 0 | 0 | 0 | 0 | 0 | 35 | 35 | 34 | 0 | 0 | 0 | 0 | 0 |
| 101 | 35 | 33 | 31 | 0 | 0 | 25 | 0 | 0 | 24 | 31 | 31 | 0 | 0 | 0 | 0 | 0 | 35 | 33 | 31 | 0 | 0 | 0 | 25 | 0 |
| 102 | 16 | 25 | 0 | 0 | 23 | 0 | 0 | 0 | 20 | 22 | 22 | 0 | 11 | 11 | 0 | 0 | 25 | 16 | 0 | 0 | 23 | 0 | 0 | 0 |
| 103 | 32 | 38 | 38 | 0 | 0 | 0 | 0 | 0 | 38 | 43 | 43 | 0 | 31 | 31 | 0 | 0 | 27 | 27 | 32 | 0 | 0 | 0 | 0 | 0 |
| 104 | 31 | 27 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 26 | 26 | 0 | 0 | 0 | 0 | 0 | 31 | 27 | 34 | 0 | 0 | 0 | 0 | 0 |
| 105 | 0 | 0 | 0 | 0 | 0 | 17 | 17 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 106 | 6 | 8 | 16 | 0 | 0 | 15 | 20 | 0 | 6 | 16 | 16 | 0 | 20 | 20 | 0 | 0 | 6 | 8 | 16 | 0 | 0 | 15 | 20 | 0 |
| 107 | 32 | 23 | 29 | 0 | 0 | 0 | 0 | 0 | 23 | 34 | 39 | 0 | 0 | 0 | 0 | 0 | 32 | 23 | 29 | 0 | 35 | 35 | 0 | 0 |
| 108 | 27 | 24 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 27 | 24 | 0 | 0 | 27 | 0 | 0 | 0 |
| 109 | 20 | 0 | 17 | 0 | 37 | 0 | 0 | 0 | 20 | 12 | 12 | 0 | 0 | 0 | 37 | 37 | 20 | 0 | 17 | 0 | 37 | 0 | 0 | 0 |
| 110 | 9 | 14 | 0 | 0 | 10 | 10 | 0 | 0 | 9 | 0 | 0 | 0 | 10 | 10 | 0 | 0 | 9 | 14 | 0 | 0 | 10 | 10 | 0 | 0 |
| 111 | 16 | 10 | 10 | 0 | 0 | 12 | 12 | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 16 | 10 | 10 | 0 | 0 | 0 | 0 | 0 |
| 112 | 24 | 18 | 29 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 24 | 0 | 0 | 24 | 18 | 29 | 0 | 0 | 0 | 0 | 0 |
| 113 | 18 | 25 | 24 | 0 | 19 | 0 | 0 | 0 | 24 | 0 | 0 | 0 | 18 | 18 | 0 | 0 | 18 | 25 | 24 | 0 | 19 | 20 | 20 | 0 |
| 114 | 25 | 26 | 26 | 0 | 31 | 31 | 31 | 0 | 27 | 27 | 27 | 0 | 0 | 0 | 0 | 0 | 15 | 15 | 15 | 0 | 0 | 0 | 0 | 0 |
| 115 | 33 | 29 | 37 | 0 | 34 | 34 | 0 | 0 | 33 | 40 | 28 | 0 | 0 | 0 | 0 | 0 | 16 | 29 | 28 | 0 | 34 | 34 | 0 | 0 |
| 116 | 23 | 28 | 35 | 0 | 38 | 38 | 0 | 0 | 32 | 23 | 20 | 0 | 0 | 0 | 0 | 0 | 30 | 28 | 0 | 0 | 38 | 38 | 0 | 0 |
| 117 | 37 | 37 | 42 | 43 | 39 | 39 | 0 | 0 | 46 | 46 | 42 | 0 | 50 | 40 | 0 | 0 | 39 | 39 | 24 | 43 | 43 | 43 | 0 | 0 |
| 118 | 43 | 36 | 35 | 0 | 0 | 42 | 0 | 0 | 0 | 30 | 24 | 0 | 39 | 0 | 0 | 0 | 43 | 36 | 35 | 0 | 0 | 42 | 0 | 0 |
| 119 | 42 | 0 | 25 | 0 | 35 | 18 | 18 | 0 | 24 | 28 | 41 | 0 | 42 | 39 | 0 | 0 | 42 | 39 | 25 | 0 | 35 | 0 | 0 | 0 |
| 120 | 26 | 33 | 33 | 0 | 34 | 0 | 25 | 0 | 29 | 27 | 27 | 0 | 28 | 22 | 22 | 0 | 26 | 31 | 31 | 0 | 34 | 0 | 0 | 0 |

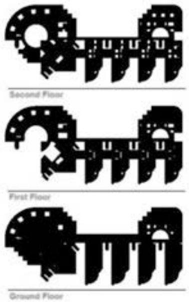
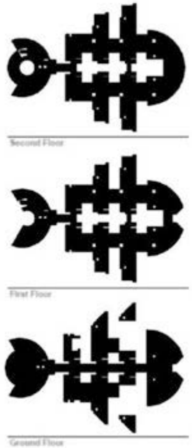
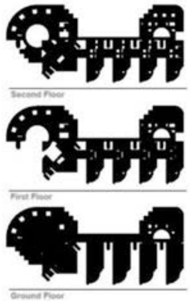
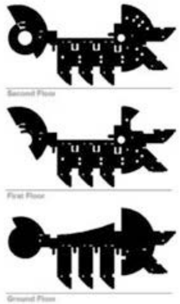
Note 5: The data gathered to measure space utilisation rate for Community College at University of Hafr Albatin (UHB), (The 2nd Semester of the Academic Year 2015–2016).

| NO. | Department | Space Code | Space Type | Planned capacity | Planned space/user | Space Size (m2) | Space Per User | Current Capacity | Count | Sum | Frequency % | Occupancy % | Utilisation % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 121 | Common | 0602 | Lecture | 60 | 1.5 | 88 | 2.3 | 38 | 11 | 339 | 28% | 81% | **22%** |
| 122 | Common | 1403 | Lecture | 35 | 1.2 | 43 | 1.4 | 30 | 12 | 257 | 30% | 71% | **21%** |
| 123 | Common | 1312 | Lecture | 35 | 1.2 | 42 | 1.4 | 30 | 7 | 94 | 18% | 45% | **8%** |
| 124 | Common | 1303 | Lecture | 35 | 1.2 | 43 | 1.4 | 30 | 13 | 183 | 33% | 47% | **15%** |
| 125 | Electrical | 1308 | Lecture | 45 | 1.9 | 85 | 2.8 | 30 | 12 | 111 | 30% | 31% | **9%** |
| 126 | Electrical | 1408 | Lecture | 45 | 1.9 | 85 | 2.8 | 30 | 9 | 150 | 23% | 56% | **13%** |
| 127 | Common | 1311 | Lecture | 35 | 1.2 | 43 | 1.4 | 30 | 6 | 84 | 15% | 47% | **7%** |
| 128 | Common | 1302 | Lecture | 35 | 1.2 | 43 | 1.4 | 30 | 13 | 207 | 33% | 53% | **17%** |
| 129 | Common | 1304 | Lecture | 35 | 1.2 | 41 | 1.4 | 30 | 12 | 199 | 30% | 55% | **17%** |
| 130 | Common | 1315 | Lecture | 35 | 1.2 | 43 | 1.4 | 30 | 13 | 113 | 33% | 29% | **9%** |
| 131 | Mechanical | 0305 | Lab | 30 | 1.0 | 31 | 1.0 | 30 | 16 | 140 | 40% | 29% | **12%** |
| 132 | Mechanical | 0311 | Lab | 30 | 2.0 | 61 | 2.0 | 30 | 7 | 54 | 18% | 26% | **5%** |
| 133 | Religion | 1202 | Lecture | 35 | 1.2 | 43 | 1.2 | 35 | 4 | 84 | 10% | 60% | **6%** |
| 134 | Common | 1206 | Lecture | 35 | 1.5 | 53 | 1.8 | 30 | 6 | 75 | 15% | 42% | **6%** |
| 135 | Electronics | 1218 | Lecture | 20 | 1.5 | 30 | 1.0 | 30 | 6 | 17 | 15% | 9% | **1%** |
| 136 | Common | 1219 | Lecture | 20 | 1.6 | 31 | 1.0 | 30 | 6 | 75 | 15% | 42% | **6%** |
| 137 | Computer | 1310 | Lecture | 45 | 2.8 | 126 | 4.2 | 30 | 12 | 32 | 30% | 9% | **3%** |
| 138 | Mechanical | 1314 | Lecture | 35 | 1.1 | 37 | 1.2 | 30 | 5 | 64 | 13% | 43% | **5%** |
| 139 | Mechanical | 1316 | Lecture | 35 | 1.2 | 43 | 1.4 | 30 | 2 | 14 | 5% | 23% | **1%** |
| 140 | Computer | 1318 | Lecture | 20 | 1.5 | 29 | 1.0 | 30 | 6 | 12 | 15% | 7% | **1%** |
| 141 | Common | 1320 | Lecture | 20 | 1.6 | 31 | 1.0 | 30 | 7 | 17 | 18% | 8% | **1%** |
| 142 | Computer | 1410 | Lecture | 45 | 2.8 | 126 | 4.2 | 30 | 6 | 51 | 15% | 28% | **4%** |
| 143 | Electronics | 1414 | Lecture | 35 | 1.1 | 37 | 1.2 | 30 | 9 | 72 | 23% | 27% | **6%** |
| 144 | Electrical | 1416 | Lecture | 35 | 1.1 | 38 | 1.3 | 30 | 6 | 24 | 15% | 13% | **2%** |
| 145 | Common | 1420 | Lecture | 20 | 1.6 | 31 | 1.0 | 30 | 9 | 24 | 23% | 9% | **2%** |
| 146 | Electrical | 1503 | Lab | 30 | 1.4 | 41 | 1.4 | 30 | 6 | 66 | 15% | 37% | **6%** |
| 147 | Electrical | 1528 | Lab | 40 | 2.4 | 97 | 3.2 | 30 | 9 | 99 | 23% | 37% | **8%** |
| 148 | Computer | 1530 | Lab | 45 | 2.8 | 126 | 4.2 | 30 | 11 | 22 | 28% | 7% | **2%** |
| 149 | Electrical | 1531 | Lab | 20 | 2.2 | 43 | 2.9 | 15 | 6 | 48 | 15% | 53% | **8%** |
| 150 | Electrical | 1533 | Lab | 30 | 2.0 | 61 | 2.0 | 30 | 6 | 51 | 15% | 28% | **4%** |

| NO. | Sunday | | | | | | | | Monday | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 121 | 52 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 52 | 0 | 29 | 0 | 0 | 0 | 0 | 0 |
| 122 | 16 | 31 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 31 | 0 | 0 | 2 | 0 | 0 | 0 |
| 123 | 0 | 10 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 |
| 124 | 17 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 15 | 15 | 0 | 0 | 12 | 12 | 0 |
| 125 | 8 | 6 | 9 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 126 | 10 | 17 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 127 | 15 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 128 | 21 | 0 | 20 | 0 | 11 | 0 | 0 | 0 | 21 | 5 | 20 | 0 | 0 | 0 | 0 | 0 |
| 129 | 19 | 0 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 6 | 9 | 0 | 0 | 0 | 0 | 0 |
| 130 | 0 | 15 | 6 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 |
| 131 | 0 | 0 | 0 | 0 | 11 | 11 | 11 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 132 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 6 |
| 133 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 32 | 0 | 0 | 0 | 0 |
| 134 | 0 | 22 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 135 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 136 | 0 | 23 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 137 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 3 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 138 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 |
| 139 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 140 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 141 | 2 | 2 | 0 | 0 | 3 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 142 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 143 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 15 | 15 | 0 |
| 144 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 0 | 0 | 0 | 0 | 0 |
| 145 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 146 | 0 | 0 | 0 | 0 | 0 | 11 | 11 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 147 | 0 | 0 | 0 | 0 | 0 | 12 | 12 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 148 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 3 |
| 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 | 8 |
| 150 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| NO. | Tuesday | | | | | | | | Wednesday | | | | | | | | Thursday | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 121 | 52 | 0 | 29 | 0 | 0 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 52 | 0 | 29 | 0 | 0 | 0 | 0 | 0 |
| 122 | 16 | 31 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 16 | 31 | 0 | 0 | 27 | 0 | 0 | 0 |
| 123 | 0 | 10 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 124 | 17 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 15 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 |
| 125 | 8 | 6 | 9 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 6 | 9 | 14 | 0 | 0 | 0 | 0 |
| 126 | 10 | 17 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 17 | 23 | 0 | 0 | 0 | 0 | 0 |
| 127 | 15 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 13 | 0 | 0 | 0 | 0 | 0 |
| 128 | 21 | 0 | 20 | 0 | 11 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 0 | 20 | 0 | 11 | 0 | 0 | 0 |
| 129 | 19 | 0 | 8 | 32 | 0 | 0 | 0 | 0 | 0 | 6 | 9 | 0 | 0 | 0 | 0 | 0 | 19 | 0 | 8 | 32 | 0 | 0 | 0 | 0 |
| 130 | 8 | 15 | 6 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 8 | 15 | 6 | 0 | 8 | 0 | 0 | 0 |
| 131 | 0 | 0 | 0 | 0 | 7 | 7 | 7 | 7 | 0 | 0 | 0 | 0 | 11 | 11 | 11 | 11 | 0 | 0 | 0 | 0 | 6 | 6 | 6 | 6 |
| 132 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 9 | 9 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 133 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 134 | 0 | 22 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 22 | 0 | 0 | 0 | 0 | 0 | 0 |
| 135 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 136 | 0 | 23 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 2 | 0 | 0 | 0 | 0 | 0 |
| 137 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 3 |
| 138 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 139 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| 140 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 141 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 142 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 15 | 15 | 0 |
| 143 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 | 8 | 0 |
| 144 | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 145 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 146 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 11 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 147 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 11 | 11 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 |
| 148 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 |
| 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 150 | 0 | 0 | 0 | 0 | 0 | 14 | 14 | 14 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Note 6: More detailed information about the five college buildings investigated in this study

| 1st Case KSU | 2nd Case UofH | 3rd Case UofN | 4th Case PSAU | 5th Case UHB |
| --- | --- | --- | --- | --- |
| College of Languages and Translation | College of Science | College of Engineering | College of Sciences and Humanities | Community College |
|  |  |  |  |  |
| Gross Floor Area 17,830 m2 | Gross Floor Area 25,940 m2 | Gross Floor Area 41,231 m2 | Gross Floor Area 25,940 m2 | Gross Floor Area 31,220 m2 |
| Planned Capacity 3,610 FTE students | Planned Capacity 2,232 FTE students | Planned Capacity 3,923 FTE students | Planned Capacity 2,232 FTE students | Planned Capacity 3,073 FTE students |
| Space per Student 5 m2/student | Space per Student 11.6 m2/student | Space per Student 10.5 m2/student | Space per Student 11.6 m2/student | Space per Student 10 m2/student |

Note 7: How to measure and manage space in higher education institutions

The proposed '*Space Management Tool*' depends on some factors, which can greatly influence the size of the university physical plant. These factors include the following:

1. Campus population (information about the existing campus users such as students, faculty, staff… etc. and the projected population in the future).
2. Campus space program (information about the space; what is available and what should be provided in the future?).
3. Focus of the university (whether university focuses more on teaching or on research. Such difference is vital, given the difference in the facilities required).
4. Acceptance rate (such percentage is significant and it is based on the admission policy in each university).
5. Ratios of Faculty to Students and Staff to Faculty (such ratios are important for space modelling).
6. Working hours (The campus can increase its capacity if the working hours are extended and hence instead of 8 h per day, 12 h per day will increase the capacity by 33%).

**Campus population**

How to collect data on the campus population (existing and near-, short- and long-term)

| Category | Students[a] | | | | Academics staff | | | | Medical staff | | | | Administration staff | | | | | | Contractors[e] | | | | Residents[f] | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sub-category | Preparatory Year[b] | Undergraduate | Master | PhD Fellow | Faculty Members[c] | Researchers | Technicians | Others | Doctors | Nurses | Technicians | Others | Administration[d] | Deanships | Agencies | Colleges | Departments | Others | Contractor A | Contractor B | Contractor C | Others | Undergraduate | Graduate Students | Faculty Members | Doctors | Nurses | |
| **2015** Population **(Existing)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **2020** Population **(Near-term)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **2025** Population **(Short-term)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **2030** Population **(Long-term)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| … | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Total** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

*Notes*

a Students are representing only the Full-Time Equivalent student numbers (FTE's)

b Preparatory Year is a program for freshmen required by most academic programs to prepare newcomers with necessary skills that support education and learning process

c Faculty Members include professors, associate professors, assistant professors, lecturers, and teaching assistants

d Administration includes for example Rectorate Office, Vice Rectors, and University Council

e Contractors include contracted companies by the University to provide services such as Operation, Maintenance, Security, Catering, Cleaning...etc

f Residents that are only accommodated on-campus. Off-campus residents can be calculated separately

**Campus space program**

How to collect data on space of university campuses (What is available and what should be provided in the future?)

| Years | 2015 | | 2020 | | 2025 | | 2030 | |
|---|---|---|---|---|---|---|---|---|
| University campuses[a] | Male | Female | Male | Female | Male | Female | Male | Female |
| Total Gross Floor Area (GFA)[b] | | | | | | | | |
| Total Useable Floor Area (UFA)[c] | | | | | | | | |

*Notes*

[a]University Campuses are all campuses including the main campus and the satellite campuses. Given the gender segregation system in Saudi Arabia, the majority of universities have two campuses; one for male and one for female students

[b]Gross Floor Area (GFA) is the 'sum of fully enclosed area and unenclosed covered area' (AAPPA 2002, 04)

[c]Useable Floor Area (UFA) or Net Internal Area (NIA) is the 'floor area measured from inside face of walls and deducting all the common use areas (such as corridors and toilets) and non-habitable areas (such as lifts, stairs, service ducts… etc.)' (AAPPA 2002, 04)

## Standardised Inventory of Space

How to collect data on space in one campus (How many square meters are available and how many should be provided in the near-, short- and long-term?)

| Male campus profile (Macro level) | (For every campus including male campus and female campus) |
|---|---|
| Campus name | |
| Campus location | |
| Total area of campus land (hectares) | |
| Total area of campus buildings ($m^2$) | |
| Total number of buildings on-campus[a] | |
| Average age of buildings | |

*Notes*

[a]If the University has other buildings off-campus, then it should be calculated separately

| Male campus zones profile | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Years | 2015 | | 2020 | | 2025 | | 2030 | |
| Gross floor area and useable floor area (GFA) & (UFA) | GFA | UFA | GFA | UFA | GFA | UFA | GFA | UFA |
| Academic zone[a] | | | | | | | | |
| Medical zone[b] | | | | | | | | |
| Sport zone[c] | | | | | | | | |
| Science park zone | | | | | | | | |
| Student housing zone | | | | | | | | |
| Faculty/staff housing zone | | | | | | | | |
| Endowment zone | | | | | | | | |
| Utilities | | | | | | | | |
| Total | | | | | | | | |

*Notes*
[a]Academic zone includes all the college buildings and the preparatory year building
[b]Medical zone includes all medical college buildings, teaching hospital, outpatient facilities, and other medical centres
[c]Sport zone includes the stadium, gymnasium, and other sport facilities

| College building (Micro level) | (For every college building on campus) | | | |
|---|---|---|---|---|
| Age of the building | | | | |
| Number of floors | | | | |
| Number of teaching rooms | | | | |
| Number of lecture hall/theatres | | | | |
| Number of computer rooms | | | | |
| Number of workshops/studios | | | | |
| Number of labs | | | | |
| Number of offices | | | | |
| Number of meeting rooms | | | | |
| Number of conference rooms | | | | |
| …etc. | | | | |
| Years | 2015 | 2020 | 2025 | 2030 |
| Total Gross Floor Area (GFA) | | | | |
| Total Useable Floor Area (UFA) | | | | |

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## Author Biography

**Naif Alghamdi** is a lecturer at the Faculty of Architecture and Planning, King Saud University, Riyadh, Saudi Arabia. As an architect, he works part-time with several professional practices in Saudi Arabia providing consultation. Naif holds postgraduate degrees in both Project Management and Architecture from the Bartlett, University College London, United Kingdom. Naif's main interest is in sustainability on university campuses in Saudi Arabia. Currently, he is doing his PhD at Delft University of Technology, Netherlands, looking at sustainability in university campuses. Professional memberships include the Society of College and University Planners (SCUP), the Association of Higher Education Facilities Officers (APPA), the Saudi Umran Society of Architects (SUSA) and the Saudi Council of Engineers (SCE).

# Reflections on Sustainable Practices: Analyzing Teaching, Research, Extension and Management of a Brazilian Public University

**Carolina Sampaio Marques, Nathália Rigui Trindade, Rodrigo Reis Favarin, Suelen Geíse Telocken and Marcelo Trevisan**

**Abstract** Concern about sustainable development has been gaining space in universities all around the world. This is revealed from the actions of teaching, research, extension and university management. This article **aims to analyze a recently founded multicampus university aiming to understand how Sustainability permeates the spaces of teaching, research, extension and university management**. The proposal seeks to analyze descriptively the undergraduate disciplines, the research and extension actions registered in the project office in 2016 and the management practices related to Sustainability in order to verify how this subject is structured within a University with 9 years of existence. The obtained results indicate that Sustainability is directly related to the area of knowledge of each undergraduate course and that research and extension actions are specific and related to specific groups within the university. In addition, the existence of several campuses makes it difficult to implement policies related to Sustainability. It was found that management is the main responsible for the insertion of Sustainability in the university, and from this point on, education, research and extension policies related to Sustainability can be developed and improved.

C. S. Marques (✉) · N. R. Trindade · R. R. Favarin · S. G. Telocken · M. Trevisan
Federal University of Santa Maria, University City—Camobi District,
Av. Roraima, 1000, 74 C, Santa Maria, RS 97105-900, Brazil
e-mail: carolinamarques@unipampa.edu.br

N. R. Trindade
e-mail: nathaliariguitrindade@gmail.com

R. R. Favarin
e-mail: rodrigo.favarin@hotmail.com

S. G. Telocken
e-mail: stelocken@gmail.com

M. Trevisan
e-mail: marcelotrevisan@smail.ufsm.br

C. S. Marques
Federal University of Pampa, Av. Pedro Anunciação, s/nº, Vila Batista District,
Caçapava do Sul, RS 96570-000, Brazil



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## 1 Introduction

The concerning with sustainable development has been gaining increasing space in the management of all types of organizations, whether they are public or private. Thus, the idea of sustainability management is increasingly present and, according to Shriberg (2002), is related to a systemic change that demand organizations to think beyond organizational processes and routines, seeking to integrate environmental and social goals in all decision-making. In other words, management for sustainability must integrate the organizational environment with the most diverse systems, demanding the achievement of environmental, social and economic results (Shriberg 2002).

In this regard, an organization perceived as a fundamental piece in the movement for Sustainability is the university, since it is seen as an important tool for disseminating and promoting the debate about sustainability in all its dimensions (Brandli et al. 2015). For Jacobi et al. (2011) there are three components used by these institutions to play this role: (i) training, exchange and education spaces; (ii) spaces for research and generation of ideas and; (iii) organizations per se, with budgets and decision-making processes. That is, this is revealed from the actions of teaching, research, extension and university management.

It can not be considered that universities are complex organizations and, as Thomas et al. (2012) mention, there are management and organizational structures as well as documents that orient administration (policies and procedures) to manage them. However, it is people, especially academics, who play a key role in this process (Thomas et al. 2012). Thus, it is not enough just to align university management systems to think about Sustainability, it is also necessary to align teaching, research and extension in order to promote more holistic and integrative approaches when dealing with the issue in question.

Therefore, considering the potential contribution that universities can bring to a change towards sustainable development and the complexity involved in this process, it is important to know the ways in which Sustainability works in the context of its activities. In view of the above stated this article aims to analyze a multi-campus university, recently founded, aiming to understand how Sustainability permeates among the spaces of teaching, research, extension and university management. The authors hope that in a young institution the concepts and practices related to Sustainability are present more effectively than in a university that had to adapt to this issue.

The importance of this theme lies in the fact that the sustainable practices observed in Brazilian universities are still reduced, which have the role of qualifying and raising awareness among citizens who form opinion in the future. While some institutions of higher education are constantly related to local of stagnation and bureaucracy, others demonstrate being able to at least start the path to sustainability. The prominent image assumed by higher education institutions in the process of technological development, in the preparation of students, and in the provision of information and knowledge, can and must be used to build the development of a sustainable and just society (Careto and Vendeirinho 2003). For this to happen, however, it becomes essential that these organizations begin to incorporate the principles and practices of sustainability, whether to initiate a process of awareness at all levels, reaching teachers, staff and students, or to make fundamental decisions about planning, training, operations or activities common in their physical areas.

This study is divided into six parts, where the introduction is the first one. There is followed by a discussion about the role of universities for sustainability and afterwards there is the contextualization about the university researched. The fourth part is the methodology of this study. The fifth brings the results of the research and there are the conclusions of this study in the last step.

## 2 The Role of Universities in the Dissemination of Sustainability

Universities have a remarkable role in the development of sustainability, as they are agents of change in society. Venzke and Nascimento (2013), which emphasize that among the roles of academia, the generation of interdisciplinary research and scientific knowledge stands out, assure this assertion.

Corroborating with the thinking above mentioned, Ávila et al. (2015) affirm that becomes important the role of public agencies and universities. Such manifestation is supported not only by being institutions capable of stimulating socio-environmental awareness with legal and scientific arguments, but also as entities that can serve as an example and reference to other organizations and to the community in general, according to their practices and attitude they adopt regarding to the issue.

Jacobi (2005) demonstrates the importance of universities and their educators, who have played a strategic and decisive role in the insertion of sustainability, in the qualification of students for a critical positioning in front of the socio-environmental crisis, having as horizon the transformation of social habits and practices and the development of an environmental citizenship that mobilizes them to the issue of Sustainability in its broader meaning. Thus, Sustainability in higher education means a new challenge, since most universities are proactive in implementing this theme; nevertheless, some research points out the existence of barriers to this insertion (Barth and Rieckmann 2012; Brandli et al. 2015).

Not only in Brazil, but also in societies considered as references, docents, researchers and academic managers focused on sustainability have been observing the slowness of insertion of environmental concerns in the university, as stated by de Ciurana and Leal Filho (2006). For UNESCO (1999), there is a need for a process to raise sensibilization and consciousness of the academic community about the importance of environmental sustainability—an issue that permeates the diversity of academic disciplines and practices—accompanied by adequate management, with full cooperation among Institutional instances and bodies, among decision makers and employees, teachers and students.

The report "Mapping of the Environmental Education in Brazilian Higher Education Institutions" (RUPEA 2005; Brasil 2007), in a sample of 22 Brazilian public and private universities from 11 states, reveals that the initiatives carried out are due more to groups of docents and researchers than to the existence of institutional policies and the encouragement of their management bodies. Only 22 of the 64 universities invited to participate in this mapping at the national level, effectively joined, which is yet another sign of a weak involvement and commitment of Brazilian university managers regarding the insertion of environmental themes in their institutions. Although the research is not recent, it is perceived that the situation has not yet advanced, inspiring attention from researchers and educational institutions.

Sustainability pleats the integration between its dimensions, and the university is a very important piece to strengthen and spread these collective and solidarity values. The intensification and multiplication of environmental crises, since the mid-1990s, have encouraged academic institutions to develop a greater commitment to Sustainability in higher education. It is observed that the different moments of emblematic events in the environmental plan, marked by happenings that impacted the environment and ecosystems, involve a set of actors from the educational universe, at all levels, enhancing the engagement of the different knowledge systems and their capacitation building in an interdisciplinary perspective with an emphasis on Sustainability (Jacobi et al. 2011).

The Decade of Education for Sustainable Development (DEDS) evidence that is needed a revisit of the education policy in the sense of to reorient the kindergarten education until university and the continuous learning in adult life, to be clearly focused on acquiring knowledge, skills, perspectives and values related to Sustainability. Schools and universities are not just places to learn about sustainable development, but places where children can actively implement good sustainable practices, for example, in energy saving, recycling, productive use of school grounds, and in the use of natural materials and resources (UNESCO 2005, p. 60–61).

The UNESCO (2005) complements that higher education must also assume a leadership role, putting into practice what teachers teach, aiming that the purchases, investments and services are sustainable and are integrated into teaching and learning. All higher education students should understand the importance of diversity and inclusion, they must be able to identify ethical values, assumptions, and systems so that they are able to make their own decisions and understand geospatial and temporal landmarks, as well as the context of information.

Higher education should emphasize experiences based on research, data collection, problem solving and interdisciplinary systems approaches, employing critical thinking. The curricula need to be developed including content, materials and tools, as well as case studies and identification of best practices (UNESCO 2005).

## 3 The University Researched

The higher education institution studied was part of the expansion program of the federal universities in Brazil, which predicted the expansion of Higher Education to regions that did not have access to free higher education. Thus, in 2008, to minimize the process of economic stagnation of the geographical area where it is inserted, was enacted the law that instituted this university that has the proposal of being committed to regional development.

The expansion of higher public education in places that previously did not have this access, in addition to accomplishing a longstanding dream of the population, allows the youth to remain in their place of origin. I addition they acquire the knowledge and information necessary to boost the progress of their region, at the moment when skilled labour is formed and the self-esteem of its inhabitants increases. In addition, there are the emergence of new families, whose children will catch a glimpse options for the development of culturally and economically independent societies. In this way, it is perceived that the region's concern with sustainability is in the purposes of the university that is the object of this study and this may reflect in the way the institution deals with these issues in teaching, research, extension and university management.

There are 10 campus at the university, distributed in 10 different cities and there were 13.730 students and 1.776 civil servants in April 2017. There are 62 undergraduate courses, 12 master degree courses and 2 doctor degrees and it is already rated as one of the best universities of the state, in the south of Brazil.

## 4 Method

According to the proposed objective, the research was classified as descriptive. According to Roesch (2005), the descriptive research has as main objective the obtaining of information about a certain population or phenomenon. The methodological option of the study was the qualitative approach of theoretical-empirical nature. According to Deslandes and Minayo (2010, p. 17), "qualitative research responds to very particular questions, because it works with the universe of meanings, motives, aspirations, beliefs, values and attitudes."

Therefore, through a case report, four stages were performed in the work:

(1) Analysis of the disciplines of the 62 undergraduate courses of the university, through reading the pedagogical projects of all the courses verifying which courses possess subjects that deal with the theme of Sustainability. When identifying the existence of discipline which in its content there were subjects related to sustainability, this discipline was described in a spreadsheet with the related general data (discipline, course, campus and knowledge area);
(2) Analysis of the research projects registered in the Project Registrations Platform in the year of 2016 in order to verify which projects are related to

Sustainability. In order to analyze the research projects, the Pro-Rectory of Research was asked to list the projects registered in the year 2016. When identifying a research project whose objective was related to sustainability topics, it was read to confirm the information and later described in a spreadsheet;

(3) Analysis of the extension projects registered in the Project Registrations Platform in the year of 2016 in order to verify which projects are related to Sustainability. In order to analyze these research projects, the Pro-Rectory of Research was asked to list the projects registered in the year 2016. When identifying a research project whose objective was related to sustainability topics, it was read to confirm the information and later described in a spreadsheet;

(4) Analysis of the management practices that are linked to Sustainability through an interview with the Pro-Rector of Administration. The choice to interview this person was because he belongs to the Sustainable Logistics Commission and it is their responsibility to develop guidelines for sustainable procurement in the institution. In the interview, there were asked questions as about the university's policies on sustainability, such as recycling, sustainable purchases, reverse logistics, planning future actions, among others.

Data collection was carried out between March and April 2017.

## 5 Results

The analysis of the results obtained in the study is presented in this section. It begins with the analysis of the undergraduate courses, proceeds with the data of the research and extension projects and, finally, the interview with the Pro-Rector of Administration of the research institution is examined.

The university object of this study has 62 undergraduate courses divided into 10 campuses. Each campus has a core vocation that makes that the courses from that campus are geared toward a related area. For the characterization of the courses, Table 1 specifies the graduations available at the university by area of knowledge according to the table prepared by Capes (Coordination of Improvement of Higher Level Personnel).

The graduation course has as characteristic the plurality of areas of knowledge available for the training of professionals, whether they are graduates, bachelors or technologists. They all have the challenge of collaborating in a society based on socially and environmentally responsible behaviour and the improvement of skills, values and human competencies for a real participation in the decision-making processes of those who seek new knowledge (de Salgado and Cantarino 2006).

In this sense, having in the curriculum of the course, subjects that deal with the issue of Sustainability becomes important as it will be these future professionals who will live in a context that challenges society to rethink habits and processes.

**Table 1** Number of undergraduate courses of the university available by knowledge area

| Knowledge area | Number of undergraduate courses |
|---|---|
| Agrarian sciences | 14 |
| Applied social sciences | 12 |
| Engineering | 11 |
| Exact and earth sciences | 09 |
| Health sciences | 05 |
| Linguistic, language and arts | 05 |
| Biological sciences | 04 |
| Human sciences | 02 |
| Total | 62 |

*Source* Elaborated by the authors based on the research data

Thus, Table 2 describes the total of undergraduate courses at the university and informs how many of these courses have subjects that deal with Sustainability.

Table 2 shows a situation that deserves our attention because the information found appears to be in disagreement with the current Brazilian legislation. Law No. 9,795, of April 27, 1999 (Brasil 1999). Article 2 of this law specifies that Environmental Education must be present, in an articulated way, at all levels and modalities of the educational process, both formal and non-formal. Therefore, all courses should have subjects related to environmental education, sustainable development and sustainability in their curricula. As all graduations of this university were created after the validity of the law in question, it was believed that they were in accordance with the legal determinations. There are other ways to work on Sustainability beyond disciplines, such as research and extension projects, however this is not usually, what happens because not all students participate in

**Table 2** Description of the undergraduate courses that have disciplines related to sustainability

| Campus | Total number of undergraduate courses | Number of the undergraduate courses that have disciplines related to sustainability | % |
|---|---|---|---|
| Campus 1 | 07 | 03 | 42.86 |
| Campus 2 | 11 | 07 | 63.63 |
| Campus 3 | 05 | 04 | 80 |
| Campus 4 | 05 | 05 | 100 |
| Campus 5 | 06 | 03 | 50 |
| Campus 6 | 05 | 02 | 40 |
| Campus 7 | 04 | 02 | 50 |
| Campus 8 | 06 | 05 | 83.33 |
| Campus 9 | 05 | 05 | 100 |
| Campus 10 | 08 | 03 | 37.5 |
| Total | 62 | 39 | 62.9 |

*Source* Elaborated by the authors based on the research data

research and extension projects in a course. The insertion of the subject in disciplines brings more security that the students are receiving the knowledge that the legislation determines and unfortunately, it is not occurring in an effective way.

It is known that the teaching of environmental practices is one of the possible strategies for achieving a sustainable society, and environmental education is an effective way to raise awareness about sustainability issues in society as a whole. Thus, the deficiency of this issue in the university damages the dissemination and diffusion of knowledge about Sustainability in the communities to which it is inserted. In order to better understand where the biggest difficulties of insertion of the knowledge about Sustainability in the undergraduate courses, the university courses in the areas of knowledge were divided and Table 3 specifies this division.

Table 3 describes the number of courses that have subjects related to Sustainability in each campus and by area of knowledge. It is observed that some areas of knowledge were not contemplated with disciplines in their undergraduate courses, such as Health Sciences and the area of Linguistics, Language and Arts. Other areas such as the Human Sciences have only one course that has subjects related to Sustainability. In addition, the area with the highest number of disciplines (Agrarian Sciences) is the area with the highest number of undergraduate courses at the university studied. This demonstrates that although Sustainability is an integrating, interdisciplinary and holistic subject in some areas, it is still difficult to insert these issues within the disciplines of undergraduate courses.

In the 39 courses analyzed, 93 subjects were found that relate to Sustainability. It is noticed that in some graduations there is an isolated discipline that deals only on the theme and in others, the subject is presented connected with a specific content, as for example, in the discipline of Civil Construction II there is the topic

**Table 3** Undergraduate courses that have disciplines related to sustainability divided by knowledge area

| Knowledge area | | | | | | | |
|---|---|---|---|---|---|---|---|
| Campus | Agrarian sciences | Biological sciences | Exact and earth sciences | Human sciences | Applied social sciences | Engineering | Total |
| Campus 1 | 01 | – | – | – | – | 02 | 03 |
| Campus 2 | – | – | 02 | – | – | 05 | 07 |
| Campus 3 | – | – | 03 | – | – | 01 | 04 |
| Campus 4 | 05 | – | – | – | – | – | 05 |
| Campus 5 | 03 | – | – | – | – | – | 03 |
| Campus 6 | – | – | – | 01 | 01 | – | 02 |
| Campus 7 | – | – | – | – | 02 | – | 02 |
| Campus 8 | – | – | – | – | 05 | – | 05 |
| Campus 9 | 01 | 03 | – | – | 01 | – | 05 |
| Campus 10 | 03 | – | – | – | – | – | 03 |
| Total | 13 | 03 | 05 | 01 | 09 | 08 | 39 |

*Source* Elaborated by the authors based on the research data

"Sustainable Constructions". According to the ideas of Almeida and Kautzmann (2012), initially there is a need to open spaces in the curricula for the environmental theme, then create informal links with other disciplines, and finally, as a major goal, to promote the reformulation of disciplines. Thus, this way, interesting examples of how to insert the topic within the most diverse subjects, can be seen.

It is noticeable, with the analyzed data above, that the subject is slightly included in the general formation of the graduations in the studied university, since this is a multidisciplinary subject and can be worked on the most diverse subjects and theories. This finding is in line with the postulate by Gonçalves Dias et al. (2009), where the authors mention the need to insert the theme in different contexts, given its multidimensionality. It is also noted that in 23 courses there is no mention in the disciplines' syllabus of subjects related to sustainability, which causes concern because these courses are formers of professionals who will play important roles in their professional careers.

Thus, after analyzing teaching activities, it was chosen to describe the university's research activities that are closely related to Sustainability, and in this way, Table 4 describes quantitatively the research projects identified with Sustainability in the year of 2016.

Table 4 specifies the total number of research projects carried out at each campus in 2016, and of those, how many that deal with themes related to Sustainability. It is noticed the low insertion of the theme in research projects, since the subject is not worked in researches in one campus analysed.

In addition, it can be noted that there are differences in the insertion of the theme in relation to each university campus, which can be derived from the type of course that each locality has. To identify this issue, Table 5 lists the research projects of each campus with the knowledge area of the project.

Table 5 shows the number of research projects on each campus according to the knowledge area of each project. Some areas of knowledge do not have any research

**Table 4** Research projects related to sustainability

| Campus | Total number of research projects | Number of research projects related to the theme of sustainability | % |
|---|---|---|---|
| Campus 1 | 118 | 04 | 3.39 |
| Campus 2 | 110 | 02 | 1.82 |
| Campus 3 | 45 | 06 | 13.33 |
| Campus 4 | 74 | 02 | 2.70 |
| Campus 5 | 107 | 01 | 0.93 |
| Campus 6 | 36 | 00 | 0 |
| Campus 7 | 40 | 03 | 7.5 |
| Campus 8 | 66 | 01 | 1.51 |
| Campus 9 | 60 | 05 | 8.33 |
| Campus 10 | 368 | 01 | 0.27 |
| Total | 1024 | 25 | 2.44 |

*Source* Elaborated by the authors based on the research data

**Table 5** Research projects related to sustainability according to the knowledge area

| Knowledge area | | | | | | |
|---|---|---|---|---|---|---|
| Campus | Agrarian sciences | Exact and earth sciences | Human sciences | Applied social sciences | Engineering | Total |
| Campus 1 | – | – | – | – | 04 | 04 |
| Campus 2 | – | 01 | – | – | 01 | 02 |
| Campus 3 | – | 01 | – | – | 05 | 06 |
| Campus 4 | – | – | – | 02 | – | 02 |
| Campus 5 | – | – | – | 01 | – | 01 |
| Campus 6 | – | – | – | – | – | 00 |
| Campus 7 | – | – | – | 03 | – | 03 |
| Campus 8 | – | – | 01 | – | – | 01 |
| Campus 9 | 02 | 01 | 01 | 01 | – | 05 |
| Campus 10 | – | 01 | – | – | – | 01 |
| Total | 02 | 04 | 02 | 07 | 10 | 25 |

*Source* Elaborated by the authors based on the research data

projects related to Sustainability such as Health Sciences, Biological Sciences and in the area of Linguistics, Language and Arts. This may be indicative of the difficulty that professors have of inserting transversal themes in their research subjects, as well as the lack of obligatory sustainability projects in the most diverse areas of knowledge. Furthermore, these questions raise the hypothesis that research related to Sustainability is being carried out by researchers and research groups that already have Sustainability as the basic theme. There may be difficulties on the part of the researchers to insert transversely in their research Sustainability, due to lack of engagement between the theme and the researcher.

In order to expand the analysis of this study, it was sought to describe the extension activities that are related to Sustainability and, thus, Table 6 describes the sustainable extension projects of the year 2016.

Table 6 describes the sustainable extension projects on each campus of the university. Thus, as in the research projects, it is noticed that there are a few number of extension projects related to Sustainability, and in two campuses there is no project in the year 2016. In addition, it is noticed that there is a disparity between the numbers of projects developed by each campus, which denotes the possibility of having differences between areas of knowledge according to what is specified in Table 7.

Table 7 demonstrates the number of extension activities in each campus according to the knowledge area of each project. The area of health sciences does not have any project related to Sustainability, and it can be considered an indicative of the difficulty of insertion of Sustainability in subjects of diverse areas. In addition, it observed that some areas (biological sciences and applied social sciences) have a larger number of extension projects than others and make some activities more related to the theme than others make. Although the theme is considered

**Table 6** Extension projects related to sustainability

| Campus | Total number of extension projects | Total number of extension projects related to sustainability | % |
|---|---|---|---|
| Campus 1 | 24 | 00 | 0 |
| Campus 2 | 54 | 03 | 5.55 |
| Campus 3 | 19 | 03 | 15.79 |
| Campus 4 | 55 | 07 | 12.73 |
| Campus 5 | 35 | 03 | 8.57 |
| Campus 6 | 34 | 01 | 2.94 |
| Campus 7 | 35 | 00 | 0 |
| Campus 8 | 52 | 04 | 7.69 |
| Campus 9 | 23 | 04 | 17.29 |
| Campus 10 | 92 | 03 | 3.26 |
| Total | 423 | 28 | 6.62 |

*Source* Elaborated by the authors based on the research data

transversal and susceptible of being inserted in any area and activity, it is not what can be perceived in the practice of university activities.

To compile all the information about teaching, research and extension activities of the researched university, Table 8 shows a summary containing the data found.

Table 8 shows the teaching, research and extension activities by area of knowledge developed at the university in the year 2016. There are important differences among each area of knowledge, such as the area of health sciences that does not have any discipline or activities of research and extension related to Sustainability. The area of linguistics, language and arts has important deficiencies that should be studied. In other areas, the relation with Sustainability is more intense, having more courses with disciplines and a larger number of research and extension projects. These affirmations reinforce what Jacobi (2005) analyzes about the importance of universities and their educators to the insertion of Sustainability, the qualification of students for a critical positioning ex ante the socio-environmental crisis, having as horizon, the transformation of social habits and practices and the Environmental citizenship that mobilizes them for sustainability in its broadest meaning.

Subsequent of the analyzing the teaching, research and extension actions, it is necessary to analyze the management activities of the researched university and, in this way, the following will be described questions regarding sustainable university management. During the interview with the Pro-Rector of Administration, it was sought to identify in which management activities that Sustainability related issues are being observed. The intention of this analysis is not to go deeper into the question, but rather to obtain subsidies for analysis of teaching, research and extension activities. It was sought to identify how the university works Sustainability in its daily management activities and what was perceived is that sustainable management presents deficiencies.

**Table 7** Extension projects related to sustainability according to the knowledge area

| Knowledge area | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Campus | Agrarian sciences | Biological sciences | Exact and earth sciences | Human sciences | Applied social sciences | Engineering | Linguistic, language and arts | Total |
| Campus 1 | – | – | – | – | – | – | – | 00 |
| Campus 2 | – | 01 | 01 | – | – | 01 | – | 03 |
| Campus 3 | – | – | – | 01 | – | 02 | – | 03 |
| Campus 4 | 02 | 01 | 02 | 01 | 01 | – | – | 07 |
| Campus 5 | – | – | 01 | 01 | 01 | – | – | 03 |
| Campus 6 | – | – | – | – | – | – | 01 | 01 |
| Campus 7 | – | – | – | – | – | – | – | 00 |
| Campus 8 | – | – | – | – | 04 | – | – | 04 |
| Campus 9 | – | 02 | – | – | – | 02 | – | 04 |
| Campus 10 | 01 | 02 | – | – | – | – | – | 03 |
| Total | 03 | 06 | 04 | 03 | 06 | 05 | 01 | 28 |

*Source* Elaborated by the authors based on the research data

**Table 8** Summary of teaching, research and extension activities related to sustainability

| | Number of undergraduate courses | Number of courses with sustainable disciplines | Number of research projects | Number of green research projects | Number of extension projects | Number of green extension projects |
|---|---|---|---|---|---|---|
| Agrarian sciences | 14 | 13 | 180 | 02 | 58 | 03 |
| Biological sciences | 04 | 03 | 93 | – | 26 | 06 |
| Exact and earth sciences | 09 | 05 | 139 | 04 | 47 | 04 |
| Human sciences | 02 | 01 | 114 | 02 | 78 | 03 |
| Applied social sciences | 12 | 09 | 99 | 07 | 79 | 06 |
| Health sciences | 05 | – | 235 | – | 60 | – |
| Engineering | 11 | 08 | 136 | 10 | 24 | 05 |
| Linguistic, language and arts | 05 | – | 28 | – | 51 | 01 |
| Total | 62 | 39 | 1024 | 25 | 423 | 28 |

*Source* Elaborated by the authors based on the research data

The bids have paragraphs that require that the raw material for wood furniture are derived from certified loggers, that the papers come from reforestation woods and that there is reverse logistics in some items such as paint cans and packages. In addition, in the biddings of the university restaurants there is the observance of correct forms of reutilization and discard of foods. However, in general, it is noticed in the other bidding processes, studies are not carried out in order to verify if there is a possibility of demanding a product or process that is more sustainable than the one currently used, such as in the case of purchase of consumption materials and computer equipment.

Regarding the waste that the university generates, it was verified that there is a company that is responsible for th adequate collection and disposal of the chemicals and biologicals. On the other hand, recyclable wastes are difficult to adequately dispose because the university is multi-campus and is also located in small cities with little infrastructure. Due to this problem, the university works in partnership with local municipalities to stimulate the formation of recycling cooperatives with the promotion of training and courses that stimulate local environmental education. There is the problem with waste from printer toners, bulbs, batteries and old tires that have not been resolved efficiently yet, with a team that is looking for solution of proper disposal.

A committee was set up to work on the University's Sustainable Logistics Plan, but the plan is still being structured with regular meetings to formulate the institution's policies and guidelines. For the Pro-Rector, there is a lack of people who have as their only activity the concern with the sustainable issues of the university so that policies leave the drawing board and are more effective. Moreover, the fact of being multicampus, harm the establishment of guidelines according to the specifics of each city, each group of teachers, technicians and students. Each place has different problems and gives different importance to each problem and the ideal is the meeting of different places to think about the whole without forgetting the parts.

Moreover, it is important to emphasize that the interviewee believes that, despite the current difficulties in implementing all the policies necessary to establish a sustainable management, the fact of being a new university is a slight more positive in the process due to the fact that there are people with more innovative mentalities and with a short time of public service, which can be a point to be explored in this process.

## 6 Concluding Remarks

Through this research, it can be seen that the Sustainability discourse is already present in most of the undergraduate courses of the researched university, however, failing to comply with the legislation that specifies that all courses must have subjects that deal with subjects related to environmental education and to Sustainability. Throughout the study, it was possible to perceive that the courses have a curricular structure focused on traditional training subjects, with little space for themes that have content integrating characteristics and that involve sustainability issues for future graduates, bachelors and technologists.

Adjusting the curricular structure of the offered courses does not only mean updating the approaches of the inserted areas in the already existing structures, but it is necessary a critical analysis of the scenario in which the future professionals will be inserted, which demands a multidisciplinary character of graduates of a quality course.

It was also observed that research and extension activities with an emphasis on Sustainability have direct relation with the area of knowledge of which they are part, being more difficult to observe in areas such as health sciences and linguistics, language and arts.

Research activities have an important component for innovation and for new perspectives and solutions to problems related to Sustainability, which they are necessary for local, regional and global development. The focus on researches for Sustainability can bring prosperity and improvements that are important to be valued. Yet the extension activities are the link between the university and the surrounding community, and its projects have a growing potential for sensitizing society to environmental and social problems. Thus, it is necessary to expand the extension actions with a view for promoting Sustainability.

Regarding the university management, it is noticed some progress, but the lack of effective policies for the implementation of actions related to Sustainability may be one of the indicatives of the low insertion of the subject in teaching, research and extension activities.

The authors hoped that in a young institution, the concepts and practices related to sustainability were present more effectively than in a university that needed to adapt to this question, but it was not observed during the study. It is suggested that senior management evaluate and deliberate more effective ways for actions to promote applied sustainability, as well as the latent need to define multiple performance indicators to improve and disseminate these actions for teaching, research and extension activities to occur the sensitization of the university community and society as a whole.

This study contributes to a diagnosis of actions related to Sustainability in universities and shows a reality of low insertion of the theme into the university context. It is then noticed the great niche to be studied and explored by the universities, whether it be through disciplines, projects, actions, training on Sustainability and the fomentation of sustainable university management policies.

As limitations of the research, there is the fact that it was carried out only in undergraduate courses and that only an interview with a senior management was conducted. As suggestions for new researches, it is suggested to broaden the scope of research, since the results do not allow generalizations in the face of the complex, heterogeneous and dynamic universe of higher education institutions in Brazil.

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# Sustainable Brazilian Universities: Composition of Characteristics, Indicators and Performance Parameters

**Eduardo Lopes Marques, Luis Antonio Verona and Ubiratã Tortato**

**Abstract** Universities, despite their limitations, have a very strong and viable ecological argument: to be able to reflect on possible ways of changing consumption and conserving natural resources. In this context, some nations have already been developing programs and operating strategic actions to reflect and act to mitigate the degradation of environmental, social and economic resources. Thus, the research listed a set of characteristics, indicators and performance parameters of universities hosted on the International Sustainable Campus Network (ISCN) website, according to the selection criterion among the countries of these educational institutions with the same Human Development Index (HDI) of Brazil, according to the Human Development Report (HDR) of the United Nations Development Program (UNDP) in 2015. The objective of the research is to build a set of sustainability characteristics, based on the analysis of the practices of the universities hosted on the International Sustainable Campus Network (ISCN) website, which allow Brazilian Universities to compose their own indicators, metrics and sustainability parameters. The result of the research may be useful for universities to align themselves with an Agenda for Sustainable Development by 2030 of the UN.

**Keywords** Sustainable Universities · Set of sustainability characteristics
Brazilian Universities · International Sustainable Campus Network
UN ASD2030

E. L. Marques · L. A. Verona (✉) · U. Tortato
Business School of Pontifical Catholic University of Parana—PUCPR,
Rua Imaculada Conceição, 1155 Prado Velho, Curitiba, PR 80215-901, Brazil
e-mail: luis.verona2013@gmail.com

E. L. Marques
e-mail: eddumarques1@gmail.com

U. Tortato
e-mail: ubirata.tortato@pucpr.br



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## 1 The Composition of a Set of Sustainability Characteristics for Universities

The objective of the research is to build a set of sustainability characteristics, based on the analysis of the practices of the universities hosted on the International Sustainable Campus Network (ISCN) website[1]—which provides a global forum to support colleges, universities and corporate campuses in the exchange of information, ideas and practices for sustainable operations, integrating the issue of sustainability into teaching, research and extension—in order to help Brazilian Universities to compose their own indicators, metrics and sustainability parameters.

The ISCN is managed by the Network Secretariat and operated by Sustainserv Inc.[2] Its strategic developments are guided by a Council, including representatives of seven Universities that host the ISCN, free of charge: Federal Polytechnic School of Lausanne, Switzerland; Federal Institute of Technology, Zürich, Germany; Royal Institute of Technology, Stockholm, Sweden; Nanyang Technological University, Singapore; National University of Singapore; Technical University of Denmark; University of Hong Kong, China.

The selection of the Sustainable Universities hosted from the ISCN website obeyed the selection criterion among the countries of these Universities with the same Human Development Index (HDI) of Brazil, according to Human Development Report 2015 of the United Nations Development Program (UNDP). From the information and data collected from these selected universities, the main characteristics of each one were listed.

The conditions of the planetary boundary were also taken into account in the conceptual framework proposed by Steffen et al. (2015) in terms of global and subglobal dynamics and their impact on the environment, society and the economy. Sustainability indicators developed by the Global Reporting Initiative (GRI)[3] were also considered in this research, in order to select those that could be applicable and adapted to the Brazilian Universities.

Also taken into account were the indicators developed by the AASHE/STARS® (Association for the Advancement of Sustainability in Higher Education—AASHE/Sustainability Tracking, Assessment & Rating System—STARS®), which offer parameters of self-evaluation in sustainability.

Finally, the set of sustainability characteristics applicable to the Brazilian Universities were confronted with the proposals of ASD2030—Agenda for Sustainable Development 2030 of the UN, whose intention was to verify the alignment and compliance with the proposed sustainability actions foreseen by ASD2030 and to propose a Set of Sustainability Characteristics (SSC), adapted to

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[1]ISCN website: http://www.international-sustainable-campus-network.org. Last Accessed on 04/15/2016.

[2]Website: http://www.sustainserv.com/en/. Last Accessed 17/04/2016.

[3]GRI is a non-profit company that offers for other companies and organizations a systematic basis for disseminating data in relation to their performance in terms of sustainability.

Brazil, with the purpose of assisting Brazilian Universities to their own indicators, metrics and parameters of sustainable performance.

The scientific research was carried out within the scope of the Research Group on Organizational Sustainability (RGOS) of the Postgraduate Program in Administration (PPAD), of Business School, at The Pontifical Catholic University of Parana (PUCPR).

In order to integrate the empirical, interpretative and critical dimensions, the orientation of which emerges from the complementarity between the Cartesian rational thought and the significant complex, the methodology used for the research was the "qualitative online", of a critical approach, through the analysis of Documents on websites.

For being characterized by "non-linearity", the texts of the Web, according to Flick (2009, p. 250), for the most part, "surpass text as a medium and are multimedia products (including images, sounds, texts, Pages, pop-up, etc.) and the fact that they are global". However, the research was not limited to the analysis of virtual data, also using bibliographical references related to sustainability, with emphasis on universities.

## 2 Sustainability in Higher Education: Path to the Goal

In order to achieve the objective proposed by the research, the following specific objectives were selected: (a) select among the Sustainable Universities hosted on the ISCN website, those belonging to the countries that have the same HDI of Brazil, according to UNDP HDR2015; (b) listing the main sustainability characteristics operationalized by these selected universities, such as programs, actions, plans, goals, etc., from the homepages of each campus; (c) verify the impact of global and subglobal dynamics, in the environmental, social and economic theoretical framework, from the conditions of the planetary boundary, based on the conceptual framework proposed by Steffen et al. (2015); (d) select GRI indicators, applicable and adapted to universities; (e) select data from the AASHE/STARS® systems, for the composition of sustainability performance parameters, applicable to Brazilian Universities; (f) select indicators and parameters of university performance based on the study made by Madeira (2008); (g) listing sustainability characteristics that are appropriate to the Brazilian universities for the environmental, social, economic and institutional areas; (h) compare the characteristics found with ASD2030 of UN; (i) propose a Set of Sustainability Characteristics (SSC) to help Brazilian Universities to compose their own indicators and parameters of sustainability performance.

Thus, we believe that this proposal can be of great importance to help raise awareness of the emergence of a real education and culture aimed at raising awareness about issues related to sustainability from the privileged *locus* of the

University as responsible for the construction and transmission of scientific knowledge, because it has historically the role of awakening ideas and represent the creative motor of societies on the face of the Earth.

## 3 Selection of Sustainable Universities Hosted on the ISCN Website, Belonging to Countries that Have the Same HDI of Brazil, According to UNDP HDR2015

As teaching institutions, Universities have the ecological virtue of reflecting, through price mechanisms, possible changes of standards in the face of scarce resources, as a regulatory mechanism for the market. Thus, Universities, despite their limitations, have a very strong and viable ecological argument: elaborate ways that provide incentives for the conservation of scarce resources, taking into account that it is the price mechanism that gives the measure of the relative scarcity, for the real scarcity of these resources.

In this context, some peoples of our planet have already been developing programs and operating strategic actions to reflect and act to mitigate the degradation of environmental, social and economic resources that are traditionally recognized as the basis of the network of relationships and which have sustained the different ways of living, although in an unsustainable way.

Thus, driven by the challenge of the antagonistic binomial formed by population growth *versus* the scarcity of natural resources, Universities are finding in information technology the tool that can lead societies to collectively seek solutions that minimize market effects in price mechanisms, since we live in limited space, whose resources are also limited. In this sense, the global computer network has offered to the Institutions the opportunity to organize globally around a problem or challenge, as is the case of considering the availability of resources in a sustainable way.

Among the various sites on the World Wide Web, one in particular was very useful for the purpose of the research, namely the International Sustainable Campus Network (ISCN), which provides a permanent global forum to support colleges, Corporate Universities and campuses through the exchange of information, ideas, and best practices for sustainable operations. This site—www.international-sustainable-campus-network.org—brings together several universities from all continents, around the theme of sustainability.

In this way, Universities located in countries with the same Human Development Index (HDI) of Brazil, according to the Human Development Report (HDR) of 2015, issued by the United Nations Development Program (UNDP) of the United

**Table 1** Sustainable universities hosted on the ISCN website, belonging to the countries that have the same Brazil's HDI

| HDI rank | Country | HDI | Continent/Qty. | University |
|---|---|---|---|---|
| 62º | Malaysia | 0.779 | Asian (1) | University of Malaya |
| 72º | Turkey | 0.761 | Eurasian (2) | KOÇ University |
| | | | | Öziegin Üniversitesi |
| 74º | Mexico | 0.756 | North American (1) | Tecnológico de Monterrey |
| **75º** | **BRAZIL** | **0.755** | | |
| 84º | Peru | 0.734 | South America (1) | PUC Peru |
| 90º | China | 0.727 | Asian (2) | Peking University |
| 93º | Thailand | 0.726 | | Chulalongkorn University |

*Source* The Authors

Nations (UN) were selected. The selection of the Sustainable Universities, listed on the ISCN website, according to HDR2015 of UN, that is, those classified as "High Development" Human, whose positions were between the 50th and 105th, considering consolidated data for 2014. At the end of 2014, Brazil was in the 75th position within this group.

Thus, the following Universities were classified according to the Table 1.

The components that form the HDI of the UNDP and that generate the classification of the member countries of UN in groups of VERY HIGH HUMAN DEVELOPMENT, HIGH HUMAN DEVELOPMENT (Group of which Brazil is a part), MEDIUM HUMAN DEVELOPMENT, LOW HUMAN DEVELOPMENT, takes into consideration and details the values of the three components of HDI: (a) longevity; (b) education (with two indicators) and (c) income. The table also shows the difference in classification by HDI and GDP (Gross Domestic Product).

## 4 Main Characteristics of Selected Universities from Their Home Page, Related to the Question of Sustainability

From the survey of the profiles of the Universities selected by the ISCN website, the next procedure was to raise the main characteristics of each one and analyze its relevant aspects (Table 2).

**Table 2** Main characteristics of selected universities related to the question of sustainability

| | University | Main characteristics |
|---|---|---|
| 1 | University of Malaya. (Malaysia) | **Focus on social responsibility**. Engagement Projects between University and Society. Solid Environmental Education Program. Master's Program in Science, Technology and Sustainability, Nanotechnology. Research on HIV-AIDS, infectious diseases, biodiversity, poverty eradication |
| 2 | KOÇ University. (Turkey) | **Focus on social responsibility**. Beware of the environment. ISO 14001 quality seal. Partner of the World Social Risk Contest. It has a startup accelerator for young social entrepreneurs. Fundamental principle: protection of natural resources. Research on basic changes in consumption method. Systemic thinking, intercultural communication and teamwork |
| 3 | Öziegin Üniversitesi (Turkey) | **Focus on energy generation and preservation of the environment**. Look for low carbon strategic solutions. Projects to improve the performance of new and existing buildings (School Building Project). Studies and applications of innovative energy together with ecological and economic issues. Energy efficiency project in non-residential buildings and public properties |
| 4 | Tecnológico de Monterrey. (Mexico) | **Focus on social, economic, political and ecological reality**. Use of active teaching and learning methodologies (Problem based learning, project oriented learning, collaborative learning, service learning, case study method, research based learning). Strategic research: management and sustainable use of water resources in Latin America and the Caribbean. Energy projects and public policies for renewable energy. It has a Business Sustainability Group that encourages the use of sustainable business strategies and the promotion of the "green market". It develops research in three major areas: (a) sustainable cities; (b) regional sustainable development; (c) energy policy and sustainability |
| 5 | PUC Peru. (Peru) | **Focus on climate change in the country and in the world**. One of the three countries most vulnerable to the ecological-environmental imbalance and climate change in the world. Investigates economic, social, environmental and technological dimensions. The main lines of research are focused on ecological, social, environmental, biodiversity, land use and renewable energy issues. It has an Academic Council of Social Responsibility, whose objective is to support and provide conditions for integration among students, professors and employees, in the conception and implementation of socially relevant initiatives and projects |
| 6 | Peking University. (China) | **Focus on understanding the causes of mechanisms of air movement, water and soil pollution, identifying innovative pollution reduction solutions and technologies**. It seeks to raise awareness of government and society about China´s environmental problems. Main achievements in terms of |

(continued)

**Table 2** (continued)

| | University | Main characteristics |
|---|---|---|
| | | research projects: (a) compliance with the Montreal Protocol; (b) Integrated Modeling for Environmental Management; (c) Control of pollution by Nitrogen and treatment of bodies of water; (d) Measurement of atmospheric pollutants; (e) Air Pollution in Megacities |
| 7 | Chulalongkorn University. (Thailand) | **Focus on sustainable development of the University (green policy)**. Free use of electric buses, bicycles, replanting of shady trees and creation of new green areas. Recycling of a variety of materials (leaves, grass, paper, plastic, styrofoam). Seeks solutions to reduce the University's carbon footprint. Its Master Sustainability Plan is based on 3 Principles: (1) sustainability performance of buildings on campus; (2) Master plan and goal setting; (3) Integration of facilities, research and education |

*Source* The Authors

## 5 Planetary Boundaries: A Concept

With respect to planetary boundaries, whose conceptual framework was proposed by Steffen et al., in 2015, it aims to "define a safe operational space for human societies to develop and thrive, based on the evolution of our understanding of the functioning and resilience of Earth" (Steffen et al. 2015, p. 1).

Based on this concept, the focus of the study is concentrated on five planetary boundaries, which have strong scales of operations in regional dynamics: (a) integrity of the biosphere; (b) biogeochemical flows (cycles of phosphorus and nitrogen); (c) changes in soil systems; (d) use of fresh water; (e) aerosol loading into the atmosphere.

In 2009, the Stockholm Resilience Center (SRC) established the concept of "planetary boundary" through 28 renowned international scientists who presented a set of nine borders of our planet within which humanity could continue to thrive and thrive toward the coming generations. The nine planetary frontiers are: (a) climate change; (b) stratospheric ozone; (c) acidification of the oceans; (d) the cycles of nitrogen and phosphorus; (e) loss of biodiversity; (f) change in land use; (g) use of fresh water; (h) biogeochemical flows; (i) new entities. According to the scientists three of these borders—climate change, nitrogen cycle and loss of biodiversity—have already been transgressed; the others are in the danger zone. The set of these nine borders of Earth is used as a framework to guide the formulation of the new Sustainable Development Objectives (SDO), proposed by the UN, through the Sustainable Development Agenda until 2030, which replaced the Millennium Development Goals from 2015.

Both the proposal by Steffen et al. (2015) and the concept of resilience, preached by the Stockholm Resilience Center, clearly indicate limits and frontiers for human action, as well as principles for living and developing as a species, without the socio-ecological systems degrade to the point where they prevent the existence of life on Earth. Studies and research on the boundaries and boundaries of living systems are very important topics for universities.

## 6 The Global Reporting Initiative (GRI)

Another important reference is the Sustainability Indicators applicable to Universities, which were listed on the basis of reports from the Global Reporting Initiative (GRI)—a non-profit company that offers other companies and organizations a systematic basis for the dissemination of data in performance in terms of sustainability, in the Form of Reports.

Thus, GRI promotes the use of Sustainability Reports (SR) as a way for companies and organizations—among them Universities—to become more sustainable and contribute to a sustainable global economy. The search for sustainability indicators applicable to universities, allowed the inclusion of topics related to each

**Table 3** Topics of economic, environmental and social areas applicable to Brazilian Universities

| | |
|---|---|
| Economic area | Economic performance |
| | Presence in the market |
| | Indirect economic impact |
| | Anti-corruption |
| Environmental area | Materials |
| | Energy |
| | Water |
| | Biodiversity |
| | Emissions |
| | Waste and effluents |
| | Environmental compliance |
| | Supplier environmental assessment |
| Social area | Employment |
| | Management/work relationships |
| | Occupational health and safety |
| | Training and education |
| | Diversity and equal opportunity (includes equal pay) |
| | Non-discrimination |
| | Free association and collective agreements |
| | Security practices |
| | Human rights assessment |
| | Local communities |
| | Supplier social evaluation |
| | Public policy |
| | User health and safety |
| | User privacy |
| | Socioeconomic compliance |

*Source* The Authors

series of the new GRI structure, which may allow the exploration of specific indicators for the economic, environmental and social areas, from the educational base (Table 3).

## 7 The STARS®/AASHE Tools

The next benchmark that is researched and possible to be adaptable to Brazilian Universities is the STARS® tool (System for Classification, Assessment and Tracking of Sustainability), which was created by AASHE (Association for the Advancement of Sustainability in Higher Education), which developed a system of awards based on Stars of bronze, silver, gold and platinum, with the intention of stimulating the wide participation of Higher Education Institutions (HEI). It is based on a self-report framework to measure the progress of HEI in relation to sustainability.

The STARS® score of a University is applicable in four categories: (1) Academics (AC); (2) Engagement (EN); (3) Operations (OP); (4) Planning and Administration (PA).

These four categories can be useful to Brazilian universities in order to compose their own scores in each one category, like a way to analyze how sustainable they are.

## 8 Relationships Between University and the Biosphere

With regard to the question of the relationships between the university and the biosphere, it is possible to list five categories of academic research, aiming at the adequacy of sustainable actions within the scope of HEI, which are: (a) education; (b) research; (c) involvement with the community; (d) operation; (e) sustainable governance. These categories represent the Institutional dimension that will be composing the Set of Sustainability Characteristics that permit be aligned with UN ASD2030 (Table 4).

**Table 4** Relationships between University and the biosphere

| | |
|---|---|
| Education | Sustainability program |
| | Courses/resumes |
| | Teaching/methodologies/assessment |
| | Commitment/conscience |
| | Ethic |
| Search | Sustainability research |
| | Involvement |
| | Incentives |
| | Financial services |
| | Knowledge generation |
| Community involvement | Student involvement |
| | Community services |
| | Continuing education |
| | University extension |
| | Student associations |
| Operation | Buildings |
| | Transport |
| | Energy |
| | Solid waste and liquids |
| | Potable water |
| | Other gas |
| | Storage |
| Sustainable governance | Institutional commitment |
| | Policies |
| | Stakeholders |
| | Sustainability office |

*Source* The Authors

## 9 Indicators of Sustainable Development

In relation to the indicators of sustainable development, they must follow some universal requirements that are agreed upon by several authors (van Bellen 2006; Madeira 2008; Spangenberg et al. 2002).

With regard to the dimensions taken as support pillars of the sustainability study applied to Brazilian HEIs, these are:

(A) Environmental: sum of the bio-ecological processes and the elements involved in these processes;
(B) Economic: includes, in addition to the formal economy, all types of informal activity that provide individual and group services, thus improving the standard of living beyond monetary income;

(C) Social: consists of the personal characteristics of human beings, such as their skills, their dedication, their experiences;
(D) Institutional: institutions are the result of interpersonal processes, such as communication and cooperation, resulting in the information and systems of rules governing the members of a society.

These four dimensions should be analyzed together because there are interactions between them that constitute network connections. These links may be characterized by interconnection indicators for two or more dimensions.

From the interconnections between the economic, social, environmental and institutional dimensions, metrics arise that allow the study of socioeconomic, socioenvironmental, environmental and institutional sustainability relations, all perfectly applicable in institutions of higher education—which now occupy the center of relations—to measure, analyze and support the decision-making of university managers.

The performance of an HEI, in terms of the sustainability of its campus, is limited, as proposed by Madeira (2008, p. 89), in the following assumptions:

- The main activities of an HEI are teaching and research (education and research);
- The existence of an HEI depends on several support services and various operations associated with them (operations);
- HEIs have positive and negative effects in their own community (involvement of the academic community);
- A sustainable HEI results from the integration of sustainability into teaching, research, operations, academic community and relationship with the surrounding community (sustainable governance).

## 10 Compatibility of Sustainability Characteristics, Indicators and Parameters Found at Universities, with UN ASD2030

ASD2030 is a plan of action for people, for the planet and for prosperity. It also seeks to strengthen universal peace with more freedom.

To this end, more than 150 world leaders from the United Nations Summit on Sustainable Development met from 25 to 27 September 2015 at the UN headquarters in New York and formally adopted a new agenda for sustainable development. This agenda will serve as a platform for action by the international community and national governments to promote common prosperity and well-being for all over the next 15 years.

The Agenda, entitled "Transforming Our World: The 2030 Agenda for Sustainable Development", agreed by the 193 UN member states, consists of a Declaration, 17 Sustainable Development Objectives and 169 goals, a section on means of implementation and a renewed partnership and a mechanism for evaluation and follow-up. They are integrated and indivisible, and balance the three dimensions of sustainable development: economic, social and environmental.

According to United Nations (2015), the seventeen Goals for Sustainable Development to be reach until 2030 are:

- Goal # 1. End poverty in all its forms everywhere.
- Goal # 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
- Goal # 3. Ensure healthy lives and promote well-being for all at all ages.
- Goal # 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- Goal # 5. Achieve gender equality and empower all women and girls.
- Goal # 6. Ensure availability and sustainable management of water and sanitation for all.
- Goal # 7. Ensure access to affordable, reliable, sustainable and modern energy for all.
- Goal # 8. Promote sustained, inclusive and sustainable economic growth, full and decent work for all.
- Goal # 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation productive employment and decent work for all.
- Goal # 10. Reduce inequality within and among countries.
- Goal # 11. Make cities and human settlements inclusive, safe, resilient and sustainable.
- Goal # 12. Ensure sustainable consumption and production patterns.
- Goal # 13. Take urgent action to combat climate change and its impacts.[4]

[4]Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.

- Goal # 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
- Goal # 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
- Goal # 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
- Goal # 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

## 11 The Construction of the Set of Sustainability Characteristics (SSC) for Brazilian Universities and Its Relationship with ASD2030 of the UN

The following will be presented the Set of Sustainability Characteristics (SSC) applicable to Brazilian Universities and a comparison will be made regarding compliance with UN ASD2030.

The construction of the Set of Sustainability Characteristics (SSC), which serve as reference to the Brazilian Universities, meet the parameters related in the previous paragraphs, besides Tables 2, 3 and 4.

As the research objective was to build a set of sustainability characteristics, based on the analysis of the practices of the universities hosted on the International Sustainable Campus Network (ISCN) website, which allow Brazilian Universities to compose their own indicators, metrics and sustainability parameters and to permit them to be aligned with the Agenda for Sustainable Development by 2030 of the UN, was built the Table below that connect the four parameters of the Set of Sustainability Characteristics (SSC) with the objectives of ASD2030 established by the United Nations (Table 5).

**Table 5** Set of sustainability characteristics (SSC) for Brazilian Universities and their relationship with UN ASD2030

| Sustainability characteristics | Goals of UN ASD2030 |
|---|---|
| Ambiental | GOAL # 01—Item 1.5<br>GOAL # 02—Item 2.4<br>GOAL # 03—Item 3.9<br>GOAL # 06—Items 6.3 e 6.4<br>GOAL # 07—Items 7.1, 7.2, 7.3, 7.a<br>GOAL # 08—Item 8.4<br>GOAL # 11—Items 11.3 e 11.6<br>GOAL # 12—Item 12.2, 12.4, 12.5<br>GOAL # 13—Item 13.3<br>GOAL # 14—Items 14.1e 14.3<br>GOAL # 15—Item 15.3 |
| Social | GOAL # 01—Item 1.5<br>GOAL # 03—Item 3.9<br>GOAL # 04—Item 4.7<br>GOAL # 05—Item 5.5<br>GOAL # 08—Item 8.4<br>GOAL # 10—Item 10.2<br>GOAL # 12—Items 12.3, 12.5, 12.8, 12.b<br>GOAL # 16—Item 16.5, 16.7<br>GOAL # 17—Items 17.6, 17.16, 17.17 |
| Economic | GOAL # 01—Item 1.5<br>GOAL # 08—Item 8.4<br>GOAL # 09—Item 9.4<br>GOAL # 12—Items 12.3, 12.4, 12.b<br>GOAL # 16—Item 16.5<br>GOAL # 17—Items 17.6, 17.16, 17.17 |
| Institutional | GOAL # 01—Item 1.5<br>GOAL # 03—Item 3.9<br>GOAL # 04—Items 4.4, 4.7<br>GOAL # 05—Item 5.b<br>GOAL # 06—Items 6.3, 6.4<br>GOAL # 07—Items 7.1, 7.2, 7.3, 7.a<br>GOAL # 08—Item 8.4<br>GOAL # 09—Item 9.5<br>GOAL # 11—Item 11.6<br>GOAL # 12—Items 12.3, 12.4, 12.5<br>GOAL # 13—Item 13.3<br>GOAL # 14—Item 14.a<br>GOAL # 15—Item 15.3<br>GOAL # 16—Item 16.6 |

*Source* The Authors

## 12 Conclusion: The Power of the Brazilian Sustainable Universities

The objective of the research is to build a set of sustainability characteristics, based on the analysis of the practices of the universities hosted on the International Sustainable Campus Network (ISCN) website, which allow Brazilian Universities to compose their own indicators, metrics and sustainability parameters. The result of the research may be useful for universities to align themselves with an Agenda for Sustainable Development by 2030 of the UN.

Despite the fact that the selected Universities belong to countries that have the same HDI of Brazil, they demonstrate a significant commitment to the issue of sustainability, both institutional and local and regional, while maintaining a focus on social and environmental issues, as the generating pole of the mechanisms of consumption and the scarcity of resources. Almost all the Universities analyzed incorporate the question of sustainability in their sets of mission, vision and values, making clear that the importance of the theme is the majority.

Having studied the conditions of the planetary boundary, based on the conceptual framework proposed by Steffen et al. (2015), it helped to understand the dimension and impact of the effects of deregulated consumption on the finiteness of natural resources, placing the position of the human being in relation of the control variables and the response variables, which were diametrically opposed.

From the study of the indicators that make up the GRI Sustainability Reports, it was possible to understand the systematics of classification and importance of the series that address the themes of the categories: economic, including aspects of anti-corruption and anti-competitive behavior; including materials and environmental compliance; including diversity and equal opportunities, human rights assessment, social supplier assessment and socio-economic compliance.

From the sustainability performance parameters applied to the Sustainable Universities by the AASHE/STARS® system, it was possible to understand the evaluation of the performance of the sustainable Universities, in relation to the dimensions related to education, research, involvement with the community, Institutional and sustainable governance. These parameters allow the Institution of Higher Education to establish its ways of relating to society and the biosphere.

The study carried out by Madeira (2008) allowed to list an extensive set of equations providing the composition of indicators and metrics and offers to decision makers the possibility to base their strategies on internal and external challenges in the university context, in order to contribute significantly for the research and development of practices that align with the numerous programs that aim at maintaining sustainability and mitigating resource scarcity.

Finally, the critical analysis of the findings and data compiled allowed us to list and propose a Set of Sustainability Characteristics (SSC) to help the Brazilian Universities to compose their own indicators and parameters of sustainability performance, being aligned with the UN ASD2030.

It is expected that Brazilian Universities will have a study reference, in terms of sustainability characteristics that will allow them to reflect, discuss, deepen this research and develop their own indicators, their own metrics and their own operational tools, in order to fulfill its role and its commitment to knowledge, science, research, sustainable development and life on Earth.

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# Sustainability and Climate Action in the Value Proposition of Science Parks and Areas of Innovation: Is the Future Already Happening?

**Diego Ramos**

**Abstract** The current survey results, achieved with collaboration of the International Association of Science Parks (IASP), allowed to assess the overall perspective of approximately 60 Science Parks and Areas of Innovation (STP/AOI) in 30 countries on key issues such as their role on sustainable development and the perceived enablers and barriers for further action. For instance, only 7% believe the role of STP/AOI is restricted to traditional growth (business as usual). On the other hand, 91% understand sustainability as a key driver for innovation. This study brings many useful data and information on value proposition for park/campus managers, as well as for policy makers and other stakeholders looking for advancements in the Science/Sustainability interface.

**Keywords** Value proposition · Sustainability · Science parks · Areas of innovation

## 1 Introduction

Areas of innovation are defined as "*places designed and curated to attract entrepreneurial-minded people, skilled talent, knowledge-intensive businesses and investments, by developing and combing a set of infrastructural, institutional, scientific, technological, educational and social assets, together with value added service, thus enhancing sustainable economic development and prosperity with and for the community*." (IASP)

Additionally, a science park is "an organization managed by specialized professionals, whose main purpose is to increase the wealth of its community by

D. Ramos (✉)
Research Fellow International Climate Protection, Alexander Von Humboldt Foundation, Bonn, Germany
e-mail: diego.gestor@gmail.com; diegoramos@alumni.usp.br



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promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions. To enable these goals to be met, a Science Park stimulates and manages the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; it facilitates the creation and growth of innovation-based companies through incubation and spin-off processes; and provides other value-added services together with high quality space and facilities." (IASP)

As areas with high demand on creativity and networking, the value proposition of STP/AOIs (Science Parks and Areas of Innovation) follows the recent trend described in the Location Theory, in which soft factors such as business environment and availability of intellectual capital are highly significant in contraposition to traditional hard factors, like location costs and proximity to consumer market (Murphy and Redmond 2008).

This evolution can be observed, for instance, in the "*The Linköping Declaration*", the resulting document of the 2014 International Symposium "*The Value of Science Parks*", held in Sweden. The document states that the critical success factors for future science parks are Business Development Support, Attractiveness, Networking, Open Innovation, Smart Specialization and Internationalization.

However, any trend on innovation environments, as well as in any other human activity, takes place in a broader context, within planetary boundaries. In this sense, sustainable development issues, including climate change, also applies to STP/AOIs as a necessary condition for future progress, and therefore, environmental matters can be treated as both a threat or an opportunity, but never ignored.

## 2 Method, Results and Discussion

### *2.1 Method*

To start answering these questions, the present research developed a framework to assess the potential contribution of such environments to the overall sustainability/climate debate (Table 1 and Fig. 1, Annex 1). The proposed is based on literature review and interviews with park managers. It has three layers of complexity in which the STP/AOIs can have initiatives related to sustainability/climate change, including (1) reducing its own impacts, (2), new technologies and outreach and (3) local development, implying that the effort and necessary coordination increases. The list of park visits and participants are included in, Tables 2 and 3, Annex 2. Acknowledgements.

Considering this framework, a survey with questions for each category was developed and, with the collaboration of IASP and submitted to its members worldwide. Finally, the study includes insights of some members of IASP's Board of Directors.

### 2.1.1 Reduction of Its Own Impacts

The main reference for the category **(1) reduction of its own impacts** is the Federal Government of Germany publication on climate concepts, specifically the section referring to universities of applied sciences (BMUB 2016). It encompasses the property itself, mobility, renewable energy, heat utilization, green IT, waste, and procurement. To this initial list, themes that emerged in the interviews with park managers were added, such as water harvest and reuse, green areas, adaptation and greenhouse gas (GHG) compensation.

### 2.1.2 New Technologies and Outreach

The main reference for the topic **(2) New technologies and outreach** is the work of Nidumolu et al. (2009) on the relevance of using sustainability as a driver of innovation, to which other subjects were added. Thus, the topic encompasses: resident companies (tenants) in the cleantech sector and/or with actual low carbon product/services; host of conferences, seminars and workshops related to sustainability; use of website, social media, and other channels to raise awareness on sustainability and climate change issues and solutions; visitors center to promote cleantech with regular visits from schools, foreign delegations, and general public.

### 2.1.3 Local Development

The main reference for the topic **(3) Local development** is the work of Wallner et al. (1996), with the basic assumption that the development towards sustainability can be introduced starting from sustainable 'islands', in which an island is an area where sustainability is reached at a local or regional level. In addition, Porter (1998) refers to the benefits of an economy based on the 'cluster' concept. To this list, the park managers added the importance of being active in the policy-making. Therefore, the category includes: permanent groups, labs or institutes for sustainability/climate change; leadership or participation in a green city development, cleantech/low carbon cluster and/or regional climate adaption plan.

## *2.2 Results*

### 2.2.1 Role, Enablers and Barriers

The survey results, held with collaboration of the International Association of Science Parks (IASP), allowed assessing the overall perspective of approximately 60 park managers in 30 countries on key issues such as the role of STP/AOI on sustainable development and perceived enablers and barriers for further action.

The survey respondents (sample or universe of analysis) included a substantial share (56 out of 276, or 20%) of IASP full members, meaning only STPs and AOIs fully operational. Mostly located in Europe (50%), but also Asia Pacific (16%), West Asia and North Africa (13%), North America (9%), Latin America (9%) and Africa (4%) (Fig. 2, Table 4, Annex 3).

Regarding the role in the sustainable development/low carbon economy (Fig. 3, Annex 3), only 7% believe it is restricted to traditional growth (business as usual), and to 16% it is only to comply with government environmental policy/regulation. On the other hand, 98% agree their role is to incubate cleantech and low carbon startups and Small and Medium Enterprises (SMEs), while 95% understand they should develop green projects (e.g. energy efficiency, green mobility, etc.).

When it comes to enablers for further action (Fig. 4, Annex 3), the STP/AOIs responded positively as being a driver of innovation (91%) and as a business opportunity (89%) while not as much to a sustainability/climate award specific to STP/AOIs (63%) and environmental pressure of stakeholders (e.g. NGOs, media, general public, etc.) (70%).

Regarding barriers for further action (Fig. 5, Annex 3), the lack of budget was identified as the main reason for not advancing green initiatives (86%) and environmental pressure of stakeholders is equally understood as an enabler and a barrier (70%). About the perceived value of having such a sustainability orientation, the respondents believe it is mostly recognized by the investors/shareholders (59%), followed by the tenants/clients (45%) and park managers (34%), respectively.

### 2.2.2 Management Practices

Considering the sustainability policies/forms of management (Fig. 6, Annex 3), the STP/AOIs have, mostly, an informal sustainability policy and related projects (61%), while others have additionally a formal (written) Sustainability Policy (39%). In some cases, this policy is followed by a specific plan with targets and indicators (29%), and it counts with a designated person or department in charge of this sustainability management (41%).

Regarding standards used to guide these Sustainability Plans, most of the respondents mentioned none (73%), followed by Global Compact (13%), the SDG—Sustainable Development Goals (9%) and others (5%). As examples of other standards there were environmental models at national level, customized standards (own STP/AOI ambitions) and ISO 14001. Specifically on climate change (Fig. 6), these plans involve mitigation (43%), adaptation (36%), both (34%) and none (55%). As an example, the Technoparc Montreal and the Utrecht Science Park plan to develop their sustainability policy and plan next year.

On reporting standards to disclose the sustainability performance, only one case (2%)—the Central Taiwan Science Park (CTSP)—declared to follow the Global Reporting Initiative guidelines (Year 2015—G4 version). Among the park highlights: “CTSP has been devoted to the economic development, social harmony and environmental protection (…) Currently, a total of seven buildings at CTSP were awarded with the Highest Ranking of EEWH—Green Building Label /Diamond Grade, three were granted Bronze Grade, eleven were granted Certified Grade, and one was granted the Green Factory from the Ministry of Economic Affairs. (…) Also, the cumulative amount of water saved in 2015 reached 1,038,279 metric tons, while electricity, also in 2015, reached 25,505 thousand kWh, showing our efforts of being environmentally friendly. (…) Under the objective of sustainable management, our belief and philosophy is based on the 'Unity of Production, Living, Ecology and Life', while on the other hand give considerations to environment sustainability and social harmony to actively create a friendly science park for coexistence and co-prosperity."

### 2.2.3 Green Initiatives

Considering the sustainability/climate initiatives, the (Fig. 8, Annex 3) demonstrates that comparing to the proposed framework of assessment, most of the practices are related to the first layer of complexity: the reduction of the own park/area impacts. For instance, most STP/AOIs replied having cycling paths, shower, and secure parking for bicycles and/or (non)electric bikes available for tenants and users (73%); waste recycling and/or composting (71%); use of virtual conference as an alternative for physical mobility (68%); green procurement practices (e.g. buying from local suppliers, preference for low carbon services/products) (66%); public transport (train, bus, etc.) options and incentive (66%); and renewable energy resources (e.g. solar, wind, geothermal) generated at the STP/AOI (55%).

In contrast, a smaller share of the respondents look for certified green infrastructure—roads, area, etc. (e.g. LEED, CEQUAAL) (32%) or certified green buildings (e.g. LEED, BREEAM) (46%).

Among the highlights of this category, there are:

**Highlight (1): Umwelt-Campus Birkenfeld (Germany)** Due to the extensive utilization of sustainable technologies, UCB is the first Zero-Emission Campus in Europe. Energy and heat are supplied by a neighboring biomass combined heat and power station, and the campus also counts with photovoltaic and geothermal energy, so that the final energy output-input balance is positive or close to zero.

**Highlight (2): Johanneberg Science Park (Sweden)** The headquarters received the Swedish Green Building Council GOLD certification, due to its design that optimizes energy efficiency and indoor health quality. Its several architectonic and technological features lead to an energy consumption <35 kWh/m$^2$/year, and the plan is to become carbon neutral. Furthermore, the building is set to serve also as a laboratory, in which future solutions can be tested in cooperation with tenants, suppliers and researchers (e.g. energy-smart solutions, direct current, solar panels, battery banks, microgrids etc.).

In relation to the second layer of complexity—new technologies and outreach—a significant part hosts conferences, seminars, and workshops on sustainability/

climate change (66%); use its communication channels (e.g. website, social media) to raise awareness on sustainability/climate change (59%); and have resident companies (tenants) in the cleantech sector and/or with actual low carbon product/services (55%). A smaller number report their visitors' center that informs schools/delegations/general public on sustainability/climate change (18%) or the host of external organization/representative related to sustainability/climate change (e.g. Climate-KIC) (20%).

**Highlight (1): University of Southampton Science Park (UK)** In a recent collaboration with its award-winning tenant, SEaB Energy installed onsite its compact anaerobic digester (MUCKBUSTER®), which is now delivering electricity from food and garden waste to the Science Park.

**Highlight (2): Utrecht Science Park (The Netherlands)** The 2014 international conference 'Smart Sustainable Innovation: The Global Perspective' was a joint initiative of HU University of Applied Sciences Utrecht (HU) and the European association Technology Innovation International (TII). The conference was preceded by a session on sustainable sciences parks, hosted by Utrecht Science Park (USP) and the Utrecht Sustainability Institute (USI), in which 171 participants from 15 different nationalities attended to the congress.

On the third layer of complexity—local development—the STP/AOI replied leadership or participation in a green city development (e.g. solar city), cleantech/low carbon cluster and/or regional climate adaption plan (43%); permanent group, lab or institute for sustainability/climate change (32%); active support for (new/existing) government policies on sustainability/climate change (beyond compliance); (30); and any other particular practice related to Circular Economy in local or regional level (e.g. exchange of waste heat or byproducts) (13%).

The highlights observed in this category are:

**Highlight (1): Gelsenkirchen Science Park (Germany)** The Science Park is the cradle of the Solar City Gelsenkirchen. The Science Park had a crucial participation as both symbol and catalyst of this development, representing a "metamorphosis" from a coal and steel city to a new-energies region. The initiative has inspired and evolved to the RUHR 2022 enterprise, a comprehensive and holistic approach to the climate metropolis.

**Highlight (2): Exeter Science Park (UK)** Exeter City Futures (ECF) is a joint endeavor between Exeter City Council, Exeter-based venture capital fund Oxygen House, and a growing list of business and public sector stakeholders. The ECF aims to develop cutting-edge approaches to city improvement through the use of technology and analytics, with the goal of delivering zero congestion and energy independence for Exeter in 10 years. The Science Park is an enthusiastic supporter of the initiative and has a period of exclusivity in place to negotiate the construction and leasing of the ECF headquarters in the Science Park.

### 2.2.4 Investment

Almost half of the STP/AOI are investing on sustainability/climate related projects (Fig. 7, Annex 3 (53%); only a fraction is generating revenues from such projects (24%). When asked about the origin of these resources, it is a mix of own finance (25%) and external funding (18%). Furthermore, regarding the respective source, it was replied private (7%); public (14%) and a mix of them (25%). To exemplify the range and diversity at this category, the Tsinghua University Science Park (TusPark) reported about 1 billion euros in investments; the TEHNOPOL Tallinn Technology Park reports having invested 150,000 euros so far in smart streetlights through the last threeD years; the Technology Park Ljubljana says their financial plan include yearly investments in "green" activities up to 10,000 euros; and the Parque Tecnológico São Leopoldo (TECNOSINOS) mention 125,000 dollars in total.

## 3 Discussion

According to Tom Mitchell (Director of the Climate-KIC, UK and Ireland and author of the Climate-KIC series on clusters) "the evidence suggests that bringing together physically organizations is helpful to improve the number of interactions and flow between different types of organizations (…) the core underpinning idea of a Science Park and its link to innovation is that you have more opportunity to creativity and creative collisions, networking, joint idea flows and cooperation if you are colocated in the same area or if that area is managed with that purpose in mind (…) an physical proximity helps build trust, and developing familiarity and personal relationships and all of those things are important for innovation."

To Richard Barker (Climate-KIC, Programmes Director) "it is all about creating an ecosystem for innovation and then the science park or area of innovation can assume some or many roles, depending on its positioning in terms of basic research and/or commercialization, but one key role should definitely be of connecting many actors."

He adds "it is a great opportunity to be part of a larger environment with progressive policy objectives like the Nordic leading cities (e.g. Gothenburg, Copenhagen, Stockholm) in order to coordinate the effort of basic research and commercialization. (…) as an example the Johanneberg Science Park, focus not on technology itself but on the mechanisms to develop its value chain. For instance, at the Buildings Technologies Accelerator (BTA), the exchange of knowledge is helping to in reduce systemic barriers to work on building retrofit. He concludes "if you are in an area where many stakeholders have the same objective and are willing to engage, the value of the Science Park increases because you are a part of a much larger ecosystem."

While colocation is a determinant factor, Richardson (Head of the University of Copenhagen Sustainability Science Centre) points out that the manner these arrangements can contribute varies, some types of parks/areas of innovation can provide tangible evidence through their physical infrastructure on how to reduce emissions and how our living standards can be maintained or improved while reducing resource use. Others such as the University of Copenhagen Sustainability Science Centre do not position themselves as physical entities to showcase their sustainability features, instead they mobilize research results into service for the community in its efforts to transition to sustainable development.

Another form to contribute can be observed iby the Fundación Hidrógeno Aragón based on the Walqa Technology Park, they produced a guide to help companies calculating their carbon emissions. The guide is also applicable to science/technology parks and considers the different climatic zones in Spain, where a pilot assessment was conducted, as explained by Jesús Simón Romeo (Head of the Technical Department at Fundación Hidrógeno Aragón).

To Katherine Richardson "we need to apply a systemic thinking towards sustainability—for example the SDG framework 'silo' or sector makes us 'blind' to the many societal co-benefits that some activities would have—even if they are not immediately economically viable. (…) because the primary enabler/barrier at the moment is, unfortunately, the economy. However, awareness is also very import."

Tom Mitchell adds to that by saying "social and cultural aspects will set the transition speed needed. (…) change is not going to be driven only by innovation or apps or whatever it might be, it is a lot wider than that (…) so, the challenge to a Science Park is to know the role it plays in the social fabric and how to foster the shift the communities need.(…) A good example of comes from Birmingham, West Midlands in UK in where science centers associated with companies are working with local school children helping they develop their own ideas on climate change and innovative approaches."

To mention another initiative, UK seeks to transform Birmingham into an 'Energy Capital', gathering key partners from academia, industry and the public sector, aiming to attract investment in smart energy technologies, research and infrastructure to deliver a wide range of economic benefits across the West Midlands Combined Authority (WMCA) region.

About the whole cleantech, low carbon and sustainable development debate Tom Mitchell believes "SP have an important role to play bringing together private, public and research organizations all of which are needed to tackle climate change. And the reason for that is that climate change does not naturally follow the law of a sector or disciplinary boundaries, it is not like a part of an industry like healthcare with defined markets where they have a long history of working in those aspects." He also adds that a Science Park focusing solely on cleantech is a secondary issue since, in his opinion, they should be good stewards of the environment anyhow. He says that now, at Climate-KIC they are discussing if it is more interesting for a Science Park to have a specific or broader set of innovations like battery storage, for instance. So they are we are still struggling with the optimum of level of specialization. His idea is that the SP should check its resources and work with the city to know its capabilities, so in that sense a narrow focus just on cleantech could be avoided.

As for the enablers to unleash a Science Park potential regarding a sustainability-related issues or any other, Tom Mitchell highlights three main aspects: long, loud and legal. Long to allow the investment community to plan. Loud to involve the leaders into action. And legal to scale up and reduce legal barriers.

On the subject of ‘long’, the Senior Adviser for Climate Innovation at the WWF International is skeptical “governments plays a determinant role in funding such environments, especially in early stages, but it is limited in terms of volume and reliability in the long term as funding priorities changes as well as the government itself.”

For the IASP (International Association of Science Parks) Board of Directors, Haofeng Lai (Asia Pacific Division President—Caohejing Hi-Tech Park—China) states “IASP and other associations of STP/AOIs could make full use of the network to spread the sustainability initiatives to the member parks all over the world. By holding forums focused on sustainability, IASP could encourage communications between the members where members may find new ways and ideas to improve sustainability. By enhancing the communication between the members, IASP could play an important role in optimizing the resource allocation and industry transformation, which help build a more environmental-friendly system in member parks. The carbon footprint could be a condition for new members to join IASP and assessment criteria for existing members.” Furthermore, STP/AOI could act as a doorkeeper when recruiting companies/projects, screening the business and investments, keeping the companies with a better carbon footprint. And convey the environment regulations to companies within the STP/AOI and guide the industry to allocate resources properly. As well as working with local government to reward the companies who reduce their carbon footprint by applying new technologies and improving their management.”

For him the barriers are the lack of effective communication channels between STPs/AOIs, pressure of economic growth requirements and large investment required to update infrastructures.

To Ali Motamedzadegan—WANA Division President (Mazandaran STP—Iran), IASP could “provide a sustainable system/environment is as the most active and globalized association by taking into account a new strategic plan, sharing ideas and experiences, opening special sections in conferences, offering more or better services/benefits, supportive internal policies, pushing local policies, focusing on new sources of energies, and environmental friendly technologies.”

While André DominTechnologiepark Heidelberg Director (Germany) points out “the topic is of such importance for mankind and is of concern to politics as well as supportive financial actions that IASP definitely has to play a major role”. He adds to that “STP,/AOIs, clusters and a rising number of SMEs as well as funds and global players will actively promote and strive for own actions to decrease $CO_2$ footprint (e.g. via zero/low emission real estate, projects, start-ups, corporate)”. The barriers he then identifies are “costs, business models, ROI, existing real estate behavior, tax, and legislation.”

Finaly, Mozhgan Yazdianpour Isfahan Science & Technology Town Director (Iran) says "if you think of 'sustainability initiatives' as guiding governmental and semi-governmental departments in policy making through expert driven research and analysis, then we as STPs/AOIs can work as facilitators. We have the opportunity and means to communicate the empirical consensus of different segments of the economy i.e. IT, ICT, Manufacturing, Biology, Energies, Green energies to our governmental authorities and decision makers. With this role, we make sure that the voice of the startup community is heard during the decision (policy) making process. This facilitation can help in shaping policies in favor of our start-up communities and ensure their growth and maturing. Strengthening our influence and ties with decision (policy) makers can help in the expansion of our role and the initiatives themselves. "Specifically on carbon emissions he argues "we can regulate the carbon footprint of our settled tenants and companies and provide an incentive basis program for the lowering of their quota. We can also look for and support our community entrepreneurs active in providing alternative methods to production that leaves less of a carbon footprint and also hold events like start –up shows with themes that promote the reduction of the carbon economy."

Among the enablers he highlights "public awareness events and start-up shows that promote the use of alternative methods for production, green and renewable energies; specialized incubators and parks for renewable energies; and creation of clusters dedicated to water and energy conservation." As for the barriers, he links "cost efficiency and public awareness."

## 4 Conclusions

The research presents a short introduction on the value proposition of science parks, a proposed framework for sustainability/climate change but it focus on the data collected on about 60 STP/AOIs of 30 countries worldwide and a series of interviews with experts and IASP Directors dealt in 3. Discussion.

In sum, they all agree that SP should play a more decisive role in the sustainable development/low carbon economy and that IASP as the most globalized forum representing the class, could become then more participatory and engaged in the process.

There is an important discussion on the several ways a STP/AOI can contribute. And an agreement that the social and cultural aspects are to be considered and put into practice if society is to speed up the change and make the necessary shift it needs.

However, there is not much agreement on the enablers that could facilitate this to happen. It ranges from investments to better tenant/start-up selection. Nor the barriers impeding it, ranging from cost, legislation and efficiency to public awareness.

## 5 Future Research

To mainstream sustainability and climate change in the STP/AOI community it is important to increase the level of exchange and knowledge among the parks, so they learn what are the available options and how the initiatives have been implemented in other contexts and how the managers rate its efficacy.

An effort to integrate these innovation players into networking and policy making could be beneficial not only for the abatement of greenhouse gas emissions and preparedness for climate impacts of the scientific infrastructure but also in the industry and economy due the interconnectivity of the supply chains and the catalytic effect of innovation.

Although the existence of a sustainability/climate award specific for STP/AOIs is not highly supported now, once it becomes recognized and desired among STP/AOIs worldwide it could foster a positive competition among them, with multiplier effect. It could be proposed awards for the different levels and categories presented in the framework of this study. In the same line, a sustainability scale would have to be created with corresponding weights and grades for each aspect with broad expert representativeness taking part in the election process.

Although different in nature, many good examples of sustainability initiatives are also found in business parks worldwide. Thus, a similar study could also apply to their case.

Furthermore, the interest in the sustainability/climate change subject, as verified in the above expected support for the survey for survey means that it could have an annual frequency, aiming for a greater regional representativeness, possibly with the participation of other park associations.

Ultimately, the expectation is that this research will not only advance the discussions on sustainability in STP/AOIs but also inspire and guide parks and policy makers in many countries for further action.

## Annexes

### *Annex 1. Framework of Contribution of STP/AOI on Sustainability/Climate*

See Table 1 and Fig. 1.

**Table 1** Categories of contribution of STP/AOI on sustainability/climate

| |
|---|
| 1. **Reduction of its own impacts** |
| 1.1. Own property |
| 1.2. Mobility |
| 1.3. Renewable energy |
| 1.4. Heat utilization |
| Green IT |
| Waste |
| Procurement |
| 1.8. Water harvest and reuse |
| 1.9. Green areas |
| 1.10. Adaptation |
| 1.11. GHG compensation |
| 2. **New technologies and outreach** |
| 2.1. Resident companies (tenants) in the cleantech sector and/or with actual low carbon product/services; |
| 2.2. Host of conferences, seminars and workshops related to sustainability |
| 2.3. Use of website, social media, and other channels to raise awareness on sustainability and climate change issues and solutions |
| 2.4. Visitors center to promote cleantech with regular visits from schools, foreign delegations and general public |
| 3. **Local development** |
| 3.1. Permanent groups, labs or institutes for sustainability/climate change research |
| 3.2. Leadership or participation in a green city development, cleantech/low carbon cluster and/or regional climate adaption plan |
| 3.3. Active participation or support for sustainability/climate policies |

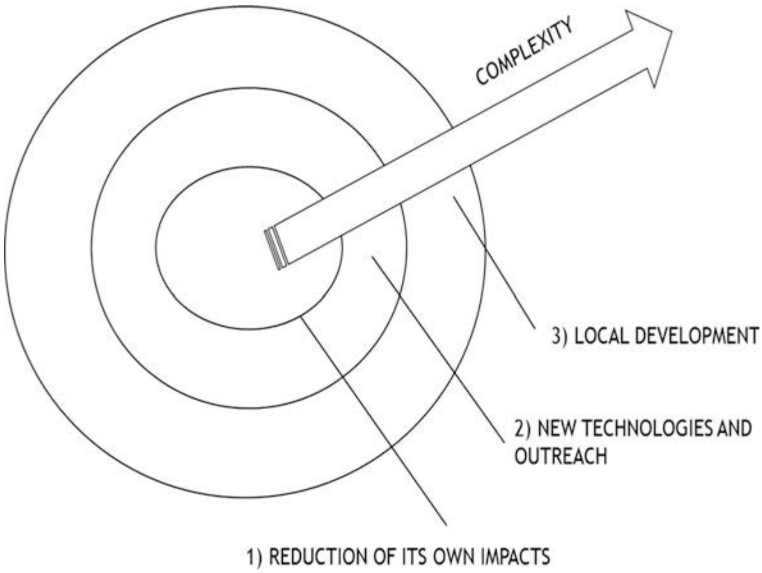


**Fig. 1** Representation of contribution of STP/AOI on sustainability/climate change

## *Annex 2. Acknowledgements*

Special acknowledgements to Alexander von Humboldt Foundation (Fellowship sponsor), IfaS (host institution in Germany), IASP's staff and members for all support with the survey.

See Tables 2 and 3.

**Table 2** Special acknowledgements

| |
|---|
| **Alexander von Humboldt Foundation** |
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| Haofeng Lai (President—Asia Pacific Division) |
| André H.R. Domin (Director—Technologiepark Heidelberg GmbH) |
| Ali Motamedzadegan (President -WANA Division) |
| Mozhgan Yazdianpour—Director- Isfahan Science & Technology Town (ISTT) -Iran |
| **STP/AOIs** |
| **Umwelt-Campus Birkenfeld/**Institute for Applied Material Flow Management (IfaS) |
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| Marco Angilella (IfaS—Sustainable Water project coordinator/Zero emission communities) |
| Jackeline Martinez (IfaS—Head of Projects in Latin America) |
| Christoph Pietz (Material flow management and zero-emission) |
| **University of Southampton Science Park (Southampton/UK)** |
| Robin Chave (Operations Director) |
| Peter Birkett (CEO) |
| Zane Clara (Senior Facilities Manager) |
| **Exeter Science Park** |
| **Gerry Shattock** (General Manager) |
| Samantha Chidley (Project Coordinator) |
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| **Mats Bergh** (CEO) |
| Eva Edman Pavic (Project Coordinator) |
| Lars Josefson (Cluster Manager, West Sweden Chemicals and Materials Cluster) |
| Ulf Östermark (Energy Manager) |

(continued)

**Table 2** (continued)

| |
|---|
| Zeno Winkels (Business Developer -Climate-KIC Nordic) |
| Björn Westling (Director of SME Relations) |
| Evdoxia Kouraki (Project Manager—Urban Development) |
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| Dr.-Ing. Sabine Wischermann (Projektmanagerin—Project Group on Future Energies) |
| **Utrecht Science Park** |
| Mieke de Bruin MA (Community Manager) |
| **Interviews** |
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| Eelco Van Ijken—Climate-KIC (Innovation Lead—Climate-KIC—The Netherlands) |
| Richard Barker (Director Programmes- Climate-KIC) |
| Dr. Tom Mitchell (Director—UK And Ireland, Climate-KIC) |
| Stefan Henningson (Senior Adviser, Climate Innovation, WWF International) |
| Jesús Simón Romeo (Head of Technical Department en Fundación Hidrógeno Aragón) |

**Table 3** List of IASP's survey respondents

| STP/AOI | Country | City | Regional division |
|---|---|---|---|
| Science and Technology Park of Crete (STEP-C) | Greece | Heraklio | IIASP Europe |
| Johanneberg Science Park AB | Sweden | Göteborg | IASP Europe |
| Feevale Techpark | Brazil | Rio Grande do Sul | IASP Latin America |
| University of Warwick Science Park, Ltd | United Kingdom | Coventry | IASP Europe |
| Associação Parque de Ciência e Tecnologia Almada/Setúbal - Madan Parque | Portugal | Caparica | IASP Europe |
| Polo de Innovación Garaia, S.Coop. | Spain | Arrasate—Gipuzkoa | IASP Europe |
| Kyoto Research Park Corp. | Japan | Kyoto | IASP Asia Pacific |
| Southern Taiwan Science Park Bureau, Ministry of Science and Technology | Taiwan (China) | Tainan City | IASP Asia Pacific |
| Technology Park Ljubljana | Slovenia | Ljubljana | IASP Europe |
| Parque Tecnológico de Andalucía | Spain | Campanillas (Málaga) | IASP Europe |
| Parque de Innovación de la Salle A.C. | Mexico | León de los Aldama | IASP North America |

(continued)

**Table 3** (continued)

| STP/AOI | Country | City | Regional division |
|---|---|---|---|
| Västerås Science Park AB | Sweden | Västeras | IASP Europe |
| Tsinghua University Science Park—TusPark | China | Beijing | IASP Asia Pacific |
| Parc Micro Sciences de Trois Rivières | Canada | Quebec | IASP North America |
| Bilkent Cyberpark | Turkey | Ankara | IASP Europe |
| Parque Tecnológico São Leopoldo—TECNOSINOS | Brazil | São Leopoldo | IASP Latin America |
| Parque Científico Tecnológico de | Spain | Gijón | IASP Europe |
| Knowledge Oasis Muscat (KOM) | Oman | Rusayl(Muscat) | IASP Wana |
| Fars Science and Technology Park (FSTP) | Iran | Shiraz | IASP Wana |
| Parque Cientifico-Tecnologico de Pando | Uruguay | Pando | IASP Latin America |
| Technopark of the JSC ELMA | Russia | Moscow | IASP Europe |
| University of Tehran Science & Technology Park | Iran | Tehran | IASP Wana |
| INNOPOLIS Foundation | Korea | Daejeon | IASP Asia Pacific |
| TEHNOPOL Tallinn Technology Park | Estonia | Tallinn | IASP Europe |
| The Surrey Research Park | United Kingdom | Guildford (Surrey) | IASP Europe |
| Innovation Place Research Park | Canada | Regina | IASP North America |
| Taguspark—Lisboa Science &Technology Park | Portugal | Oeiras | IASP Europe |
| Incubadora—Agência Inova Sorocaba | Brazil | Sorocaba | IASP Latin America |
| Kaunas Science and Technology Park | Lithuania | Kaunas | IASP Europe |
| Technoparc Montreal | Canada | Saint-Laurent, Québec | IASP North America |
| WISTA Management | Germany | Berlin | IASP Europe |
| Technology Park Malaysia Corporation Sdn. Bhd. | Malaysia | Bukit Jalil | IASP Asia Pacific |
| Mazandaran Science & Technology Park | Iran | Sari Mazandaran | IASP Wana |
| Kulim Technology Park Corporation Sdn Bhd | Malaysia | Kulim | IASP Asia Pacific |
| Central Taiwan Science Park Bureau, Ministry of Science and Technology | Taiwan (China) | Taichung City | IASP Asia Pacific |
| Poznan Science and Technology Park, Adam Mickiewicz University Foundation | Poland | Poznan | IASP Europe |

(continued)

**Table 3** (continued)

| STP/AOI | Country | City | Regional division |
|---|---|---|---|
| Mjärdevi Science Park | Sweden | Linköping | IASP Europe |
| Modares Science and Technology Park | Iran | Tehran | IASP Wana |
| PIIT Parque de Investigación e Innovación Tecnológica (Research Park) | Mexico | Monterrey | IASP North America |
| Joensuu Science Park Ltd | Finland | Joensuu | IASP Europe |
| Menai Science Park (M-SParc) | United Kingdom | Bangor | IASP Europe |
| Wroclawski Park Technologiczny S.A. | Poland | Wroclaw | IASP Europe |
| The Innovation Hub | South Africa | Pretoria | IASP Africa |
| Science & Technology Park of Kurdistan | Iran | Sanandaj | IASP Wana |
| Thailand Science Park | Thailand | Pathumthani | IASP Asia Pacific |
| Autonomous Institution of Khanty-Mansiysk Region "High Technology Park of Yugra" | Russia | Khanty-Mansiysk | IASP Europe |
| York Science Park | United Kingdom | Heslington | IASP Europe |
| Teknopark Istanbul | Turkey | Istanbul | IASP Europe |
| Gyeonggi Institute of Science and Technology Promotion | Korea | Suwon-si | IASP Asia Pacific |
| TECHNOPARK®-Alliance | Switzerland | Zurich | IASP Europe |
| Village des Technologies, de l'Information, de la Communication et de la Biotechnologie Mahatma Gandhi - VITIB | Ivory Coast | Région des Lagunes | IASP Africa |
| Ester Limoges Technopole | France | Limoges, Cedex | IASP Europe |
| Porto Digital | Brazil | Recife | IASP Latin America |
| Yazd Science & Technology Park (YSTP) | Iran | Yazd | IASP Wana |
| High Tech Campus Eindhoven | The Netherlands | Eindhoven | IASP Europe |
| Utrecht Science Park | The Netherlands | Utrecht | IASP Europe |

## *Annex 3. Survey Results*

See Table 4 and Figs. 2, 3, 4, 5, 6, 7 and 8.

**Table 4** Survey results—sample

| Region | Respondents | | Members | Sample (respondents x members) (%) |
|---|---|---|---|---|
| IASP Africa | 2 | 4% | 6 | 33 |
| IASP Asia Pacific | 9 | 16% | 6 | 18 |
| IASP Europe | 28 | 50% | 50 | 18 |
| IASP Latin America | 5 | 9% | 154 | 31 |
| IASP North America | 5 | 9% | 16 | 25 |
| IASP Wana (West Asia and North Africa) | 7 | 13% | 20 | 23 |
| | 56 | 100% | 30 | 20 |
| Total | | | 276 | |

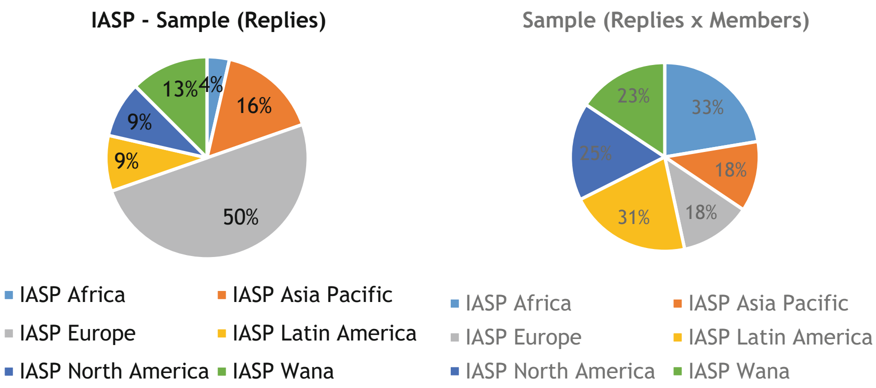


**Fig. 2** Survey sample

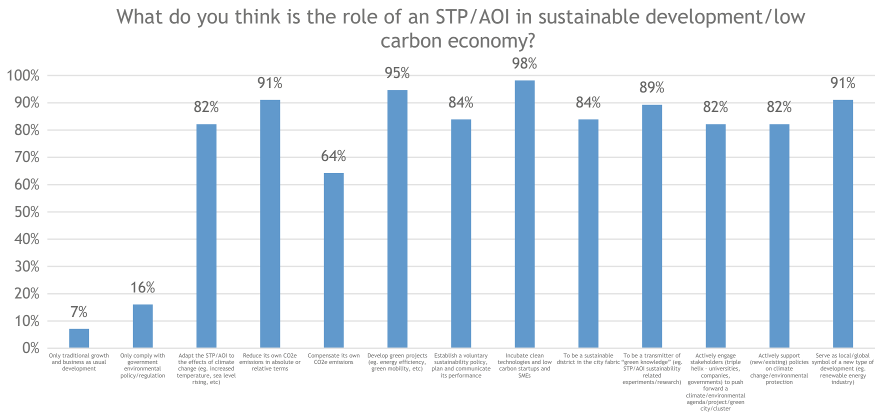


**Fig. 3** Survey result—the role of STP/AOIs in sustainable development/low carbon economy

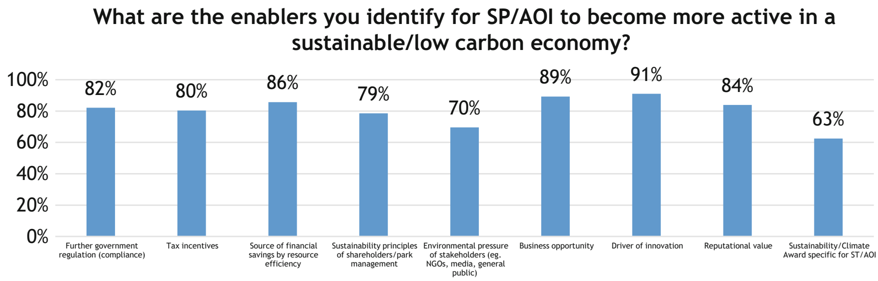


**Fig. 4** Survey results—enablers for STP/AOI to become more active in a sustainable/low carbon economy

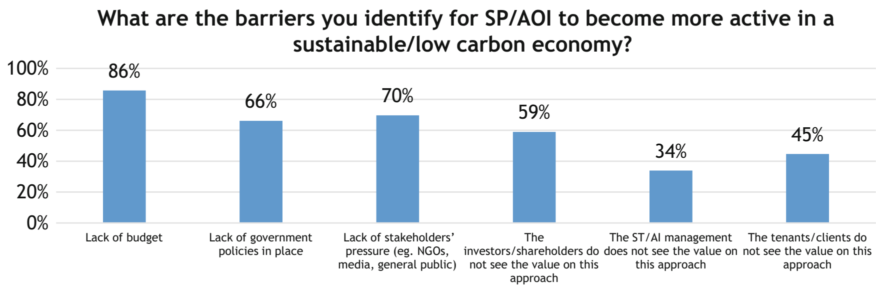


**Fig. 5** Survey results—barriers for STP/AOI to become more active in a sustainable/low carbon economy

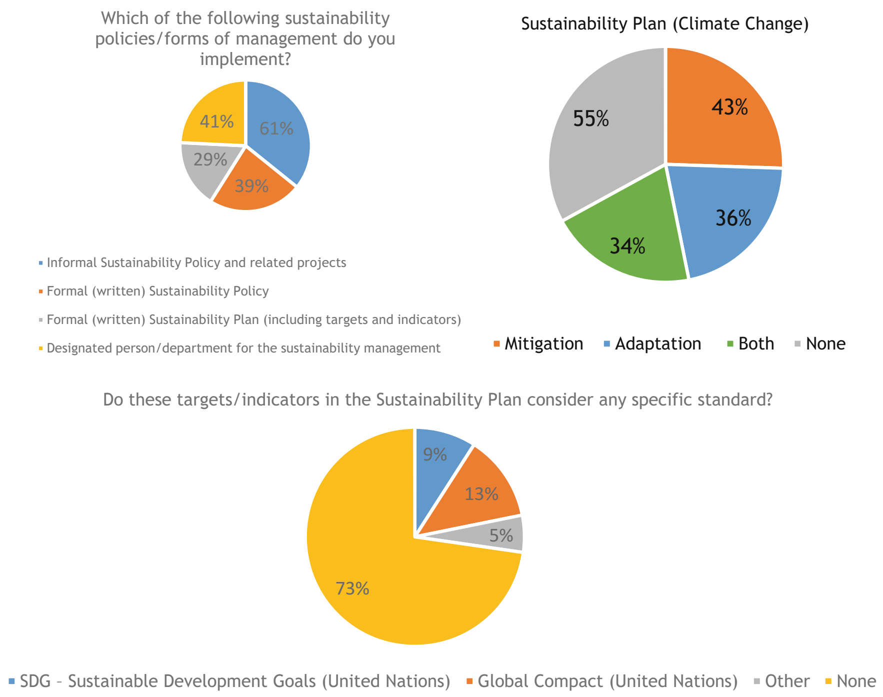


**Fig. 6** Survey results—management practices

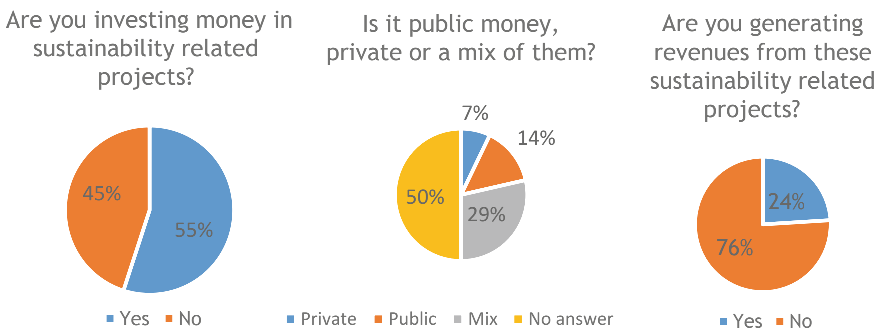


**Fig. 7** Survey results—investment

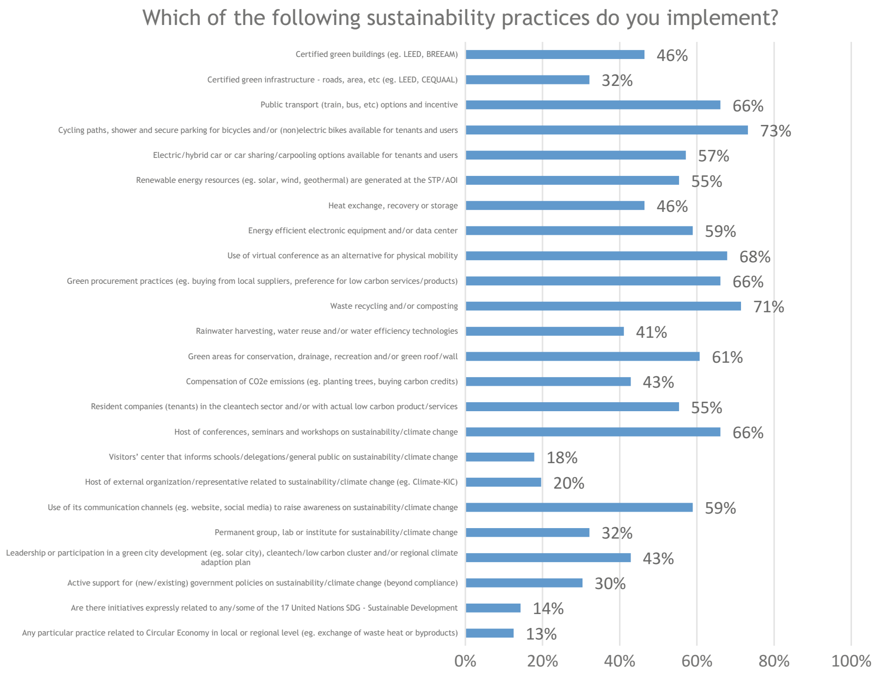


**Fig. 8** Survey results—green initiatives

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# Campuses in the Global South: Is Sustainability Possible Without Considering Social and Territorial Dimensions?

**Gabriel Mazzola Poli de Figueiredo**

**Abstract** Sustainable Campus projects usually focus on the campus itself and do not consider the social and urban characteristics of the surrounding area. This paper intends to study the case of the University of São Paulo (USP) and show that, in Brazil—as well as in the rest of the Global South—this can be especially problematic. One of the top Latin-American higher education institutions, USP lies adjacent to a *favela*, and the ever more frequent cases of sexual assault, theft, carjacking and robbery created an environment where the public perceive the *favela*-dwellers and other so-called outsiders as those responsible for making the campus a violent and unsafe place. The demand for security policies skyrocketed and the answer to these demands has been limited to surveillance, increasingly controlled access, reinforcing walls and other means to "keep the perpetrators out"—a segregative approach that this paper expects to expose as socially and ethically unsustainable. This paper provides new insights, based on USP's experience and context, to the importance of considering social and territorial dimensions of sustainability when working with campuses in the Global South. The study hopes to provide assistance to those interested in developing Sustainable Campus projects that consider their social and territorial context, valuing the role of higher education institutions in promoting community well-being and social change.

**Keywords** Sustainability · Favela · Global South · Campus

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G. M. Poli de Figueiredo (✉)
Faculdade de Arquitetura e Urbanismo, University of São Paulo, Rua Oscar Freire, 1546 apt. 203, São Paulo, SP CEP: 05409-010, Brazil
e-mail: gabriel.poli.figueiredo@gmail.com



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## 1 Introduction

The University of São Paulo (USP) is one of the most respected higher education institutions in Latin America. Its main campus, Cidade Universitária Armando de Salles Oliveira (CUASO) is located in São Paulo's southwest quadrant, boasting 3,650,000 $m^2$ and a daily circulation of around 90,000 people. It is home to dozens of graduate and post-graduate courses, over 30 academic buildings and several research institutes, museums, schools, student residences, sports facilities and a hospital (PUSP 2016). Frequently featured in rankings and lists, the competition to enter is fierce not only because of the university's prestige, but also because of tuition costs—in Brazil, while private institutions often offer costly education, public education is free.

USP's sustainability program is focused on using the campus as a lab for city technology to foster sustainable actions and pursue zero carbon emissions. This program's efforts have been led by twelve workgroups, each focused on an area deemed crucial to the institution's notion of sustainability—Water, Green areas, Sustainable buildings, Environmental education, Emission reduction, Energy, Fauna, Mobility, Waste management, Administrative sustainability, Land use, and Environmental policy (SGA 2017a).

At first glance, these workgroups seem sufficient to address most campuses' issues, but when USP's spatial and social context is considered, other concerns come to light. As several Brazilian public university campuses, USP lays adjacent to an informal settlement—a favela called São Remo (Fig. 1a–c).

## 2 The São Remo Favela and Its Relationship with USP

São Remo's history has always been closely intertwined with USP's own. In close resemblance to what transpired in Brasilia[1], the campus' construction required a cheap workforce for whom a temporary camp was built. What began as a temporary settlement became the basis of a permanent—albeit underdeveloped—occupation that grew into the São Remo of today. One could even argue that the favelas neighboring USP were a direct consequence of the unmet housing needs[2] of people working in the campus' construction and maintenance (Fig. 2).

[1]To understand how Brasilia was constructed dependent on government-created informal settlements (which became the main favelas Brasilia has today) and an impoverished workforce, see Ferro (2006) and Holston (1989).

[2]Maricato (1996) argues that a key aspect to understand Brazilian favelas and spatial segregation is that, while urbanization happened, minimum wage was never meant to suffice paying for housing. This lead to an unequal, excluding and precarious form of urbanization such as seen in Brazil's metropolis.

**Fig. 1** **a** USP (upper left) and **b** São Remo (upper right). Image & map data ©2017 Google. **c** São Remo in closer detail (bottom). *Source* USP Imagens

**Fig. 2** Construction of the campus' student residences. "Construção do CRUSP". Acervo Digital da USP, accessed August 3, 2017, http://200.144.182.66/acervo/items/show/205

Initially, USP sought to regain use of the land on which the settlement grew, but after decades of legal struggle, the university decided to give in and issued a usage concession to the families of São Remo. This was certainly a positive step, but the neighbors' relationship continued troubled by other conflicts. Rocha (2016) described how students, faculty and staff reacted to São Remo's resident's—especially children and teenagers—presence in the campus, clearly evidencing a general perception that they did not belong. She proceeds to explain this perception through Erving Goffman's notion of stigmatization, in which the stigma is not a characteristic a person possesses, but the fact that certain individuals, being expected to adhere to a set of standard, routine and structured behaviors and social roles, cause shock or surprise when their actions differ from those expectations. This is viewed as a transgression from norm and can be met with fear and animosity from others or even be purposefully used by the stigmatized as means of defense against the non-stigmatized.

The stigmatization of the favela's population persists until this day. The favela is criminalized, as the actions of a few represent the whole. Most of the crimes on campus are generally attributed to those people and there is a widespread belief that the favela is a pit of criminals, drugs and other threats (Garcia 2015; Oliveira 2007), even though many of its residents work—formally or informally—at USP (Piloto 2011). This is deeply rooted in racial, economic and social inequalities that express themselves spatially.

To illustrate the spatial dimension of this conflict, it is necessary to understand the profound sociodemographic gap that occurs in the frontier between these two territories. In São Remo, 65% of the population is colored and over half has an income of under two minimum wages (Cavalcanti; Silva; Vyunas, 2013 *apud* Rocha 2016). By crossing one of the only two available entrances—each a tiny guarded cage, by all effects—into USP, one will find an entirely different demographic (Fig. 3).

Although racial and economic quotas have recently been adopted, the entry exam—called *vestibular*—ends up being a strong socio-economic barrier: in 2016 63.6% of the new students came from private schools, 76.4% were white and 34.9% had a household income of over ten minimum wages, while only 28.7% came from

**Fig. 3** São Remo's entrance into USP. *Author* William Nunes

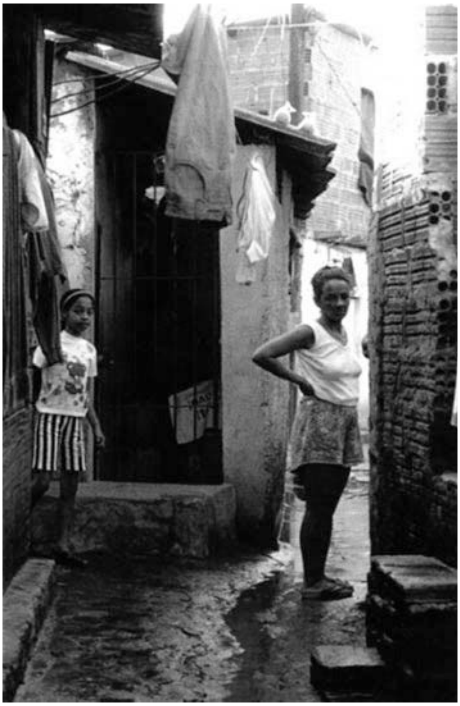

**Fig. 4** A portait taken at São Remo. 1995 *Author* Bethany Opalach

public schools, 16.3% were colored and 17.7% had a household income of three minimum wages or less (FUVEST 2016). Considering the teaching staff, in 2015 only 2% declared themselves black (Silva 2015).

To put this data in perspective, in Brazil 46.2% of the population is white, 52.9% is colored and 53.4% has an income of three minimum wages or less. In the metropolitan region of São Paulo, 59.2% is white, 39.1% is colored and 40.4% earns three minimum wages or less (CMSP 2013). Clearly, USP's population does not compose a representative portrait of Brazil's population—or even São Paulo's, for that matter (Fig. 4).

## 3 Unsustainable Campus

In this scenario, where a conflict—as symbolic as it is concrete in nature—manifests spatially between two very distinct demographics, a couple of questions seem worth considering: would surveillance and access control have a racial profile? Is it possible that access control could target demographics that *seem like they do not belong*? Could fear of being discriminated against by access control inhibit people from using these facilities to avoid embarrassment and the constant feeling of not belonging?

While technical potential is repeatedly—and wrongfully—presented as neutral and universal, every choice of sensor, operational routine and institutional value is the result of what is ultimately a political decision. It is imperative that the complexities of the conflicts and phenomena materialized in urban space be considered in the project's conception if its potential is expected to confront these issues. In this sense, technology plays a key role: São Paulo's office of public security, for example, is in the verge of implementing a program called Detecta (Paneghine 2015), which integrates databases and live video feed from the city's cameras to detect and prevent potential threats and crimes. What at first might seem like a reasonable idea soon turns sinister when taken into account the criteria used to identify suspicious behavior and what constitutes adequate means of preventing crimes. In São Paulo, the police traditionally practices racial and cultural profiling, and the vast majority of people killed by the police are young black males (Sinhoretto 2014). Improving the police's capabilities and situational awareness, without adequate discussion and reform of the underlying institutional values of the corporation could quite possibly lead to an increase in police violence and lethality against this and other marginalized demographics.

The frontier between the campus and São Remo is an iconic example of how the security policies of the university—ignoring these symbolic, social and spatial dimensions of the violence manifested on campus—often clash head-on with its very role as a public university and its future as a sustainable campus.

Before 1994, there was no physical wall around the university and the campus was an open public space. The constant presence of São Remo's children and teenagers around the campus, often doing informal work or playing around, was frequently pointed out as the cause of a general feeling of insecurity by the campus' population, linked to a rise in thefts and robberies. This prompted the dean to *build a wall around the campus, effectively materializing the already symbolic frontier between the two territories and their dwellers*.

In 1997, Daniel, a 15-year-old boy from São Remo, had gone swimming with his friends in the campus' rowing lake, when campus guards spotted and chased after them. The guards' version and the coroner report say that the boy dove to hide from them, got trapped in the mud and drowned. The other children, however, told a different story, in which the guards chased them, caught Daniel and beat him to death (Cabral and Oliveira 1997; Schivartche 1997). His body appeared floating in the lake four days later and, in anger and disbelief, the relatives and neighbors held an angry protest inside the campus, which ended with a bus and a car set on fire. The university's response was to *quick and covertly reinforce the controlled access point and put protocols in effect—forbidding children and teens to enter the campus after certain hours or on Sundays, for example* (Rossetti 1997) (Fig. 5).

In September 2016, history once again repeated itself as a young man was killed in a police operation at São Remo. After distraught residents entered the campus to protest and set a bus on fire (G1-SP 2016), *USP closed the access point, effectively walling off the favela's residents from the campus*. Soon after, residents tore a hole through the blockade and eventually USP gave up on the idea of closing the access


**Fig. 5** Boy painting the São Remo wall. 2011 *Author* Beatriz Montesanti

point, choosing instead to reform it, *building a new—reinforced and bulletproof—guard station*.

The segregative policies also manifest themselves in the institutes: in the last ten years, most buildings have installed cameras and identification checkpoints to avoid thefts and patrimonial damage, after students and faculty cried out against an ever growing feeling of insecurity and fear.

*Shouldn't security policies in a serious research and education institution such as USP learn from the knowledge produced by its own researchers and evolve beyond the segregative approach, in order to ensure long term sustainability and a more inclusive and diverse environment?*

Another example worth considering is mobility. One of the main directives of the mobility workgroup is equity (SGA 2017b). In 2012 USP had a major overhaul of its internal bus lines, which now serve as an integration with the external subway station. While the quality of busses improved (they are not maintained by the university anymore), and the connection to the subway is indeed welcome, this system is no longer free-of-charge as it was before.

Now only those with an institutional card, issued to students, teachers and direct staff, can enjoy gratuity in these lines. Outsourced employees, visitors, neighbors and others who desire to somehow use or enjoy the public space that is CUASO—in all considerations, rightfully theirs—have to pay a full bus fare of R$3,80 or a bus/subway/train/connection fare of R$6,80 (PUSP 2017a, b). Considering that USP is progressively outsourcing security, maintenance and other services to low paying contractors and considering the fact that minimum wage is presently R$937, this extra expense can be quite a burden on those lower income families, effectively establishing a paywall for the fruition of an essential service of a public university campus (Oliveira 2012) (JORNAL USP LIVRE 2012). When the large distances between institutes and the overall dimensions of the campus are taken into account, the burden imposed on those workers and families is even greater: the nearest subway or train station is in between 4.5 and 5 km walking distance, while a worker indirectly employed at the administration building would have to walk around 4 km from São Remo to his workplace, whether it rains or shines.

## 4 Campus Sustainability in the Global South

In Brazil—and in the Global South—cities are subject to severe social and economic inequality, making the role of the public university and its campus even more important, not only as a producer of high quality research focused on improving said cities, but also as a beacon of diversity, social justice and community outreach.

If the sustainable campus is meant to be a lab for prototyping city technology, it must recognize that cities have institutions—both formal and informal—that reinforce social, economic, gender, racial and spatial segregation. Urban phenomena such as favelization, spatial segregation, violence and (i) mobility involve vast amounts of often confusing or incomplete information, a large number of players with conflicting values and interests, and are so intertwined that their workings and ramifications have yet to be clearly understood.

It is unlikely that a sustainability model or framework that does not directly address the complexity of the social processes and conflicts reproduced in its territory, or that does so on vague terms, could promote any meaningful transformation in this complex context. Such model or framework would most likely aggravate the social divide instead of presenting positive change.

A model that addresses theses aspects could be within reach if it takes into account the social[3] dimension of sustainability, along with the territorial—or spatial—dimension. The Avizinhar program (Rocha 2016), implemented after Daniel's death in 1997, is a good example of a program that considered such dimensions. Whenever a conflict occurred between USP dwellers and São Remo's kids, the program's workers were called to mediate the resolution, often bridging the gap between the two populations' differences. This required knowledge from both realities, which could only be acquired first-hand, through experience, by working closely with the community. Rocha (2016) thoroughly describes the program's results in her work, which also signals another important policy that is slowly being implemented in USP: *diversity*. The perspective she offers, as a young black woman researcher, who lived in São Remo during her graduation at USP, is invaluable in deconstructing the barriers and distance between USP's academia and the population of São Remo. Perhaps if USP was composed of a more diverse population, the scientific studies and projects produced could be imbued with the actual knowledge on the social and territorial challenges that our cities present.

The very few good-quality quantitative or qualitative studies about São Remo's population, their history, their relationship to USP or even their thoughts, feelings and ambitions seems to be an important indicator of how blind the academia is towards the reality next door. This, in fact, could be considered the main limitation of this study. There is very little up-to-date information regarding the social practices of São Remo's inhabitants and their relationship to USP. This is due, in part, by the informal nature of the settlement and the progressive out-sourcing of USP's workforce, which lead to a more unstable environment that makes data highly

[3]For a review on Social Sustainability, see Dempsey et al. (2011) and Dillard et al. (2009).

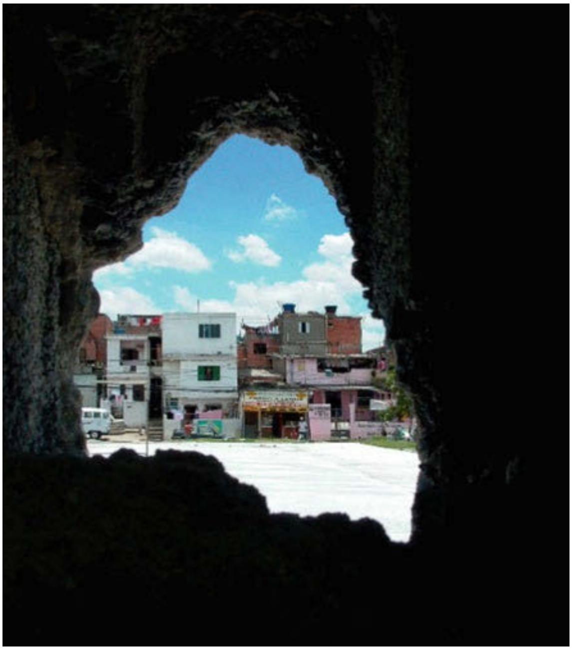

**Fig. 6** São Remo through the wall. *Author* Leonardo Sakamoto

time-sensitive. As first-hand structured interviews and quantitative data collecting were not possible due to time constraints of this study, further investigation is needed to assess the actual impact of the mentioned policies in the lives of the families of São Remo. Any such investigation or policy should be designed and conducted together with people from the favela in order to reduce the aforementioned gap between both communities' demographics and experiences—this is, by itself, a notable challenge that might warrant an investigation of its own (Fig. 6).

## 5 Conclusion

Cities in the Global South often face severe inequities and urban conflicts. These stem from deep and complex social phenomena and have a meaningful territorial component in the way they manifest themselves. In order for university campuses to be truly sustainable in this context, there needs to be an *active* effort to recognize the social and territorial dimensions of sustainability. It is unlikely that programs and policies that do not directly address the complexity of the social dynamics and conflicts—or that do so vaguely—could stimulate the development of transformative technology in such an intricate setting. They would most likely aggravate the social divide instead of presenting positive change.

In USP's case, social technologies such as diversity-supporting policies and conflict mediation between different communities have shown promise, albeit their slow adoption by the university has hindered their impact when associated with the consistent adoption of segregative measures in the fields of security and mobility, for example. Further research is required to accurately determine the effect of the campus' policies in the adjacent favela and to what extent USP could be considered sustainable. Evidence suggests, however, that it is paramount that higher education institutions—especially public ones such as USP—evolve beyond the use of segregative policies, in order to ensure long term sustainability, recognizing the campus' role as a beacon of diversity, social justice and community outreach in the harshly unequal cities of the Global South.

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## Author Biography

**Gabriel Mazzola Poli de Figueiredo** studies Smart Cities and their applications in the context of Latin-American cities. Currently a graduate student at the Architecture and Urbanism College at University of Sao Paulo (USP) under the advisory of Prof. Dr. Artur Simões Rozestraten, he coordinates a study & research group at USP focused on smart cities, technology and future urban scenarios.

Graduated in Electronic Engineering from the University of São Paulo in 2014, he is a certified project manager in development by APMG International and has been involved with social development projects since 2011, of which his main experience was having worked from 2013 to 2015 as a director for the NGO TETO in Brazil, a youth led Latin-American organization that works towards the promotion of community development in slums, fostering social awareness and action, and political advocacy.

In 2012 he represented Brazil and USP at the X Intel Cup—Embedded Systems Design Contest, in Shanghai. The presented project, an EEG brain controller module for an electric wheelchair, won a third prize.

# Sustainability Dimensions and Public Relations Practices in Public Health System

**Simone Alves de Carvalho**

**Abstract** The importance of this article is its objective to analyze the sustainability dimensions of the public health sector in Brazil, criticized for its economic, social and environmental planning. The methods used were analyzes of the official sector reports. As a result, we find that the areas of public health and public relations must have greater convergence, so the public will have access to the information they need. Finally, some practical measures such as planning strategic public relations promotes the recognition of the importance of the sector, the relevance of its activities, the reputation of its organs and the relationship with its different publics.

**Keywords** Sustainability · Public relations · Public health

## 1 Introduction: Public Relations and Sustainable Practices in Public Health

This article is important because it is the beginning of a research about the sustainability dimensions in the public health sector. As this research has just started we still have a long road ahead us. Our goal is to identify the use of these sustainability dimensions and whether they are disseminated using the principles of public relations integrated communication.

The analysis methodology used is the content analysis (frequency of occurrence of the terms) and the object of analysis are the Annual Management Reports of Ministry of Health, between the years 2011 and 2015.

S. A. de Carvalho (✉)
School of Communications and Arts (ECA), University of São Paulo (USP),
Av. Prof. Lúcio Martins Rodrigues, 443, Butantã–São Paulo, SP 05508-020, Brazil
e-mail: carvalho.simone@gmail.com; simonecarvalho@usp.br
URL: http://lattes.cnpq.br/0292256803545128



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## 2 Dimensions of Sustainability in Public Health in Brazil

To begin this research, we use the four sustainability dimensions principles, as proposed by the UN, namely: the social dimension, which refers to the empowerment of groups previously considered minor, diversity and inclusion, peaceful resolution of conflicts, and healthy living in society; the economic dimension, focusing on the rational use of natural resources used in the industrialization and supply of goods and services, financial and food support, and responsible and solidarity economy; the ecological dimension, which reflects on the relationship between man and nature, seeking to reduce the impact of the extractive relationship; and the holistic worldview, which thinks about the relationship of man to himself and to other living beings, with ethics and responsibility in those relationships.

These dimensions should be considered and applied in all sectors of human development, including public health, which is a concept that must apply these dimensions in their daily activities, since it is directly linked to all of them.

The concept of public health is not a consensus. Minayo (1998, p. 37) presents several meanings, important for the understanding of the health área, from the anthropological point of view: disease is the "pathological manifestation in biomedical language"; illness is the "subjective perception expressed in common sense language"; sickness is the "cultural expression of disease". Illness, for Sevalho and Castiel (1998, pp. 67–68) is equivalent to disorder or disease, while the "technical construction of disease as a disease" as well as in the "social construction of illness and economic-political that includes the phenomenon considered pathological" (Menéndez 1998, p. 90, 92). This myriad of meanings demonstrates the difficulty in creating a unique concept for health.

The definition of what is health is troubled, since it can be analyzed from different angles. According to Callahan, the World Health Organization defines health as the "state of complete physical, mental, and social well-being, and not merely absence of disease or disability" (Callahan 1973, p. 77). This definition is not fully accepted in all circles because it ignores that even though one may have a chronic illness, one can feel good, even physically. For Almeida Filho, "the feeling of health can not be illusory, a fleeting appearance, since the sense of well-being does not imply that the disease is effectively absent. The feeling of the disease, this yes, will be undoubted and without appeal: to feel bad would always mean lack of health" (2011, p. 14). Therefore, we must think about the dimensions of sustainability for public health within this profusion of meanings.

Almeida Filho's proposal to decode the meaning of health explores different dimensions of this, namely: problem, which discusses the science itself in this field; phenomenon, which defines as organic function, absence of diseases and incapacities; metaphor or idea, "ideological representation, structuring the worldview of concrete societies"; measure: "demographic and epidemiological indicators"; value, "social law, public service or common good, part of contemporary global citizenship"; praxis, "a set of social acts of care and attention to needs and needs of health and quality of life, conformed in fields and subfields of knowledge and practices institutionally regulated, operated in sectors of government and markets, in social and institutional networks"; and synthesis in "that one can not speak of health in the singular, but of several 'health', depending on the hierarchical orders, levels of complexity and emergency plans considered" (Almeida Filho 2011, p. 96).

These meanings go back to the social construction of the concept of health and public health, whose history has long been related to myths and religions, due to the lack of information on the origins of ills. In the West, it dates from ancient Greece and its mythology to the origins of words we currently use, such as hygiene and panacea (that remedies all evils). The Greeks worshiped, besides the divinity of medicine, Asclepius or Aesculapius, two other goddesses, Hygieia, the Health, and Panacea, the Cure. Hygieia was one of the manifestations of Athena, the goddess of reason; and if Panacea represents the idea that everything can be cured, it should be noted that healing for the Greeks was obtained by the use of natural plants and methods, not only by ritualistic procedures. On the other hand, Asclepius or Aesculapius, was associated with Apollo: muses and medicine, beauty and health (Scliar 1987, pp. 16–17).

In medieval Europe, where there were numerous cases of death, caused by plague and leprosy, the first shelters for the sick and destitute appear. The ineffectiveness of magical or religious procedures was compensated by charity. It was in the Middle Ages that the first hospitals—more appropriately hospices, or asylums—appeared, in which patients received, if not proper treatment, at least spiritual comfort. In regard to science, medical care and even hygienic measures there was distrust and even hostility (Scliar 1987, pp. 23–24). This scenario is being modified gradually, with the advance of the scientific discoveries in the health field.

Over the years, the social and economic scenarios have allowed improvements in the health field, with constant discoveries in the sector, such as penicillin, organ transplantation, less invasive surgeries and more detailed examinations. Every day, health presents technological innovations that influence its dimensions of sustainability and the communication of its activities.

## 3 Public Relations and the Dimensions of Sustainability

Public organizations in their different spheres should use public relations actions and strategies to improve their relationships with their stakeholders, which make up all social actors, in their different stands and purposes.

Initially, public relations planning was structured using the concept of integrated communication, as proposed by Kunsch (2003), which establishes the guidelines for internal/administrative, marketing and institutional communication, and, with this alignment, it is created the strategic planning. It is observed that in order to reach each public of interest, it is necessary to create a targeted strategic planning.

For Marcondes Neto (2017), public relations planning must be focused on achieving results, such as recognition, reputation, relevance and relationship. There is a need for integrated strategic planning again.

The public relations activities need a systemic vision of the institution and insertion in the dimensions of sustainability, independent of the sector. Some intrinsic factors are continuous education, stakeholder choices, including citizenship as an engaged participant in the process, and ethics. Corporate social responsibility emerged as a new field of public relations management at the beginning of the 21st century, offering some punctual solutions to unsolved problems by local political management, in exchange for strengthening its institutional communication.

The socially responsible company is based on the social, financial and environmental tripod. All these dimensions are directly related to those of sustainability, and those influence the good institutional development.

The Global Pact (2013) proposed by the UN must be respected inside and outside the institutions and its own cultures to ensure alignment with the dimensions of sustainability:

Human rights

1. Businesses should support and respect the protection of internationally recognized human rights;
2. Ensure their non-participation in violations of these rights.

Job

3. Companies should support freedom of association and the effective recognition of the right to collective bargaining;
4. The elimination of all forms of forced or compulsory labor;
5. The effective abolition of child labor;
6. Eliminate discrimination in employment.

Environment

7. Businesses should support a precautionary approach to environmental challenges;
8. Develop initiatives to promote greater environmental responsibility;
9. Encourage the development and diffusion of environmentally friendly technologies.

Against corruption

10. Businesses should combat corruption in all its forms, including extortion and bribery.

(UN 2000).

Public relations professionals who develop their profession in the public sector have the challenges of convincing the organizational leadership to accept and work within the framework proposed by the Global Pact; create and make available appropriate management reports, covering these dimensions; work strategically and integrally with other areas of the institution; and establish dialogues with the various stakeholders. In addition, the Codes of Ethics of the sectors involved should also be followed.

| Year/ Dimension | Social | Economics | Ecological | World view |
|---|---|---|---|---|
| **2011** | 0 | 0 | 0 | 0 |
| **2012** | 0 | 0 | 0 | 1 related to national development (p. 72) |
| **2013** | 0 | 1 "need to increase financial contributions to ensure the sustainability of these initiatives." (p. 80) | 0 | 1 related to national development (p. 65) |
| **2014** | 0 | 1 "a policy will be developed to encourage the marketing of Individual Plans and the monitoring of the economic and financial sustainability of the operators and impacts in the sector" (p. 72) | 0 | 1 related to national development (p. 73) |
| **2015** | 0 | 0 | 2 "technical cooperation the Sustainability - Sanitation and Sustainability in Rural Areas program, which aims to raise awareness among the population about the aspects of Health and Environmental Sanitation, with prioritization of the positive effects of the consumption of treated water" "promoting the sustainability of rural sanitation actions based on the involvement of the community benefiting from education actions in environmental health and sanitation" (p. 112) | 1 related to national development (p. 93) |

Source: created by the author based on the
Annual Management Reports of the Ministry of Health from 2011 to 2015

**Fig. 1** Quotations of the dimensions of sustainability—Keyword: sustainability

| Year/ Dimension | Social | Economics | Ecological | World view |
|---|---|---|---|---|
| **2011** | 0 | 0 | 0 | 0 |
| **2012** | 1 "to implement actions of basic sanitation and environmental health, in a sustainable way, for the promotion of health and reduction of social inequalities" (p. 88) | 0 | 0 | 2 (index) sustainable development (p. 72, 74) |
| **2013** | 1 "to implement actions of basic sanitation and environmental health, in a sustainable way, for the promotion of health and reduction of social inequalities" (p. 78) | 0 | 0 | 2 (index) sustainable development (p. 65) |
| **2014** | 1 "to implement actions of basic sanitation and environmental health, in a sustainable way, for the promotion of health and reduction of social inequalities" (p. 88) | 0 | 1 "promoting the sustainable use of biodiversity" (p. 69) | 2 (index) sustainable development (p. 73) |
| **2015** | 1 "guidelines for Sustainable Growth and Citizenship" (p. 109) | 0 | 1 "Promoting the sustainable use of biodiversity" (p. 88) | 2 (index) sustainable development (p. 93, 112) |

Source: created by the author based on the
Annual Management Reports of the Ministry of Health from 2011 to 2015

**Fig. 2** Quotations of the dimensions of sustainability—Keyword: sustainable

## 4 The Annual Management Reports of the Ministry of Health

These reports are free, unrestricted, can be found on the Internet in PDF format and are available in the Virtual Library of the Ministry of Health. These reports prioritize the financial dimension of the public health system.

What is striking is the lack of interlocution of the reported activities with the dimensions of sustainability—especially when we analyze the public health sector, which is umbilically linked to sustainability in all its spheres. Moreover, the lack of dissemination of this information is also highlighted, as it is important that such data are transparent to the general population. It is also interesting to observe how this report is evolving through the years in its quality. The results are synthesized in Figs. 1 and 2.

## 5 Conclusions

With this research in progress, we can continue to affirm the importance for integrated and strategic planning in institutional, internal/administrative and marketing communications of public and private organizations in the health sector.

Aligned with this need to obtain and maintain relationships, reputation, recognition and relevance, are the dimensions of sustainability, which should be based not only on the discourse of organizations, but also on their sectoral performance.

The Virtual Library of the Ministry of Health reports showed that the financial dimensions of the public health system are the priorities when it comes down to sustainability issues. However, it is known that only the financial worries are not enough to guarantee the success of sustainable initiatives.

As this article is the beginning of a larger research about the sustainability dimensions and public relations practices in public health system, we still have a long pursue in this work. For the next steps, the intention is to study how university hospitals deal with the sustainability dimensions.

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## Author Biography

**Simone Alves de Carvalho** is graduated in Public Relations, has a Master degree and is a Ph.D. student in Communication Sciences at PPGCOM-ECA-USP. She is also a certified ombudsman by ABO-SP, MBA in Business Management (FGV), a specialist in Advertising and Marketing (USJT) and in Management and Innovation in Distance Education (FEA-RP-USP). She has been working as a university professor since 2002.

# The Divestment from Fossil Fuels Movement and the Commitments Settled Within Universities—Proactive Examples in the Transition Towards Clean Energy

**Amália Simões Botter Fabbri**

**Abstract** Campaigns to the divestment from fossil fuels have been significantly increasing worldwide in an attempt to speed the transition towards clean energy. Several universities have already committed to divest from fossil fuels and to increase investments in renewable energy, as a new best practice to promote sustainability on campuses. This is the fastest divestment campaign is the history and the movement gained even more strength after the entry into force of the landmark Paris Agreement, that recognizes the urgency to tackle climate change, bringing nations to undertake their best efforts to combat its causes and effects. In light of this, this work investigates the divestment from fossil fuel campaigns, explaining its concept, aims, evolution, motivations and effects. Also, based on the movement's background and the commitments in place, a draft of an agreement to divest from fossil fuels and to support renewable energy, to be reached within universities, is proposed, by suggesting gradual targets and establishing a condition of no significant financial impact on academic activities. This paper is thus important because it shows what are the divestment campaigns and how educational institutions can participate in them in a reasonable way. In addition, the paper is important because it shows the agreement as a tool that might encourage society, private and public sectors to re-construct their practices in relation to the use of fossil fuels, increasing their support for low-carbon alternatives.

**Keywords** Climate change · Climate agreement · Fossil fuel divestment Universities

A. S. Botter Fabbri (✉)
Environmental Law Firm, Pires Castanho Environmental Consultancy, Rua Artur de Azevedo, 1767, 81/82, Pinheiros, São Paulo 05404-014, Brazil
e-mail: amalia.botter@gmail.com

A. S. Botter Fabbri
University of São Paulo Environmental Law Research Group (GEAMA/USP), São Paulo, Brazil

 
W. Leal Filho et al. (eds.), *Towards Green Campus Operations*, World Sustainability Series, https://doi.org/10.1007/978-3-319-76885-4_7

## 1 Introduction

Climate change is considered a global threat by the majority of the climate scientists and political leaders, as reflected in the IPCC Reports and the Paris Agreement that entered into force on 4 November 2016. Taking the burning of fossil fuels as the main factor to rising global temperatures, the reduction of fossil fuels' use is fundamental. Scientific studies have concluded that there are more fossil fuels on the ground than what can be burned in order to maintain the global temperature below 2 °C, which means that the current exploitation of fossil fuels is incompatible with the commitments to the temperature limit (Oil Change International Report 2016). Hence, changes on fossil fuels exploration and other measures to reduce GHG emissions are obligations that require immediate and proactive actions at all levels.

In this respect, campaigns focusing on the divestment from fossil fuel have been increasing especially within universities. Besides the advances of sustainability on campuses, through the implementation of good operational practices related to GHG emissions and energy consumption (Thomashow 2014), the campaigns claim that universities can go beyond by ceasing the support for companies that continue to expand activities related to the burn of fossil fuels and by increasing investments and partnerships with companies of renewable energy (Apfel 2015). The Paris Agreement was a significant, but a small part of the road against climate change, meaning that its success depends heavily on the climate movement influencing society, governments and the fossil fuel industry, which is exactly what the divestment movement aims to do. Thus, proactive actions are needed immediately at all levels and institutions, including universities, that are expected to support the transition process to clean energy by increasing awareness of the topic. After all, this one of the roles of a sustainable university:

> a higher educational institution, as a whole or as a part, that addresses, involves and promotes, on a regional or a global level, the minimization of negative environmental, economic, societal, and health effects generated in the use of their resources in order to fulfill its functions of teaching, research, outreach and partnership, and stewardship in ways to help society make the transition to sustainable lifestyles (Velazquez et al. 2006).

In light of this, this work will discuss the campaigns to divest from fossil fuels and the divestment agreements reached especially within universities, revealing that the pressure on the fossil fuel industry is growing. The paper will first explain the concept and the aims of the divestment movement. Then, it will address its historical evolution and the main motivations for the divestment movement, which can be divided basically into the scientific, ethical, legal and financial pillars. After that, it will discuss the effects of the divestment campaigns inside and outside universities. And, finally, it will finish providing a framework draft for a divestment from fossil fuel agreement that could be applicable to universities, without compromising its development. The paper is important thus to clarify what are the divestment campaigns and how educational institutions can participate in them in a reasonable way. In addition, it shows the agreement as a tool that might encourage society, private and public sectors to re-construct their practices in relation to the use of fossil fuels, increasing their support for low-carbon alternatives.

## 2 The Concept and Aims of Divestment from Fossil Fuels Movement

There have been some divestment campaigns throughout history, targeting the tobacco industries, the apartheid in South Africa and the violence in Darfur, western Sudan, for example. Divestment means to removal investments, such as stocks, bonds or funds, from certain institutions, due to prejudicial activities developed by them. More than that, some activists claim that divestment is to cease relationships, such as sponsorship and partnerships deals, with corporations related to activities whose effects threat nature and human well-being (GoFossilFree 2017a). Thus, divestment from fossil fuels means the removal of investment from companies dedicated to find and burn oil, gas, and coal, due to the harmful effects their activities cause to the climate system. Although the campaign seems to have financial purposes, it aims actually to discourage, delegitimize or stigmatize companies that are not putting efforts to the necessary transition to clean energy. By denying a social licence to fossil fuels burning, it intends to leverage the power of the fossil fuel industry in relation to policy change, to raise public awareness of fossil fuel impacts, to raise the financial market concern and to drive investments into renewable energy (Apfel 2015; Seidman 2015).

## 3 The Movement's Evolution: From Universities to the World

As well-known, universities have been playing an important role in the promotion of sustainability, which evolved through different segments, such as campus greening, research, teaching and curriculum, as mentioned by Disterheft et al. (2015). Taking the climate concern into consideration, universities have been developing climate and energy researches and educational programmes, operational measures and informational campaigns to reduce GHG emissions and energy consumption, green supply chain management, among others (Aronoff et al. 2013; Thurston and Eckelman 2011). Other examples are the establishment of climate action plans, as what happens in English universities that have to set a carbon reduction target for 2020 (HEFCE 2017); or the construction of universities' own energy centres, as happened at the University of St Andrews in Scotland, where their Kenly Wind Farm and the Guardbridge Biomass Energy Centre support the electricity of the campus, helping the country to achieve its objective of producing 100% of energy from renewable sources by 2020 (University of St. Andrews 2017).

Besides all these ongoing initiatives, however, students have been going further, bringing the divestment agenda to the universities, based on the main argument that investment policies are also important to tackle climate change and need to be in line with the sustainable measures and goals already in place within universities. The divestment from fossil fuel is, thus, a bottom-up movement started mainly by students within campuses on North American colleges in 2011. Today, there are 732 different institutions and more than 58,000 individuals that have already divested, representing around 5.45 trillion dollars in assets (Go Fossil Free 2017b). And as stated by researchers from Oxford University (Ansar et al. 2013), this movement has been showing the fastest growth in the history of divestment mobilizations.

Due to the alumni activism, the divestment from fossil fuels campaigns have spread through universities worldwide. There are 40 educational institutions fully or partially committed to divest in the US, 46 in the United Kingdom, 11 in the rest of Europe, 10 in Australia and New Zealand, and other 4 spread over continents (GoFossilFree 2017b)—though there are no universities committed to divest in Latin America, Africa or Asia, which is likely to be related to the lack of funds and other difficulties still faced by the higher education institutions in developing countries. Examples of institutions that have fully or partly divested are: University of Cambridge, Oxford, Columbia, Stanford, London School of Economics and many others remarkable institutions; and there are also students' organizations still seeking to compel high standard universities, such as the 'Divest Harvard' or the 'Fossil Free MIT'.

Besides the universities, the divestment movement has reached the financial mainstream, that starts to understand that investments in fossil fuel companies can be considered risky investments; in such wise, investors have been taking long-term economic decisions by establishing divestment strategies and looking for fossil-free options to invest (Carrington 2016). Between 2015 and 2016, the fossil fuel divestment funds have doubled to 5 trillion dollars and more than 80% of the funds have already committed to divest as reported at the end of 2016 (Arabella Advisors 2016). Among several examples, one that reflects a shift taking place is the Bill and Melinda Gates Foundation that has sold out around 85% of its fossil fuel investments at the end of 2016, although Bill Gates has said that fossil fuel divestment would be a "false solution" one year earlier (Carrington 2016). Similarly, in 2014, the Rockefellers Brothers Funds decided to divest around 50 billion dollars over a period of five years, despite the history of the family within the oil industry (Goldenberg 2014).

Furthermore, the divestment from fossil fuels movement has spread over other segments. One example is given by Allianz, the largest insurance company in the world, that decided not to invest in companies with more than 30% of its sales coming from coal mining or if more than 30% of its electricity relies on coal; the company will rather double wind energy investments to 4 billion euros (Associated Press 2015). Another case is the BMO Global Asset Management that decided to dump 20 million GBP of shares in fossil fuel firms, excluding companies with fossil fuel reserves from being part of its responsible fund's range, recently in May 2017. The Director of the Fund showed that an ethical motivation was also behind the decisions: "if all current known reserves are extracted and burnt, we know that the world would not meet the 2 degrees temperature limit established under the Paris Agreement. As such, we have come to the view that investment in companies with fossil fuel reserves is increasingly incompatible with the ethical and sustainability objectives of the responsible strategies range that we run", as reported by The Guardian (Collinson 2017).

Several cities and states have also decided to fully or partly divest, revealing that governments start to understand that investments in fossil fuel companies are financially or ethically risky. Some examples are: San Francisco, Berkeley, Santa Monica, Oakland, Seattle and Portland in the United States; Paris and other 30 cities in France; Oxford, Cambridge, Bristol, Berlin, Copenhagen, Stockholm and Oslo in Europe; Melbourne, Sydney, Newcastle in Australia; and there is also a whole country committed to divest, such as Ireland (GoFossilFree 2017b).

In addition, faith groups have divested, such as the Quakers (2016), the World Council of Churches (Arbib 2014) and the Islamic Society of North America (GreenFaith.org 2016). And there are ongoing campaigns in the health sector too, such as the British Medical Association that has committed to divest and is engaged with the campaign, by, for example, publishing the guide 'How to Divest a Health Institution' (Munro 2017). Similarly, there are cultural institutions ceasing relationships with fuel companies, such as the London's Science Museum, that has not renewed a sponsorship deal with Royal Dutch Shell (Vaughan 2015) or the American Museum of Natural History in New York City, whose policies encourage managers to consider climate risks and invest in renewable energy (Stoddard 2016).

Finally, it is worth mentioning that the United Nations have been welcoming the divestment campaigns, especially in relation to coal mines. In 2014, for example, the UN secretary general, Ban Ki-moon sent a message to investors: "Please reduce your investments in the coal- and fossil-fuel-based economy and [move] to renewable energy"; in the subsequent years, the position was reinforced (Carrington 2015, 2016). All these support and advances reveal an impressive evolution of the divestment from fossil fuels mobilisation.

## 4 The Pillars of the Divestment from Fossil Fuels Movement

Besides the origin and development of the divestment movement, it is important to consider the arguments behind the campaign, which can be divided into four main pillars: the scientific, the ethical, the legal and the financial, as explained below.

The first main pillar of the movement is the scientific studies that confirm that human activities are impacting the climate system since 1950 and the more it continues to happen, “the greater the risks of severe, pervasive and irreversible impacts for people and ecosystems” will be (IPCC 2014). Scientists have pointed out the need to keep the temperature below 2 °C in relation to pre-industrial levels, requiring “an urgent and fundamental departure from business as usual” (IPCC 2014). This means that the business such as the burning fossil fuels will have to change. According to the Oil Change International report (2016), the world’s carbon budget could be considered 800 gigatonnes, in order to the world have a chance of stabilizing the global temperature below 2 °C. However, the coal, oil and gas mines in operation already represent 942 gigatonnes of $CO_2$. Thus, the number of fossil fuels of the developed mines overcome the limit of exploitable fossil fuel, which means that the reserves that still waiting to be exploited will have to be kept in the ground. McGlade and Ekins (2015) have also estimated the percentage of how much of each kind of fossil fuel would have to be unburned to the stabilization of temperatures: approximately 82% of coal, 49% of gas and 33% of oil.

To worsen this scenario, scientists have already confirmed that there is a gap between the Intended Nationally Determined Contributions (INDCs), which are the parties’ proposals to reduce GHG emissions within the Paris Agreement, and the pathway that would be in accordance with the limits of 2 °C (Boyd et al. 2015). This shows that the climate targets are unlikely to be respected, based on the parties’ proposals. Hence, there is ground to believe on the necessity of further actions from sub-national and non-state levels (Rogelj et al. 2016), which leads to the strengthening of the divestment movement that calls for measures addressing the roots of GHG emissions: the fossil fuel business.

The second pillar of the divestment movement is essentially moral or ethical. As seen above, it seems that there is no alternative to fighting climate change rather than decreasing the extraction and the burning of fossil fuels. Therefore, the public and private sectors will have to make ethical decisions to respect the scientific findings. If there is no concern to protect current and future generations and no voluntary initiatives by fossil fuel companies or by the governments themselves, further actions are needed to encourage and pressure the shift in the energy sector. This gives space for other institutions to challenge the ethical use of money and the morality of decision-makers and powerful private institutions. In this regard, among the segments of the divestment movement, the educational institutions are highlighted as remarkable and trustful for their functions of critical thinking, investigating, teaching and informing. Ethical and consistent values are expected from them and, in this context, once more the divestment movement gain strength, especially in relation to educational institutions, that are considered sustainable when they “act upon its local and global responsibilities to protect and enhance the health and well-being of humans and ecosystems. It actively engages the knowledge of the university community to address the ecological and social challenges that we face now and in the future” (Cole 2003).

Also, there are legal aspects that are indirectly strengthening the divestment movement. Despite the lack of enforcement measures, the Paris Agreement constitutes a treaty according to the Vienna Convention, being binding upon the parties (Bodansky 2016), and these parties have been recognizing the climate goals through domestic climate legislations worldwide. Therefore, the absence of actions or actions against the climate goals has the potential to boost more litigation. And as stated in Article 2, 1 (c), the Paris Agreement aims to combat the threat of climate change, by, inter alia, "making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development" (UNFCCC 2015). This means that investments are expected to be in line with the movement against climate change. And the more it is postponed, the more the effects of climate change are felt and the more litigation is brought against companies and governments remaining in the opposite direction. As stated by Nachmany et al. (2017), the number of new climate lawsuits has been increasing each year and this is a trend due to the significant number of existing climate change laws (1200 in the world), that are being challenged and discussed in courts. This climate litigation reveals the risks to invest and engage with the fossil fuel industry in a legal perspective, which also gives the divestment campaigns ground to grow worldwide.

Finally, there is a financial aspect to be considered as a ground to divestment. If there is a legal climate agreement in place, based on scientific proof that burn of fossil fuels is a massive threat, there is a trend of governments to adapt plans, programmes and policies (PPPs), which necessarily might mean less incentives to PPPs involving oil, gas and coal, especially in countries that are ready to rely more on alternative sources of energy. Thus, concerning the shift to clean energy, "it is clear that this will require capital to be redirected away from fossil fuels" (Carbon Tracker 2017). In this scenario, the companies' stock markets have started to reconsider the true costs of carbon, in order to avoid a 'carbon bubble'. That is why financial institutions, such as the World Bank and the Bank of England, are studying the risks of inflated fossil fuel assets. Overall, it is possible to say that there is a now a real concern about the instability of the financial system and the problem that investors will face with stranded assets in the future (McKibben 2015).

Overall, the mobilizations taking place in universities are supported by the arguments above and especially in the belief that high educational institutions should play its part in the transition needed and that there is a moral controversy of promoting research on climate change and preparing people for the future by profiting from activities that will worsen climate change. This connection between the universities' purposes and actions was called by 'Toronto Principle' by Franta (2016), due to the process of divestment from fossil fuel in the University of Toronto (Toronto350.org 2015), and it implies that educational institutions have the responsibility to contribute to the Paris Agreement goals and can use their status to tackle clean energy.

## 5 Effects of Divestment from Fossil Fuels

Based on a report from Oxford University (Ansar et al. 2013), the financial impact of the movement can be considered small in relation to the companies' market capitalisation, the size of state-owned enterprises and the capacity of fossil fuel companies to look for other funds. After all, the stocks divested can be bought by others investors and thus the campaign would not represent a significant financial loss. However, the movement has potential to affect the industry's reputation, when there are no actions being taking in order to reduce the projects on fossil fuels and increase and improve projects of renewable energy. The previous divestment campaigns have shown that stigmatisation can affect the companies when they start to be rejected by governments, customers, suppliers, potential employees and also when shareholders start to demand changes in the companies' management and these reactions can weaken the powerful political dominance of these companies (Carrington 2013).

Therefore, the ones against the divestment could say that the movement is not financially impacting the fossil fuel industry. Also, they can say that companies' stigmatization could reduce the voice that educational institutions might have with the fossil fuel industry, as stated by the President of Harvard University, who decided to not divest Harvard from fossil fuels (Faust 2013). Another argument could be that there is an inconsistency in divestment from companies that provide products and services demanded by society, such as energy, technical facilities, clothes, beauty products etc. (Faust 2013). This could be worse especially in relation to developing countries that are still building their economies and could be negatively affected by the reduction of use of fossil fuels (Ridley 2015). The same idea could be reflected within universities that are still trying to develop and improve its systems, staff and operations in developing countries. These institutions tend to prioritize their growth, by investing and establishing partnerships with consolidated companies, such as the fossil fuels ones. Indeed, there are many different types of ongoing relationships between educational institutions and fossil fuel companies, such as sponsorships that cannot be suddenly disrupted to the detriment of research processes or students' development. Hence, the divestment process should be reasonable and gradual in order to mitigate negative impacts on fragile institutions, starting first with an attempt to engage and communicate with the energy sector to require actions towards renewable energy.

On the other hand, the ones in favour of divestment from fossil fuels point out that the movement is not suddenly ending up with the sector or immediate changing the society's reliance on their services and products. It is actually influencing companies to take more proactive actions and change strategies to speed the transition to clean energy, based on the scientific, ethical, legal and financial aspects mentioned in the previous section. In the view of institutions that have divested, the movement is raising society's voice and encouraging energy companies to reinvest and develop stable and accessible renewable energy. However, the businesses' strategies of the fossil fuel industry are still disconnected with the international climate agreement because they continue to spend billions of dollars in looking for additional oil and gas reserves to exploit, thus the movement has ground to grow and spread (GoFossilFree 2017a). In relation to the universities, there is a consensus that many other sustainable measures have been implemented and that divestment is only one of them, however, more universities have been adopting the movement, mainly due to ethical reasons.

Moreover, it is worth noting that the divestment movement within universities has been showing effects inside and outside the campuses. Internally, it showed that bottom-up initiatives can have a significant impact, by pressuring and changing the universities' governance. This kind of initiative reveals the power of students engagement and, as stated by Disterheft et al. (2015), "the political dimension of participatory approach in sustainability and can be seen as a field of learning of democratic values and encouragement to enact a responsible citizen role, as projected in Agenda 21". Also, the movement shows that the effects go beyond universities, raising public awareness, changing perceptions and engaging the community in the combat to climate change, as proven by the fact that different segments have adhered the campaign started within universities (financial, medical, religious). Indeed, the divestment commitments can strengthen the message that all parties need to take actions, influencing other public and private institutions to change their policies and maybe influencing individuals' actions to a more sustainable way of life.

All in all, it seems that if the divestment from fossil fuels processes develop reasonably and proportionally, without losing sight of the ultimate purpose of the global climate targets and also respecting the conditions of each institution, the movement is able to positively contribute to speed the solutions to climate change, in a confluence between organisational and policy responses (Linnenluecke et al. 2015).

## 6 The Divestment Commitments Established Within Universities

The tangible result of the divestment campaigns within the universities is the settlement of a divestment agreement or policies, which can be based on different contents and standards. Some universities divest from all fossil fuel companies, some from specific sectors (especially of coal and tar sands), some from specific companies, some only freeze new investments, divesting from existing holdings, some divest immediately or some divest gradually, based on different timelines and extents (Arabella Advisors 2016). In this last section, a framework for a divestment agreement is provided in an attempt to contribute to a reasonable divestment process that respects the capacity of each educational institution. In this regard, the proposal suggests gradual targets and is subject to the condition of no significant financial impact on academic activities.

This agreement could be signed between the University Direction, the Environmental Department Management, the Students' Union and others internal specific environmental groups possibly involved in the topic, remembering that, despite the difficulties of bringing all parties to a consensus, the more participation and transparency, the more legitimacy and chances of success the agreement will have.

Finally, it should be mentioned that the starting point for the proposal was a recent agreement reached on 8 March 2017 between King's College London (KCL), King's College Climate Emergency (KCCE) and the Students' Union (KCL 2017). However, different expressions and clauses were included, in order to make some aspects clearer and more complete. By any means, the proposal has the intention of exhausting all the possible clauses, neither taking all the possible different contexts into consideration. This is a framework to be adapted according to different circumstances and constantly developed pursuant further reflection.

**[University—*specify*] Agreement to Divest from Fossil Fuels and Support Renewable Energy**

Pursuant to the obligations established by the international climate agreement that entered into force in November 2016, which was based on scientific evidence brought, inter alia, by the Inter Panel Climate Change (IPCC) reports;

Taking into account the [*National/Regional/Local Climate Acts*—specify] applicable to the places where the campuses of this University are based;

In pursuant of the objectives of the [*Internal Environmental Policy*—specify], the [*Investment Responsibility Policy—specify*] and the previous commitments settled by the University in relation to the reduction of greenhouse gases emissions and the generation of clean energy [*if applicable*]; and

Recognizing the concern shared by this University community about the threats of human-induced climate change and the importance of the involvement of this University with actions that aim to contribute to the achievement of the climate targets;

The [*Parties*—specify] have agreed on the following points:

1. Divestment from fossil fuels means the non-promotion or investment in activities dedicated to find and burn oil, gas and coal and it is considered one of the measures that can be adopted in order to seek the reduction of greenhouse gases emissions, the main factor for climate change.
2. This University commits to divest from [*all or specific*] fossil fuels by the end of the year [*specify*], subject to the condition of no significant financial impacts on academic activities.
3. This University commits to reinvest the amounts that will be divested in renewable energy, including solar, wind and biomass and also to increase gradually its partnerships with institutions interested in the development of clean energy solutions.
4. The University [*specify department*] commits to analyse the possibilities of [developing/expanding] its own energy power centres with the purpose of generating renewable energy to supply the facilities on campuses;
5. The University commits to be 'carbon free', with the net emissions from its own use of fossil fuel being zero by the end of the year [*specify*], subject to the conditions of technologies available and accessible and no significant financial impacts.

6. The Parties commit to regularly [*specify frequency*] meet to discuss the advances towards delivering the targets, releasing the minutes of the meeting on an official website and informing the university community by e-mail and social media.
7. The University [*specify department*] commits to provide a formal annual consolidated report on progress and a target plan to each subsequent year.

This proposal is a legal-based contribution that can help educational institutions to clarify how they can start to divest from fossil fuels and to support clean sources of energy in a reasonable way. Also, it might encourage society, private and public sectors to re-construct their practices in relation to the use of fossil fuels, increasing their support for low-carbon alternatives.

## 7 Conclusion

The divestment from fossil fuel campaigns have been raising the necessity to speed the transition to a low-carbon global economy, based on scientific evidence, ethical values, legal agreements and financial risks related to the adverse effects of climate change. This student-led movement started within college campuses, but has now spread to several educational institutions (40 in the United States, 46 in the United Kingdom, 11 in the rest of Europe, 10 in Australia and New Zealand, and other 4 spread over continents (GoFossilFree 2017b), faith groups, philanthropic organizations, governments, pension funds, insurance companies and healthcare associations worldwide, being the fastest divestment movement in the history.

As high centres of education and science, universities should play their part in the changes needed to reduce the burning of fossil fuels and to build clean energy sources, taking ethical decisions to encourage private institutions and policymakers to raise awareness and encourage different sectors to adopt proactive strategies. This is part of the role of sustainability in universities that have a special responsibility to enhance the protection of humans and ecosystems. It is worth of mention however that the transition towards clean energy requires time, planning and accessible technologies, reason why the divestment from fossil fuels process within the universities need to be gradual, respecting the context and conditions of each institution.

In an attempt to contribute to reasonable processes, agreements to divest from fossil fuels and support renewable energy are proposed, willing to contribute to the global and regional climate agreements and, at the same time, to respect the financial capacity of the universities. The main objective of the divestment agreements is to reduce progressively the universities support for the use of fossil fuels and to strengthen the investments in renewable energy, an emergency measure needed to tackle climate change. For this purpose, the draft provides an agreement that suggests gradual targets and is subject to the condition of no significant financial impact on academic activities. Perhaps the gradual proposal will encourage more institutions worldwide. This is a reasonable constructive step among many others that can be taken in this fraught path to a low-carbon society.

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## Author Biography

**Amália Simões Botter Fabbri** is a Brazilian qualified lawyer, working with environmental law since 2006. She is an LL.M Candidate in Environmental Law, focused on Energy/Natural Resources, at Queen Mary University of London (QMUL). She is a Researcher at the University of São Paulo Environmental Law Research Group (GEAMA-USP), Brazil. BA Geography Degree, from University of São Paulo (USP). LL.B, with honour, from Catholic University of São Paulo (PUC-SP). She is also a teaching assistant on Environmental Law and Environmental Licensing modules at PUC-SP.

# Arts-Based Approaches for Environmental Awareness in University Campuses

**Andressa Schröder**

**Abstract** The role of aesthetics and arts-based research to address environmental problems has slowly been incorporated in the debates about sustainability. Its visibility is though still small, or, in some cases, holds a misguided conceptualization. Through practical examples, this papers aims to explore the potentials that aesthetics and arts-based approaches have to strengthen inter- and transdisciplinary dialogues in relation to environmental problems and to increase environmental awareness at the individual and collective levels. If university campuses are considered as 'living labs for connecting the nexus energy, climate and sustainable development', it is a necessary step to consider the dynamics of the people (living organisms) that circulate in these areas; how they interact with each other and the surrounding environment; as well as the inner/embodied aspects of sustainability which compose their perception of the environment. Furthermore, it is fundamental to find creative forms in which awareness and engagement towards the environment can be enhanced and improved. Aesthetics and arts-based research play a key role in instigating alternative, imaginative, and new possibilities not only to integrate sustainability in university campuses, but also to generate environmental awareness and enrich the debate for an ecological citizenship.

**Keywords** Arts-based research · Environmental aesthetics · Inter- and transdisciplinarity · Sustainability · Permaculture

A. Schröder (✉)
International Graduate Centre for the Study of Culture—GCSC, Justus Liebig University Giessen, Alter Steinbacher Weg 38, 35394 Giessen, Germany
e-mail: Andressa.Schroeder@gcsc.uni-giessen.de



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## 1 Introduction: Emergent Sustainability in University Campuses and Transdisciplinary Concerns

The pressing symptoms of environmental degradation have generated multiple forms of concerns and responses from a large ambit of social organizations and institutions. Since the 1970s and more prominently after the report *Our Common Future* issued by the World Commission on Environment and Development in 1987, sustainability has emerged as one of the most debated strategies in search for more balanced relationships between humans and nature. In academia, the topic has been turned into a new field of research, *sustainability sciences* (Jones et al. 2010; Disterheft et al. 2013). This new field of research has emerged in the late 1990s and beginning of 2000s with the intent to "investigate the complex and dynamic interactions between natural and human systems and how these can be transformed in a sustainable way based on a long-term perspective" (Disterheft et al. 2013). However, the concept of sustainability was framed under a narrow definition that compromised meaningful efforts for collaborative research and for the integration of unconventional forms of knowledge and non-academic participation. The boundaries of sustainability sciences have slowly been challenged and expanded to integrate interdisciplinary and practice-oriented methodologies, as well as transdisciplinary thinking processes that are open for the integration of non-conventional knowledge and methods, participatory research and cooperation with non-academic stakeholders (Lang et al. 2012).

There are, however, different forms in which the topic of sustainability in university campuses can be thought of and in which it is usually approached. Common approaches address aspects of the sustainability sciences, creating and investigating programs of Education for Sustainable Development (ESD),[1] what their agendas comprise and the variety of courses offered in them. Other approaches address measures adopted by the universities and higher education institutions in order to reduce their environmental impact, like alternative energy generators, food and waste management projects, among others (Lozano et al. 2011). This paper seeks to explore yet another dimension of the integration of sustainability practices and concerns in the academic environment through considerations of environmental aesthetics and arts-based research. This dimension is reflected in the two previous approaches and it integrates important characteristics of participatory methods to increase awareness and generate responsibility towards the environment. It has the potential to enhance levels of self-reflection and imagination and to instigate the inner dimension of sustainability, which encompasses embodied knowledge and multisensorial environmental perception. Although such levels of sustainability are

[1]ESD has grown as an influential definition for the standards of international education for sustainable development, internationalized and institutionalized through the Agenda 21 issued by the UN Earth Summit in Rio de Janeiro (UNCED 1992), the UNESCO report "Education for a Sustainable Future" (UNESCO 1997), and the launch of the UN Decade on Education for Sustainable Development (2005–2014).

not measurable in the same sense as the effects of pro-environmental actions implemented in, for example, campuses governance, they are part of an important dimension of the processes of identification and engagement with sustainability.

Through the investigation of a few examples, this article indicates the role of environmental aesthetics which is intrinsic to many approaches to environmental issues, but which is not always considered as a fundamental element of the environmental thinking and research. Thus, many times it is misinterpreted and reduced to the analysis of superficial and formal qualities of design, landscape appreciation, or as marketing strategies to seduce and entertain. In this article the emphasis lies on examples of arts-based projects for the implementation of sustainability on campuses, or examples that can be read as arts-based projects (even though they might not have been explicitly designed as arts-based ones). However, it is important to highlight that the aesthetic quality of perception and experience is not limited to artistic practice or appreciation, nor, in these cases, to arts-based methods. Aesthetic qualities can be perceived in different forms of interrelations (of humans among themselves and with the environment) and its significance is therefore expanded to multiple areas of social and environmental concerns (Berleant 1991).

## 2 Initial Considerations About Arts-Based Research and Environmental Aesthetics

Before going into the analysis of the specific examples of projects concerned with sustainability in university campuses, there are a few considerations about arts-based research and environmental aesthetics that should be indicated.

The focus on arts-based research has been growing in different fields of academia, mainly since the 1990s and there are different ways in which it can be interpreted. In a more conventional sense, it can be understood as the analysis of "artistic products" through qualitative methods adapted from other disciplines, as in examples of readings and interpretations of objects of art that help to fundament theories in art history, anthropology, or psychology—research *about* art. Another way to think arts-based research, which has been growing mainly in the social sciences, is using art as a method of research to analyze different kinds of social and cultural phenomena—research *with* art. This approach has been common in for example visual anthropology, cultural geography, or various areas of research in education (Pickering 2008; Knowles and Cole 2008; McNiff 2013). A third approach to arts-based research is considering the very process of artistic and creative thinking as a form of research method—research *through* art. This focus has been growing mainly in practices of art therapy and art education (McNiff 2013; Hernandéz 2013; Barone and Eisner 1997), but there have been scholars from other fields also interested in artistic thinking as a research method, also in ecological and sustainability research (Kagan and Kirchberg 2008; Curtis et al. 2014; Dieleman 2013; Kagan 2011). Furthermore, considering that many artists over centuries have held the habit of writing about their creative process and have in many situations collaborated with other professionals, this is not such a new approach. Despite of that, all of these forms of arts-based research bring forward important characteristics of the artistic practice and interpretation and they highlight the evident interdisciplinary essence of arts-based research. Besides, they are not mutually exclusive and different methods of arts-based research can be simultaneously applied or identified.[2]

In relation to sustainability, it is possible to identify different levels of concern with arts and aesthetics, ranging from more instrumental approaches, as for example the aesthetic qualities emphasized in sustainable design and architecture, to techniques that arouse the sensibility to the surrounding environment, as in sensorial, self-reflexive, and imaginative methodologies. These characteristics are further explored in the examples analyzed in the next section of this essay.

Environmental aesthetics is also an important dimension of environmental experience. The philosopher John Dewey defined aesthetics as a fundamental element of the experience of an organism embedded in its environment in a fluid rhythm that affects both (1934). Following Dewey's pragmatic conceptions of the aesthetic experience, the philosopher Arnold Berleant examines the environmental aesthetics as an experiential and sensorial perception that strengthens our sensory capacity, which is integral to this fluid exchange and continuity between organism and environment (Dewey 1934; Berleant 1992). He emphasizes, therefore, that environmental aesthetics is not related only to the superficial qualities of the world. In other words, it does not concern only landscape, design, or architecture appreciation. On the contrary, environmental aesthetics is intrinsic to the conditions in which humans (as living organisms embedded in their environment) perceive, participate and engage with the world around them (Ingold 2000). Therefore, "an aesthetics of the environment profoundly affects our moral understanding of human relationships and our social ethics" (1992, 12) and it is a fundamental step to recognize an expanded role of aesthetics in debates about environmental issues in order to overcome the common instrumentalist limitations attributed to it.

In this sense, aesthetic perception and appreciation can be perceived as the outcome of a complex and continuous process of multisensorial interactions and experiences (Merleau-Ponty 1962, Ibid. 1968), involving also imaginative capacities (Brady 1998) and constant processes of transformation (Deleuze/Guattari 1987 [1980]). Furthermore, aesthetic perception is always contextual, timely and culturally situated. The psychologist, curator, and activist Adrienne Goehler also defines aesthetics as the "consciousness of the senses […] the participation of all senses in feeling, perceiving, and fashioning the world. Here, the arts have to be understood as agents of aesthetics, and artists increasingly as the procurators of social perceptivity" (2012). Thus, there is a fundamental role to be played by artists

[2]I have developed a more thorough reflection about the different forms of arts based research identified here as research *about, with* and *through* art, in another paper of mine. (Schröder. *The Integrative Potentials of Arts-based Research for the Study of Culture*—forthcoming 2018).

and the arts in interdisciplinary approaches to environmental problems and solutions in order to initiate the process of recognition of the aesthetic dimension withheld in environmental experience.

## 3 Engaging Aesthetically with Sustainability in University Campuses

### *3.1 Arts-Based Environmental Education: Merging Science and the Arts*

Pioneering efforts to merge arts and environmental education can be identified in the historical paradigm shifts of the Finnish school system. In the 1960s and 70s there was a shift in the Finnish curriculum for art education away from a formalist focus to a cultural and semiotic approach in which environmental problems were perceived as part of a political, cultural, and economic net and therefore as integral elements of the cultural and semiotic aesthetic perception and artistic education. Environmental education was, in this sense, also perceived as involving matters of political, social, ethical and aesthetic importance, besides its ecological, scientific and technological dimension (Pohjakallio 2007). Throughout the decades the bases for this merging and the significance of the environment for art education, as well as the arts for environmental education were reconsidered and the relation between the disciplines was constantly modified.[3] Nonetheless, this pioneering investment in combining arts and environmental education enabled a wider understanding of environmental aesthetics and of arts-based environmental research to emerge within the Finnish education system.

The concept of arts-based environmental education was coined by Finnish scholar Mantere (1998) and was intended to emphasize the processual condition of education instead of framing it as a static content or a goal to be achieved. Besides, Mantere “stressed that ecological thinking and action should be regarded as the guiding principle of all education and that art can bring [them] new forms” (Pohjakallio 2007, 7). In identifying environmental thinking and action as the guiding principles of all education, Mantere not only highlights the all-encompassing dimension of environmental education, but also indicates the implicit interdisciplinary characteristics and requirements of environmental education. Arts and aesthetics can, in this sense, also be understood as an all-encompassing dimension of environmental appreciation, thinking, and action, in a similar sense as it has been highlighted by Berleant (1992).

Following this tendency to integrate arts-based research to environmental education already existing in the Finnish school system for practically 50 years, in the

[3]In the 1980s the focus on environmental education within the arts lost its strength and it came back into the curriculum in the 1990s. More about this process can be read in Pohjakallio, 2007.

beginning of the 21st century there were some significant efforts in the Finnish higher education system to include an interdisciplinary agenda to address environmental issues and education. The recognition of the role of the arts has been prominent and one good example of these efforts was the creation of the Aalto University in Helsinki, which was established through the merging of three major Finnish universities: the Helsinki University of Technology, the Helsinki School of Economics, and the University of Art and Design Helsinki.[4] The efforts taken at the Aalto University envisioned the combination of the arts and sciences in order to instigate interdisciplinary and cooperative projects, where the arts worked as a unifying agent.

The Aalto University has propitiated the advancement of the *Research Group for Arts-based Environmental Education*,[5] which was initiated by the University of Art and Design Helsinki. This group worked as a platform to increase the visibility and importance of arts-based environmental education. It also provided the dynamics for the development of new methods and concepts for environmental education through the arts, as well as a space for scholars to share their practices and experiences. The research group performed several collaborative projects with international artists and scholars, exploring cutting edge fields of research on topics like creative processes, environmental awareness, wellbeing, and human interaction with nature. Unfortunately, it seems that the group has not been active since 2015, however, it is possible to follow the documentation of the projects and respective outcomes in their website.

Furthermore, the Aalto University has recently created a new Master's Program on *Creative Sustainability*, unifying students from the School of Arts, Design and Architecture, the School of Business, and the School of Engineering. The aim of this joint program is to address current environmental challenges through a "multidisciplinary learning platform [in order to] increase understanding of different disciplines and enable adapting a holistic approach."[6] The conceptualization of the program holds a rather utilitarian perspective on the role of the arts and aesthetics. Nonetheless, it is an enriching step to encourage collaborative research and allow for interdisciplinary dialogues to emerge in relation to environmental problems and solutions.

Another instigating effort to rethink sustainability on campus and the role of the arts and aesthetics at the Aalto University can be tracked in the current plans for the amplification of the Otaniemi Campus in Espoo.[7] The campus is being restructured to hold all the main activities and schools of the Aalto University by 2021.

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[4]More information about the formation of the Aalto University may be found at: http://www.aalto.fi/en/about/ (last access 05/27/2017).

[5]More information about the project is available at: http://www.naturearteducation.org (last access 05/27/2017).

[6]Information available of the website of the MA Program: http://acs.aalto.fi/ (last access 05/27/2017).

[7]Information about the campus can be found at: http://www.aalto.fi/en/about/campus/ and updates about the construction at: http://onecampus.aalto.fi/ (last access 05/27/2017).

Besides the sustainability considerations taken in the planning and construction process of the campus, the amplification plans envision also the facilitation of an interdisciplinary communication among the different schools of the university, as well as a transdisciplinary potential to open the university borders for the surrounding society and incorporating different platforms for knowledge exchange. “The Otaniemi campus environment is being developed through art. The development project will pay particular attention to the spaces between buildings, focusing on aspects such as lighting, orientation, navigability and visitor guidance, and transit in and around the campus area.”[8]

### *3.2 Aesthetic Thinking and Imagination in Meta-Levels of Collaboration for Sustainability*

A rather different example of aesthetically thinking sustainability is the project *University of the Trees*, idealized as a long-term social sculpture project and created in a collaboration between the *Social Sculpture Research Unit (SSRU)* at Oxford Brookes and the *Centre for Contemporary Art and the Natural World (CCANW)*[9] in Exeter, in 2007. Following the conceptualization of the artist Joseph Beuys about social sculpture and an expanded understanding of art and environmentalism,[10] the project of the University of the Trees envisioned incorporating multidimensional approaches to environmental action. Although this is not an example of a tangible university campus, because the University of the Trees is an online network, it brings forward important elements of the transdisciplinary requirements of thinking sustainability (on campus or not). Furthermore, although the University of the Trees is not founded in a physical space, its actions have taken place in several different spaces in a period of seven years.[11] Therefore, it instigates one to think about multiple levels of collective action and collaboration, overcoming not only disciplinary boundaries to generate interdisciplinary research, but also national borders and academic borders in order to integrate multiple forms of knowledge, activism, and experiences—generating a platform for transdisciplinary exchanges among scholars, activists, artists, and citizens in general.

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[8]Information available at: http://arts.aalto.fi/en/artisticactivity/artoncampus/ (last access 05/27/2017).

[9]More information about the project is available at: http://www.universityofthetrees.org/ (last access 05/27/2017).

[10]According to Beuys, every human being has an inherent creative potential and society should be perceived as a big work of art in which every act has a significant influence: “This most modern art discipline—Social Sculpture/Social Architecture—will only reach fruition when every living person becomes a creator, a sculptor, or architect of the social organism” (Beuys 1977).

[11]Unfortunately there is no updated information about the project after 2014.

A new *main forum* for the University of the Trees can be initiated in any region of the world.[12] The regional group has to identify a specific area of trees where an initial performance can be realized. This area does not have to be a pristine forest, since each particular woodland area is considered to have a specific history of their own that can be the starting point for communication of important environmental issues and generate rich debates and meaningful actions towards them. In the initial performance, seven to twelve tree-bands are placed in the selected woodland area (s), which mark the initiation of the communication processes in that region. The performance works as a symbolic action to raise awareness towards the trees and recognition of their knowledge and their role as "teachers of humanity." The main forum works as a platform to define and establish the context for subsequent activities with *mobile labs* and *large-scale forums*. In order to make these subsequent actions accessible to members of the community, the project requires a transdisciplinary collaboration and engagement among the participants and an organization or a coordinating network who work as facilitators for the organization and access to further activities.

In this process of transdisciplinary and interspecies awareness and communication, aesthetics is framed as an "instrument of consciousness" that helps to expand the perception of its human-participants to a "participatory consciousness" with the trees and surrounding environment. In this sense, the understanding of aesthetics comes close to the definition expressed by Adrienne Goehler as the "consciousness of the senses" (2012). This kind of shared consciousness is practiced though the development of "new organs of perception" (expression adopted at the University of the Trees from Goethe's work, which was also used by Beuys in his artistic and teaching approaches). These new organs of perception refer to an unconventional understanding of aesthetics that goes beyond the traditional association with mainly vision (and to some extent hearing and touch). It embraces the capacity to communicate and empathize with nature and the environment.

Another crucial aesthetic quality highlighted in this project is the instigation of imaginative perception. "This long-term project emphasizes the role of imagination in working toward an ecologically sustainable world. It involves a wide spectrum of people from different regions of the world to participate in individual and collective imagining processes, dialogues and potential actions that grow out of listening to the trees and to each other."[13] Shelley Sacks, idealizer of the project, emphasizes that aesthetics does not entail a passive form of appreciation. On the contrary, it is the ability to respond, or in other words, it is an active process of response and response-ability towards the environment: "In this 'university', perceptual and intuitive modes of consciousness complement the rationalist approach, linking

[12]Information about the dynamics of the main forum of the University of the Trees is available at: http://www.universityofthetrees.org/about/main-forum.html (last access 05/27/2017).

[13]Information available at: http://www.universityofthetrees.org/about/our-ethos.html (last access 05/27/2017).

imaginal thought to the process of becoming more response-able in our work to shape a sustainable future" (2011).

Under this unconventional frame and understanding of 'university,' this project highlights an important dimension of incorporating aesthetics and arts-based approaches into environmental research and sustainability strategies—the self-reflexive ethical one. Even though it is important to invest in technological development and scientific research in order to find sustainable solutions for environmental issues (on campus or not), that is not enough. It is fundamental to explore alternative ways in which to engage people in ethical environmental thinking and not just within the borders of academic research. Furthermore, even though the combination of such investments in scientific and technological research with aesthetics and artistic approaches has been growing and receiving more credibility in the academic environment, it is fundamental to overcome the biased conceptualization of aesthetics and the arts and to expand this debate beyond the borders of academia. Aesthetics goes beyond usual associations with matters of superficial qualities of design, or the definitions of beauty, or even as a mere form of entertainment. As argued so far, it raises up the potential for multisensorial perception, meaningful experiences, and environmental engagement (Berleant 1991).

### *3.3 Pragmatic, Ethic, and Aesthetic Environmental Thinking in Permaculture Projects*

The last example of this article is not situated in one specific campus either, but it refers to a practice that has been increasingly adopted in several higher education institutions in different regions of the world—the practice of *Permaculture on Campus*. Permaculture is a good example of how artistic thinking processes can be integrated into environmental research and practice and perhaps in a more pragmatic form than the project of the University of the Trees.

Permaculture refers to an agricultural design system based on principles of ethics of the human co-existence with nature. The term derives from the definition of *permanent agriculture*, which was introduced in the 1970s by the Australian scholars Bill Mollison and David Holmgren. Its definition was soon amplified by the authors in order to incorporate the comprehension of permanent culture as an interdependent process of the design of agricultural systems (1978). Similarly to Dewey's definition of the aesthetic experience, in permaculture, human beings are perceived as an integrant part of nature, interdependent and not only co-existing with it, and involved in a rhythm of organic processes of interrelations and ruptures.

The approaches put forward through the philosophy of permaculture enlighten a current growing and necessary move towards the entanglement of theoretical and ethical concerns with practice. The general approaches to permaculture are based on twelve guiding principles: 1-Observe and Interact; 2-Catch and Store Energy; 3-Obtain a Yield; 4-Apply Self-regulation and Allow Feedback; 5-Use and Value

Renewable Resources; 6-Produce No Waste; 7-Design From Patterns to Details; 8-Integrate Rather than Segregate; 9-Use Small and Slow Solutions; 10-Use and Value Diversity; 11-Use Edges and Value the Marginal; and 12-Creatively Use and Respond to Change (Mollison 1988). These principles connect practical ecological considerations of agricultural design with the unavoidable ethic and aesthetic dimensions that emerge from these kinds of interactions between humans and the environment. They also emphasize the dynamic relations between global issues and local actions in their variety of top-down and bottom-up strategies. Furthermore, similarly to the project of the University of the Trees, the principles of permaculture indicate an important epistemological issue of embracing unconventional forms of knowledge-production and sharing.

The implementation of permaculture in university campuses provides the opportunity for students to have a closer relation with their surrounding environment (and for many even the opportunity of a first contact with the actual practice of planting and gardening). There are different forms in which permaculture is adopted in the academic environment and the number of universities and higher education institutions willing to integrate it into their curricula has been growing.[14] In some cases it is integrated as a core course of specific programs, but it can also be offered as a co-curricular option, or as an interdisciplinary research group. Most of the practical programs are adapted from *Permaculture Design Courses* (PDCs), which tend to last longer and can sometimes be financially inaccessible for university students. Therefore, it is a very significant step to have such adaptations made available in the university campuses and in some universities the option of obtaining a certificate after attending a permaculture course is also possible, which can increase the interest of the students to attend the course.[15]

According to students and teachers that have worked with permaculture projects in university campuses, the gardens work as a living laboratory that uncover new opportunities for students to develop practical skills, become informed about ecological and agricultural systems, and get engaged in pro-environmental thinking and action.[16] In many universities, the staff also gets involved and actively participate in the creation, learning, maintenance, and teaching processes. This enables various levels of collaboration to emerge, not only between students and professors of several disciplines, but also between them and employees of different areas of the university. The interdisciplinary range of permaculture also goes beyond the planning of the projects, or the planning of the gardens. In many universities, students have the opportunity to have practical courses to learn about specific

[14]Based on the MA research of Kat Zimmer, this site offers a directory of current institutions in the US and Canada that have adopted permaculture in their programs: https://universitypermaculture.com/directory/ (last access 05/27/2017).

[15]https://universitypermaculture.com/2015/12/22/a-snapshot-of-permaculture-in-higher-ed/ (last access 05/27/2017).

[16]Inspiring accounts of permaculture projects in universities in the US can be seen in the series of videos Growing Solutions: Permaculture on Campus, available at: https://universitypermaculture.com/2016/05/11/growing-solutions-video-series-launch/ (last access 05/27/2017).

subjects, as for example the behavior of specific insects or plants in the space of the garden and not just as a theoretical piece of information presented indoors.

In this sense, the aesthetic dimension of permaculture goes beyond the physical qualities of the design systems implemented in the gardens. "In the various facets of permaculture, the alternatives for developing 'functional, though ecological' systems can be closely related to the importance of developing a critical and conscious awareness of the body and its interaction with the environment" (Schröder 2016). By being exposed to the gardening practice and at the same time required to consider the ethical principles of permaculture and of their own behavior, the participants are able to experience a meaningful relationship with that environment and develop the 'new organs of perception' reclaimed in the University of the Trees.

## 4 Concluding Remarks

This article has been set out to investigate the potentials of aesthetics and arts-based research to generate environmental awareness and improve the debates about sustainability in university campuses.

After some initial considerations about the emergence of sustainability as a field of research in the academic environment, the inter- and transdisciplinary implications that this new field of science requires, as well as considerations about different forms of arts-based research and conceptualizations of environmental aesthetics, the article was expanded on the analysis of three different examples of arts-based approaches to sustainability on campus.

The first example explored the creation of the Aalto University in Finland. This new university stands out in its initiatives to combine the arts and sciences for the investigation of sustainability, following an already existing and long tradition in the Finnish school system. Three different aspects of the approaches performed at the Aalto University were briefly introduced and despite the very inspiring initiative that this example brings, the role of the arts and aesthetics does not seem to be clearly stated and there is an evident danger of instrumentalism of aesthetics and of sustainability in their approach.

The second example was more unconventional and presented the project of the University of the Trees. This is a university that is not situated in a specific physical campus but is a collaborative long-term social sculpture that had the potential to be expanded to multiple areas. The project frames aesthetics in its capacity to enhance different forms of environmental perception and imagination, as well as of interspecies empathy and communication. It can be perceived as a rather utopian approach (mainly because the project does not seem to be currently active). However, it addresses important characteristics that enhance the political and ethical dimension of aesthetics and that usually get shadowed in the instrumentalist interpretations of it. Furthermore, this project required a continuous and committed international and inter- and transdisciplinary collaboration in order for its outcomes to be feasible and meaningful.

The third and last example enables a similar unconventional understanding of the role of the arts and aesthetics in environmental thinking with more pragmatic outcomes visible in university campuses through the practice of permaculture. It also highlights the importance of the unconventional (and perhaps utopian) approach present at the University of the Trees. Besides, through the practices of permaculture, it is possible to investigate the pragmatic dimensions of the aesthetic approach to sustainability without necessarily instrumentalizing it or reducing it to the idea of the beautiful forms of the garden. Of course, there are also varied interpretations and approaches to permaculture and in some of them such superficial qualities might be more emphasized than in others. Nonetheless, because of its emphasis on the ethical principles that involve a project of permaculture (and any relationship between humans and nature), this kind of approach enables the integration of a more sensitive understanding of aesthetics to environmental thinking and practice.

The examples explored in this article demonstrate that there are various forms in which aesthetics and arts-based approaches can be interpreted and integrated to environmental and sustainability research. They also indicate that there is a fruitful potential in combining environmental thinking with an expanded interpretation of aesthetics that might increase interest, participation, responsibility and environmental awareness in general. The article was not intended, though, to bring an exhaustive investigation or any conclusive statements about arts-based sustainability (on campus and beyond). There are many more layers of the integration of aesthetics in environmental debates that can and should be explored. The goal in this article was instead to instigate unconventional forms to think about sustainability on campus and to expand the potentials that aesthetics brings to the inter- and transdisciplinary collaborations, which are fundamental to rethink the topic and achieve more truly sustainable initiatives.

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# The Application of Eco-efficiency in University Buildings: Policies and Decision-Making Processes

**Marcos Antonio Leite Frandoloso, Albert Cuchí i Burgos and Eduardo Grala da Cunha**

**Abstract** In recent years, a growing interest about energy efficiency have become significantly relevant both in terms of environmental and economic aspects. Several initiatives have been launched by national and international regulations and have awakened environmental responsibility within universities worldwide. From these initiatives, reference values and index ratings were obtained for energy performance in the Universities' building stock. The evaluation of the positive and negative features lead, thereby, to a methodology that could verify its applicability at the University of Passo Fundo—UPF, located in southern Brazil. Four aspects have been developed during the study: consumption of energy resources; comfort conditions; decision-making processes and eco-efficiency reference indexes. A simulation using the software *DesignBuilder* was applied in order to obtain diagnosis, real and ideal condition models. As the present study identifies and assesses the evolution of incident factors towards energy consumption, it is expected that universities promote a reflection in their practices in order to develop tools, which contribute for Educational Sustainability measures. It is imperative that making-decision practices follow guidelines to evaluate inversions and costs when measuring environmental management strategies and their implications. This paper

M. A. L. Frandoloso (✉)
Universidade de Passo Fundo, Campus I, BR 285, km 292, B. São José,
Passo Fundo/RS 99052-900, Brazil
e-mail: frandoloso@upf.br

A. Cuchí i Burgos
Universitat Politècnica de Catalunya (ETSAB-UPC), 649 Diagonal Ave,
08028 Barcelona, Spain
e-mail: alberto.cuchi@upc.edu

E. G. da Cunha
Universidade Federal de Pelotas, Benjamim Constant St.,1359,
Pelotas, RS 96010-020, Brazil
e-mail: egcunha@terra.com.br



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contributes to the debate on university policies, from an inclusive perspective as it includes infrastructure and sustainable practices and, consequently, its relation to concrete exemplars in order to improve Sustainability Education practices.

**Keywords** University sustainability · Energy efficiency · Sustainability guidelines Education for sustainability

## 1 Introduction

Throughout previous decades, an academic debate has focused on developing sustainability in conjunction to promoting economic, social and cultural aspects. These conceptual underpinnings present partial performances but are mostly under discussion and consolidation.

The experiences that shape the principles of a sustainable society, become gradually more representative. However, hesitations on how to asses such outcomes derived from specific contexts are present due to the peculiarity of each condition or environment.

As an institution and part of this society, a university has an important role to contribute to this process of transformation. Such process of transformation has been recognized by the Talloires Declaration (USLF 1990) and UNESCO as a *Decade for Education and Sustainable Development*—DESD, 2005–2014 (UNESCO 2004). It is also and often referred to as "Education for Sustainability"—EfS.

According to Leal Filho (2014) DESD was responsible for overseeing global efforts focused on using education as an instrument to address social, environmental, economic and cultural challenges in the 21st century. It has determined that *climate change*, *biodiversity* and *disaster risk reduction* would be the three main issues for the promotion of sustainable development through education practices. However, by handling urgent academic tasks such as final assessments (UNESCO 2014), universities have not effectively incorporated the proposed guidelines for sustainable development into the process of teaching and learning practices.

The university is responsible to include central sustainability goals into their education, and research programs. In addition, such goals can be incorporated into the institution's own internal policies. One of the challenges presented by the *Talloires Declaration* (ULSF 1990) is for universities to *"*become an example of environmental responsibility by establishing conservation of resources, recycling and waste reduction programs*…"*.

The expansion of university centers in Brazil has increased significantly in the past 30 years. The economic transformation of the information and knowledge's tertiary sector is responsible for such expansion. As a result, besides expanding the number of students; new courses and institutions have been created in order to respond to this growing demand. Therefore, it is imperative to establish universities as centers that promote such policies. They can contribute to incorporate all community and academic agents to work towards sustainability measurements.

The absence of management strategies to execute contemporary urban structures, resulted in several issues related to the urbanization of rural areas. It has also impacted the city and suburban accessibility and mobility (access, traffic, means of transport).

In regard to construction issues and the current production system, Braungart and McDonough (2009) present a correlation with natural systems. Their former *Cradle to Cradle Framework* (Braungart and McDonough 2012), proposes "new paradigms for a new design, in order to promote essential changes in the concept of product-and-scrap". The construction field aims to "create a building that celebrates a range of cultural and natural agencies—sun, light, air, nature, even food—in order to enhance people lives…" (2009, p. 74). It also proposes foundations new design ideas called eco-effectiveness that compare buildings as trees. "They produce more energy than they consume and purify their own waste waters" (2009, p. 90).

Tavares (2006) states the construction impact on natural resources in Brazil follow international standards based on reduced information, especially due to lack of data concerning a building's life cycle. For that reason, the author proposes a methodology to evaluate the impact on residential buildings by calculating their Life Cycle Assessment—LCA. Studies suggest (John et al. 2007), however, that buildings consume 75% of natural resources as the clear majority being non-renewable resources. They are also responsible for about 47% of electrical energy consumption (Lamberts, Dutra and Pereira 2014), 21% of water consumption, 75% of wood usage from the Amazon region (Souza and Deana 2007) and finally 60% solid waste production (Araújo and Cardoso 2010).

In 2011, building construction represented 46.7% of the total electrical energy consumption. Housing represented 23.3%, business 15.4% and the public sector 8.0%. The *National Energy Balance*—BEN—from 2013 (EPE 2014, p. 20) which includes all urban sectors such as transport points to housing as representing 9.1% of consumption and services 4.6%. Industrial production, cargo and mobility transportation represents 66% of the primary energy consumption in the country.

The present paper displays a briefly version of the thesis entitled "The inclusion of eco-efficiency in Brazilian University buildings: policies and decision-making processes", presented at the Department of Technology and Architecture of the Polytechnic University of Catalonia—UPC, in Spain. It presents an overview of assessment methodologies applied to a Brazilian university—University of Passo Fundo—UPF, located in the southern Brazil. Such methodologies have focused on energy performance, indoor conditions and users' thermal comfort. After evaluating the influence on energy and comfort, guidelines to include policy action plans to contribute to decision-making processes have been presented.

In short, the main goal of the present article is to promote the debate on UPF's building stock, based on the principles of sustainable construction and natural resources management. It seeks to transform the university campus, henceforth UPF, as a feasible academic and practical laboratory to assist EfS provided to students, teachers and staff.

## 2 UPF Premises on Energy and Environmental Planning

A previous study was developed in order to identify the university's environmental planning and its state of art it. It focused on analyzing incidental factors in the University buildings' energy consumption resources. It has implemented energy audit methodologies (Bosch Gonzáles et al. 2006; López Plazas 2006) as they were also included in previous investigations from the Polytechnic University of Catalonia—UPC. In addition, an analysis of PECRs (Plan of Efficiency on Resources Consumption) energy performance and the Projects of Energy Use—POEs (UPC 2012a, b, c) was included (Bosch Gonzáles et al. 2006) as reference tools for effective measurements.

As a result, the following processes have been proposed:

- Identifying UPF's eco-efficiency issues, with emphasis on energy use and resources and its building stock;
- Evaluating well-being condition in academic spaces. Estimating the performances of corresponding architectural variables and building systems;
- Proposing criteria for decision-making processes involving energy eco-efficiency, depending on performance factors, demand and use management;
- Evaluating buildings' actual conditions and confronting it with theoretical "ideal" models. Adopting simulations for buildings' thermal and energy performance in order to increase environmental quality of the spaces though the building envelope and/or systems.

The analysis and diagnosis of the evolution of incidental factors in energy consumption is intended to demonstrate how it is possible for UPF's administration to develop strategic plans. It can assess investments, costs and the implications of environmental management and design in regard to corresponding power and emissions strategies. As a result, the following questions have arisen based on such proposition:

Can these strategies be effectively applied or left-aside by economic and administrative budget cuts or by commonly adopted administrative practices? What is the real impact between the decision-making process impacting administrative policies and the positive outcomes from an eco-efficient building stock?

As a result, the overall objective of this research focuses on proposing methods and processes of application criteria to implement eco-efficient energy at UPF. It specially focuses on transforming such methodology into a feasible and operational instrument. In other words, it aims to build up a tool for decision support to improve eco-efficiency of existing and new buildings; to allow an accurate assessment of the impact of incidental factors in energy consumption. The main challenge of such assessment, however, is to rationalize the decision-making process, in order to reduce the cost of use and management and to develop alternatives to stocks and investments.

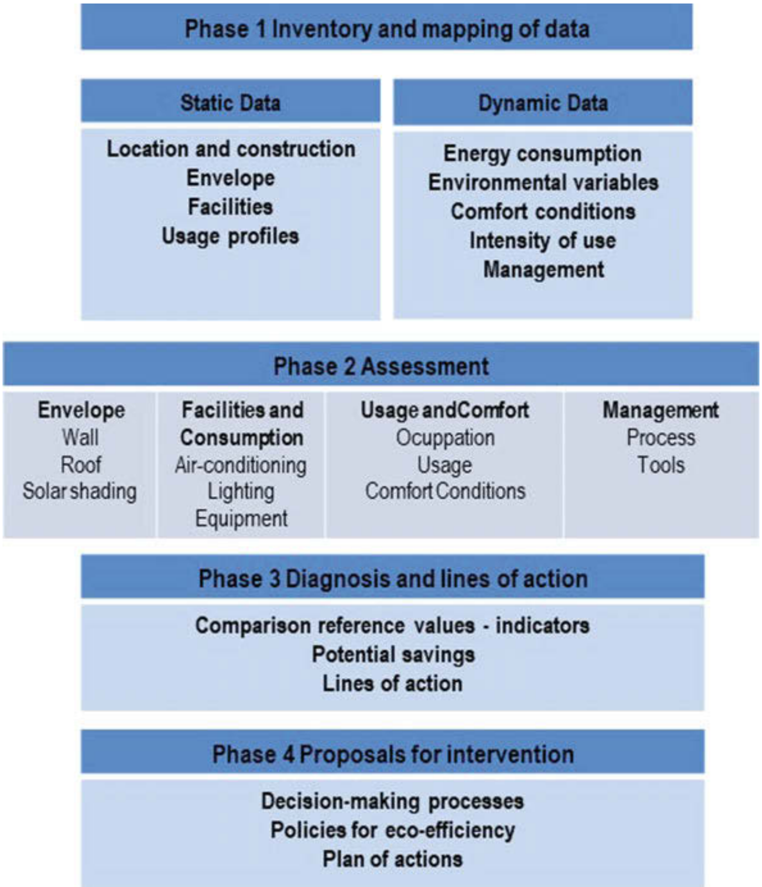


**Fig. 1** Energy assessment methodology for UPF's building stock

The methodology used to analyze eco-efficiency at the university UPF buildings derived from *Energy Audits*, previously used at Polytechnic University of Catalonia—UPC. In addition, data from PECRs (Bosch Gonzáles et al. 2006), POEs—Project of Energy Optimization—(UPC 2012a) and the document entitled *Guiò per a la preparació del POE* (UPC 2012b, c)[1], were used as reference.

According to Cuchí and Burgos (2009), environmental and eco-efficiency criteria implementation in buildings, aims to impact the way design, construction, use and building operations are conceived. The inclusion of an environmental sustainable perspective becomes relevant in a university setting such as UPF.

The PECRs methodology was adapted to fit UPF's specific context, as it is shown in Fig. 1

[1]Available at: https://www.upc.edu/gestiosostenible/recursos-i-formacio/eines-practiques-per-a-coordinadors-de-poe/guio-ajuda-poe/view.

## 3 Assessment of UPF's Energy Management and Well-Being Conditions

According to Frandoloso and Brandli (2015), Campus I (UPF's main campus) was selected for the methodology application. Its current use of energy was identified with 341 ha. Two buildings were selected in conformity with UPF's building stock: The Department of Engineering and Architecture—FEAR. These buildings are representative of the diverse construction typologies as well as their usage and occupation factors from Campus 1. Figure 2a displays the administrative and teaching blocks from the Department Engineering and Architecture (Building G1). Figure 2b presents a building with laboratories and classrooms. It hosts the FEAR and Centre of Research in Agriculture (CEPA). Two rooms from each building, located in opposite directions, were selected.

The analysis presented previously, on Fig. 1, is based on two sources of information: the "static" data related to the building's location (outdoor and indoor conditions), its physical characteristics (architecture and construction), its systems and infrastructure and energy resources. Conversely, the "dynamic" data was obtained by modelling the occupied area, the number of users and types of promoted activities. The building's energy performance was used and obtained through an automatic control of energy consumption (Bosch González et al. 2006; Frandoloso et al. 2010).

The real conditions of the buildings were obtained through record cards, temperature and humidity measuring devices (Data-loggers *Testo*, models 175-H2 e 175-T1), analogical energy gauges and softwares (*SmartGateM—Gestal*). The comparative analyses of the thermal performance were generated by the software *DesignBuilder*.

In order to gather physical property values of technological suitable materials for Brazil's reality, a collection developed from LabEEE-UFSC investigations (Ordenes et al. 2003) has been adopted and incorporated into NBR 15220 (ABNT 2005), NBR 15575 standards (ABNT 2013) RTQ-C (PROCEL 2010a, 2013) and RAC basic requirements (PROCEL 2010b).

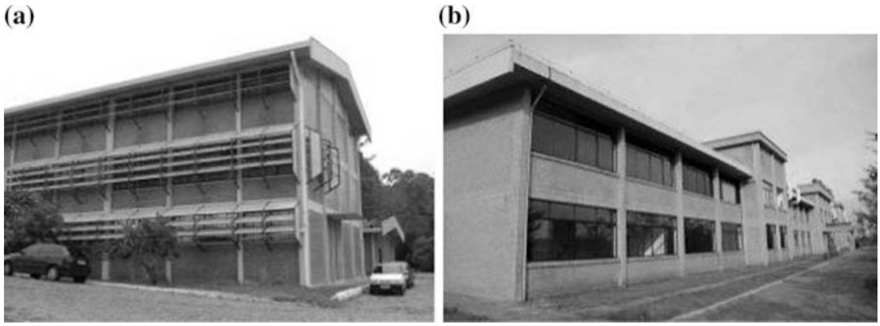

**Fig. 2** G1 building—North facade (**a**); L1 Building—North facade (**b**)

The values acquired from the regional adaptations displayed above, have been incorporated into DesignBuilder (2011) calculations. The results for heat transfer *U*-value are presented below on Table 1.

Conversely, according to the methodology RTQ-C (PROCEL 2013, p. 24), commonly adopted envelope assessments, for one to obtain a level *A* in ZB2 (bioclimatic zone 2) for covers, the *U-value* permissible values are 0.50 $W/m^2K$ for artificially conditioned environments and 1.00 $W/m^2K$ for non-conditioned environments. For exterior walls, the admissible value is $U \leq 1.00\ W/m^2K$. Table 2 displays additional permissible values, separated by (not)conditioned cover in naturally or artificially conditioned environments.

A preliminary assessment classifies both buildings G1 and L1 as level *B* in regard to both walls. *U-value*s for covers were considered low quality (*C* or *D*) and the poorest features are presented by roofs. These data can be best analysed in Phase 2, as they are integrated to supplementary variables.

Based on dynamic data and theoretical energy demands, the facilities features were obtained along with their respective energy usage. The highest power demand (62.10%) is linked to computer labs in building G1. Conversely, building L1 presents a total of 63.67% of power associated to research laboratories. The upgraded surface is low in both buildings: 23.16% in G1 and 29.17% in L1. Table 3 presents these values.

Energy consumption on Campus I corresponds to an astonishing 85% of the total university consumption. Consequently, it is important to seek tools to control and manage energy consumption in order to diminish energy costs and promote financial control.

Energy consumption control used to be centralized on campus. However, a program was set up in all energy consumption units, (*SmartGateM—Gestal*) between 2009 and 2012. This equipment made it possible to control and monitor on-line energy consumption, in order to detection specific related issues. Energy consumption monitoring automatically takes place when pre-established limits are exceeded. In addition, energy dependent installations can be disconnected or activated with an independent generator (Frandoloso and Brandli 2015).

**Table 1** *U*-values from building envelop

| Building | Roof ($W/m^2K$) | External walls ($W/m^2K$) |
|---|---|---|
| G1 | U = 2.212 | U = 1.334 |
| L1 | U = 2.167 | U = 1.134 |

**Table 2** Permissible U coefficients based on ZB2 RTQ-C quality standards

| Quality level | Roof | | |
|---|---|---|---|
| | Air-conditioned | No conditioned | External walls |
| A | $U \leq 0.5\ W/m^2K$ | $U \leq 1.0\ W/m^2K$ | $U \leq 1.0\ W/m^2K$ |
| B | $U \leq 1.0\ W/m^2K$ | $U \leq 1.5\ W/m^2K$ | $U \leq 2.0\ W/m^2K$ (**G1 y L1**) |
| C and D | $U \leq 2.0\ W/m^2K$ (**G1 y L1**) | | $U \leq 3.7\ W/m^2K$ |

**Table 3** Characterization of static data and theoretical demand for energy (2012)

| Bld. | Surface ($m^2$) | Occup. | Condit. surface ($m^2$) | Condit. power (%) | Equip. power (%) | Light. (%) | Total power (W) | Density ($W/m^2$) |
|---|---|---|---|---|---|---|---|---|
| G1 | 2,696.56 | 863 | 624.11 | 25.56 | 62.10 | 12.34 | 304,668 | 113.06 |
| L1 | 3,389.77 | 645 | 988.70 | 29.28 | 63.67 | 7.05 | 539,660 | 159.21 |

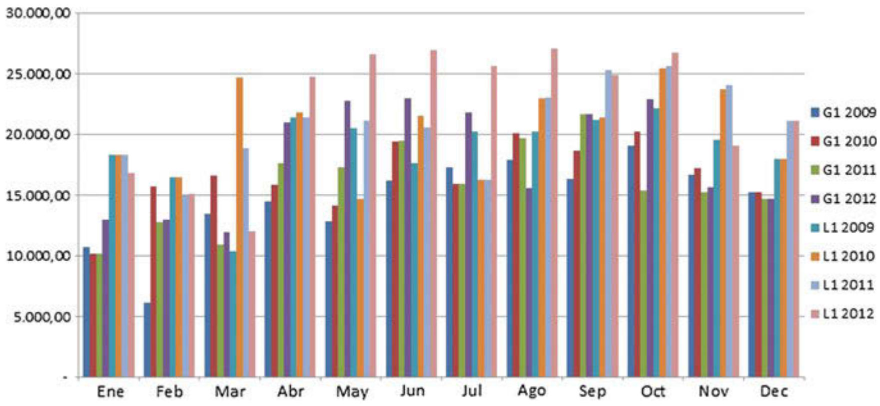


**Fig. 3** Comparable monthly energy consumption in buildings G1 and L1 from 2009 to 2012 (kWh)

Bases on these results above (from 2009 to 2012), it was possible to trace the evolution of energy consumption (see Fig. 3). Greater energy demands were compared to the newer equipment installation (laptops) as well as to an increasing number of students which represented approximately 118% from 2003 to 2014 and 28.10% from 2009 to 2012.

In order to assess students' well-being, the Fanger's Predicted Mean Vote—PMV (Fanger 1970) and Fanger and Toftun (2002) were used. PMV includes internal and external environment variables averages (radiant temperature, temperature, humidity and relative air speed) and the global temperature in order to generate a standard value.

The model that predicts thermal comfort values for building and their users. In addition, internal environment thermal tolerance is subject to an ISO 7730 pattern regulations (ISO 2005). The PMV or analytic sensation of thermal comfort value was obtained through the thermal balance between man and environment. The heat generated by the human body after an activity must be dissipated at same rate as the environment, through thermal exchanges, meaning convection, radiation, evaporation and conduction mechanisms.

*DesignBuilder* was used to identify a room's comfort conditions. A total of 4 rooms from both buildings were evaluated and classified according to the ASHRAE Bedford thermal sensation scale (ASHRAE 2004). Table 4 presents real indoors

**Table 4** Reported comfort conditions in thermal areas based on *DesignBuilder* simulations

| Bld. | Room/solar orientation | Summer discomfort (h) | Winter discomfort (h) | All seasons (h) | Annual PMV PMV |
|---|---|---|---|---|---|
| G1 | Arch. and Urb. (NO) | 1958.00 | 1465.00 | 929.50 | −1.067 |
| | Environ. Eng. (SE) | 2592.00 | 2592.00 | 2592.00 | −0.847 |
| L1 | Meat Laboratory (NNO) | 3395.25 | 3176.00 | 2968.00 | +0.567 |
| | Practices Lab. (SSE) | 2481.5 | 2374.25 | 2363.5 | +0.224 |

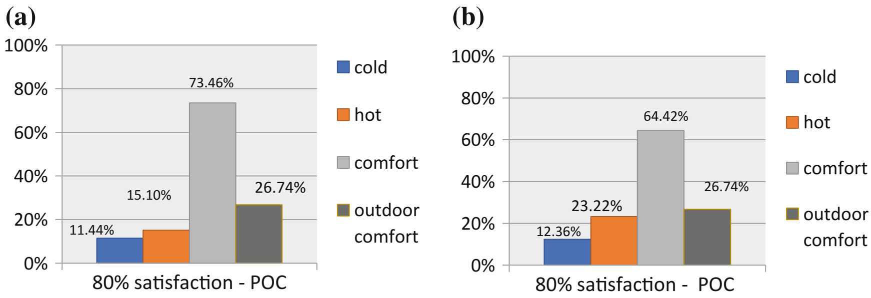


**Fig. 4** Reported adaptive comfort condition in POC: G1 (**a**) and L1 (**b**)

conditions by using *data-loggers*. Furthermore, Fig. 5 displays a comparison of all 4 thermal areas based on its environmental monitored variables. These areas are the following: *Zone 5* situated at the ground Floor where registrars and administrative offices for the College of Architecture and Urbanism are located. *Upper zone 1*—College of Environmental Engineering. *Ground floor 2/2A*—Processed Meats Laboratory and *Ground Floor 5A*—Classroom Practices Laboratory.

Even though annual PMV thermal zones index values state that spaces from building G1 present sensations close to −1 (comfortably cool). Values from building L1 are classified in the scale Bedford as positive (hot). A heat discomfort sensation was reported at the Meat Lab due to the heat generated from the cooking equipment.

According to the characteristics of the buildings systems, air-conditioning systems are reduced, a methodology of adaptive comfort was adopted (Humpheys and Nicol 1998; Nicol and Humpheys 2002; de Dear and Brager 1998; 2002), referenced in the ASHRAE Handbook—Fundamentals (ASHRAE 2009; Negreiros 2009).

Considering the percentage of occupied hours—POC, generated by usage reports (from 8 am to 10:30 pm), there is a predominantly comfort sensation of 73.46% of the hours in building G1. The heat conditions slightly exceeded cold ones, 15.10 and 11.44% respectively, as showed in Fig. 4.

## 4 Diagnosis and Lines of Action

The analysis models generated a comparison between the simulated reference and real measured data for each building. The following scenarios were established based on theoretical models:

- Theoretical model $T_1$ proposes conditioning of all permanent use areas, in order to cover activities demands. Conditioning will improve well-being sensation—criteria established by the RTQ-C and RAC Brazilian regulations (PROCEL 2010a, 2010b, 2012; Brasil 2013), for level *A* certification;
- Theoretical model $T_2$ recommends, in addition to the conditioning of the spaces, evaluating the impact of laptops expanded use (by students). It also recommends changes in the envelope according to criteria RTQ-C and RAC;
- Theoretical model $T_n$ proposes the development of alternative models by combining results, in order to meet projections derived from previous assessments;
- Theoretical model $T_{ideal}$ defines the best suited model of a given research's conditions and requirements.

The models above intend to increase eco-efficiency, either by implementing architectural features (envelope isolation and absorption, solar protection and shading, transparent enclosures/windows), or by enhancing equipment and systems management of and use.

Figure 5 depicts the theoretical model ideal $T_{\mathrm{ideal}}$, which is based on the comparison between real results, and measurement generated by the *SmartGate* system. After identifying δ differentials between simulated (ideal) real situations (measured); equivalence values for the actual building $\Delta_{Real\ Bld.}$ are generated and the definition of the final theoretical model $T_{final}$ created. The development of all models enabled the identification of the most efficient solutions for best energy performance, as well as for enhanced indoor comfort conditions.

Briefly, $T_{final}$ energy impacts results for both theoretical buildings propose:

- G1—Expanding the conditioned surface, promoting upgrades in the air-conditioning system and improving the envelope (model $G1\_T_2$ adjustments), anticipates an increase by 3.30% in energy consumption;
- L1—Besides expanding the conditioned surface and improving the envelope; the model proposes window protection from the sun (model $L1\_T_3$). Such propositions anticipate an increase of 13.92% in energy consumption.

Based on these data, it is possible to state that supporting comfort conditions means improving the envelope and conditioning permanent use spaces. It means proposing integrated investments that go beyond the installation of air conditioning systems (commonly proposed UPF's administration). Each specific action must be contextualized and include long-term economic results. The projections obtained from theoretical models above only represent an orientation.

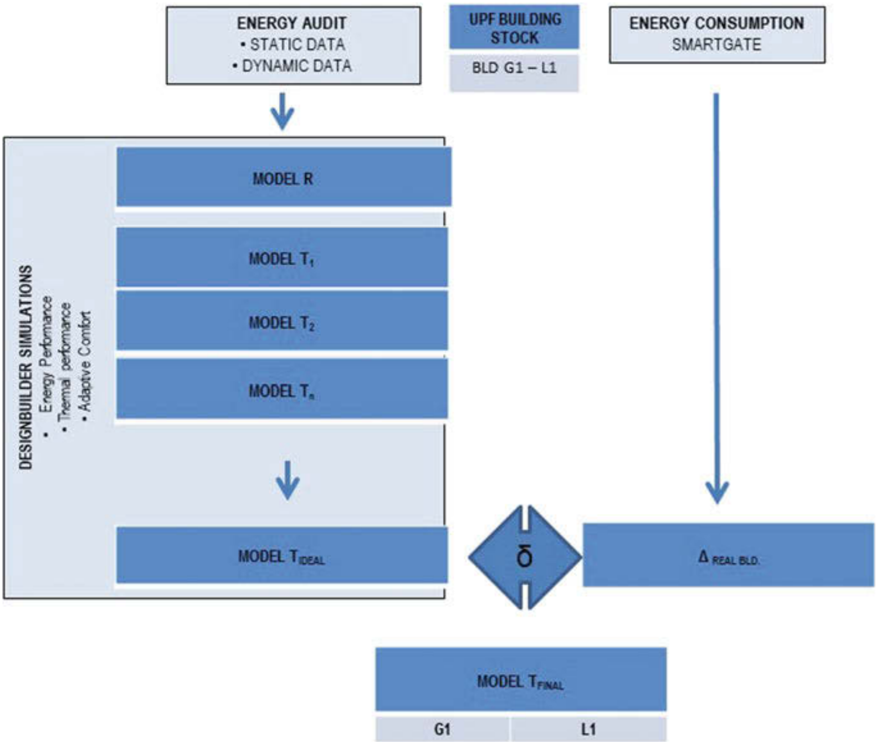


**Fig. 5** Simulated models and real inputs

It is important to note that isolated investments in air-conditioning can certainly expand the use of energy resources and as a result, impact the institution financially. They do not necessarily mean an improvement to an environment efficiency and conditions of use. For that reason, the following guidelines and procedures are presented.

Even the current study presents detailed results from each of the real and theoretical models; it is imperative to point out to a major issue: the increased electric energy consumption costs. In this regard, it becomes relevant to invest in new systems and envelope changes. Procedures that convert non-measurable variable into financial terms such as comfort condition of academic environments (classrooms, offices, laboratories, etc.) and its use. Such guidelines have already been incorporated into UPF's strategic plans, but they have not been concretely and efficiently implemented.

Not only demand, but also management and performance have been incorporated to the present results. By considering the theoretical projection $T_n$ models, it is possible to recommend priority practices and measuring packages with the integration of three main factors:

1. Adjusting profile settings (use and occupation) and focusing on delivering at least 80% of comfort during business hours POC;
2. Improving facade functioning by adapting it to minimum values ($U \leq 1.00$ W/m$^2$K, based on RTQ-C level A;
3. Improving envelope quality by rehabilitating and retrofitting the roof. Applying $U \leq 0.50$ W/m$^2$K values for air conditioning buildings and $U \leq 1.00$ W/m$^2$K for unconditioned ones, based on RTQ-C level A;
4. Installing sunscreens and shading devices in building L1;
5. Adopting strategies to ensure natural ventilation, based on 0.19 m/s summer parameters and 0.16 m/s winter parameters, with air renewals of >27 m$^3$/hour/person;
6. Adapting individual actions in order to obtain comfort conditions based on adaptive criteria (Nicol and Humphreys 2002);
7. Conserving existing conditioning systems maintenance;
8. Established systematic heating temperatures of 20 and 26 °C for cooling. Expanding current RTQ-C limits of 22 and 24 °C, respectively;
9. Implementing or gradually replacing conditioning systems based on energy performance criteria. Preferably using VRF systems with reverse cycle equipment classification A (RTQ-C): CoP 3.81 for facilities with less than 19 kW and 3.22CoP/3.78ICoP for higher ones (between 19 and 40 kW);
10. Retrofitting lighting systems, with potential savings of approximately 47%;
11. Adjusting the effectiveness of computer science and laboratories teams, as well lab conditions and usage profiles by considering their consumption values;
12. Identifying and reducing background consumption, identified in lower occupancy and use intervals.

It is important to note however that these "packages" are directly attached to eco-efficiency decision-making processes and policies, presented below.

## 5 The Decision-Making Process

Energy is fundamental on the organization of campus sustainability efforts. Tomashow (2014, pp. 11–12) states reflecting upon energy management and use in activities is more than considering it as mere building delivery. It is considering sustainability as a direct connection between campus and biosphere. It is part of "the nine elements of a sustainable campus" along with food, material flows, governance, investment, wellness, curriculum, interpretation and aesthetics. According to the author, these elements feed the community decisions. Its integrated implementation can generate leadership and effective results for the campus transformation. its agents and community. The university has the responsibility of promoting the *sustainable ethos* to the local community. In addition, a university campus serves as a new way to (re)think higher education.

In order to obtain positive results, it is essential that decision-making processes be inclusive and participatory. Energy consumption can be reduced more efficiently and effectively when supported by human scale changes. According to Tomashow (2014, p. 31), power consumption behaviours are more likely to change when there is satisfactory infrastructure that affects and influences its users' conducts (students, teachers, administrative staff, managers and the external community). For that reasons, it is important to incorporate essential mechanisms to include energy efficiency or more broadly eco-efficiency methodologies into the organizational structure of University of Passo Fundo.

For this purpose, the current structure and proposed changes were identified in the current study for further development. It was initially based on UPF's strategic planning and currently waits for faculty and staff revisions. Additionally, an applicability control system and systematic evaluation process can be proposed as well.

An important detail for these procedures positive outcome is related to administrative decisions in regard to forming a specific sector for energy management. Firstly, the Campus Conservation Sector does not have a certified electrical engineer. Secondly, former management proposals (discussed in Phase 1) have not been implemented. Finally, the *SmartGateM* system is not currently operating.

A significant influence is that control of electric power expenses points to a preliminary projection of much higher electric power costs in 2016 when compared to 2015. Such escalation was due to rate changes applied by the federal government.

As mentioned previously, conditioning classrooms and other sectors of the university is part of UPF's Institutional Development Plan—PDI 2012–2016- 3.1.6 (UPF 2012, 2013), which is to be executed by the end of 2016.

Two additional actions from PDI's plan (article 3.1) entails describing work and study environment conditions.

- 3.1.8. "Implementing permanent campaigns to raise awareness and rationalize resource use". To be executed by April 2013;
- 3.1.11. "Developing an institutional program in order to manage a sustainable environment and promote eco-efficiency". A program elaborated under the provost's responsibility of the rectory, to be executed by December 2013.

The status of 2015s programs (UPF 2015) pointed out that while the "package" was "underway", awareness campaigns were on 'standby' and management programs "in development". The PDI plan is in the process of being updated for the next administrative term: a decisive and crucial time to verify the execution of previously planned goals.

Although the program has been developed (Mistura et al. 2013), two thematic axes were established: a. energy efficiency and b. planning, construction and occupation of spaces. Based on its guidelines, principles and goals were outlined. However, its respective responsibilities and deadlines were not taken into account. In other words, the effective decision-making process is still open; but the necessary

**Table 5** Principles and goals for energy efficiency (adapted from Mistura et al. 2013)

| Theme | Principles | Goals |
|---|---|---|
| Energy efficiency | • Energy efficiency in all sectors;<br>• Management and minimization of energy waste;<br>• Research about new non-conventional and sustainable energy sources | • To optimize energy use;<br>• To implement an integrated programme and measures to fight against energy waste;<br>• To reduce energy related consumption costs;<br>• To promote research projects that focus on the sustainable energy generation |

methodologies or indicators to actually achieve the established challenges were not established. Table 5 presents key principles and goals for energy efficiency.

From different phases of the thesis, the results of the methodology application enable the establishment of guidelines for the rating and, consequently, a greater eco-efficiency for UPF's building stock. Both new and existing buildings were included in the "Program of environmental and eco-efficiency energy designed for the University of Passo Fundo".

## 6 Conclusions

The application of simulations with *DesignBuilder* for improved energy performance, indicates the possibility to present different scenarios and to allow adjustments in all factors of building its use. That way, the degree of eco-efficiency of each theoretical model can be compared to corresponding reference or real models.

Similarly, the developed models assessed the conditions of indoor comfort, including simulations for envelope thermal performance improvements (walls and roofs). It was pointed as deficient in comparisons to Brazilian regulatory parameters, but later integrated to thermal conditioning and use from UPF's institutional policies, as well as in a requirement indicated by tools to evaluate climatic context.

In terms of UPF's planning, the University's view in regard to sustainability is still facing early stages of implementation, as it has been identifying institutional procedures to include of environmental and social policies into academic regulations. It is imperative to reinforce the structure generated by this new vision so that it can turn into real goals and actions. Always keeping in mind, however, previously formulated goals, waiting to be effectively implemented and revised in a continuous feedback process.

The main point to be highlighted, however, is the result of the agglutination of isolated actions that are developed by administrative research groups responsible for UPF's management. These actions should converge into union's efforts, and especially integrate all community participants such as students, teachers, technical and administrative and maintenance staff.

New research may be generated from the present work, that seeks to evaluate different buildings and to achieve a balance and compatibility between comfort and economic costs. They can be a result of (under)graduate Architecture and/or Engineering, completion studies.

The construction social and environment policies, certainly indicates a paradigm change at UPF. However, it is essential to establish effective procedures that incorporate sustainability throughout the university campus, and that constant generate commitment and responsibility at every stage of its decision-making process.

The channel of communication between society and university is essential. It is especially vital for the philanthropic nature of an educational institution, and consequently expands the institutions' role to promote education practices and regional sustainability.

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## Author Biographies

**Marcos Antonio Leite Frandoloso** is a Ph.D. by the Polytechnic University of Catalonia, Barcelona, Spain. His research focuses on eco-efficiency and university campi's environmental management. He holds a bachelor's degree in Architecture and Urbanism at Federal University of Pelotas (1986) and a Masters in Architecture from the Federal University of Rio Grande do Sul (2001). Professor Frandoloso has vast experience in Architecture and Urbanism with emphasis on building and environmental planning. His research interests involve energy efficiency, energy and the environment, sustainable construction, bioclimatic architecture, architectural heritage, eco-design and urban ecology. He has been a faculty member from University of Passo Fundo since 1995. He has been teaching Architecture and Urbanism, Environmental Engineering and Product Design courses at University of Passo Fundo as well as other graduate courses promoted by different institutions.

**Albert Cuchí I Burgos** is an Architect (ETSAB 1983) and head professor at the Department of Technology and Architecture from Universitat Politècnica de Catalunya. He has been directing research on Architecture and its demand for sustainability, in an attempt to generate novel approach along with applicable instruments in the field of Architecture. He has been a faculty member at the Masters of UPC (Official Master) and of Màster Arquitectura Energia i Medi Ambient (Official Master). Professor Burgos is a founding member of distinct groups such as the "Architecture and Sustainability" group of the Collegi d'Arquitectes de Catalunya and the GBC Spain (Spanish capitol of the World Green Building Council). He has served as an advisor for various institutions such as the Govern of the Generalitat de Catalunya and the Government Espanyol. As faculty, Professor Burgos has directed or co-directed over 15 doctoral theses at UPC, Politècnic de Milà (PoliMilano), Politècnic de Gènova, and the College of Architecture from University of Porto (FAUP).

**Eduardo Grala da Cunha** is an Adjunct Professor at the Federal University of Pelotas, an Adjunct Graduate Program Coordinator in Architecture and Urbanism from PROGRAU, a former coordinator of the college of Architecture and Urbanism from University of Passo Fundo, UPF. Former Deputy Director and lecturer at the Faculty of Architecture and Urbanism, FAURB/UFPel. Professor Cunha has a bachelor's degree in Architecture and Urbanism (1994), a Specialization (1995), a Masters (1999), and a Ph.D. (2005) in Architecture from Federal University of Rio Grande do Sul, UFRGS. He has developed Post-Doctoral (2008) studies at the University of Kassel, Germany. Professor Cunha also works as an Ad hoc advisor for CNPq, CAPES, the Foundation for Research Support of the State of São Paulo, the Foundation for Research Support of the State of Alagoas, the Foundation for Support to Science and Technology of the State of Pernambuco. He is currently a member of the advisory committee of the National Institute of Metrology, Quality and Technology. Professor Cunha is also reviewer of several journals in the field.

# Organic Waste Composting and Vermicomposting as Sustainable Practice in Higher Education Institutions

**Jacqueline Rogeria Bringhenti, Adriana M. Nicolau Korres, Ana Maria Maniero Moreira, Solange Martone Rocha and Wanda M. Risso Günther**

**Abstract** A case study is being developed in two higher education institutions belonging to the metropolitan regions of São Paulo/SP and Vitória/ES, Brazil, aiming the evaluation of the use and operation of composting methods. Different household operational systems are being evaluated in the institutions involved. Quantitative and qualitative methods were used for characterization and quantification of generated organic waste. Operation of the various systems of selective collection and composting are also evaluated. The main results refer to the evaluation of small-scale composting in institutional environments and different methods, under both health and environmental viewpoint. Strengths and weak points are being raised. While it appears that local composting initiatives do not represent a significant gain in quantitative organic waste recovery and may represent a slight diversion of the load of landfills, their potential for implementation is very important. This paper is relevant because it shows that is possible to implement composting methods in home environment, either in external or internal areas, and in environments such as schools, public squares, teaching and research institutions,

J. R. Bringhenti (✉) · A. M. N. Korres
Coordination of Environmental and Sanitation Engineering, Federal Institute for Science and Technology of Espírito Santo State, Av. Vitória 1729, Vitória, ES 29040-780, Brazil
e-mail: jacquelineb@ifes.edu.br

A. M. N. Korres
e-mail: akorres@gmail.com

A. M. M. Moreira · S. M. Rocha · W. M. R. Günther
Department of Environmental Health—School of Public Health, University of São Paulo, Av. Dr. Arnaldo 715, São Paulo, SP 01255-001, Brazil
e-mail: anamariainforme@hotmail.com

S. M. Rocha
e-mail: martone@usp.br

W. M. R. Günther
e-mail: wgunther@usp.br



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among others, allied the pedagogical component of the development of composting influencing the behavior of the generators of waste.

**Keywords** Organic solid waste · Selective collection · Composting
Solid wastes management and sustainability

## 1 Introduction

One of the great challenges of the beginning of this century is the growing and diversified generation of municipal solid waste (MSW) and the problems faced by its managers. The MSW composition is quite variable and depends on several factors, such as population purchasing power, population size and behavior, habits, educational level and development, climate variations also varying according to the seasons (FUNASA 2006).

The Pan American Health Organization (PAHO 2005) estimates that the generation of organic waste in Latin America and the Caribbean is about 56% of total MSW. Similar values were identified in a gravimetric analysis of the household residues generated in the São Paulo city, in which the compostable organic matter was 51% of the total, while 35% were dry recyclable waste and 14% tailing (São Paulo 2014).

Improper disposition of organic waste, still frequent in most Brazilian municipalities, causes known environmental impacts, such as gases release and odors, leachate and percolated liquids generation, air, water and soil pollution, as well as the risk of landslides and great visual impact. In addition, it represents an important sanitary problem, being the cause of attraction and proliferation of several diseases vectors, such as insects, arthropods, birds and rodents (Günther 2005; FUNASA 2006; Adhikari et al. 2010).

Home-made composting is a strategy aimed to reduce the amount of biodegradable waste sent to sanitary landfills (Edgerton et al. 2009), and it has been adopted in some countries.

According to the Brazilian Association of Technical Standards (ABNT 1996), composting is defined as a biological decomposition process of the biodegradable organic fraction of the waste, by a diverse population of organisms under controlled aerobic conditions and other parameters. The process occurs in two distinct stages: active degradation and maturation.

European countries, such as Austria, Germany, Greece, Luxembourg and the Netherlands employ the selective collection of organic waste. However, while in Austria and Germany 75% of this waste is sent to composting, in Greece, Ireland and England this percentage is still less than 10% (IPEA 2012).

One of the difficulties is the cost required for the differentiated collection and transportation (Adhikari et al. 2010; Andersen et al. 2011), which has led to the adoption, in some Asian countries, of a new composting model, based on local community initiatives. The composting would be done on smaller scale and the plant located near the place of waste origin, bringing a better life quality to populations (IPEA 2012), as a result of the replacement of chemical fertilizers by organic ones (Andersen et al. 2011).

Composting is an ancient practice in Brazil, which is used successfully by residents of rural or peri-urban areas, where there is still a deficiency of the municipal waste collection service (Lamanna and Günther 2008).

Thus, although it is not an alternative treatment for all organic wastes, this practice can be considered as a supplementary solution (Andersen et al. 2011).

Therefore, the appropriate treatment of organic waste directly at the generation site represents an important contribution for sustainability in the planet, with composting and vermicomposting being interesting and appropriate alternatives. These strategies also contribute to mitigate impacts such as greenhouse gas emissions resulting from transport and waste disposal. Well-operated, household composting produces compost with equal or even higher stability level if compared to industrial composting (Barrena et al. 2014).

In this context, universities (which have several activities with environmental interfaces) should have a pioneering role in the study and implementation of projects involving composting as a waste reuse modality, aiming to generate new knowledge and indicators for its proper operation.

To Beynaghi et al. (2016), it is recommended for universities to keep on transforming and adapting their structure, functions and governance in accord with the changing social, environmental and economic challenges of this century.

This chapter presents the composting experiences report of two higher education public institutions: Federal Institute for Science and Technology of Espírito Santo State (IFES) and Faculty of Public Health/University of São Paulo (FSP/USP), both located in important cities in the Southeast Brazil—Vitoria and São Paulo, 1000 km apart one from the other.

The methodological concept used was based on a double case study. The efforts, and the qualitative and quantitative results achieved by both universities are presented, compared and discussed, regarding the implementation of the domestic composting technique in their respective dependencies.

## 2 Composting Experience at School of Public Health (FSP/USP)

FSP/USP, created in 1918, currently offers two undergraduate courses (Nutrition and Public Health) and six postgraduate programs sensu stricto: Environment, Health and Sustainability; Entomology in Public Health; Epidemiology; Nutrition in Public Health; Global Health and Sustainability; and Public Health.

In the Public Health Postgraduate Program, the Environmental Health area has contributed with its research to propose new methods and technologies for the development of public policies, correlating environmental impacts and health effects, as well as inputs for public and private management programs in the country.

FSP/USP had in 2016 more than 1500 members, made up of 96 professors, 586 undergraduate students, 511 graduate students (324 master's and 187 doctoral), 76 specialization and 327 technical-administrative staff. It also has the participation of commissioned and outsourced employees and a variable circulating population, composed of researchers, scholars, interns and visitors.

It is located in a central and very complex urban area of São Paulo city, installed in a 19.400 $m^2$ built area, surrounded by a large garden, within a territorial area. Within the same field there is a Primary Healthcare Center, which provides services for surrounding population and a nursery that serves USP employees and student's children.

In 2009, a group of volunteers, made up of teachers, employees and students, started a pilot project of home-made (simplified) composting inside their dependences. The area selected for the implantation is approximately 54 $m^2$ and is located in a garden space away from the usual activities and services, easily accessible, protected from wind and direct sunlight and sufficient slope for rainwater drainage. It allows for the creation of several windrows, easily stirring of the latest one and storage place for the oldest ones (Fig. 1).

At the beginning, the volunteers received theoretical and practical training by an agronomist from the City Hall of São Paulo and after that some composting manuals (Kiehl 2004; EMBRAPA 2005) were used as reference.

Since then, different teams are responsible for the weekly selective collection of organic waste previously segregated by the internal community. In addition, the team performs the composting operation, maintenance and monitoring and is responsible for developing studies and quality analysis as well as verifying the feasibility of the project.

**Fig. 1** Composting windrows at FSP/USP, São Paulo city (Pictures presented were taken by the authors)

## 3 Composting Experience at Federal Institute for Science and Technology of Espírito Santo State (IFES)

Created by the Federal government in 1909 to meet the country's industrial growth demand, the institution began its activities with a focus on technical education. After more than 100 years, IFES is now a reference in education and has 17,000 students in technical courses, undergraduate and postgraduate, distributed in 22 campuses and 35 centers of distance education, with great turnover of people and waste generation, including organic waste.

Motivated by the example of FSP/USP, the composting practice was introduced in 2013 at Vitória Campus, which is the oldest, encompassing about 4000 students, 293 teaching staff, 175 technical-administrative staff and 80 external collaborators. Vitória Campus also has large landscaped areas that favor composting practice.

IFES adopted a similar operational dynamic to collect organic waste, but with small adjustments. The system is based on the weekly exchange of segregated organic waste jars, involving volunteers and professors. The IFES Sanitary and Environmental Engineering Coordination (CESA) houses the project, developing an earlier stage to collect data concerning generation of organic solid waste in order to evaluate the potential of in situ composting.

Thus, both FSP/USP and IFES have practiced selective collection and small-scale composting programs in operation for several years, mainly to work with the concept of environmental sustainability in their institutional practices.

These two units started in 2013 a series of parallel activities in order to visualize positive points, improvements in actions and mutual assistance in coping with difficulties, joining efforts and exchanging experiences regarding their individual projects.

Operational similarities and differences of project in both institutions are presented in Table 1.

The first result was the approval of an integrated research project with a Brazilian scientific development agency, which provided resources for the acquisition of some equipment, laboratory analysis and cost of travel for face-to-face meetings.

The main accumulated results are:

1. Dissemination of environmental education, training and awareness of the importance of individual contribution to the global development of sustainability.

As part of this context, different cultural levels of the internal community are integrated in a joint effort to maintain the continuity of the two fundamental stages of the project: segregation/collection of the organics in its origin and operationalization/monitoring of the compost process.

In relation to the variations in collected organics quantity and quality, it is observed that they happen in a similar way to the recycling programs, and that it is necessary to maintain dissemination and information actions. Smith and Jasim (2009)

**Table 1** Comparison of the applied techniques in both institutions

| Unit | FSP/USP | IFES |
|---|---|---|
| Technique adopted | Homemade aerobic composting on soil and manual stirring | Vermicomposting in boxes (earthworm area) |
| Start of operation | 2009 | 2013 |
| Responsible for compost collection, operation and monitoring | Volunteer team (professors, students and effective/ outsourced staff) | Volunteer team (professors, students, interns and staff) |
| Sectors of organic waste origin | Several departments, such as Nursery day care, healthcare center, library and restaurant | Coordinating of courses, administrative areas and restaurant |
| Waste generators and collaborators | Professors, students and effective/outsourced staff | Professors, students and effective/outsourced staff |
| Composition of organic waste segregated/ collected for composting purposes | Peels and leftovers of fruits, vegetables (rich in Nitrogen); grass and garden leaves (rich in Carbon); coffee dregs (N and C) and eggshell (rich in Calcium) | Peels and leftovers of fruits, vegetables (rich in Nitrogen); grass and garden leaves (rich in Carbon); coffee dregs (N and C) and eggshell (rich in Calcium) |
| Containers and storage locations | Under refrigeration, inside pots or plastic bags in departments, sectors or composting area. Stored, after collection, in the composting area | Under refrigeration, inside pots or plastic bags in coordinations and sectors. Stored, after collection, at CESA |
| Frequency of compost feeding, operation and monitoring | Weekly | Bi-weekly |
| Monitored parameters | Incorporated organic mass, temperature and humidity of the most recent windrow, environment temperature and humidity, pH, vectors presence and odors | Incorporated organic mass, temperature, humidity, vectors presence, odors and slurry generation |

conducted small-scale composting research in London for three years and found that approximately 20% of the families involved were engaged in the practice because of diverse factors.

As a result of dissemination and sensitization conducted in the two studied units, the following aspects are noteworthy: the project has survived uninterruptedly (for eight years at FSP/USP and four years at IFES); the acceptance of inclusion in the organic residues originated from the residences project (attending some community members request) and the transmission of this knowledge to other teaching and research units, such as the composting experience at the Butantan Institute in São Paulo.

It is important to maintain a routine of uninterrupted operation and monitoring, counting on workforce with physical and trained strength to support the volunteers' operational activities, and avoid routine failures during school vacations. A significant achievement in the last years, with FSP institution's management, was the inclusion in the contract of the outsourced gardening service of the need to participate in the collection of leaves and grass for feeding the compost and weekly stirring.

2. Creation of Biotechnology and Sustainability Laboratory (LABIOTECS) at IFES

A curriculum embracing education for sustainability requires a broader approach than just discipline knowledge. In this case, students will benefit from hands-on experience with sustainability, while the university may also benefit from students' work creating a bridge between education and professional practice (Leal Filho et al. 2016).

The researchers, together with the management of IFES and the advance of research and extension activities in the selective collection and disposal of solid waste area created the Biotechnology and Sustainability Laboratory (Labiotecs). This laboratory has its design linked to the idea of having a place of study integrated to the external environment, allowing the execution of experiments both in protected environment and outdoors simultaneously (Fig. 2).

**Fig. 2** Undergraduate students sifting the organic compound (Pictures presented were taken by the authors)

Labiotecs is an environment that can host activities of several disciplines, such as Microbiology, Biotechnology, Solid Waste, Recovery of Degraded Areas, among others.

3. Research material grants for disciplines, internships, scientific initiation programs, undergraduate and postgraduate courses

In situ composting has been the subject of different course completion, scientific initiation works and dissertation of professional master's degrees. It is also subject in several undergraduate and postgraduate classes, such as Microbiology, Biotechnology and Waste and Sustainable Technologies (IFES), and Fundamentals of Environmental Health (FSP/USP).

Furthermore, bibliographical research surveys in the national and international literature have been developed regarding organic solid waste and composting, showing the paths of this theme in different countries and institutions, as well as the main techniques used.

Deviation calculations of organic from landfills and sustainability analysis have been the object of the researches in order to point out the benefits of the activity for the Campuses and, consequently, for the environment, as for example, in the reduction of greenhouse effect gases (GHG).

In IFES case, due to restrictions of physical space use, the selected method was vermicomposting in plastic boxes with holes in the bottom (Fig. 3). In the composting process the organic material is degraded by microorganisms in an aerobic way, generating final compound rich in nutrients for the plants. When composting is done with the use of earthworms, the process is called vermicomposting (Aquino et al. 1992).

The vermicomposting process has been accompanied by physical, chemical and microbiological analyzes and using optical and electron microscopy, which is a current way of monitoring the degradation of plant fibers during the process.

4. Deviation of organic solid waste from landfills, increasing their useful life and ensuring significant resource savings for the generator

Quantitative data resulting from weighing the residues are recorded in specific worksheets containing information such as date, origin of material collected and type of residue (peels and leftovers of fruits and vegetables, coffee dregs or leaves). This record is very important for monitoring data, as highlighted by Costa et al. (2016), which reports that 58.45 kg of organic solid wastes were collected from the


**Fig. 3** IFES vermicomposting process (Pictures presented were taken by the authors)

participating areas in the selective collection at Campus Vitória in a six-month period.

From the beginning of its implementation in 2009 until the end of 2016, more than 19 tons of organic waste was incorporated into the FSP composting project. The monthly average was approximately 207 kg and the most productive year was 2013.

At IFES, although the composting experience still does not quantitatively represent a significant gain in waste recovery and diversion of organic matter from landfills, its potential for implementation is enormous. The pedagogical component resulting from the performance and involvement of waste generators, the learning and multiplication of knowledge and the benefits of local use of the natural compound produced are important contribution to the creation of healthy eating habits of those involved and also in environmental terms.

5. Evaluation of compound parameters

Considering that monitoring is an important activity in order to evaluate the results obtained and to provide experiences for students, some physical, chemical and biological parameters have been monitored (Fig. 4).

Measurements of temperature and humidity (prior of stirring) are parameters controlled weekly and recorded in spreadsheets.

The proportion of dry and moist residues is also monitored, since the Carbon/Nitrogen (C/N) ratio is important to regulate the action of the microorganisms that transform the residue into compost, in an effort to maintain the ratio of 30 parts of Carbon to each part of Nitrogen (EMBRAPA 2005).

Composting has been shown to be viable in the environments in which they were implanted, with no neighborhood impacts such as unpleasant odor and presence of vectors with sanitary importance (flies, mosquitoes, rats and cockroaches). Those impacts are a source of fear of some members of the community of the institutions which in principle, did not recommend its implementation.


**Fig. 4** Compost samples for analysis, Vitória (Pictures presented were taken by the authors)

6. Evaluation of compound efficacy

Much of the organic compound produced is used in the gardens and vases of ornamental plants of the institutions, which allows input savings and allows on-site evaluation of compound's effectiveness. Figure 5 shows a garden plot of FSP/USP, whose monitoring was recorded by photograph before and after (a few months later) of the application of the compound.

7. Dissemination of knowledge in events and distribution of compound samples

Often, residents of large cities do not have private gardens because of space and time restrictions, but it is very common that they have ornamental vases and, recently, vertical gardens on apartment balconies or residences with little outside space. Considering domestic composting as a sustainable option, but scarcely disseminated in the country, both FSP/USP and IFES adopted the strategy of participating in events aiming to spread the practice.

Every year since 2010, at FSP/USP, scientific technical events and awareness-raising activities are held as a celebration for the "World Environment Day" (June 5th). The programming involves lectures related to environmental health and other activities, such as guided tours to the composting area and track monitored by the gardens. These activities have always been complemented by the distribution of samples of the organic compound produced in college and guidelines on how to use it (Fig. 6).

The IFES group has participated since 2014 in the "Environment Week of Vitória Campus", offering workshops (2015), as well as poster presentation and exhibition of composting area (2015 and 2016). In these events (Fig. 7), the public is informed about the subject and participants receive samples of organic compost produced by the project, as a way to encourage them to practice selective collection and composting in their homes.

The "Composting Workshops" extension project offered in 2015 at a municipal school located near Vitória Campus, stands out for its relevance. The activity had

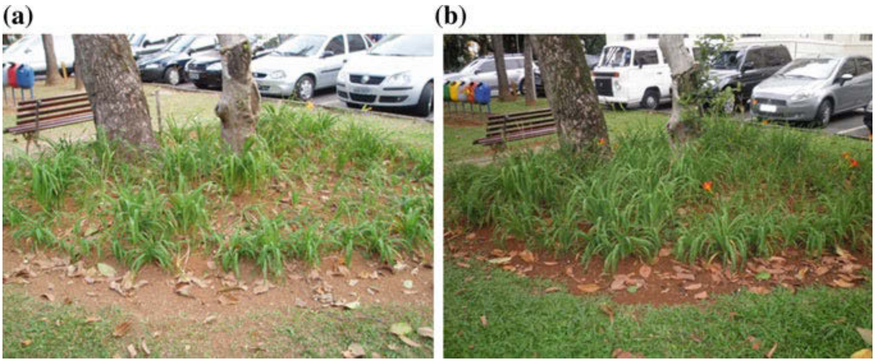


**Fig. 5** FSP/USP garden area. **a** Before application of the compost and **b** four months after application (Pictures presented were taken by the authors)

**Fig. 6** Distribution of compost sample at commemorative events in FSP/USP (Pictures presented were taken by the authors)


**Fig. 7** Compost sample distribution in IFES (Pictures presented were taken by the authors)

theoretical exposition about composting and its importance, followed by a 2-h practical activity of operation in the composting. Twenty-seven children aged 8 to 9 and two teachers participated in the event (Fig. 8).

In 2016, the group developed the extension project “Sustainable Practices in Institutional Environments”, which aimed to disseminate the practice of composting and its relationship with sustainable development. In all extension activities, there was a direct involvement of Sanitary and Environmental Engineering students. In this event they had the opportunity to disseminate the contents discussed in a school environment with different audiences attended by the activities executed. In one of the actions, students of the first year of a public high school were invited to

**Fig. 8** Workshop on IFES campus with public school students (Pictures presented were taken by the authors)

**Fig. 9** Extension activity with high school students (Pictures presented were taken by the authors)

participate in an activity on the importance of microorganisms in the cycling of nutrients and their sanitary and environmental importance (Fig. 9).

8. Evaluation of the user's perception of the compost quality

A study in Greece (Papadopoulos et al. 2008) identified that among people who practice home composting, environmental awareness increases, taking more initiatives and making more efforts to protect the environment. In addition, such people consider the practice of simultaneous separation and composting of biodegradable household waste as a common daily activity, generating increased value products from their waste. Because of this, they actively participate in other materials recycling programs and acquire a sense of responsibility for their own waste.

In June 2016, during the compost distribution in both institutions in a commemorative event of the "World Environment Day", a quiz was used to evaluate the receptivity of the compost.

At FSP, 34 people answered the questions, 25 (73.5%) were cadre employees and one of them outsourced, three professors, three students and two visitors. Only one person still did not know the project. The majority (70.6%) had already withdrawn the samples for at least three previous years, with some withdrawing every year. Only 35.3% of those who took the compost did not contribute taking organic waste for composting. Almost all (85.3%) perceived benefits to their plants when using the compost. Among the benefits, most (70.6%) realized that the plants became greener, lush, strong, beautiful and evolved rapidly.

9. Publications and participation in Congresses

Few publications are found in the literature on the feasibility of composting in institutional environments.

In 2010, the FSP compost project was presented at the Environmental Forum of Alta Paulista, and in the same year, the book "Pathways of Sustainable Public Health" was published by FSP containing a chapter dedicated to the composting project.

The IFES working group has published its results in annals of qualified events of the area since 2013, for a total of seven complete papers in national and international events and one simple summary in an international event.

## 4 Conclusion

The practice of composting is an important form of social and environmental mobilization on university campuses, contributing to the minimization and valuation of organic waste.

Brazilian Solid Waste Policy underscores the systemic view on solid waste management, as well as cooperation between the different spheres of public power, the business sector and other segments of society (Brazil 2010).

The diversion of organic solid waste to sanitary landfills increases its useful life, ensuring significant savings for city management and reducing the environmental and health impacts of population.

This paper is relevant because it shows that the simplified composting method has proven to be feasible and can be employed not only in teaching and research units but also in other institutional environments. It demands a simple operation, does not require high technologies and has low cost. The resulting compost is rich in nutrients, offering the possibility of application in gardens and ornamental plants, reducing costs with inputs for gardening and receiving the approval for its quality by the internal community of the units.

Several factors have contributed to the success of the project, such as: characteristics of the organic waste; continuous and sufficient availability of gardening debris; appropriate space for deployment and operation; organization and willingness of volunteers to participate in activities and the rapid search for a solution to any adverse event. Academic papers, publications of the experiences, and results in journals and scientific events are an incentive and motivation for the academic community to continue working and expanding the scope of sustainability actions, embedding composting as an integral component of their daily lives.

The following limitations have been noteworthy: the need of institutionalizing a team for operationalization and monitoring; the lack of economic and human resources, hampering its continuity; instabilities in the quantity of organic matter segregated/collected, considering periods of holidays; and poor adherence of segregators/collectors.

Future expectations include the production of a standard operating procedure in order to collaborate and encourage other institutions to practice selective collection and composting.

Finally, it is evident that those projects have become examples of how simple actions can contribute for institutional sustainability, even in environments that at first seemed unsuitable for this purpose.

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# Evaluation of Sustainable Bin for Recyclable Solid Waste

**Jacqueline R. Bringhenti, Adriana M. N. Korres, Rodrigo Varejão Andreão and Wanda M. Risso Günther**

**Abstract** The study reports the planning steps, development, and testing of a recycle bin prototype in a Brazilian university. After studies with users and assessment of equipment available on the market, a group of criteria was selected to be assessed, such as: aesthetic/visual; feasibility; quality and material resistance; cost; compatible accessibility dimensions; safety (users and employees); ease of cleaning, and sustainability, which should be considered in the prototype development. The prototype was built with recycled materials, presenting a harmonious aspect and practicality in the use. The recyclable manifold is in testing stage, and the results pointed constructive improvements to be implemented in the future. The weekly monitoring showed presence of vectors in the equipment installed near a restaurant, indicating that that recyclable materials could had been discarded with food and beverage remains. Educational strategies and equipment relocation are being tested to solve the problem. Aiming to optimize the logistics of collection and assessment of the users' participation, a mechanism for monitoring the remote fill level of the equipment is being developed. In general, the prototype proved to be a good education toll for the university students and an alternative in selective collection for use in schools, condominiums, shopping malls, etc.

J. R. Bringhenti (✉) · A. M. N. Korres · R. V. Andreão
Coordination of Environmental and Sanitation Engineering,
Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo,
Av. Vitória 1729, Jucutuquara, Vitória, ES 29040-780, Brazil
e-mail: jacquelineb@ifes.edu.br

A. M. N. Korres
e-mail: akorres@gmail.com

R. V. Andreão
e-mail: rodrigova@ifes.edu.br

W. M. R. Günther
Department of Environmental Health—Faculdade de Saúde Pública,
Universidade de São Paulo, Av. Dr. Arnaldo 715, São Paulo, SP 01255-001, Brazil
e-mail: wgunther@usp.br



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**Keywords** Solid waste · Management · Recycling bins · Behavior
Sustainability

# 1 Introduction

Universities daily produce significant amounts of solid waste and consume valuable human, financial, and environmental resources for a properly management of them. Several Selective Collection (SC) initiatives are being implemented in educational institutions aiming to divert the locally produced recyclables from landfills. These initiatives contribute with the adoption of sustainable practices by the community, which will reflect throughout the society, being utmost important the existence of adequate infrastructure for its performance and sustainability (Barros et al. 2013; Günther and Besen 2010; Kwasny et al. 2016; Miller et al. 2016; O'Connor et al. 2010).

For instance, University of Alberta in Canada has a selective collection system whose goal is to collect 75% of the organic solid waste generated and send them to an anaerobic digestion plant (Kwasny et al. 2016).

Federal Institute of Espírito Santo (IFES) is a public higher educational institution, which conducts research and extension activities with the local community and some of them are associated with the environmental preservation and sustainability. This paper reports the experience of a group that includes professors and students in a work with the community that culminated in the development of a prototype of recycling containers for selective collection for institutional environments.

## *1.1 The Reciclideias Project—10 Years*

The project called Reciclideias has started in 2007, involving a group of professors, volunteers and undergraduate students. The initial objective was to provide these students a practical experience, in addition to contribute to SC sustainability in high solid waste production places. The first stage comprehended five years (2007–2011) and focused on educational actions and technical support for selected SC initiatives such as residential condominiums, public schools, and churches. The dynamics consisted in periodic visits of the students to the places of study, where they provided technical orientation, monitored the recyclables production, promoted workshops about reusable materials and elaborated educative tolls, among other activities. Social media was used for communication.

The results were presented to the participants through an instrument called "recyclometer", developed by the group, where the total recycled material recovered at the site was transformed into the amount of natural resources saved (water, energy, trees, etc.) and the deviation percentage of landfills. The economic feasibility of selling recyclables directly by the producer as an alternative income, involving gravimetric composition tests, research of prices of recyclable material (RM) in the local market, evaluation of requirements and storage time considering transport logistics was also studied (Fig. 1).


**Fig. 1** Actions of Reciclideias Project (All pictures presented were registered by the authors)

The problems and identified issues were discussed in classes from several relevant subjects of the Sanitary and Environmental Engineering graduation course, with the purpose of student's engagement, developing their skills in problem solutions. The discussions and results of this interaction were recorded and systematized by the researchers and volunteers. The experience awakened attention to failures in the Collection and storage stages of RM which compromised its quality and negatively reflected the operational cost, besides the user's opinions was taken in consideration (Fig. 2).

The second stage of the project Reciclideias started in 2012 and focused on development of instruments and technologies for SC with the inclusion of organic waste. First, the challenge was to create a collector for recyclable materials segregated via SC called recycling box prototype, for establishments with large solid waste generation.

The exchange of information and techniques with those responsible for the USP Recicla Program at the University of São Paulo's School of Public Health (FSP–USP), which have accumulated experience in the subject, was very important to support the project Reciclideias.


**Fig. 2** Storage of the collected recycle material

## 1.2 *The Prototype of Equipment for Waste Selective Collection*

The team defined that in the development of the prototype, operational simplicity, environmental aspects, and compatible cost should be considered to foment new SC initiatives in social technology. The development steps were organized (Fig. 3).

The starting point for developing the RM collector prototype was the survey and analysis of similar products available on the market (positive and negative points), associated with literature and document review (S1). The existing manifold equipment, developed by the technical team of the city hall (handmade production) and used basically in schools and public agencies to pack RM, has also been exhaustively evaluated.

In the next step (S2) the criteria to be considered in the development of the prototype project were defined and the students were stimulated to research, discuss, and assign importance of these technical parameters. The group sought contact with users and with the operational team responsible for the collection of

| PLANNING (S1) | PROJECT (S2) | CONSTRUCTION (S3) | EVALUATION AND ADJUSTMENTS (S4) |
|---|---|---|---|
| . Data collection on similar products on the market<br>. Bibliographic search<br>. Evaluation of manifold equipment used by municipal SC program | . Technical, environmental and health criteria selection<br>. Material selection<br>. Prototype *layout* definition | . Prototype construction<br>. Installation site selection<br>. Pretest of manifold existing equipment<br>. Develop monitoring spreadsheet | . Installation and evaluation of the equipment<br>. Adjustments and new tests |

**Fig. 3** Steps to create selective collection equipment prototype

**Fig. 4** Collection of materials contained in the equipment by the City Hall team

the city hall RM, and followed the collection operation to identify ergonomic and production aspects, among others (Fig. 4).

The market survey evidenced the high cost of SC equipment available in Brazil, often imported, and less adapted to the national reality, with formats and dimensions incompatible for reduced spaces, which made it difficult to increase participation in SC initiatives. After this analysis, it was concluded that the existing equipment, manufactured by the city hall, would be used as a reference for the development of the prototype. Despite the operational failures, the collector in use was considered as a low cost and of simplified operation, and already adapted to the existing collection vehicles.

Visual aspects, hygiene conditions, ergonomics, protection against rain, and use of sustainable materials were the main points to be corrected in the construction of the prototype. The main positive aspect was the operational simplicity, based on the exchange of empty bags. These assumptions set the standard for an appropriate collector that should have modern and aesthetically harmonious visual. The bottom away from the ground, coverage for RM protection on rainy days, recycled materials in its manufacture, and compatible collection costs. To facilitate the monitoring and adjustment of the prototype, the Vitória campus of IFES was chosen for installation and testing place, encouraging reflection on the future of the planet and adherence to sustainable practices with the help of informative posters.

The equipment was made using slabs of recycled long-life packages, provided by a manufacturer and reforestation wood for its structure. Difficulties were detected in the application of the recycled slabs in the assembly of the recycling box, which were very flexible, in need of adjustments in the design (S3).

Before starting tests with the prototype, the selected site was evaluated using the old handmade collector. The equipment was installed in August 2014 and a banner was placed with information about the materials that could or not be deposited in the place. The point was closer from the restaurant, copier, library and a bank stand, with great amount of people passing by and it was made a weekly monitoring with help of a pre-elaborated form.

During this period, it was necessary to identify the quality of recyclable materials and social participation, then a gravimetric study of RM produced by the community of Vitoria campus of IFES was executed, with the help of Sanitary and

**Fig. 5** Gravimetric test with selective collection material

Environmental Engineering student's volunteers. The materials were segregated in: plastic, paper, glass, aluminum, hazardous and tailings (Fig. 5).

The results showed that users were bringing recyclables from their homes because of the significant presence of glass (43%), which is a package with restrictions of use in the restaurant of the institution for safety reasons. The paper group represented 39% of the recyclable mass evaluated, a result already expected. The plastic packaging group, highlighting the polyethylene terephthalate (PET), represented 13% of the sample. The percentage of tailings found (4%) was considered low, indicating that the dissemination strategy used was efficient.

Timlett and Williams (2008), emphasize the importance of developing simple and more embrace scope, such as the dissemination of information with themes of daily interest to increase SC.

In terms of pre-treatment of packaging, it was observed that the practice of reducing its volume did not exist, which would be especially interesting for paperboard boxes, long-life packaging and PET. In terms of hazardous waste, batteries were found. Such aspects should be explored in educational matters, in order to reduce doubts and encourage more participation.

It was observed the eventuality appearance of vectors such as mosquitoes, which led to complaints, and it was necessary to relocate the equipment to another point in the same area previously mentioned. The transference allowed to observe different composition of RM collected due to changes in the user profile.

Previously there was a strong presence of recyclables originating from leftovers from snacks, such as glasses and pet bottles, but in the new place, the predominant materials found were paper and paperboard, mainly deposited by cleaners. This aspect was noticed as an important issue to be evaluated for selective collection points in educational institutions and the subject was discussed in class with the students.

A study performed with students, administrators, staff and visitors of a public university located in southeastern Texas has found that location of recycling containers is a critical factor that directly affects their use (O'Connor et al. 2010).

Sidique et al. (2010), studying the profile of people using selective collection facilities in the United States, reported that that their use stems from the perception by those involved that recycling is a practical activity and depends on familiarity with localities. In a comparative study of urban solid waste management in Berlin and Singapore, Zhang et al. (2010) also suggested that increasing the accessibility of recycling facilities is an important factor that stimulated population participation.

Tests with the prototype (S4) started in 2015, and continued with the use of the monitoring spreadsheet from the previous step. A group of students weekly evaluated their functioning: verifying physical conditions, the amount of RM accumulated, the presence of vectors and inappropriate materials.

The comparison of performance between equipment demonstrated that prototype installation was positive in terms of increasing the participation in SC. The demand for empty bags exchange was gradually increasing. During the period of functioning, the old manifold equipment needed biweekly or monthly collection of RM. The prototype, differently, from the second month of installation, demanded weekly collection. Over time, it was necessary to double the storage capacity, installing another prototype next to the first one, due to the difficulty of increasing the collection frequency by the city hall vehicle.

The results were discussed by the group, which started to adopt the strategy of working information for recyclable volume reduction. IFES' cleaners staff had no understanding of the importance of the practice, and often disposed paperboard boxes and other bulky materials at the point of selective collection. A meeting was held with the staff and the cleaning manager to report about volume reduction of RM, clarify doubts and hear suggestions.

The waste volume reduction in the generating source, still with few educational actions, is an important measure that assists the selective collection and directly affects the collection frequency. Consequently, it reduces transport costs and contributes to increase landfill life.

After three months of evaluation, the prototype was sent for maintenance. The main proposed adjustments were related to the prototype closure system, which proved to be fragile, generating instability in the equipment when the bag was changed. The proposed modifications included reducing the height while maintaining the storage capacity (ergonomics), the door locking mechanism and color adjustments. The installation of wheels and cover was also considered important, but not performed immediately due to project financial constraints (Fig. 6).

The prototype has informative panels and guidelines for users, 1000 L capacity and weighs about 20.0 kg.

In recent years, there is a tendency in Brazil to shift responsibility for the waste collection and treatment from municipal urban cleaning services to large generators. This situation will certainly represent an increase of expenses and budgets in the universities and this could be solved in part, through the increase of recycling in the campuses. That is why studies like the one reported here must be encouraged.


**Fig. 6** Prototype of recycling bins of selective collection in institutional environments

## 2 Conclusion: The Prototype Development Represented an Excellent Study Tool for Students and a Social Technology

The developed prototype proved to be adequate and efficient, representing a contribution to the expansion of SC in large generators, as well as an excellent study and research tool for students. The use of recycled materials resulted in an interesting visual identity of the equipment, which was visually attractive and more practical to the user. Low cost, hygiene conditions, ergonomics and protection against rain should also be considered in the construction of the prototype.

The approval of the National Solid Waste Policy (Brasil 2010) has contributed to increasing the number of cities with selective collection programs, since it incorporates modern concepts and inductors, such as shared responsibility in relation to the solid waste destination. In this scenario, higher education institutions have a prominent role, and their initiatives have the potential to reach a significant portion of a city's population, as well as interactively show the benefits of having a conscious and sustainable way of life.

Also, worthy of note is the contribution of this experience in training more qualified technical professional to deal with solid waste management, which represent an important gap in countries like Brazil.

In conclusion, the development of the prototype is a technology associated with selective collection of solid waste and is in line with the current research for mitigation of environmental impacts and the participation in the actions aimed at environmental preservation.

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# Assessment of Outdoor Comfort Conditions Based on the Application of a Participative Model in Open Urban Spaces

**Leonardo Marques Monteiro, Jun Okamoto Junior, Erika Vanoni Peixoto, Júlio Sevarolli Assis, Karina Miyuki Suzuki and Alessandra R. Prata-Shimomura**

**Abstract** This paper presents the development of a mobile device application for the implementation of a participative model for evaluation of open spaces. Participants would be users of the Cidade Universitária Armando Salles Oliveira (CUASO) Campus. The objective is to verify their perception of open spaces with regards to thermal environmental conditions; acoustics; daylight and ergonomic, and enable quick acquisition of these opinions. Thus, the name of the application: Opine. The participative model will provide quantitative subsidies as to the number of users of open spaces and their perception of these spaces and point towards a possible calibration which represents the process of climate adaptation. Studies in the area of environmental comfort and climate in open spaces presuppose the acquisition of data pertaining to environmental conditions, the physical characterization of spaces and

L. M. Monteiro (✉) · E. V. Peixoto · J. S. Assis · K. M. Suzuki
A. R. Prata-Shimomura
Laboratory of Environmental and Energy Studies, Department of Technology,
The Faculty of Architecture and Urbanism of the University of São Paulo,
Rua do Lago, 876, São Paulo, SP 05508-080, Brazil
e-mail: leo4mm@usp.br

E. V. Peixoto
e-mail: erikalu2@hotmail.com

J. S. Assis
e-mail: juliosevarollia@gmail.com

K. M. Suzuki
e-mail: karina.miyuki.suzuki@usp.br

A. R. Prata-Shimomura
e-mail: arprata.shimo@gmail.com

J. Okamoto Junior
Department of Mechatronics and Mechanical Systems Engineering,
The Polytechnic School of the University of São Paulo,
Av. Professor Mello Moraes, 2231, São Paulo, SP 05508-030, Brazil
e-mail: jokamoto@usp.br



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users' opinions, gathered by subjective answers. The last years have shown that, despite the technology used in field researches, part of this information could be acquired in a more dynamic manner. The development of the application led us to think of it as merely a questionnaire, as it would be more direct and easy to understand. Furthermore, an application with a questionnaire could be interesting, as campus users can voice their opinion and make their criticisms (or compliments) heard. The mobile application was developed, initially, for the investigation of user comfort in open spaces of the Campus Cidade Universitária Armando Salles Oliveira, in São Paulo, Brazil, but can also be used for the analysis of other open urban spaces. The application was developed for Android systems, with the following characteristics regarded as relevant: easy to understand; clear; organized; easy to read. It should also be visually instinctive to the user, making the data acquisition process more agile and also enabling the rapid and dynamic treatment of the data, providing fast and easy further calculations based on the index of Temperature of Equivalent Perception (TEP) for the assessment of outdoor comfort.

**Keywords** Outdoor comfort · Urban space · Participative model
Temperature of equivalent perception

## 1 Introduction

The development of a mobile application (OPINE) aims at speeding up and automating the acquisition, treatment and availability of collected data; as well as verifying the viability of the adequation of this methodology to the day-to-day routine of acquisition of primary data in researches with in loco measurements of environmental variables and user's perceptions. More than 50% of people in the world live in cities (United Nations 2014) and—thus—knowledge of urban climate contributes to the understanding of urban sustainability. Also, when projected with potential global climate changes (PBMC 2014), urban climate should be contemplated in the parameters for urban planning and qualification of open spaces. Urban climate is one of the elements of the physical environment which—although affects health, laboral performance and human psychological state—is frequently neglected in urban planning and design of cities and urban spaces. Quality of urban spaces contributes to quality of life, and knowledge of the relations between urban micro-climatic patterns and their implications to users' environmental comfort is a practical and effective solution.

Knowing the relations between microclimate and user comfort provides tools for large-scale planning and design, enabling a better living for people in urban spaces. According to Mills (2006), had climate studies been incorporated into the zoning of cities, many environmental problems could have been reduced.

Whenever exposed to open urban spaces, users are subjected to large-scale climate conditions and the surrounding built environment. On the one hand, geometry and density of the urban environment influence the trapping of solar radiation and of long-wave radiation emitted by the surfaces, the reduction of turbulent heat transport and losses to the atmosphere, and the quantity of anthropogenic heat thrown into the atmosphere through engines in general, as per Oke (1987).

These conditions may cause the user to feel comfortable or thermally stressed, particularly in warmer periods of the year—when they result from air temperature and humidity, exposure to solar radiation and radiation exchanges with the surrounding environment. It is clear that natural ventilation conditions, characteristics of garments and the activity engaged in by the pedestrian (walking, running, sitting, etc.) also contribute to a greater or lesser stress experienced by the users while in open spaces. This same logic applies during colder periods. The relations of the climate variables (temperature, humidity, air velocity and thermal radiation), in conjunction with the mapping of the urban fabric (physical building characteristics) and their respective positioning in the grid of the urban fabric can aid in the analysis of responses obtained from the users.

Empirical studies are necessary not only for determining specifics of the adaptation and acclimatization characteristics of a population in a given climatic context, but also for the calibration of comfort indexes for open spaces (Monteiro and Alucci 2011).

The main individual factors commonly considered are those relating to physical activity, which determine different metabolic rates and clothing. These, in turn, determine different thermal insulation. Thus, a few different factors that can influence the thermal sensation are (Monteiro 2008): 1. general personal factors such as gender, age and ethnicity, and specific, personal ones such as food, posture, body constitution, circadian rhythm and menstrual cycle; 2. geographic location and its climate, considering both the person's birthplace and length of acclimation to a given place; 3. thermal transient, in which the person is subject to different conditions over time; 4. uneven heating or cooling of the body, in which the person is subject to different conditions in space, as in situations of asymmetric radiation fields, drafts and hot or cold floors; and, 5. several other factors, common in open spaces in urban areas, such as overcrowding or physical factors such as rain, noise and glare.

Studies in the area of environmental comfort and climate in open spaces presuppose the acquisition of data pertaining to environmental conditions, physical characterization of spaces and users' opinions (subjective answers), (Monteiro 2008). Knowledge of environmental and physical conditions, as well as users' perceptions becomes paramount for an analysis and/or evaluation of our cities/open spaces. It was observed in the last years that, despite the technology employed in field researches, part of the information could be obtained in a more dynamic way.

## 2 Methodology and Procedures

The need for instruments applied to the more agile process of data acquisition for urban microclimatic variables (temperature, humidity, air velocity and thermal radiation) and subjective variables (perception of thermal sensation and comfort) is fundamental to the optimization of the process and to ensure reliability of the data collected automatically.

The participative model—mobile application—aims at investigating the user's perception of environmental conditions (thermal, acoustic, daylight and ergonomic) and physical characterization of environments, with subjective answers acquired remotely. The application will receive data in real-time from two weather stations installed in the CUASO campus—in areas with the highest pedestrian traffic, in order to establish the most comfortable area and show this to the Campus user. These weather stations are two automatic units by Vaisala, model WXT520, with sensors to measure precipitation; wind direction and velocity; atmospheric pressure; temperature and humidity. The data collected will be transmitted online via GRPS (General Packet Radio Service) to a server at LABAUT/FAUUSSP through FTP (File Transfer Protocol).

We chose to develop a participative model/mobile application for a few reasons:

a. For the increasing quantity of users with mobile devices—Applications are increasingly gaining space on the users' daily lives, thus it is only natural to follow this trend of process automatization, a user research—in this case;
b. Eliminate the need for an interviewer—The need for volunteers, or hired labour, is common practice in many data gatherings in order to approach the largest possible number of people. Furthermore, the manner in which users are sampled requires consideration, to ensure the lowest possible bias in the answers, thus ensuring a random sampling;
c. Promote a more interactive and pleasant interface for the user—The user will answer a series of questions, so the more comfortable he/she is with the tool, the more reliable will the answers be;
d. Ease of data acquisition—The data can be acquired at any time, unbound by interviewers' working hours. Furthermore, this application is aimed at outdoor environments, so people can answer during their displacements on foot or bicycle with no need to interrupt their activities, thus optimizing their time;
e. Accuracy of the time of information acquisition—One of the biggest difficulties is to know if the survey was taken in the morning, afternoon or evening. With mobile acquisition, the time-stamp from the data transmission from the users' devices will enable a precise analysis of the influence of the time of day on the comfort perceptions.

## 2.1 Study Area

The first idea of developing the OPINE app was for it to be used in the *Campus Cidade Universitária Armando Salles Oliveira* (CUASO), São Paulo University (USP), Brazil. The relevant mathematic indexes used are those pertaining to the city of Sao Paulo. Naturally, use of the app in a different city would require re-programming with different indexes.

The *Anuário Estatístico—USP* (2015) states that the majority of USP's population is comprised of undergraduate and graduate students (70% of the people on Campus).

Figure 1 shows some examples of the different special conformations (streets + medians + sidewalks + green areas + buildings) which affect the space's surface temperature conditions faced by the users as they circulate around the Campus.

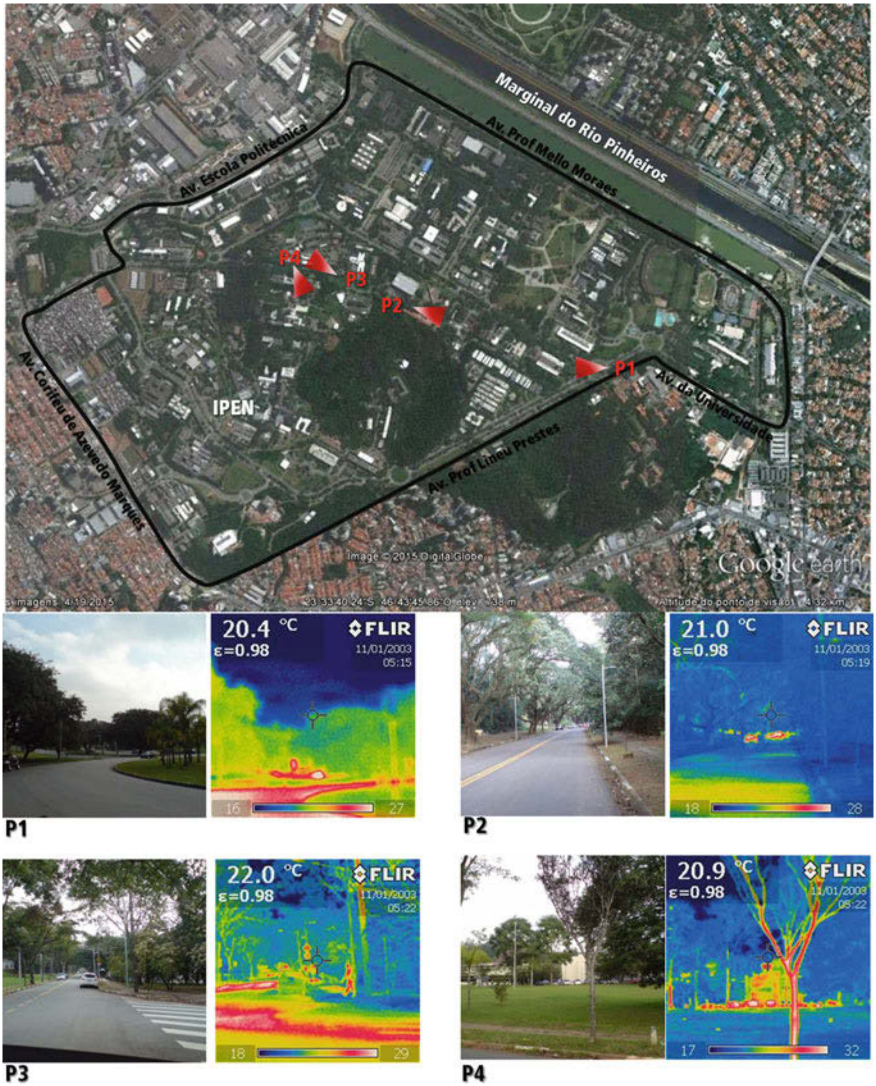


**Fig. 1** Map of CUASO with some thermal images taken on open spaces of the Campus. *Source* Images from the authors

This variation occurs due to the areas being exposed to the sun or shaded. The detection of paths—or routes—more commonly taken by the users will enable verification of the spaces chosen by the users as more comfortable.

## 2.2 Opine—Development

The OPINE app was developed in Java programming language (Deitel and Deitel 2005) and Android (Lecheta 2015). The platform chosen for the app was the Android system, for its larger audience reach when compared to IOS—an operational system developed by Apple.

Android is currently the undisputed leader in Brazil, with a 89.5% share of mobile devices. Windows Phone is second with 5.9% share and Apple is third, with 3.5% share (Tudo cellular 2016).

The system, as a whole, is comprised of a mobile device and two weather stations (currently under implementation), which feed a data bank with users' subjective answers and climate conditions, respectively, connected through a server.

With each answer from the users, the data is directed to the system's data bank. Figure 2 presents the process of routine development and the acquisition system. The participative model can already be used for subjective data (users' answers) acquisition.

## 2.3 Opine—Variables for Collection

Some pre-requisites were settled upon for the development of the app: 1. Contain a clear survey: 2. Easy and quick to answer: 3. Questions and its possible answers must be easy to understand; 4. Lead users to answering all mandatory questions; 5. Use of a visual language which appeals to the target audience (students); 6. Compel the user to answer it; 7. Generate feedback which can be used in comfort indexes; 8. Ergonomic should be designed for ease of navigation; and 9. Be made so as to reach a large audience.

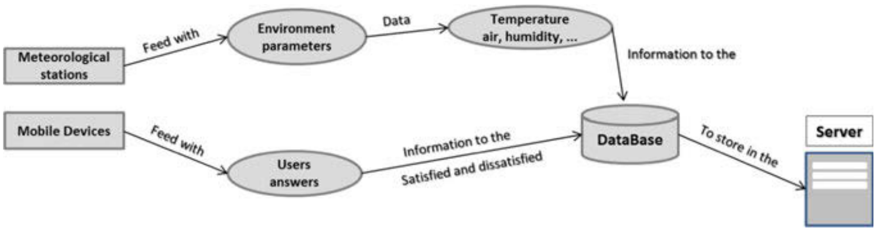


**Fig. 2** Development system diagram—participative model. *Source* Images from the authors

The user's contribution, on opening the app, is to answer questions pertaining to his/her perception of the Campus' open spaces, in regards to thermal environmental conditions, acoustics, illumination and ergonomy.

The user accesses the app through the phone's menu, by clicking the OPINE logo. The splash screen shows the slogan "Are you comfortable?" ("*Você está confortável*?"), as an indication of what the questionnaire is about. Subsequently, on the MENU option, a text is shown explaining what the app is about, also making an alert about the use of the device's battery and stating the information will not be used if the user so chooses (Fig. 3):

"Welcome!

This app is intended as means to obtaining, in a practical and dynamic manner, information on users' perceptions of environmental conditions in outer open spaces of the Campus.

Your answers are very important to a critical analysis of the procedure developed for the remote acquisition of data, for evaluation of the comfort conditions of urban open spaces.

Thank you!"

After accessing the app, the user inputs some data—essential to understanding his/her positioning in the built environment, as well as information pertaining to: age, sex, height, attire, physical activity (still, walking, running…) as well as his/her mood at that specific point.

Figure 4 shows some examples of the screens for input of users' initial information.

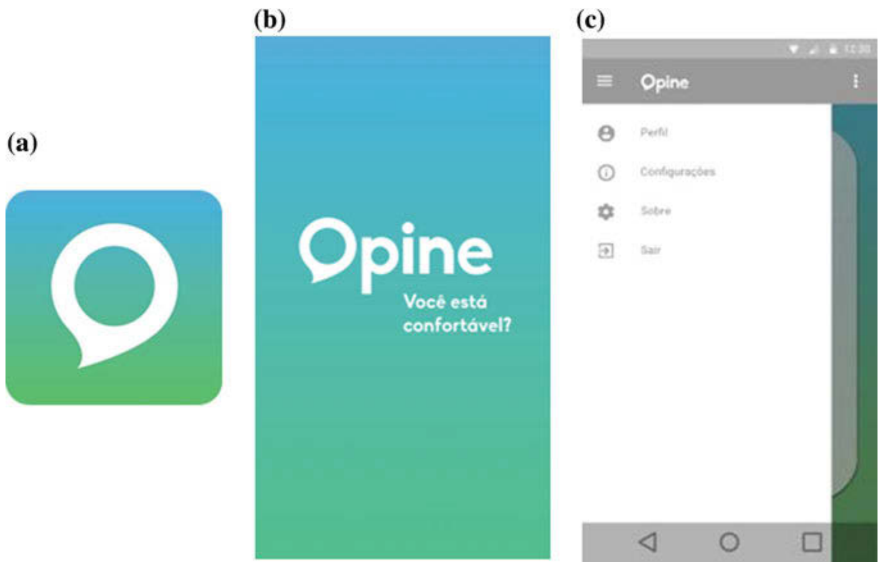


**Fig. 3** **a** App icon/logo which will be shown on the device's menu; **b** Splash screen; and; **c** Initial screen—information. *Source* Images from the authors

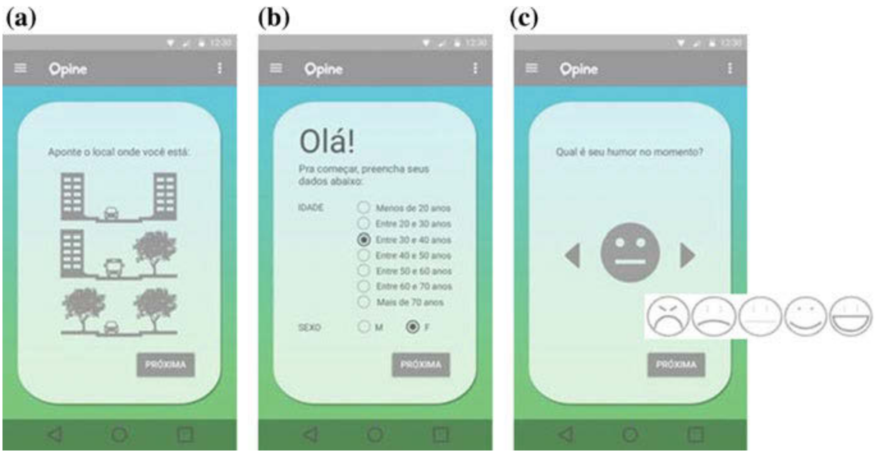


**Fig. 4** App screens: **a** Question about user's location—and if there are more trees or buildings; **b** User information (age and gender); and **c** Current mood. *Source* Images from the authors

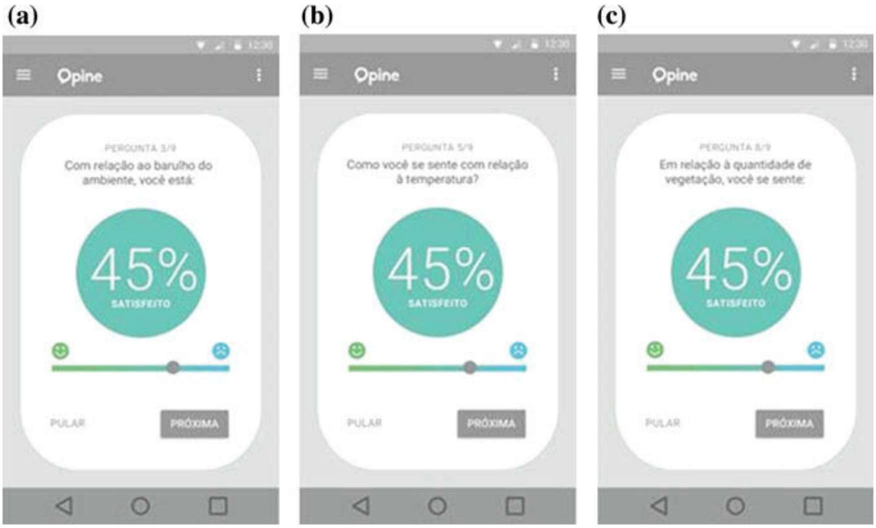


**Fig. 5** App screens—user's opinion. *Source* Images from the authors

The input of initial information is followed by nine screens which try to obtain from the user information as to his/her satisfaction as to environmental and spatial parameters of his/her current location. For these information the user uses slide-bars going from 0% to 100% satisfaction. Figure 5 shows some of these nine screens.

Information requested are: 1. How do you feel about this place?: 2. How do you feel about air quality at this time?; 3. How do you feel about ambient noise at this time?; 4. How do you feel about light reflected from buildings, passing cars and

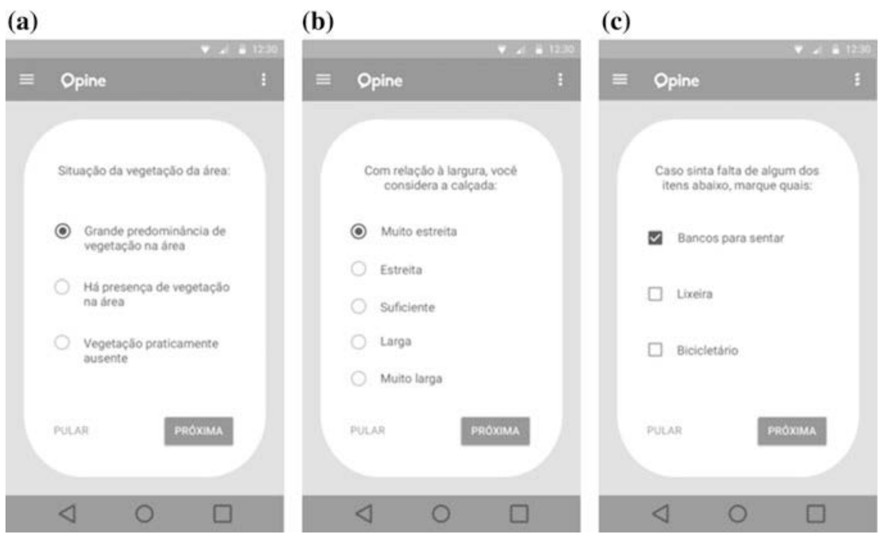


**Fig. 6** App screens/additional information—user's opinion. *Source* Images from the authors

ground at this time?; 5. How do you feel about temperature at this time?; 6. How do you feel about the sun at this time?; 7. How do you feel about the wind at this time?; 8. How do you feel about the quantity of vegetation?; 9. How do you feel about the sidewalk?

Three additional questions comprise the App and have more of an informative character: a. Predominance of the vegetation in the area; b. Do you consider the sidewalk width (from too narrow to too wide); and c. Please check any items (urban furniture) you miss: benches/trash bins/bicycle rack (Fig. 6).

## 2.4 *Opine—Calculations*

Monteiro and Alucci (2005), reviewing the state of the art of outdoor comfort modelling researches, observe that there is a tendency to use equivalent temperatures instead of interpretative ranges, since an equivalent temperature itself, without an interpretative range, would give a notion of the thermal sensation, taking into account a reference environment.

Comfort assessment in outdoor spaces requires the comprehension of additional factors, which are not taken into account in a typical indoor situation. Short-wave radiation and winds, considerable sweating rates or variable clothing, different human activities and expectations, among other factors, bring more complexity to the analysis. TEP—Temperature of Equivalent Perception is a comfort index proposed by Monteiro (2008) that allows the verification of the thermal adequacy of outdoor spaces in the subtropics.

The method adopted is experimental inductive, by means of field research of micro-climatic variables and subjective answers, and deductive, by means of regression analysis. The significance of the results is verified by comparison with the ones obtained by simulation of predictive models.

Thus, Opine, in order to calculate the TEP—Temperature of Equivalent Perception, considers four microclimatic variables commonly used in studies of thermal comfort and allows for general situations the prediction of thermal sensation for a population adapted to the conditions of São Paulo, within the limits set for adjustment/calibration (Monteiro 2008).

The final equation of Temperature of Equivalent Perception (TEP) highlights the microclimatic variables, the variables metabolic rate and thermal insulation of clothing, acclimatization and acculturation, indicating previous climatic trend, compared to average hourly air temperature outside the past thirty days.

The equation can be described as:

$$TEP = 29.877 + 0.4828 * t_{ar} + 0.5172 * t_{rm} + 0.0802 * UR - 2.322 * v_{ar} \\ + 5.118 * M + 38.023 * I_{cl} - 0.1742 * t_m$$

where:

$t_{ar}$ Air temperature, in °C;
$t_{rm}$ Mean radiant temperature, in °C;
$UR$ Relative humidity in %;
$v_{ar}$ Air velocity in m/s;
$M$ Metabolic rate in met;
$I_{cl}$ Thermal resistance of sensitive heat clothing in clo;
$t_m$ Average annual temperature of the climate database used in °C

It is noteworthy that using this equation, when activities are practiced in the external environment (people sitting, standing still and walking), it is necessary to consider the reference value $M$ equal to 1.3 met. If there is no available database for the hourly average air temperature of the thirty days prior, or the air temperature will average the previous month, the reference value $t_m$ equal to 19.3 °C should be used.

Table 1 shows the limits of all the variables involved in the index, based on empirically observed data, except for the case of metabolic activity data, which were simulated.

The Temperature of Equivalent Perception (TEP) of a given environment can be defined as a thermal sensation scale which presents values numerically equivalent to those of the air temperature of a reference environment (mrt = ta, rh = 50%, and va = 0) in which the thermal sensation perception is the same to the one verified in the given environment.

Following the equation above, one may observe that the air temperature of neutrality, in the case of a reference environment, is approximately 23.4 °C. Yet the advantage of equivalent temperatures is the intuitive interpretation of their values, it

**Table 1** The range of interpretive ranges of values and feelings for that index *Source* Monteiro (2008)

| Variable | Minimum value | Maximum |
|---|---|---|
| $t_{ar}$ | 15.1 | 33.1 |
| $UR$ | 30.9 | 94.7 |
| $v_{\mathrm{ar}}$ | 0.1 | 3.6 |
| $t_{rm}$ | 15.5 | 65.5 |
| $M$ | 1.0 | 2.4 |
| $I_{cl}$ | 0.3 | 1.2 |
| $t_m$ | 16.0 | 22.6 |
| TEP | 13.7 | 45.3 |

**Table 2** TEP index—interpretive bands *Source* Monteiro (2008)

| TEP | Sensation |
|---|---|
| > 42,4 | very hot |
| 34,9 ~ 42,4 | hot |
| 27,3 ~ 34,8 | low heat |
| 19,6 ~ 27,2 | neutrality |
| 12,0 ~ 19,5 | slightly cold |
| 4,4 ~ 11,9 | cold |
| < 4,4 | very cold |

is also interesting to provide an interpretative range, since the intuitive interpretation is only possible after the exposition to several environments and their respective equivalent temperatures.

Table 2 shows limiting values of the variables involved in the TEP index (Monteiro 2008).

It is worth noting that the equation was obtained from data included in certain environmental situations (Table 1). For use in other situations, it is necessary to check the correlation of results of possible extrapolations with observed data in situ.

## 3 Conclusion

We present here the development of a mobile application for the acquisition of data from the user. It has several desired qualities: easy understanding, clarity, organization, readability, images to make it more intuitive, is made for Android devices and its visual identity is related to the theme.

Moreover, it provides a comfort index which can be properly used for predicting comfort in outdoor spaces in a subtropical climate. The Temperature of Equivalent Perception (TEP) presents good correlations with the data gathered in different scenarios of the city of Sao Paulo (Monteiro and Alucci 2009). In sum, the research provided a simple, easy-to-use and reliable index to assess comfort in outdoor spaces in a subtropical climate.

The app was developed in Portuguese and can be translated to English in the future. Its use in other cities/spaces can aid in several environmental comfort researches. The app will also support the researcher in the data collection task.

The greatest challenges are to motivate the user to answer—recurrently—the app survey in different days, times and seasons; to obtain/create/produce a data bank capable of subsidising the changes and/or creation of a comfort index for outdoor environments (physical and environmental characteristics), based on this user profile.

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# Sustainability in University Campuses and Environmental Education Policy: Complementary Governances Toward Consciousness Structure in Carbon Emissions Reductions

**Paulo Santos Almeida, Anderson Soares Lopes and Beatriz Decarli Oliveira**

**Abstract** Currently, cities have been increasingly demanding of their managers concerned with their ability to adapt to climate change in the face of their environmental impacts as happens with the management in the university campuses, although, with its perspectives of lower dimensions. In this sense, the university can promote involvement through integrative actions with the surrounding community in order to build the educational environment of carbon reduction applicable to the resilience and city's sustainability. This paper focuses on the Brazilian environmental public policies constitutional debate and the feasibility of encouraging legal instruments toward inclusion of educational initiatives to change the cultural environment to approach the community as an instrument to raise consciousness and environmental consciousness in participatory development by measures of optimization of Logistics and mobility of users or citizens. Its objective aims to investigate and discuss the feasibility of partnerships for the direction on main integrated community structure in university campuses with the dedication of urban mobility instruments. The methodology of legal and documentary primary doctrinal analysis of the principles of participation and sustainable development demonstrates the comparative argumentation of a participatory and democratic society. The hypotheses indicate that a participatory system increases people's

P. S. Almeida (✉) · B. D. Oliveira
School of Arts, Sciences and Humanities, University of São Paulo,
São Paulo, Brazil
e-mail: psalmeida@usp.br

B. D. Oliveira
e-mail: beatriz.decarli.oliveira@usp.br

A. S. Lopes
CIDSGAM Research Group-City, Sustainability and Environmental Management
(EACH-USP), University of São Paulo, São Paulo, Brazil
e-mail: aslturjp@yahoo.com.br



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consciousness and Social Environmental Commitment (SEC) and their life quality. In general, the efforts of university governance involving its human capital and its environment in these actions contribute to evidence of integration and protection of the common good leading to careful outcomes with the cities in parallels.

**Keywords** Sustainable university campus · Sustainable cities mobility
Environmental educational environment · Participation · University governance
Carbon reduction

## 1 Introduction

Sustainability and the demands of the century to 2030. The United Nations in September 2015, Sustainable Development Summit, where Member States and civil society have negotiated their contributions to the next steps to global sustainability. Was presented the Sustainable Development Goals (SDG) through 2030 Agenda: "transforming our world: the 2030 Agenda for sustainable development" (United Nations 2015), defined by the United Nations as part of a new sustainable development agenda that must end the work of 08 goals of Millennium Development Goals (MDGs). As made, a difference in people's lives and this progress may be expanding in most countries with strong leadership and responsibility.

Member States led the process towards the post-2015 development agenda with the participation of major groups and stakeholders of civil society. The agenda reflects the new challenges of development and is linked to the outcome of the Rio + 20—the UN Conference on sustainable development, which was held on June 2012 in Rio de Janeiro, Brazil (UN 2012).

The limitation and the importance of this paper is discussion of sustainability in the environment of college campuses and public policies that aid in Brazilian constitutional environmental consciousness for the need of reducing carbon emissions.

The paper discuss issues associated with the relationship between climate change and sustainability management in the urban environment (Brown et al. 2012; Carmin et al. 2012; Childers et al. 2013; da Silva et al. 2012; Glaeser 2011; ISC 2012; IPCC 2007; Kernaghan and da Silva 2014; Pickett et al. 2013; Piérola and Santos de Almeida 2016; United Nations Population Fund 2007; Victor 2015).

This study we look that the institutions and standards, as the Brazilian Public Environmental Education Policy develops awareness of the importance of environmental education (Almeida 2009; Carmin et al. 2012; Fiorillo 2011; Fourati-Jamoussi et al. 2015; Jacobi and Bensen 2011; Savelyeva and Douglas 2017; Vincent and Mulkey 2015).

This paper debate on University Campuses develops as spaces to complement public policies (Andersson and Ostrom 2008; Boquet 2014; Foss 2005; University

Acts: Portaria GR nº 5.648, de 05.06.2012, and Portaria GR n.º 5.837, de 20.09.2012; University of São Paulo—USP 2017a, b).

In this perspective, to align the concepts associated with sustainability are the actions and a set of practices in the context of university governance when integrated tend to provide low environmental impact, and distinct benefits for your time comes to involve the human capital and the environment.

Through a documentary analysis methodology and doctrinal principles of primary participation and sustainable development demonstrates a comparative argument of a participatory and democratic society. So this research if they propose analyzing the sustainability parameters arranged in college campuses Brazil's territorial boundaries laid out.

In this perspective, the objective of this research is to investigate and discuss the feasibility of partnerships for the direction of the integrated structure of the main community on college (university) campuses with the dedication of instruments of urban mobility.

Their hypotheses indicate that (1) a participatory system increases people's consciousness and the Social Environmental Commitment (SEC) and their quality of life, and (2) the university governance efforts that involve their human capital and their environment in these Actions contribute to the evidence of integration and protection of the common good leading to careful results with cities in parallel.

## 2 The Cities and Sustainability: Climate Change and the Reality Scientifically Discussed

The cities were conceived as having a core density, in which most non-residential functions are concentrated, surrounded by rings of less and less dense residential and smaller commercial or manufacturing functions, however today in industrialized countries currently the density profiles of urban areas are flattened because they spread (Pickett et al. 2013).

These days it appears that high share of cities remains dedicated to capital accumulation, economic development, and urban agendas and policies aimed at support of the economy (Carmin et al. 2012). However, in addition to the financial benefits related to employment, for example, these cities provide people facilities such as access to education and the promise of a life easier (Glaeser 2011; Pickett et al. 2013), these places focus on a greater number of public and private services.

These characteristics make people seek to live in urban environments, instead of searching for rural areas. However, this does not reflect reality in all locales on the planet (Piérola and Santos de Almeida 2016).

On Asia most of the population of urban residents In low-elevation coastal areas prone to danger, (3) and the largest urban population that faces perennial and seasonal water shortages today, as well as the lack of water due to climate change projected to 2050. (4) there are in Asia and other countries, and the third tier cities already face a daily struggle to provide infrastructure and services, with limited institutional capacity and finance restricted (Brown et al. 2012).

Thus, as estimated that the urban growth in the coming years will focus on medium-sized cities that have a population of 500,000 to 1 million people (Pickett et al. 2013; United Nations Population Fund 2007). In addition, it turns out that more than 60% of this population projection will occur in a single continent, Asia (Brown et al. 2012), which further aggravates this reality.

This is relevant information, since these intermediate-sized cities along your population increase may seek to adopt different ideas and practices in the parameters of sustainability (Childers et al. 2013; Pickett et al. 2013).

These actions sometimes directed to sustainability parameters are associated with providing the population a better quality of life, while decreasing the environmental impacts resulting from activities on a daily basis and consequently adapt climate change.

It is observed that in the face of climate change scenario, in which experiencing in planet new weather patterns (Carmin et al. 2012; IPCC 2007), which in your time comes the cause in urban areas changes of temperature, natural disasters, heat waves and water scarcity (Carmin et al. 2012), for example.

In the face of this reality, in Asia the initiative of donor bodies with the purpose of catalyzing the consciousness about the impacts of climate change in urban environments and start processes that allow cities to adapt and become more resilient, among these organizations, as the Rockefeller Foundation, 1 UN-HABITAT and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), make significant investments in the process known as urban climate change resilience-UCCR (Brown et al. 2012; da Silva et al. 2012; Kernaghan and da Silva 2014).

It should be noted that climate mitigation initiatives are taking place in cities around the world. However, despite the high visibility that adaptation has the political agenda and the global imperative to initiate actions, relatively few have made concerted Efforts to develop dedicated adaptation plans or to define adaptation initiatives in motion (Carmin et al. 2012).

However the financing becomes insufficient to develop significant changes that provide, for example, carbon emission reduction, especially in front of a scenario in which is displayed the absence of national policies in this context, as well cities such as Durban and Quito feature innovative experiences in the fight against climate change (Carmin et al. 2012; ISC 2012; Kernaghan and da Silva 2014).

The science of ecology has to contribute toward the goals of urban sustainability through the understanding and helping to design and manage existing and emerging cities (Pickett et al. 2013). The cities have required more and more the concern of their managers with your ability to adapt to climate change in the face of their environmental impacts through the diplomacy governance, and evolution on their technologies, as it were the discussion in COP-21, in Paris (Victor 2015).

## 3 Brazilian Policy of Environmental Education: A Tool for Consciousness

City plans and planning processes generally reflect targets local public officials, representatives and communities seek to advance. According to neo-institutions, municipal governance theorists also shaped by the local institutional setting (Carmin et al. 2012). The location becomes the ideal environment for the human and environmental development (Fiorillo 2011).

The Brazilian Public Environmental Education Policy has focused on consciousness and the social and environmental consciousness. In the legal Act No. 9795/99, formal education, non-formal or cultural has been the basic strategy for local, regional, and federal people (Jacobi and Bensen 2011); with the inclusion of content focused on sustainability since fundamental education levels for children as viewed by Almeida (2009) toward university education and vocational technical or professional (Fourati-Jamoussi et al. 2015; Vincent and Mulkey 2015).

Society and governs could be building on the benefits of sustainability implementations in the Academy through greening, sciences and curricula to its main beneficiaries—the young generation of students—are less certain. (Savelyeva and Douglas 2017).

The transformation of environmental has to pass to brush it up, and the view of Senge, transformative learning "involves the movement of mind [that] gets to the heart of what it meant to be human". Other important characteristics of transformative learning are that it grants one the ability to re-create oneself; to do something one never thought to be capable of; and to re-perceive the world and one's relationship with it" (Senge *apud* Savelyeva and Douglas 2017).

As view of Savelyeva and Douglas (2017) about experiences of Hong Kong as "it is hypothesized that within a formal educational setting, a sustainability curricular module ignites transformative learning, which fosters a sense of global consciousness and increases the sustainability consciousness of young Hong Kong citizens who have entered tertiary education; this might be a common case also for many other secondary school graduates who did not enter the tertiary education system."

## 4 University Campuses: Spaces for Management and Complementation of Public Policies

In general, university governance efforts involving their human capital and their environment in these actions contribute to the evidence of integration and protection of the common good leading to careful results with cities in parallel.

More examples of these initiatives have been considered of Non-Governmental Organization (NGO) also, it insists on clear behavioral foundations adopts an economizing perspective and examines efficient alignment between knowledge transactions with diverse characteristics and governance structures and mechanisms with diverse capabilities of handling these transitions. Boquet (2014), Foss (2005), although there are notorious differences of the atmosphere about organizations. Some university there are owner policies to environmental management that could be great model for governance outside theirs gates. Decentralizations and reforms (Andersson and Ostrom 2008) involve the transfer of rights, resources and responsibilities related to the governance of environmental and academic community life, participation on decisions are instrumental for changing social scenarios in development behavior, also interesting for innovations.

Thus, in Brazil there is good model as show us University of Sao Paulo, which it has a Superintendence of Environmental Management (SGA) to work with planning, implementation environmental plans and policies that involve the academic community, and local user toward changing sustainability in society (University of São Paulo—USP 2017a, University of São Paulo—USP 2017b).

The main plans and actions have been developed through the initiatives called "Pilot-Projects", which could asked from their professors or departments of whole campuses university about various environmental goals. Furthermore, the SGA is keeping in its structures a efficiently programs of reduction, and recycle of waste; use equality and efficient water and energy in their campuses. Actually, these experiences could be replicated in cities because the ESC has been identificated as a social built. (University of São Paulo—USP 2017a, University of São Paulo—USP 2017b).

University and State must to be aligned. As public policies Brazilian about all environmental demand to sustainability governance delineated by law, in the campuses university always shaw to replicate as in whole society in federal, regional and local Law State. In this sense, University of Sao Paulo has their environmental programs about efficient maintenance of water, forest, energy (University Acts: Portaria GR nº 5.648, de 05.06.2012, and Portaria GR n.º 5.837, de 20.09.2012, for example), although, the expectative of it have being increased with new projects in partnerships.

The Environmental Education gives attention special from their governance because USP has interlinked with other program in other campuses USP as integration to work together. Then, we can affirmate that Social Environmental Commitment (SEC) have be comprehensive that all attitude, involvement and actions, which aim built the sustainability and equality environmental around the public governance, and community.

## 5 Conclusions

In conclusions of governance and policy toward sustainability in the University Campuses, reflections on the reality and development of cities were made considering factors that affect people's quality of life such as climate change and its environmental impacts, which cause in the urban environment different consequences such as, for example, heat waves and water scarcity. Into this scenario, it is observed that governments and organizations are still insufficient to reduce carbon emissions and to adjust the political agenda of countries facing this global script, however, are changing for governance initiatives for sustainability.

Brazil there is opportunity to increase the benefits and sustainability in education in every sense. With this, there will be an increase in the socio environmental consciousness and commitment of all the actors involved in this scenario. As an example, Hong Kong exposes ways to sustainability through formal education from high school teenagers before entering higher education.

There have been scope for linking initiatives in universities governance to connect the environment and human, community and academic community life to raise consciousness, also commitment and efficiency for environmental preservation of water, energy, forest and climate use through planning, and to overcome the limits of these institutions to improve the quality of life of people with responsible management of whole environmental and administrative resources for Environmental Social Commitment (ESC).

In this perspective, is important to introduce in the future research possibilities of study, for example, environmental education, human beings, natural resources, sustainability, universities, cities, the climate change and reducing carbon emissions.

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# Diagnosis of Chemical and Special Waste Management in a Higher Education Institution: A Methodology for Data Acquisition and Processing

**Renata Martins Pacheco, Ariane Laurenti, Bruno Eduardo dos Santos Silva, Iascara Mattes and Sara Meireles**

**Abstract** Special waste management represents a major challenge for higher education institutions due to its particularities regarding generation, logistics, treatment, and final disposal. Despite the difficulties encountered, special waste disposal in landfills can no longer be considered as an adequate solution for this particular waste. An integrated waste management system requires a global perspective, which considers from its generation to its treatment/reuse, thus involving appropriate technical and socio-environmental practices. The construction of a waste management system that prioritizes low levels of environmental impact starts with methodologies that, while producing a situational diagnosis, involve and compromise generators along the process. Within this context, the Federal University of Santa Catarina (UFSC) obtained a special waste diagnosis through an institutional research project involving members of the university community. For this study, several exploratory techniques were applied, as well as field visits to specific waste generation places. The complexity and large amount of data obtained, coupled with

R. M. Pacheco (✉)
Coordenadoria de Gestão Ambiental—SEOMA, Universidade Federal de Santa Catarina—UFSC, Trindade, Florianópolis, SC 88040-900 Brazil
e-mail: renata.mp@ufsc.br

A. Laurenti
Centro de Ciências da Saúde—Departamento PTL, Universidade Federal de Santa Catarina—UFSC, Trindade, Florianópolis, SC 88040-960, Brazil
e-mail: ariane.laurenti@ufsc.br

B. E. dos Santos Silva
R. João Pio Duarte Silva, 404/101 B, Córrego Grande, Florianópolis, SC 88037-000, Brazil
e-mail: bruno.silva@rotaria.net

I. Mattes
R. Dr. Agostinho Sielski, 127, Santa Mônica, Florianópolis, SC 88035-320, Brazil
e-mail: iascaraa@gmail.com

S. Meireles
Prefeitura Universitária—PROAD, Universidade Federal de Santa Catarina—UFSC, Trindade, Florianópolis, SC 88040-900, Brazil
e-mail: sara.meireles@ufsc.br



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the project's high demands required a specific level of treatment and standardization. In this sense, this article presents the methodological procedures used to acquire and extract response data from a broad and diverse set of special waste generators in a higher education institution, making them accessible for future use at UFSC.

**Keywords** Chemical waste · Campus UFSC · Higher education institutions sustainability · Qualitative-quantitative research · Methodological procedures

## 1 Introduction: Sustainability in Higher Education Institutions

The growth of higher education institutions around the world, in terms of its space and complexity, has been an important factor for their managers to take an active position regarding the so-called "sustainability on campus". Alshuwaikhat and Abubakar (2008) highlight the different levels of impact that a university can cause to the environment, resembling a city, mainly due to the diversity of human activities developed in this type of territory. In this way, several educational institutions have implemented policies for the improvement of sustainability on campus (Rodriguez et al. 2002), including strategies related to the management of greenhouse gases, consumption of electric energy, and application of environmental analysis tools. These tools (AASHE 2013) analyze from the university's fleet of vehicles to the systematization of processes involving solid waste generation.

Alshuwaikhat and Abubakar (2008) present a few ways that universities have sought to achieve better levels of sustainability, one of them being through "environmental improvement and management", which can be exemplified by a systemic management of waste generation. These institutions should stimulate systemic, integrated and consistent practices, aiming at community involvement and facilitating the success of the actions (Armijo de Vega et al. 2008). In this sense, it is particularly important for the campus waste management to be institutionalized (Evans 2011).

In addition to the systemic aspect, it is highlighted the fact that waste generated in a higher education institution should be considered "special" in most cases. Lara et al. (2017) apply this statement especially to chemical waste, which presents risks associated with quantity, danger, and variety of its composition. Biologic risk waste is also considered "special" in Brazil.

Notwithstanding the technical aspects, the formulation of an integrated waste management system requires other types of commitments. The principles of precaution, prevention, sustainability (Tickner 2009), responsibility in generation, disposal, use, and consumption of waste products must be included in the system design and implementation. These principles should be considered in every action and, in addition to the compliance regarding legal guidelines, work should be collaborative in an inter/transdisciplinary way.

## 2 Waste Generation at the Federal University of Santa Catarina

The present study was carried out at the Florianopolis campus of the Federal University of Santa Catarina (UFSC), located in the city of Florianopolis—state of Santa Catarina, Brazil—which covers an area of more than 20 million square meters, distributed in 11 academic and administrative main centers, as well as a few independent sectors. UFSC has around 40.000 community members, most of them contributing to the generation of different types of waste.

Based on the concepts of integrated systemic analysis of Alshuwaikhat and Abubakar (2008), as well as on the experiences of other universities, the authors of this project made a diagnosis of the current situation of special waste at UFSC. Due to the complexity and quantity of generators at the university, a specific methodology was developed for the acquisition, processing and presentation of qualitative-quantitative data. The methodological procedures are presented throughout this article. Through this research, it was possible to locate and quantify 304 laboratories, of which 182 were producing this type of waste (Laurenti et al. 2015; Laurenti 2016). Figure 1 brings part of the labs location, spatially displayed in a GIS system developed during the study.

## 3 Data Acquisition Methodology: Planning, Instruments, and Interviews

The first question considered during this project design was its institutional and social scope. Although the research project was limited to UFSC Campus in Florianopolis, the process developed by the study should be able for future extension to other Campuses of this Institution to generate a unified program of waste management (UFSC campuses are located in the cities of Florianópolis, Araranguá, Blumenau, Curitibanos, and Joinville—Santa Catarina).

It is essential to emphasize that the project deals with environmental issues, which require an interdisciplinary approach, and its development must be articulated with actions in the fields of teaching, research, and extension of the institution. Therefore, in the conception of the project, the socio-environmental sphere was intended to reach directly the entire university community and indirectly all the environment around the Campus, as well as the ecosystems of surrounding regions.

A second aspect considered was the composition of the team. It was essential that the project should not only address the logistical dimension, which generally prevails in this type of study, but also address concerns in the fields of environmental education, environmental awareness and safety. The team was formed by professors, students, and UFSC staff, all of them related to at least one of the sectors of Sanitary and Environmental Engineering, Chemistry, Toxicology, Biology, Occupational Safety, and Education in Chemistry.

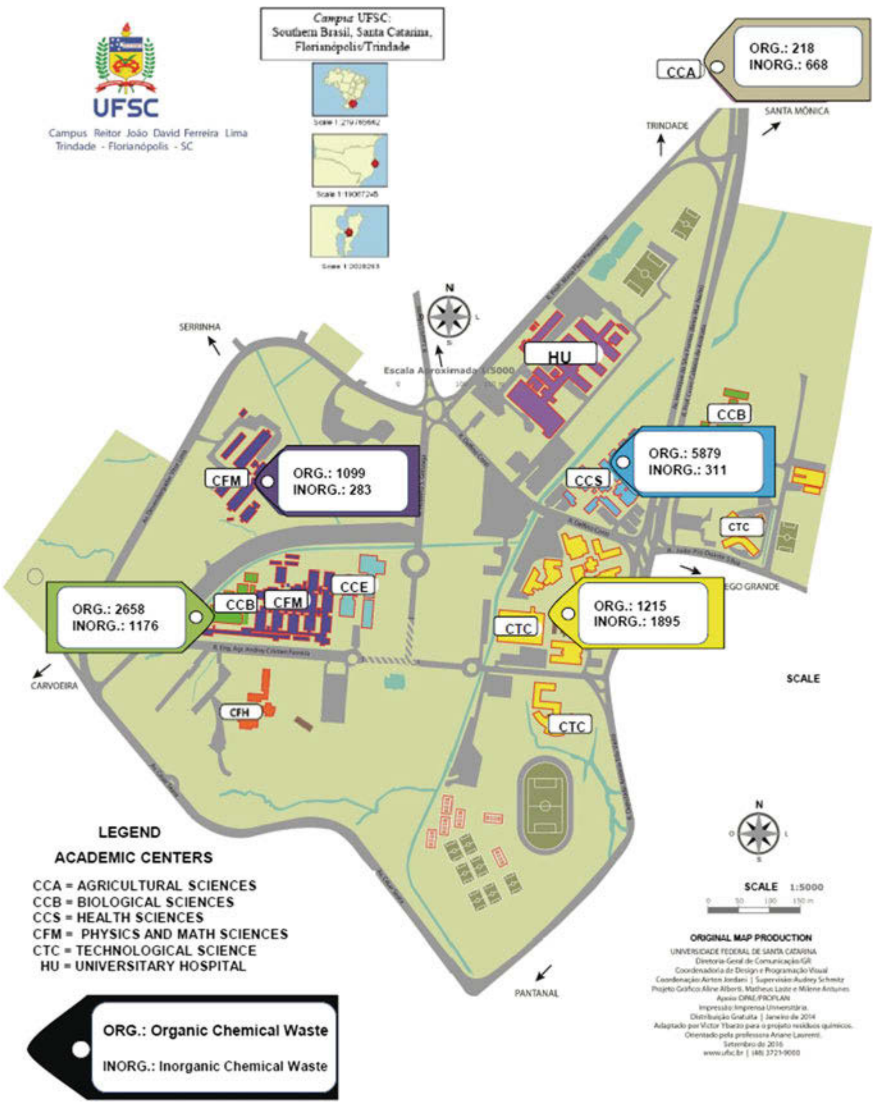


**Fig. 1** Distribution and quantity (liter) of Chemical waste in the main generators labs (four months average) at *Campus* UFSC/Trindade/Itacorubi (*Source* Adapted from LABTATE base map: http://labtate.ufsc.br/.)

The method selected to include the set of dimensions and scope discussed was the elaboration of an instrument of data collection considering: the collective formulation of issues addressing both the technical aspects of special waste generation and treatment, as well as environmental education, awareness and security; and the interviewer's visits to the laboratories potentially generating chemical and biological waste.

Within this context, several meetings were held between members of the research group and experts in the subject. Thus, it was defined that the study would follow a qualitative-quantitative approach, followed by Laville and Dionne (1999) suggestions regarding the acquisition of data that, besides representing measurable information, would also add a person's perception. This factor is especially important in safety and accessibility aspects related to the waste generator laboratory.

In relation to the objectives of the study, it was decided to apply an exploratory-descriptive research: exploratory, to provide flexibility in data comprehension (important due to the complexity of the set of generators), effective in the diagnosis of unknown situations (Zikmund 2000); and descriptive, to allow a deeper analysis of the system characteristics and, eventually, make it possible to establish relationships between variables (Gil 2008).

Regarding the data collection techniques, it was opted for the application of structured questionnaires and a field observation script. The application would be through interviews at the place of waste generation. According to Marconi and Lakatos (2007), "interviews" are the meeting of two people so that one of them obtain information on a certain subject, during a conversation in a professional nature.

According to the same authors, "standardized or structured interviews" are those in which the interviewer follows a preliminarily established script, and the questions to be asked of interviewees are predetermined, and usually performed with the help of a form (Marconi and Lakatos 2007). The form used in this study was constructed from a relevant bibliography, based on the opinion of experts and preliminarily calibrated with a pre-test submitted to the institution's laboratories.

The form elaborated by the project team served as a script for the interviews, as well as a means of recording the information collected and observed. This instrument was applied to all research and extension laboratories, once the University did not have reliable data regarding the spatial location and precise quantity of generators. 304 potential generators were visited, with spatial data reported through spatial references and geographical location via GPS, later registered in a Geographic Information System. This system was later made available for the University Waste Management sector.

The form used as an instrument was structured in a logical order, which provides information regarding the following aspects of laboratory waste management:

- General characterization of the laboratory: users, activities and purposes;
- Procedures of chemical segregation residues carried out;
- Characterization of generated waste, in terms of variety and quantity;
- Description of the treatments applied;
- Applied ways of packaging and identification of waste;
- Applied ways of internal and external storage of waste;
- Type of internal collection carried out, when applicable;
- Characterization of aspects related to safety, legislation, and internal management of chemical waste.

In the described aspects, 47 quantitative and qualitative questions were applied in the form of interviews.

For the interviews, it was adopted as strategy to send a team of three people in each visit, aiming better precision and reliability in the understanding of the registered answers. At least two student members of the project were accompanied to the laboratories by a UFSC staff, each one filling an individual form, besides observing aspects of easy visual identification such as the presence of Collective Protective Equipment, and the provision of waste storage elements and waste packaging.

After the interview, the responses were compared and a single version was recorded on a digital table. In case of disagreements, the interviewee was contacted and, when necessary, the lab was visited again. Once in possession of a single, digitized form, data could be forwarded for analysis and processing.

## 4 Data Analysis and Processing

At the end of the visit to the laboratories and labor sectors, the analysis of the collected data was started. As previously discussed, data collection instrument consisted of 47 questions with open answers, which resulted in a large volume of information without standardization. Therefore, to extract the main characteristics and information from answers received from the laboratories, it was necessary to develop methodological procedures for the analysis of collected data.

After each interview, the laboratory responses provided to the project team were compiled and typed into a data table. This procedure was performed with the purpose of keeping a digital archive of the information collected during the interviews, in the form, as close as possible of how they were provided by the laboratory representative. However, this form of registration does not necessarily allow easy processing of data. Because of that, it was necessary to structure a more practical method to treat and analyze data. For this reason, the project team created an integrated workbook containing index functions, database, and analysis tool, as well as information related to the person who compiled data, allowing future verification.

In order to organize and enable the job division among project members, it was initially decided to process the information of each issue separately. For each of them, a data table with several "tabs" was created, some of which were common to all of the issues.

As shown in Fig. 2, the first tab had an index of all laboratories visited, assigning a code for each of them. These codes were also associated to the geographic information system containing the spatial location of laboratories. In this same table was also made the distinction between the laboratories that generate chemical and/or special waste.

A second worksheet contained the original answers obtained from laboratories. This tab had the function of "database support" for quick queries, which sometimes

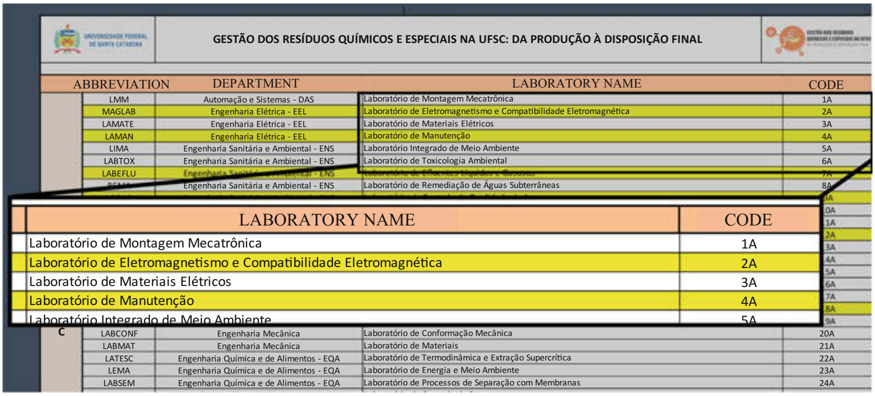


**Fig. 2** Labs index system

became necessary during the processing and analysis of information. The other data tabs had the function of assisting in the treatment and analysis of data more properly.

During data first analyzes, the lack of standardization of the information collected from the laboratories was noticeable, although its themes were often recurrent. By this fact, it was decided to elaborate a new worksheet in the workbook to allow the standardization of the answers obtained. This material was based on methods of prior information analysis.

Each lab's original answer was kept for eventual consultation, being agreed to call it "raw data". Once raw data of a specific question was collected, a preliminary analysis of the answers content was made. The purpose of this process was to find patterns in the information passed by the laboratories, creating "categories" for later analysis. This task was initially performed by project members and later validated by UFSC staff (including professors and technical staff).

For qualitative data, a discourse analysis was performed (Costa 1989, 1994), identifying patterns and characteristics common to the message in a systematic way. Quantitative data were categorized according to ranges of values proposed by the literature in the study field (Fig. 3).

After this, new columns were added to the spreadsheets according to the number of categories found in the analysis of the questions. Firstly, an "yes or no" analyses were made, whether the laboratory developed the activities covered by the question, or whether that question eventually did not apply to the case.

In some cases, laboratories would fit into more than one category of analysis. For this reason, a method of "summation" questions was used to analyze these combinations. Thus, for each identified category a base 2n number (1, 2, 4, 8…) was assigned, the occurrence of the category with the respective number in the worksheet was recorded, and the values added. In this way, each "sum" corresponds to a specific combination of categories.

Figure 4 illustrates this process.

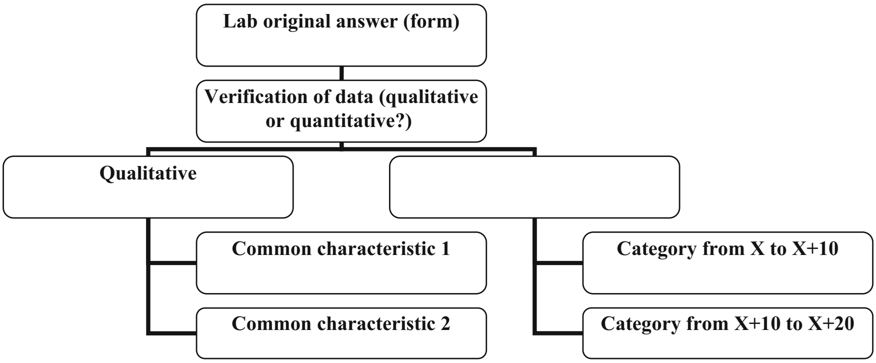


**Fig. 3** Data initial categorization process

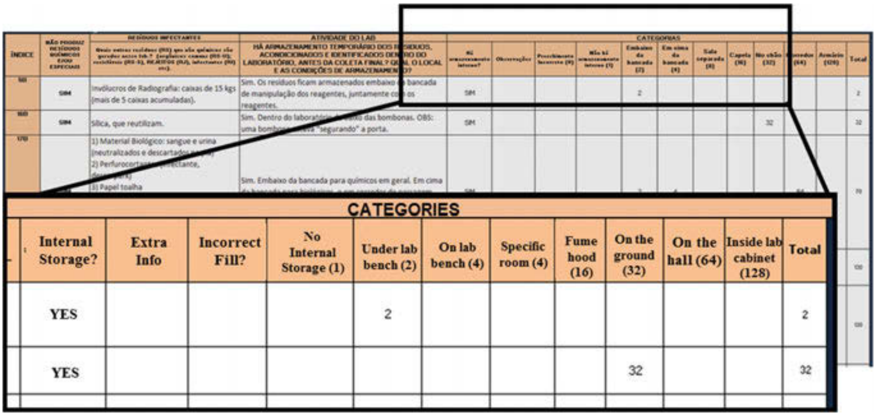


**Fig. 4** "Summation system" for the categorization of labs fitting in more than one regular category

## 5 Processed Data Presentation

Since the study was related to the educational institution, it would be necessary to provide a final report. This report should be accessible for future studies regarding the waste management system.

In the way in which data collection instrument was structured, sometimes the analysis of a single question contained several answers that could be analyzed. Therefore, for each question were defined "variables", which corresponded to the questions applied. These variables were divided into "categories", as previously described.

For better presentation of this information, flowcharts and graphs were constructed. However, during this process it was necessary to adopt some definitions in

**Table 1** General standardization adopted to present information in a report

| Issue | Standardisation |
|---|---|
| Some answers could not be interpreted, were inconsistent or were in blank | Decided to call it "**invalid data**". They represent the answers that could not be understood, even when analyzing other related questions |
| Laboratories that do not develop the activity analyzed in the question | Decided to call it "**do not apply**" |
| Laboratories that answered the question in a clear and coherent manner. The responses that were classified as "Invalid Data" and "Do not apply" were removed from this group | Decided to call it "**valid answer**" |
| General subject on which the issue is concerned. Ex.: Waste identification, Internal storage, among others | Decided to call it "**subject matter**" |
| Questions contained within each "subject matter" | Decided to call it "**analyzed variable**" |
| Options of answers displayed according to the form. These are the divisions that allow standardization and enable statistical analysis | Decided to call it "**answer category**" |
| This type of graph shows the frequency distribution of all combinations (responses) within a given analyzed variable (question within a question). In this type of graph the sum of all frequencies results in the sample (valid data) of the question | **Distribution graph** |
| It shows for each category of analysis the number of labs that present the defined characteristic. In this type of graph, the sum of the numbers may exceed the number of the sample analyzed in the question | **Occurrence graph** |

order to standardize data once more. Table 1 presents the general standardization adopted for the presentation of the information.

As previously explained, it was chosen to present the data collected in the project in the form of flowcharts. This choice was made because, as some of the analyzed variables depended or were related to others, the presentation of only isolated graphs would make it difficult to contextualize and, consequently, to understand the information. Figure 5 gives a generic example of the flowchart structure developed in the project, by "subject matter".

As a way of illustrating and detailing the information presented in the flow charts, graphs were elaborated for each "analyzed variable", showing how the behavior of the labs (categories) was at UFSC and, where appropriate, aggregate by teaching center or work sector.

As previously stated, two types of graphs were adopted. The "distribution" shows the frequency of the responses in each category defined for the analyzed variable (without multiple counts of laboratories), as shown in Fig. 6.

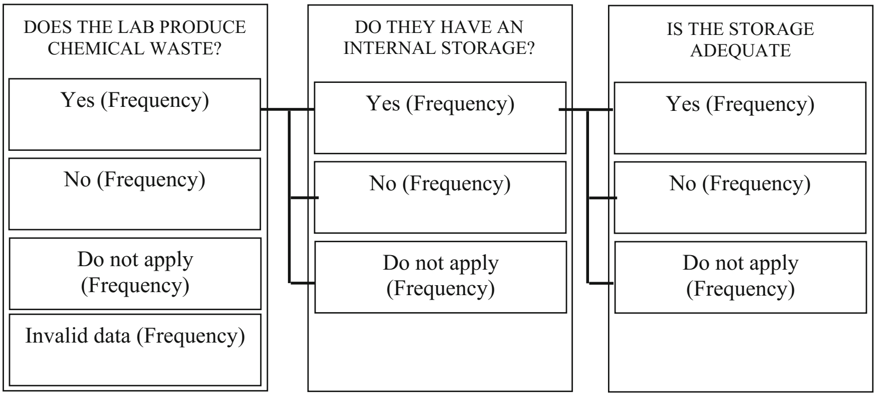


**Fig. 5** Example of flowchart

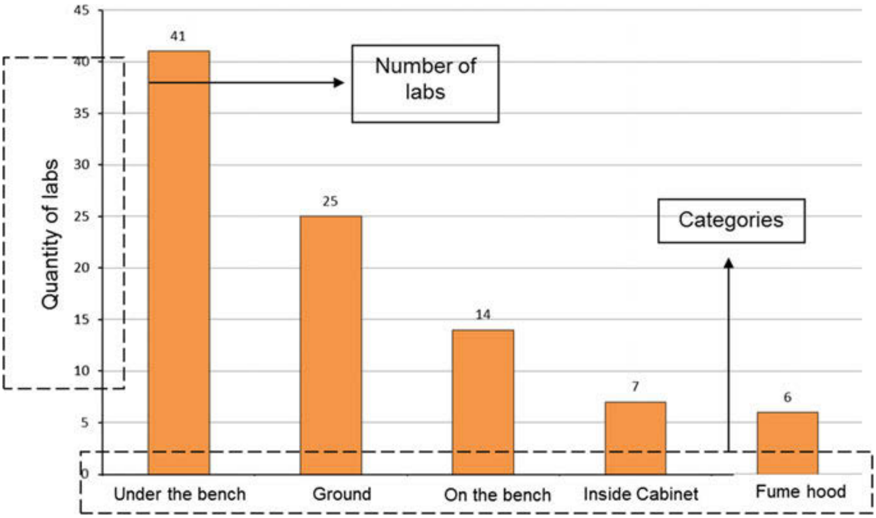


**Fig. 6** Example of distribution graph (distribution of labs)

The second type of chart, the "occurrence graph", shows how many times a category has occurred, regardless of its combinations (i.e. in this case multiple counts of a single laboratory may occur).

Figure 7 shows an example of an occurrence chart.

These two different types of graphs would fit into different purposes. For example, the distribution graph info could be useful to compare how many labs where doing the "right thing". The occurrence graph would not show this information because it would count the same lab twice, if the lab mentioned something

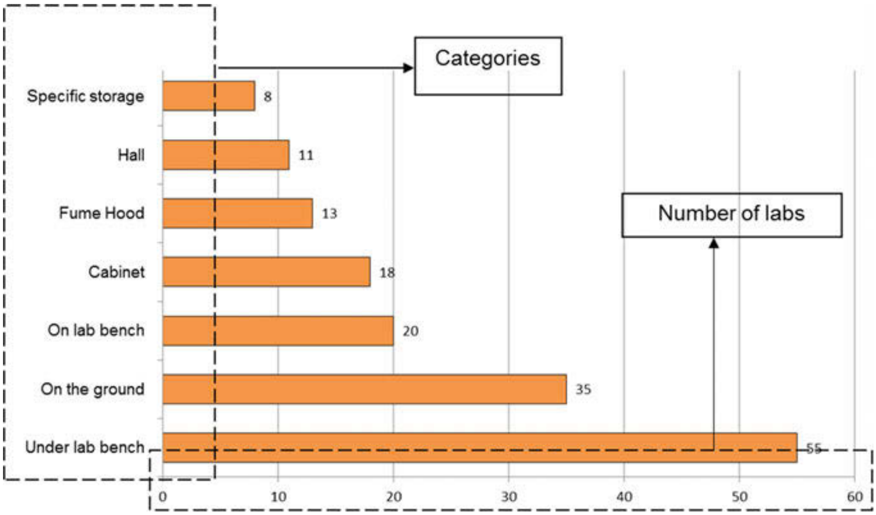


**Fig. 7** Example of occurrence graph (occurrence of categories)

related to the specific category twice. On the other hand, the occurrence graph would be more precise to determine, for example, how common it is to behave in a "category 1" way.

By the use of these standardization methods, information became ready for presentation in a report containing the situational special waste management diagnosis at UFSC. This report would address a few institutional objectives: to provide easy access information for administrative sectors; to be the first step for a systemic waste management system at UFSC; and to be a guide (technical and motivational) for special waste generators.

## 6 Conclusion

The treatment of data involving a large University presented itself as the great challenge of the project presented in this paper. It was possible to observe that the standardization of processes and the concentration of information in a single database are extremely important to the success of a waste diagnosis.

Given the complexity of data generated by a special waste diagnosis in an institution of higher education, this work demonstrated that it is possible, with few resources, to perform standardization and simple statistical treatment, delivering a good final result. Information provided will serve as a basis for projects involving waste management and, in a larger scope, sustainability on the campus of Brazilian institutions.

Additionally, this paper suggests that this process should be applied to public research institutions, which have a similar profile to that of Brazilian public universities. A combination of good digital spreadsheets, co-ordinated and tested date acquisition methods, training interviewing members, and processes involving the use of geographic information systems can yield interesting results to support the implementation of an efficient waste management system.

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## Author Biographies

**Renata Martins Pacheco** is part of the Federal University of Santa Catarina engineering staff. She majored in Sanitary and Environmental Engineering and has a Master degree in Environmental Engineering, both from the Federal University of Santa Catarina. Currently, she is a Ph.D. student at the University of Porto—Portugal.

**Ariane Laurenti** lecturers on Toxicology (Department of Pathology) at the Federal University of Santa Catarina (UFSC) since 1997. She has a major in Chemistry (Bachelor and Licentiate) from UFSC and a Ph.D. in Environmental Sciences from Università Degli di Venezia—Italy (1993). Ariane also holds the position of Socio-Environmental Management Advisor at UFSC since 2013, representing this Institution in environmental matters involving government agencies and the Federal Public Ministry. Currently, her activities are focused on the didactic-pedagogical field, with the development of research projects and actions in the environmental area.

**Bruno Eduardo dos Santos Silva** holds a major in Sanitary and Environmental Engineering from the Federal University of Santa Catarina (2016), including a graduate exchange in Environmental Engineering at the University of Melbourne—Australia. He currently works as an engineering project analyst at Rotária do Brasil, with focus on energy efficiency in the sanitation sector.

# Educational Institutions and Universal Accessibility: In Search of Sustainability on University Campus

**Adriana Gelpi and Rosa Maria Locatelli Kalil**

**Abstract** The paper reports proposals and solutions of the design and implementation for universal accessibility at the university campus, complying with current legislation and community demands. It addresses the challenges of raising academic awareness about the subject and of the accessible route project overcoming the campus large dimensions, urbanized areas and rugged topography. It is the result of a project and an accessible route shared through pedestrian and motorized routes and with its implantation overcoming barriers in the implementation. The theme was conducted with a focus on social sustainability, as it is a requirement to obtain the universal and legitimate right to higher education and the benefits of the university campus as a community educational, environmental and leisure urban equipment. The results of the article demonstrate that universal accessibility, more than a legal requirement for educational institutions, contributes to social sustainability. The spatial adequacies allow the universalization of the possibility of entry and stay of persons with disabilities or reduced mobility in the university campus, expanding their training at an higher level.

**Keywords** Accessible sidewalks · Acessibility technical norm
Accessibility project · Universitary campus

## 1 Introduction

According to the Brazilian Association of Technical Norms (ABNT NBR 9050, 2004), accessibility is "the condition for the use, with safety and autonomy, total or assisted, of spaces, furniture urban equipment, buildings, transportation services

A. Gelpi (✉) · R. M. L. Kalil
Faculty of Engineering and Architecture, University of Passo Fundo,
BR-285, km 292, Passo Fundo 99025-020, Brazil
e-mail: agelpi@upf.br

R. M. L. Kalil
e-mail: kalil@upf.br

 
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devices, systems and communication means and information by a physically disabled person or whose mobility is limited". The objective of this paper is to present the challenges and possibilities of an infrastructure adaptation Project at Campus I of Passo Fundo University in order to adapt it to the conditions and reality of the university's urban area to provide universal accessibility to its users, mainly those whose mobility is limited. Based on a bibliographic and legislation research, an accessibility diagnostic was carried out in the urban space and open areas of the Campus, proposing guidelines for its implementation, adequacy and qualification.

The UPF's Campus I was conceived in the mid-twentieth century and built outside the urban area of Passo Fundo city, settling the university infrastructure gradually, with no urban project or a master plan for future expansions. Vehicle traffic was prioritized rather than the pedestrians' and universal accessibility to the buildings was completely ignored in its urban surroundings and interior.

Urban mobility and universal accessibility are issues related to the citizen's right to come and go and are directly related to the right of a full urban life. In this sense, barriers that limit or prevent the access, freedom of movement, safe traffic and the possibility for people to communicate or having access to information cannot be accepted.

In the growing urban expansion context and on it differentiated displacements, the importance of implementing infrastructure grows even more quick in order to make mobility feasible. New requirements need to be incorporated in the Project guidelines practice, which didn't existed before and that must be included in architecture, urban planning, and also to their works of art.

Concerning the 1988s Federal Constitution, it defines "the law shall determine norms of construction of public places and buildings of public use and manufacturing of public transportation vehicles, in order to guarantee adequate access for disabled people" (Brasil 1988, 31). In 2000, Laws 10.048 (Brasil 2000a) and 10.098 (Brasil 2000b) also established different treatment, general norms and basic criteria for the promotion of autonomous accessibility of disable people to buildings, urban spaces, urban furniture and equipment. Both were regulated by Federal Decree 5.296 of December 2nd 2004 (Brasil 2004), with deadlines for the adaptation of buildings to the norms of accessibility of NBR 9050 2004.

It's in this context that it is included the Passo Fundo University problem with its system of multiple campus, that receive students, professors and the community for academic activities and university extension and services.

This paper is important because it report and reflects an experience of both awareness about the universal accessibility among the administration staff of the university and the implementation in an already built university campus. The legislation application and the spatial adequacy of the educational institution of higher education seek to meet social sustainability by allowing a greater inclusion of students, and other publics. In addition, it tends to serve as a model and benchmark for other educational institutions in the region.

## 2 Methodology and Methods

The methodology of this research occurs in three stages. The first one, which is developed in an office, aimed collecting information through bibliographic review on universal accessibility norms, legislation and bibliography references; case studies, data collection and interviews with the maintenance technicians to recognise the road system, vehicles and pedestrians traffic and flow; understand the organization and urban implementation map of Campus I in sectors, in order to prepare the field survey for diagnosis of the existent sidewalks and the recognition of, at least, one layout of accessible route. After the bibliographic research, the Project was organized with universal draw, standard models of accessible sidewalk, urban furnishing and works of art that were implemented in the accessible route and fitted to the reality diagnosed at the Campus.

The second stage occurs through the field survey: it counted on a survey evaluating sidewalks, traffic areas, areas of access and urban furnishing, with photography record to diagnose the infrastructure available to the pedestrians traffic, analysing if it assures the requirements for universal accessibility; lanes, sidewalks and pedestrian crossings conditions were verified, measuring widths and observing where was possible the enlargement for circulation, inclusion of works of art and existing urban furniture; observation, record and measurement of the vegetation that could interfere in the sidewalks circulation and that, possibly, could interfere in the accessible route.

The third stage, held in office, counted with the organization of all data collection, analysis of the information researched in field and the elaboration of diagnosis on the traffic and access spaces about the data surveyed. After that, a layout of an accessible route, defined "in loco", was carried out, it contained a team discussion on the preliminary studies and subsequent elaboration of the urban Project and digital detailing of the works of art at the accessible route: pedestrian crossings, ramps, paths, downgrades, raisings and furnishing.

## 3 Principles of Universal Accessibility

### *3.1 Urban Mobility*

According to Herce (2009), the main objective of the urban mobility planning is to make people to walk on short dislocations, and to use public transportation for longer displacements. But it was necessary to advance towards the idea of projects of urban development and territory organization that are linked and integrated to the use of the soil. Thus according to Navas (2010), contemporaneous urban problems, are due to, in their majority, the lack of comprehension of a territorial and urban planning that integrates mobility networks, or their plan, linked to the soil use.

In this sense, a planning that consider pedestrians, the bicycle use, public transportation, private vehicles and the rational distribution of goods, searching for sustainable mobility, seen as the one that is accomplished within a determined period of time, with reasonable costs and minimizing the negative effects on the surroundings and peoples' life, would be well accepted. With relation to urban mobility and universal accessibility, it is observed a gradual advance towards the comprehension of this problem and implementation of public policies for the inclusion of this idea in the construction of urban infrastructure.

Urban infrastructure can be understood as the set of physical components necessary to the services which are important for a society in a determined space and time. It is the set of lanes, networks and buildings that structure the town territory and provide public services to the dwellers. In the case of the university campus, the infrastructure consisted of a road system, energy and communication networks, education and management buildings. To Mascaró (1989), the road system can be formed by one or more traffic networks, according to the type of the urban space, in order to receive vehicles (private and public), bicycles or pedestrians. Legislation and the improvement of technical norms have contributed significantly to this reality.

## *3.2 Universal Accessibility*

To Duarte and Cohen (2010), accessibility is reached when the spaces are attractive, easy to cross, clear to understand, where they are spaces that make meeting and living easier, and it will only be reached from the urban attitude that re-evaluates the notion of deficiency, thus the spaces are not good enough when they do not suit everyone.

Accessibility became a contemporaneous challenge, where elimination of architecture and urban barriers are necessary in the cities, buildings, urban surroundings, communication and transportation. It also can be understood as the citizen's right to come and go, including those people who are occasionally or permanently disabled.

Spaces must allow traffic and access to all spaces in the city such as public buildings, institutions, use of transportation, public equipment and urban furniture like telephones, restrooms, banks net, booths, seats, water dispenser, etc. Important and priority, it is in the approach of architecture, urbanism and urban mobility through universal draw, accessible, creating a city which is within every citizen's reach, whether they are disabled or not, democratizing all spaces, seeing the universal draw as the ability to communicate and integrate everybody.

### 3.3 The Inclusive School, the Universal Design and Accessibility

In relation to teaching spaces, the school's role in social inclusion was incorporated to the educational system through the Guidelines and Basis Law of National Education (LDB), followed by the federal constitution of 1988, where it was reinforced in Education seminars and meetings, reaching priority and progressive theme detailing in the late decade of 1990. With the LDB n° 9.394/1996, the inclusion of physically or intellectually disabled student was improved beyond the Special Education, recommending his or her enrolment, preferably, in their own public regular teaching net.

According to Duran and Esteves (2010), from the 2000s, in response to legal requirements, to the public power inspection and the society's own demand, school buildings began to be designed and adapted, meeting the norms of NBR 9050, trying to guarantee accessibility to all environments. Thus it is undeniable that an accessible environment qualifies the performance and production of activities, mainly when it comes to school activities.

In the schools, universal design becomes a tool for the equalization for opportunities in the development of all students. To Cruz and Pires (2010), the promotion of accessibility is a Project attribute, which must contain the basic conditions for the promotion of access and permanence in all environment designed.

But, besides this, it is very important that the conditions to make the school or any other space inclusive also consider the building surroundings, solving access and traffic, reducing or eliminating unevenness, searching for regular floors, providing visual, tactile and sound signalling, adapting environment and furniture. As surrounding adaptations, pedestrians' crossing raised to the sidewalk level, when the traffic of people is higher than the vehicles, and sidewalks lowering with tactile signalling, when the inverse situation occurs. Parking spaces, embarking and disembarking must be signalled.

### 3.4 Space Adequacy and Implementation of an Universal Accessibility: Experiences in Educational Institutions

For Bittencourt et al. (2004), because of the multiplier character that a university has, it is important that it serves as a parameter of a universality for the other sectors of society, receiving in its space all those who wish to have access to it, regardless of their differences.

In this context and through a survey of Cambiaghi (2012) on universal design and teaching, research and applicability in Universities, one of the precursors of universal design has been the United States, and Professor Raymond Lifchez, University of California.

Still in the 1970s, the teacher promoted classes and interviews with people with disabilities, contributing significantly to the awareness of the problem with the courses and students of architecture and urbanism, engineering and design. These initiatives evolved into specific disciplines for educational projects for universal design, for the creation of research centres and centres for inclusive design and environmental access.

The awareness, initially disseminated through lectures and also by community demands, has been disseminated academically, evolving to specific studies in anthropometry, universal accessibility in homes and public buildings, for public spaces, friendly cities, specialized publications, model residences projects, evaluations Post-occupation, on-line universal designs and visitable housing among others, have been and are being developed in universities worldwide.

A particular study, conducted for the review and implementation of the Universal Design at Oregon State University (2014) entitled "OSU Campus Accessibility Survey and Assessment," suggests that the research project now forwarded to the University of Passo Fundo is in the right direction and contributes to its implementation and especially its management.

Oregon State University develops a comprehensive improvement plan at its Principal University Campus located in Portland. To do so, it reviews buildings already built, since the institution is quite old, and applied legislation and quality standards superior to the minimum standards, in the planning, implementation and correction of the accessible routes and of the universal design in its facilities.

The process, which has been under way since 2011, began with an evaluation of the external areas of the campus buildings, verifying the conditions of the accessible routes, the ramps, the parking lot, the accessible transportation, the exterior signs and the schedule and costs for the implementation and Correction of existing routes and accessible routes.

The plan, carried out in partnership with several consultative committees of the OSU and the city, provides a five year horizon for the implementation of new accessible routes and/or correction of existing routes. The overall goal is to create an accessible main route, covering all buildings, because strategically, without first developing a connection accessible to each building, the internal accessibility to the teaching and research facilities extension, could not be fullfiled.

The recommendations established by the OSU evaluation committee do not specifically address the construction of the accessible environment, but direct the management for maintenance, preservation and planning of universal accessibility in university campuses, which is very welcome, that to correct routes, routes and buildings that do not contemplate universal accessibility, is often impossible due to its financial unfeasibility.

The authors Bittencourt et al. (2004) note that because of the multiplier character that an university should exert, it is important that it be a reference or a parameter of universality for the other sectors of society, receiving in its space all who wish to have access to regardless of their differences. They report on and analyze the research and extension project for the subsequent implementation of an accessible route at the AC Simões Campus of the Federal University of Alagoas [UFAL], Brazil, titled "Accessibility and citizenship: architectural barriers and social exclusion of people with physical disabilities" carried out by the Tutorial Education Program Of Architecture (PET/Arq.) Supported by the MEC.

According to the report, the first stage of the project was developed from the understanding of the concepts that underpin the Universal Design as a proposal and adaptation of spaces and equipment for all people, addressing the following work methodology: theoretical and conceptual basis training on the subject, training of work teams with promotion and participation in lectures and professional training courses, focused on the theme of accessibility and extensive to the academic community and technicians of public agencies, aiming to raise awareness on the subject.

The problems raised in the diagnosis in relation to the open areas of the Campus were the discontinuity of the routes, inexistence of accessible integration between external spaces and buildings, presence of physical barriers of various natures such as vegetation, furniture, the sidewalks deterioration and materials, the absence of signage and inadequate furniture. In relation to the proposal for the establishment of an accessible route on campus, the objective was that it cover the entire external area of the teaching unit and conduct with safety and autonomy to persons with disabilities within the scope of UFAL. According to Bittencourt et al. (2004), "routes are spaces designed to achieve the continuity of flows and free paths of physical barriers (architectural and urban) represent an opportunity to participate in social life in conditions similar to other. In order to do so, a study was conducted finding the most probable routes between the Campus buildings that guided the delimitation of routes and accessible spaces."

As a conclusion of this analysis on the UFAL campus, Bittencourt et al. (2004) report that many of the accessibility problems in the spaces studied could be avoided if there was a concern on the part of the designers and executors of the work for the elimination or non-creation of physical barriers and in the promotion of continuous routes with the principles of universal design. The authors emphasize that reforms and adaptations to routes or buildings to make them accessible are much more costly than building them accessible, besides the fact that the correction is often impossible. In this sense, it is essential that accessibility is a condition of project design, with the same relevance as the plastic, functional and structural constraints.

Regarding the relation between accessibility and sustainability, Borges (2013) analyzes the Brazilian and the international regulations and initiatives, especially those consolidated at the UN Rio +20 Conference, which caused a precursory dialogue between sustainability and accessibility, placing these concepts as central elements at the UN system discussions. In addition, when investigating the case of the Pontifical Catholic University of Rio Grande do Sul [PUCRS] located in Porto Alegre, Brazil, the author concludes that although Brazilian universities have recent initiatives, they are still dependent on the institutional program's decisions, people and management. These universities do not have, therefore, a long-term consolidation that guarantees the internalization of an environmental culture in the institutional scope. So, the Brazilian universities still face the major challenge of building environmentally oriented professionals for a sustainable and accessible future.

### *3.5 Adaptation of Campus I of Passo Fundo University*

Passo Fundo is classified as a regional hub in the northern state. It stands out as an important railroad intersection, strengthen the region of medium soybean producing properties and its economic development occurs mostly around productive arrangements of regional character, where the industry is linked to rural activities. It has a population of 190.000 inhabitants, with 780 km$^2$ territorial area and 50 km$^2$ urban area, being a hub city for more than 100 towns.

The central campus of Passo Fundo University is a regional educational reference, bringing into it vehicles from many towns of northern RS, from automobiles, buses and bicycles, besides vehicles for supply and load. Due to all these characteristics, this campus becomes a reference as an educational institution in the state, with around 14 thousand students, considering that 26 present disabilities (visual, hearing disabilities and wheelchair users). Counting on greater access and demand of students for college education and to the system of campi of UPF, it came up the need for adapting spaces to the new demand of XXI century, City Statute, Guidelines of MEC and universal accessibility, lacking greater attention to several legal and social requirements with relation to accessibility and democratization of public spaces and democratic teaching in the institution from these guidelines.

With the diagnosis of the problems related to the lack of accessibility and the study of the current legislation in order to draw an accessible route with universal design, strategic points, which are going to be worked, were established, such as: ramps, raised crossings, bus stops adapted, sidewalks, intersections and flow of vehicles (Fig. 1).

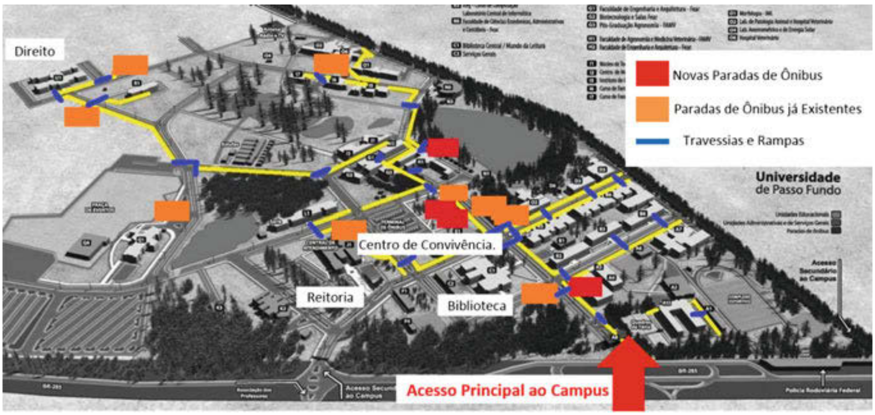


**Fig. 1** Draw of accessible route at Campus I UPF *Source* organized by the Authors

# 4 Definition on the Accessible Route of the Path

Implementation of directional line upon and at least on one side of the sidewalks already existent, along the campus, observing the norms related to sidewalks width, alert and directing by tactile tiles floor, ramps slope and suitable paving.

## 4.1 Ramps

The sidewalks must be lowered along with the pedestrian crossing lines whenever there is pedestrians flow. The sidewalks lowering must be built in the direction of pedestrians flow and presenting slope of 8.33%. The ramp minimum width accepted is 1.20 m and the minimum recommended is 1.50 m. In the case of raised crossing, the ramp must be as wide as the crossing line.

In Fig. 2 left, the ramp showed various errors before the norm, such as inadequate slope, insufficient width, unevenness between the crossing and lowering, besides inadequate flaps slope and length. In Fig. 3 right, the ramp already modified presents necessary lowering, adequate signalling with a tactile tiles floor, correct flaps width and slope according to the crossing.

## 4.2 Sidewalks

Sidewalks and pedestrian routes must have minimum width of 1.20 m, but pedestrian crossings must present minimum width of 4 m long or according to the flow of people. In the case of service crossings, the sidewalk must present the following dimensions of Fig. 3:

**Fig. 2** Ramp before and after modifications

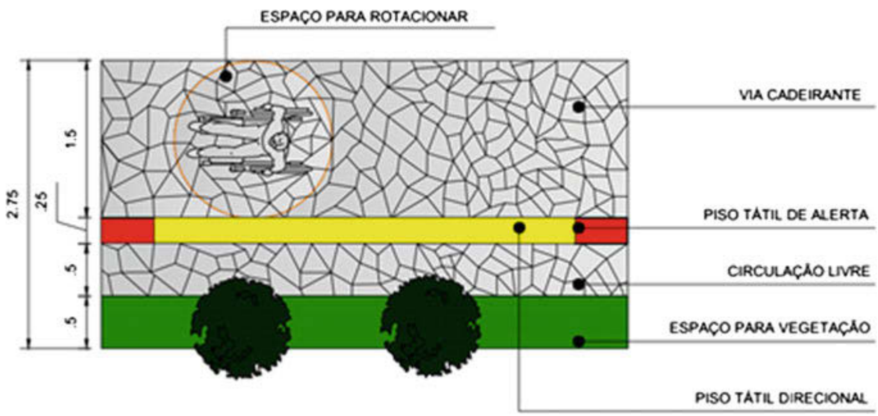


**Fig. 3** Sidewalk according to NBR 9050. *Source* draw carried out by team responsible for the accessibility project, 2015

**Fig. 4** Sidewalk before modifications and in the stage of the project implementation

In Fig. 4, the sidewalk is in the stage of implementation with of the local markings where the tactile tiles floor will be implemented. According to the image, the sidewalk does not present the minimum dimension recommended, then being necessary to enlarge the sidewalk.

## 4.3 Raised Crosswalks

According to the Brazilian Norm ABNT NBR 9050: 2004, raised crosswalk is the increase of the path level, consisting on the raised flat area, signalized with crossing line and ramp for vehicles crossing. It is addressed to promote balance between the

**Fig. 5** Raised sidewalk before and after modifications

levels of the sidewalks in both sides of the lane. Yet, it must present transversal slope of 3% maximum. The raised crossing must show minimum dimension of 4 m width, being dimensioned according to the traffic of people in the local (Fig. 5).

## *4.4 Passengers' Embarkation and Disembarkation Sites*

The idea and the project of public spaces must plan access conditions and use by disabled people. According to the Brazilian Norm ABNT NBR 9050 (ABNT 2004), along with the accessible routes, together with traditional seats (fixed seats), spaces for wheelchair people must be planned, allowing their access to the boarding platform. The local must contain tactile embossed signalling, braille or embossed figures, but it is necessary to implement alert tactile floor (Figs. 6, 7).

With relation to urban furnishing, the existing project was revitalized, suggesting small adaptations like placing a seat, lateral protection in transparent polycarbonate and, of course, the planning of a local for wheelchair users. The sites are still being implemented (Fig. 8).

## *4.5 Limitations and Constrains*

Although the development of urban accessibility projects gave priority to implement technical norms and the principles of inclusion and sustainability, adaptation of the university campus occurred in a partial way. There were budgetary and operational restrictions, as well as the physical conditions of the campus, as some roads and sidewalks could not be modified due to the accentuated topography, the presence of large trees and the small vehicular roads. The connection between the sidewalks and the buildings still present barriers for the universal accessibility of pedestrians and wheelchairs. In the coming years, the proposed adaptation of the

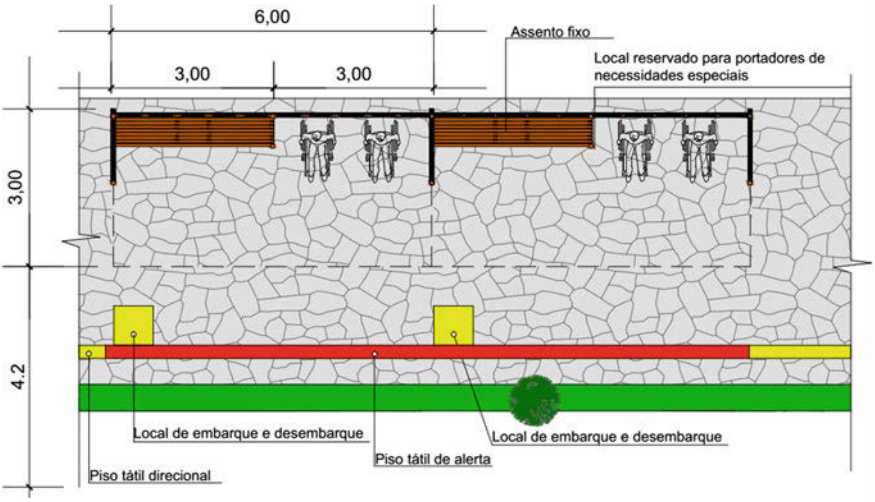


**Fig. 6** Passengers' boarding and disembarkation sites according to ABNT NBR 9050 (ABNT 2004). *Source* performance carried out by the team responsible for the project of accessibility, 2015

**Fig. 7** Perspective of the boarding and disembarkation site. *Source* design carried out by the team responsible for the Project of Accessibility, 2015

campus will be complemented, as well as the periodic post-occupancy evaluation of the spaces already adapted to verify the users' awareness, perception and satisfaction.

In spite of the limitations of this work, due to the focus on only one university campus, this work demonstrates the adequacy challenges of Brazilian higher education institutions, which have not consolidated the guidelines for accessibility, inclusion and social sustainability.

**Fig. 8** Embarkation and disembarkation sites after modifications

## 5 Conclusion

Universal accessibility must be present in all urban spaces, assisting the most diverse groups of society. With relation to school environments, the term inclusive school and the use of universal design become essential so that the search for knowledge may occur in such adequate manner.

In relation to the implementation of an accessible route at Campus I of UPF, the authors report that many of the problems related to accessibility in the spaces studied could be avoided if there was concern by designers and work performers as for the elimination or "no creation" of physical barriers and in the promotion of continuous routes taking into account the universal design principles.

The authors emphasize that adaptations and improvements of routes or buildings in order to make them accessible are even more expensive than built them accessible, besides the fact of, very often, being impossible to fix them. So it is important to consider accessibility in the architecture and urban infrastructure project idea as being in the same relevance plan as the plastic, functional and structural factors. The path to sustainability in higher education necessarily involves the possibility that people can access university institutions with dignity and easily. Therefore, there is a close relation between the physical accessibility at the campus and social inclusion as a principle of social sustainability.

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## Author Biographies

**Adriana Gelpi** graduated in Achitecture and Urbanism—Vale do Rio dos Sinos University. Expertise in Urban, Energetic and Environmental Planning—IEAL/Esp. Facultat Latin American of Environmental Sciences/Arg; and Center of Energy/Federal University of Rio Grande do Sul. Technician Urbanist Institute Studios and Administración Local/Esp. Master in Urban and Regional Planning—Propur/Federal University of Rio Grande do Sul. Doctor in Architecture and Urbanism—São Paulo University. Post-doctoral trainnings—Engineering School/Directed Center for Building Innovation /Federal University of Rio Grande do Sul and Superior Technical School of Architecture of Barcelona/Barcelona. Head professor of the Architecture and Urbanism Course and Program of Post-Graduation in Civil and Environmental Engeneering and researcher extensionist professor of the Laburb—Laboratory of Urban and Regional Studies of Passo Fundo University.

**Rosa Maria Locatelli Kalil** graduated in Architecture and Urbanism—Federal University of Rio Grande do Sul, and in Economic Sciences—Passo Fundo University. Expertise in Social Pedagogy—Passo Fundo University and Professors Formation in Distance Education—Federal University of Paraná. Master in Engineering—Federal University of Rio Grande do Sul. Doctor in Architecture and Urbanism—São Paulo University. Head professor of the Architecture and Urbanism Course and of the Post-Graduation Program in Civil and Environmental Engineering, researcher and extensionist professor of the Laburb—Laboratory of Urban and Regional Studies of Passo Fundo University.

# Socio-environmental Agenda: A Planning Instrument to Improve Sustainable Development in University Campi

**Maria F. C. Lemos, Luiz F. G. Rego, Melissa C. Antunes, Renata A. Lopes and Thais C. C. de Abreu**

**Abstract** One of the keys to promote sustainability in a university is the establishment of a solid planning instrument. The Pontifical Catholic University of Rio de Janeiro (PUC-Rio), which had already built a pact for sustainability on its campus in 2009, is now reviewing its directives in order to add innovative social and environmental concepts, as well as new topics to the agenda. This paper presents the strategy and methodology being used by PUC-Rio to build its socio-environmental agenda with the participation of its entire community. The agenda is based on the principle of community cooperation and having the campus as an example of sound sustainable practices. Interdisciplinary working groups designed the new agenda on principles, diagnoses, guidelines, goals, projects, indicators and monitoring strategies for 6 distinct topics: water; biodiversity; energy; waste; constructed and living spaces; mobility; as well as 5 crossing topics—education, health, communication, information technology and resilience to climate change. The revised agenda intends to strengthen socio-environmental agreements between academia and society, as well as reinforce rules to use the campus as a model of sustainability practices.

M. F. C. Lemos (✉) · L. F. G. Rego · M. C. Antunes · R. A. Lopes
T. C. C. de Abreu
Interdisciplinary Center for the Environment – NIMA, Pontifical Catholic University of Rio de Janeiro, Rua Marques de São Vicente 225, Gávea
Rio de Janeiro 22451-900, Brazil
e-mail: mariafernandalemos@puc-rio.br

L. F. G. Rego
e-mail: regoluiz@puc-rio.br

M. C. Antunes
e-mail: melissa-nima@puc-rio.br

R. A. Lopes
e-mail: renata.alencar@aluno.puc-rio.br

T. C. C. de Abreu
e-mail: thais.abreu@esp.puc-rio.br

 
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**Keywords** Higher education · Socio-environmental agenda · Sustainability
Living lab · Laudato si'

## 1 Introduction

Understanding the effectiveness of the social, environmental and economic actions taken by organizations to promote sustainability still represents a great challenge (Zdanyte and Bronius Neverauskas 2014).

Within the scenario of socio-environmental crisis, this challenge is exacerbated by climate change, the impact of the role of society of new technologies (telematics, genetics, nanotechnology, and artificial intelligence), economic globalization, population growth, and the urbanization of the developing world, together with its consequential increase in inequality, social segregation and poverty in such countries (Schneide et al. 2010; Satterthwait 2013).

The goals established worldwide to achieve sustainable development are challenging and they presuppose that society acts together in the search of solutions. Although the important concepts of sustainability for preserving the environment and promoting social equality have been discussed and applied for some decades, there is a clear need to improve the actions and practices that lead to concrete transformation (Biermanna et al. 2017).

To a large extent, the understanding and implementation of sustainable initiatives are driven by organizations or professionals from diverse backgrounds, who guide their practice of and research in sustainability according to their specific knowledge. However, for the effective application of such initiatives, a transversal and multidisciplinary approach in guiding such actions must be implemented (Janssen and Goldsworthy 1996; Dedeurwaerdere 2013).

Therefore, multidisciplinary knowledge becomes an essential factor when training professionals to be aware of the socio-environmental aspects and impacts of sustainability in order to obtain a real transformation of performance standards, which brings a greater role and responsibility to institutions of higher education that will prepare professionals in this field (Marcomim and Silva 2009).

Universities are constitutional agents of transformation. Education is a process of human development which is constantly updated, as well as responsible for reviewing and updating scientific concepts for innovation and technological development (Leal Filho et al. 2015).

Sustainable development and the global threats related to this subject have created an imminent need for universities to adapt their curricula to reflect their responsibility beyond the study of concepts and the dissemination of knowledge, reinforcing the importance of universities to set an example of how to implement initiatives and practices for sustainability (Tiyarattanachai and Hollmann 2016; Peter et al. 2016).

In this leadership role, universities are responsible not only for constantly updating knowledge and disseminating information, but also acting as a role model that contributes knowledge to the community at large through social engagement, participation and inclusion (Weerts and Sandmann 2010).

In line with such transformation among institutions of higher education, the Pontifical Catholic University of Rio de Janeiro (PUC-Rio 2016) is recognized for its pioneering efforts in the development and dissemination of knowledge, as well as its practices for preserving the environment and promoting social development.

More than a center of knowledge on the topics related to sustainability, PUC-Rio is also known for its philanthropic initiatives involving society.

PUC-Rio has approximately 22,000 students, including undergraduate, graduate and continuing education students (approximately 3000 staff, around 12,500 undergraduate students and 2600 postgraduate students) from Rio de Janeiro, other Brazilian states and from abroad (PUC-Rio 2016).

PUC-Rio's main campus is located in Gávea, a neighborhood in the southern part of the city of Rio de Janeiro, a city of approximately 6.5 million people within 1200 km$^2$, according to the Brazilian Institute of Geography and Statistics (IBGE). The area surrounding PUC-Rio is one of the most affluent, occupying only a small fraction of the municipal territory. The city suffers from great social and territorial inequality and the Gávea neighborhood, in fact, is quite an example of the city's social diversity, since it is home to everything from shantytowns, such as infamous Rocinha, to modern multifamily buildings, and even traditional mansions.

This diversity is also a characteristic of PUC-Rio: whilst considered an expensive university compared to Brazilian standards, as a philanthropic institution, PUC-Rio has included 52% of partial and 27% of full scholarships, to students who come from the most diverse backgrounds and neighborhoods of the city and its enormous metropolitan area, as well as from less affluent states of the country.

PUC-Rio is surrounded by the Atlantic Forest (Fig. 1). It is located at the foot of the Tijuca National Park, one of the world's largest urban forests and where the renowned Christ the Redeemer statue is located. The park is part of the watershed

**Fig. 1** Gávea Campus, PUC-Rio

of the Rainha River, which runs through the higher part of the neighborhood, passing through shantytowns, mansions and the university before reaching the sea at the beach of Leblon.

The natural environment in which PUC-Rio is found is greatly valued by the institution. The river's edge is preserved within the campus, the trees have been identified and PUC-Rio traditionally invests in several educational projects, such as a youth project with local city schools for the last two decades.

In 1999, the Interdisciplinary Center of the Environment (NIMA) was founded at PUC-Rio with the mission of acting within a multidisciplinary perspective to harmonize the activities of research into teaching and extension of socio-environmental topics developed at PUC-Rio by empowering such activities to strengthen the interaction among the university, society and the environment in which they are located (both natural and built).

The creation of NIMA was an important instrument for PUC-Rio and allowed it to institutionalize initiatives on the environmental agenda and to enable discussion with the local community and organizations of civil society for the environmental preservation of its surroundings, in addition to promoting the research and action of its teachers in the region.

To create a sustainability plan, PUC-Rio developed an Environmental Agenda in 2009, being one of the first Brazilian universities to adopt this internal management tool for the socio-environmental sustainability of the institution.

Contemporary society, on the other hand, still seems far from achieving the goals of sustainability. Therefore, a great effort is still needed to build a sustainable and resilient future.

Joining efforts on this concern, Pope Francis's Encyclical Letter *Laudato Si*, published in 2015, reached out beyond the borders of the Christian community to global community by addressing issues related to sustainability and inviting reflection on the path taken by society in search of economic development, on values, and on the respect for the other human beings and all living creatures on the planet. It is an invitation to reflect on the importance of caring for the common home (Francisco 2015; Geiser 2016; Siqueira 2016).

According to Siqueira (2016), the *Laudato Si'* presents a mission for the universities, encouraging them to increase the effectiveness of actions for the sustainability of both their campuses and the assets of Creation.

Following the advent of the *Laudato Si'* in 2016 PUC-Rio started a review process of the 2009 Environmental Agenda through NIMA, which included new topics and more emphasis on the social aspects of sustainability. The review is called Socio-environmental Agenda of PUC-Rio (NIMA 2016).

The present paper discusses strategies and methods used by PUC-Rio to construct a new socio-environmental agenda, which will emphasize strategies for community inclusion in its process and the transformational potential of a management instrument of such nature when a pact with the community, as well as its impact when including the agenda items that transform society as a guide towards sustainability.

## 2 The Social Pact and Sustainability at PUC-Rio

The concept of sustainability defines ethical principles of action on spaces, groups and individuals. Expanding the sustainability of groups and places implies transforming patterns of behavior, consumption, and relationships that are embedded in these groups (Too and Bajracharya 2013; Amui et al. 2017). When seeking the sustainability of a group or place, the interference in the life of each individual can be huge and require a lot of dedication, commitment and disengagement.

This means that decisions and actions for sustainability will be recurrently immersed in a universe of conflicts, and therefore their success will be conditioned to the ability of the groups—in all their heterogeneity—to debate, collaborate and agree on the actions for transforming the future (Orenstein and Shach-Pinsley 2017; Hardin et al. 2016).

The success of a transformation plan depends on its legitimacy within that group and hence on the capacity of the process of commitment to include differences of ideas, habits and knowledge, in the diversity that comprises communities (Beynaghi et al. 2016).

A strategic agenda of actions, such as the Social and Environmental Agenda (SEA) of PUC-Rio, is a powerful management tool that precisely represents a community pact to move towards the sustainability of the institution (Parenteau 1994).

The construction of such an agenda is ideally carried out through an inclusive, collaborative and multidisciplinary discussion process. In this case, the process is fundamental for the success of the agenda itself. One of the biggest challenges is precisely to involve, mobilize and compromise the whole community through an active participation (Vasconcelos and Silva 2015).

In addition to the function of management support given to the SEA, this instrument can promote the expansion of community awareness about the agenda items (environmental responsibility, social justice, sense of belonging and community), besides prioritizing actions to transform the development patterns of the institution in its collaborative process of construction (Velazquez et al. 2006).

It was in this scenario that PUC-Rio published its first SEA in 2009. The document established a set of practices that allow and encourage sustainability and socio-environmental quality of life on the Campus, based on humanitarian, scientific and ethical principles (NIMA 2009).

In order to ensure the legitimacy of the SEA's commitment, some essential conditions for the feasibility of the agreement were included (NIMA 2009):

- A collaborative position among all actors;
- Understanding that the responsibility for solutions must be shared and worked out among everyone;
- Flexibility to accept that which is new and different, since it is sometimes necessary to break old habits;
- The maintenance and stimulation of interdisciplinary studies and participation of the PUC community in the process.

In 2016 PUC-Rio started the work of revising the SEA, evaluating and continuous updating its management tools, the socio-environmental changes of recent years, the new discoveries of science in the environmental field and, distinctly, the publication of the “Encyclical Letter Laudato Si’: on care of our common home”.

The reflection brought by the Encyclical proposes a vision and a systemic, inclusive and transdisciplinary approach to the ecological crisis we are experiencing. It inspires a new look at elements of the integral ecology, including the human and social dimensions—an environmental, economic, social, cultural and daily-life ecology—which brings us to the theoretical dimensions of sustainability.

The discussions on sustainability were updated on the SEA of PUC-Rio to include topics regarding the socio-environmental crisis and contemporary society itself, such as the globalized economy; climate change that is exacerbating the environmental problem and creating an urgent call to action; and the new communication technologies that have transformed behavior, daily life, kinds of work and relationships throughout society. Topics such as these require rethinking the idea of sustainability.

It will not be possible to achieve sustainability, a directive to guide actions that impact the future, without considering not only the present context, but also the tendencies for the future.

## 3 The PUC-Rio Socio-environmental Agenda: A Vision of the Future

The starting point for the work of reviewing the SEA considered the need for an essentially systemic, interdisciplinary and inclusive approach on the socio-environmental issues, as well as on the desire to reflect the pressing issues that challenge the society in the current context, especially the ethical and humanist principles emphatically renewed by the *Encyclical Laudato Si'*. Thus, SEA was based on some primary requirements:

- The process of building the agenda should be open to an extensive participation of the community and should have its progressive results permanently disseminated to the community;
- The content of the agenda should reflect the understanding that the university is not an:island”, but rather a complex and diverse community that, located in a complex and diverse physical space (the Gávea Campus and its extension units), interacts intensely and is interdependent with the community of Rio and with its physical environment (natural and built);
- The structure and content of the agenda should be based on the integration of the topics, with the participation of teachers and students from the different areas of knowledge;

- Its content should address the most urgent and compelling issues for the society and the community in the current times, noting the university's potential for innovation in the search for solutions;
- The people affected by the Agenda should be the focus of investment needed to broaden their awareness and socio-environmental responsibility, enabling them to play the role of multipliers of environmentally fair standards and habits, from the example of their own change, turning the university into an example too.
- The agenda should incorporate the spirit of care for the common home, as presented in the Encyclical Laudato Si', reflecting its values and sharing the goals for sustainability that are expressed in the Encyclical.

An analysis of the effectiveness of the current SEA since 2009 concluded a need for institutional investment with goals and actions that go beyond focusing on indicators of sustainability to collaborate with strategies for measuring results, controlling and updating measurement, as well as define the agenda itself.

The emphasis on priorities is paramount to the management tool, so that actions remain efficient, defined and resources are not wasted or dispersed among secondary items. It is also paramount that the results of actions are monitored, in order to establish a productive and continuous cycle of improvement and adaptation of the measures taken in a complex and dynamic socio-spatial system.

Therefore, the new SEA is being structured in seven parts:

(1) *Principles:* they should guide the action, aiming at an optimal degree of socio-environmental sustainability in the University;
(2) *Diagnosis:* of the University's sustainability status, synthesizing present and future challenges and opportunities, in order to reach an optimal degree of socio-environmental sustainability at PUC-Rio;
(3) *Guidelines:* for action aiming at sustainability, which should correspond to the broader level of orientation for the set of actions to be proposed, offering a direct response to the diagnosis and aiming to comply with the principles;
(4) *Goals:* they should detail the guidelines, rank and prioritize actions to meet them with sufficient precision so that their effectiveness can be measured and monitored, and strategies can be revised as needed;
(5) *Projects:* to achieve the goals, equally ranked and prioritized;
(6) *Indicators:* to measure the effectiveness of actions for the University's sustainability;
(7) *Strategies for Monitoring:* defining methods, responsibility and deadlines for monitoring the effectiveness of actions for the sustainability of PUC-Rio.

Principles, diagnosis and guidelines have already been worked out during the first year (a rather elongated period due to the data collection for the diagnosis). The second phase of collective construction process began in June 2017 in the discussion of Goals and Projects, which are consistent with the values that guide the SEA and its construction methods, as well as all the content already agreed upon is open for further discussion and re-evaluation at any point in the process. The SEA is a living document.

Eleven topics to be addressed with emphasis on the Agenda were elected in the collaborative process. Five of these themes were inherited from the 2009 Agenda: (1) Water; (2) Biodiversity; (3) Energy; (4) Waste (treated as "materials and waste" in the 2009 agenda); and (5) Education (treated as "environmental education" in the 2009 agenda). Six other topics were incorporated into the new Agenda: (1) Health; (2) Constructed and Living Spaces; (3) Mobility; (4) Communication; (5) Information Technology; (6) Resilience to Climate Change.

During the process of discussing the topics, a more transversal character (highlighted by its relatively detachment from concrete environment) of some of them became evident while always focusing on the intrinsic relationship and interdependence among them. Therefore, the topics were distributed accordingly: "basic" (Water, Biodiversity, Energy, Waste, Constructed and Living Spaces and Mobility), covered in separate chapters, but with no restriction to interrelated them; and "transversal" (Education, Health, Communication, Information Technology; and Resilience to Climate Change), to be covered interrelatedly with other topics. The latter two are of importance, since they meet the demand for SEA orientation regarding challenges society can face in its search for sustainability.

## *3.1 The Process: Steps and Methods*

In order to promote the collaborative and inclusive construction of the new SEA, several methods were used in the following stages.

Initially, a group of volunteers met systematically for four months to define a work plan of a basic proposal for the structure of the new SEA, and the methods and strategies for implementing and expanding the participatory process itself. This stage 1 was called Preparatory Stage. The working group was formed through an open call to the community at large, but eventually ended up the interdisciplinary team of teachers, students and employees that collaborate with NIMA in the Consultative Council and coordination sections. A group of fifty people approximately.

At the end of the four-month period, a second stage was started, called the *PDD*, the Portuguese initials for principles, diagnosis and guidelines. This stage incorporated into the basic team research scholarship holders, within an integrated project of scientific initiation, as well as new students and volunteer teachers. In this stage, the first meeting of the PUC-Rio community was held to discuss principles, diagnosis and guidelines for sustainability at PUC-Rio to discuss SEA items, resulting in 11 topics to be developed. The meeting lasted for the week of the XXII Environment Week (*SMA*) of PUC-Rio. For the success of the meeting, a wide publicity campaign was carried out, which resulted in the participation of about two hundred students and teachers in the topics and transversal discussions held on the SEA.

Throughout the SMA, lectures were held to level out the information on each topic and to provoke criticism, followed by workshops for discussion and the proposition of principles, guidelines and goals for each topic. During the SMA, the diagnosis was established from the perception of participants on the obstacles and potentialities related to each topic, in order to reach an optimal degree of sustainability at PUC-Rio (Figs. 2 and 3).

In the months that followed the 2016 meeting, the face-to-face contribution was continued by social networks, as well as working groups that held weekly meetings and activities to mature the ideas and proposals gathered in the SMA. In this period, from the "sensibility diagnosis", surveys and new discussions were carried out for its accuracy and deepening. Further discussions were also held to improve the proposals concerning the principles and guidelines. The result of the work subsequent to SMA 2016 was presented and re-discussed with the community in the SMA of 2017, which demonstrated the openness of the work, where inputs of a given stage are reviewed in the next stage in an extensive process of maturation.

The working groups in step 2—*PDD* used a common online working tool (a database and registry of analyses for all the working groups), by the whole team in a virtual storage space (free Google platform), which allowed for managing the extensive content and interaction among topics, as well as following their development (Fig. 4).

The third step, currently underway, was called *MPI*—the Portuguese initials for goals, projects and indicators. At this stage, the dissemination campaign was intensified, aiming not only to invite collaboration in the process, but mainly to present the results already obtained from the SMA 2016 database for consolidation by the community in SMA 2017.

After confirming the potential of different strategies and means utilized in stage 2 for broader public in SMA 2016, the launch of the campaign was set. Besides several different communications, media and social network campaign, an exhibition of preliminary results to be debated at workshops was held at the main entrance hall of PUC-Rio for three weeks (Fig. 5). The virtual participation environment and the working groups continued to be active and the general meeting for discussion

**Fig. 2** Lectures of XXII SMA, 2016

**Fig. 3** Workshop of XXII SMA, 2016

| PRELIMINARY SPREADSHEET OF SYSTEMATIZATION | | | |
|---|---|---|---|
| **PRINCIPLES** | **DIAGNOSIS** | **GUIDELINES** | **DISCIPLINARY INTERSECTION** |
| **1.Preliminares principles** | **1.Preliminary approach** | **1.Preliminary guidelines proposed at 2016 EW** | |
| 1.1.Proposed at the 2016 EW (Environmental Week) | 1.1.Topics of Sensitive Perception at the 2016 EW | | |
| 1.2.Proposed at the WG (working group) | 1.2. Topics proposed at the WG | | |
| | **2. Data survey** | | |
| | 2.1.Required data | | |
| | 2.2.Obtained data | | |
| **2.Justification** | **3. Analyses** | | |
| | 3.1.Potencialities | | |
| | 2.2.Obstacles | | |
| **3.Principles synthesis** | **4.Diagnosis synthesis** | **2.Guidelines synthesis** | |

**Fig. 4** Process for developing principles, diagnosis and guidelines of the Social-Environmental Agenda (SEA)

and proposal of MPI took place in the SMA of 2017 (Fig. 6). In this event, the information-leveling lectures were replaced by more extensive workshops, consolidating debate of the results, detailing proposals in the SMA of 2016, and debating goals and projects, preparing the basis for developing the indicators.


**Fig. 5** Exhibition at the University, 2017

**Fig. 6** Workshop of XXIII SMA, 2017

The work currently at hand consists of the systemizing, analyzing, and detailing of goals and projects proposed in SMA 2017 by the work groups, using the same methods of the earlier stages, aiming for greater Community participation via digital communications, such as the NIMA site and Facebook, where all the information will be made available for follow-up and collaboration. The transversal topics in the basic content will become more prominent with the input of the community workshops. Together with the detailing of goals and projects, indicators and monitoring strategies will be proposed and presented for discussion and consolidation with the Community in the third workshop of the new SEA for December of this year.

The collaboration of the whole community and the inclusion of a great number and diversity of people impacted by the Agenda not only grants legitimacy to the tool, but also foster the sense of collective belonging in all those who relate with each other at PUC-Rio. The interdisciplinary and transversal nature of the topics demand the heterogeneity of the professionals, students and teachers involved, making this whole process even richer and more inclusive.

## 4 Discussion

The transformational potential of Community participation to make a pact for the sustainability goals of PUC-Rio became evident in several ways: the voluntary engagement of several students of the NIMA work groups; the presence of several students in the first and second SMA, the maturation of the discussion between the two workshops; the diverse initiatives of students organized after the first SMA to promote curricular changes in their courses or activities, as well as their campaigns to promote sustainability at PUC-Rio, among others.

The level of participation at the first and second workshops was quite impressive (almost 200 people on average), demonstrating the latent interest of the community in progressively constructing a more sustainable university. Considering the challenge of reconciling the schedules of students and professor to participate for an entire work week, the number of participants is even more impressive.

So far, the positive result in revising the SEA, which has been understood as a an extension of the university, a research activity running parallel to the scientific initiation studies of undergraduate and graduate students involved in the "Sustainable University" project, ended up founding the beginnings of the workgroups.

Concerning the methods utilized in the process, the common tool implemented (the online platform for shared analysis by the workgroups) demonstrated itself as quite efficient, despite its simplicity, since it guaranteed the interdisciplinary unity and coherence among the workgroups by efficiently sharing day-by-day information, as well as also making the meetings of the workgroups more dynamic.

The biggest challenge so far has been effectively integrating the transversal and basic topics in the discussion with the Community. This is most probably due to the very nature of the transversal topics, which are not as materially connected to territory. This is most evident in the topics of Information Technology and Resilience to Climate Change, which are exactly those included due to their specific relevance for contemporary Society. This is the main challenge for the current stage at hand.

## 5 Conclusion

Sustainability in all geographic dimensions—local, regional, national, continental and planetary—has become one of the great challenges of our time. This challenge can also be found in universities that must produce professionals with strong disciplinary training and deliver the overall vision of how to rationally use available resources, so that they remain available for the future generations.

The university campus as a space for the coexistence of kinds of knowledge is a strong and very provocative motto, as long as it can offer students and teachers daily situations that must be solved from other perspectives, moving from a short-sighted and utilitarian culture to an understanding of the processes in medium- and long-term dimensions of sustainability.

The sustainable campus needs to a living laboratory, where research, teaching and extension are integrated, providing the student's education with a differentiated environment, which allows harmony among the humanities, the environmental precepts and sustainable development with social equity.

The PUC-Rio Campus is dedicated to such actions, taking advantage of the physical proximity among the college faculties and of its geographical position in the Gávea Valley—with its preserved remnants of the Atlantic forest being an element that connects the Dois Picos Municipal Park and the Tijuca National Park, besides the Rainha River that runs through it, forming the drainage system of the Valley that reflects the socio-environmental conditions of its branches.

Sustainability is not a thing, but a state that transforms and reconfigures itself from various understandings of reality that dialogue and reach a collective consensus. Sustainability is a process that changes over time, requiring constant evaluation and review processes. There is no absolute sustainability, but a huge range of possible 'sustainabilities'. In this perspective, the whole process described in this article is fundamental. The institutional pact that ensures fluidity and dynamics to the commitments assumed by the PUC-Rio community guarantees the collective, participative and dynamic vision of sustainability in the university campus.

Interdisciplinary studies are the great academic challenge of universities regarding issues of sustainable socio-environmental development. The precept of academic research is still sharply shaped in reductionism, simplification. The socio-environmental issues are hyper-complex and the elimination of one variable changes the relationships among the others. The next step does not presuppose disciplinary elimination; on the contrary, it is necessary to recognize it as the basis of all humanity's contemporary success, but going further, developing methods and procedures for communication and interaction among the kinds of academic knowledge that allow the group to be based on less competitive and more cooperative principles, considering the common good, and the planet Earth—which, just like humanity, must be managed sustainably.

A sustainable campus needs to be alive and present in its local reality. The knowledge generated in research laboratories must transcend and generate concrete results for society, according to the demands and limits expressed by society itself. The university needs to be expanded beyond its walls and be present in the life of the community.

PUC-Rio seeks the socio-environmental responsibility of the campus by taking a look at the campus and the Gávea Valley, which involves a plethora of problems. A program with participation and equity in the pursuit of sustainability is a huge challenge that stimulates and makes students and teachers engage in multidisciplinary interaction.

The sustainable campus must be an attraction for students in their professional training, which is our final mission. The campus must provide a daily routine where the physical precepts of sustainability are respected and evident in the work developed in the eleven topics chosen for the new Social and Environmental Agenda, described in this article. At the same time, subjects that face the multidisciplinary problems in the socio-environmental subject need to be offered broadly in the curricular programs, where students need to find research and extension projects that grant experience as trainees, scholarship holders or researchers to establish the basis for a professional and personal vision for sustainability. With strong multidisciplinary academic research, teaching and extension activities in socio-environmental issues, such training enables students to become agents of transformation, extending to all dimensions of their lives, the precepts of which are built in their experience at a sustainable university campus.

The main external element which triggered the review process of the Environmental Institutional Agenda of PUC-Rio was the Pope's *Encyclical Laudato Si'*, which offers an integrative vision where nature and society cannot be disconnected, thereby suggesting the concept of integral ecology, where parties must harmonize themselves and guarantee the perpetuation of life relations as we know it, through sustainable development in all its dimensions and, mainly, with social, religious and cultural equity. This expansion is expressed in the title of the new agenda, which now includes the term environmental partner. This change presupposes that multidisciplinary research and extension projects equate our social responsibility, ensuring that technical environmental solutions are in line with the social, cultural and religious reality of the community in which the action will take place.

The methodological proposal for a collective and participatory implementation of the Social and Environmental Agenda of PUC-Rio has proved to be efficient to contribute to the process of building sustainable universities. The reported experience values the process and clearly shows that configuring the schedule will depend on the context of where it is being implemented. The common goal of educating students to be more aware of the key issues that humanity needs to address is a concrete and positive contribution to change the current pattern of relationship between nature and society.

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# The Role of Universities to Promote Sustainable Practices and Climate Change Adaptation: Analysis of the 22 Conferences of the Parties Using Text Mining

**Issa I. Berchin, Sthefanie A. da Silva, Flávio Ceci, George M. Gabriel, Talita C. Anhalt and José B. S. O. A. Guerra**

**Abstract** Higher education institutions have a critical role in shaping societies by educating future leaders to think critically and solve problems, especially in a changing climate context and with many sustainability challenges. Therefore, these institutions play a key role in educating about climate change and sustainability, how to adapt to it and mitigate its effects, through knowledge creation and dissemination, through research, education and community outreach. The aim of this paper is to analyze through text mining the 22 Conferences of the Parties (COPs)' documents to understand the role of universities to promote sustainable practices and climate change adaptation. This analysis demonstrates that terms related to the goals of higher education institutions (i.e. education and research, but also outreach) are at the core of the debates at the COPs, from education to innovation, research,

I. I. Berchin (✉) · S. A. da Silva · F. Ceci · T. C. Anhalt · J. B. S. O. A.Guerra
Research Center for Energy Efficiency and Sustainability (Greens), University of Southern Santa Catarina (Unisul), 219 Trajano Street, Florianopolis, SC, Brazil
e-mail: issaberchim@gmail.com

S. A. da Silva
e-mail: sthefanie.sads@hotmail.com

F. Ceci
e-mail: flavio.ceci@unisul.br

T. C. Anhalt
e-mail: talitac.anhalt@gmail.com

J. B. S. O. A.Guerra
e-mail: baltazar.guerra@unisul.br

G. M. Gabriel
Department of German and Russian Studies, College of Charleston,
66 George Street, Charleston, SC 29424, USA
e-mail: gabrielgm@g.cofc.edu



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learning, capacity building, awareness, knowledge, and so on. Thus, the COPs also call for sustainable development, which would be achieved by engaging civil society, creating and disseminating knowledge, building capacities, developing technologies and transforming them into innovations. This would engage the private sector, raising funds to finance the process, to promote a sustainable and resilient society to climate change, not only in the short term, but also in the long term.

**Keywords** Sustainable development · Higher education institutions Universities' campuses · Living labs · Climate change · Text mining

## 1 Introduction

In 1990, considering environmental degradation and the challenges of sustainable development, the University Leaders for a Sustainable Future (ULSF) emitted an action plan, recognizing that universities possess fundamentality of education, research, political development, as well as the distribution of necessary knowledge in order to guarantee a sustainable future. This plan, known as the Talloires Declaration (ULSF 1990), contains ten fertile actions that could positively influence the sustainability of Higher Education Institutions (HEIs). These actions are based on: the augmentation of consciousness of environmental sustainable development, to create an institutional culture based on sustainability, to educate in order to make citizens aware of environmental responsibility, to search an environmental alphabetization for all, the practice of institutional ecology, to involve the collaboration of all stakeholders for interdisciplinary approaches, augmenting the capacity of primary and secondary schools, amplifying institutional services and national/international outreach, as well as maintaining the movement for a sustainable future (ULSF 1990).

From the Talloires Declaration, the implementation of sustainability requires a strong institutional commitment, leading the experience on campus, and the focus of sustainability in education, research and awareness of the local community (Gómez et al. 2015). Accordingly, actions to green HEIs' campuses, besides reducing the ecological footprint of these institutions also contribute to raise the awareness of students, professors, and members of the surrounding communities on sustainable development. Thus, green campuses operate as living labs of sustainability learning and practice, inspiring both members of academia and students, as well as the local community to behave more sustainably; therefore, HEIs lead by example.

In a context of global climate and environmental changes, the role of HEIs is even more important to promote resilience and build strategies to adapt to these changes and mitigate their effects. With this, the aim of this paper is to analyze through text mining the 22 Conferences of the Parties' documents to understand the role of universities to promote sustainable practices and climate change adaptation.

## 2 Literature Review

### *2.1 Higher Education for Sustainable Development*

HEIs play vital roles in the societal incorporation of sustainability through their dissemination of knowledge and promotion of certain sustainable development principles and practices. Their participation in sustainable development provides skills and values that guide the lives and professions of their students and academics. According to Cortese (2003, 17), the promotion of sustainability by HEIs is a necessity, as HEIs "bear a profound, moral responsibility to increase the awareness, knowledge, skills, and values needed to create a just and sustainable future".

In order for HEIs to become promoters of sustainable development, the creation of an institutional agenda can aide the organization of a specific objective of the institution, monitoring and evaluating its actions during a determined period. Therefore, seeing that the adoption of sustainable principles in the mission of HEIs reinforces and institutionalizes the commitment of the theme, permitting the greatest efficiency in the implementation of politics and environmental education programs (Gómez et al. 2015; Guerra et al. 2016; Ramos et al. 2015; Waheed et al. 2011). With the development of an institutional agenda to stablish the commitment of HEIs with sustainable development, transparency and accountability are essential, particularly for sustainability disclosure of the institution (Waheed et al. 2011; Waas et al. 2010).

These are necessary steps in order to achieve an institutional agenda for sustainability:

- Include every academic community (professors, students, residential communities around the university) in the decision and planning processes, augmenting the representation of the institution and its impact in the commitment of the people with executive action necessary for the implementation and success of environmental education programs, following the principles of an inclusive institution (Guerra et al. 2016).
- To be inclusive while also considering cultural, social, and ethnic diversity, as well as gender present in the institution, additionally permitting the access of knowledge to every group of individuals, creating a democratic environment (Gómez et al. 2015; Guerra et al. 2016).
- To have constant monitoring and evaluation, analyzing and divulging the result of sustainable actions in order to augment the credibility of the institution at the front of the community (Guerra et al. 2016; Lambrechts et al. 2013; Waas et al. 2010).

Like the base of HEIs, teaching is a tool capable of molding and changing society. In the sense that when fully developed, it shall become an essential auxiliary piece in order to amplify knowledge and necessary capacities in order to resolve sustainability challenges (Azeiteiro et al. 2015; Gómez et al. 2015;

Lambrechts et al. 2013; Lozano et al. 2013, 2015; Ramos et al. 2015; Steiner and Posch 2006; Waheed et al. 2011; Yuan and Zuo 2013).

In this sense, the institutions must promote the teaching of sustainable development in all their aspects, searching for the innovation in the teaching and training of students, professors, the residential community, creating incentives for them to think and act based on a sustainable model (Gómez et al. 2015; Lambrechts et al. 2013; Lozano et al. 2013, 2015; Ramos et al. 2015; Leal Filho et al. 2016).

The teaching of sustainable development, therefore, must account for the inclusion of practical activities, such as case studies, which permit students to be in contact with the application of the learnt theories in the classroom, collaborating for the development of critical thinking and the ability to resolve issues (Steiner and Posch 2006; Leal Filho et al. 2016). The formation of critical and systematic thinking brings the questions of sustainability to academic discussions, turning cognitive learning into an essential tool in the promotion of environmental education (Lambrechts et al. 2013; Lozano et al. 2013; Waheed et al. 2011).

The maintenance of environmental education and its insertion in the academic community will guarantee life-long education, initiating since the first years of academic formation, developing competencies such as critical thinking and creativity, as well as continuing such actions outside of the HEIs' campuses (Azeiteiro et al. 2015; Guerra et al. 2016).

Between the strategies of lifelong education, HEIs meet participation standards, contribute to the creation and divulgence of learning, workshops, talks and conferences as interesting means of promoting the development of learning through the insertion of local and academic communities, stimulating debate on sustainable development (Gómez et al. 2015; Guerra et al. 2016; Lambrechts et al. 2013; Lozano et al. 2013, 2015; Ramos et al. 2015).

HEIs incorporate research as a means of investigation of the phenomenon and generation of necessary knowledge in order to promote societal changes, stimulating the learning process, developing critical thought, as well as contributing to the comprehension and resolution of environmental complexities based on daily contemporary challenges (Azeiteiro et al. 2015; Guerra et al. 2016; Lambrechts et al. 2013; Lozano et al. 2013, 2015; Ramos et al. 2015; Waheed et al. 2011; Yuan and Zuo 2013).

Therefore, the research strategies must be done in collaboration, specifically between HEIs, sharing knowledge, methods and experiences, meeting the necessary cooperation at a local, national and international level in the promotion of sustainable teaching practices, being able to achieve partners for innovative projects, which shall ultimately benefit the community (Adomßent et al. 2014; Lozano et al. 2013, 2015; Ramos et al. 2015; Stephens and Graham 2010; Yuan and Zuo 2013).

Another strategy to promote teaching is the implementation of outreach programs focused on sustainable development, which permits the insertion of students, professor, the community and stakeholders involved in projects, which would stimulate a creative way of thinking and acting in response to the environment and society. Thus, creating experiences and becoming a specific tool, transferring knowledge and a form of conquering the barriers of innovation for sustainable development, in local and regional communities (Guerra et al. 2016; Ramos et al. 2015; Steiner and Posch 2006; Stephens and Graham 2010; Leal Filho et al. 2016).

With the presented strategies, HEIs become disseminators of knowledge, becoming interesting tools to stimulate the knowledge received from education and critical thinking, apart from representing a mechanism for the creation of sustainable thoughts and actions in order to achieve the resolution of problems with direct impact in local communities, academics and stakeholders (Guerra et al. 2016; Leal Filho and Brandli 2016).

## 2.2 *Universities' Campuses as Living Labs*

HEIs have been increasing their impact in the promotion of sustainability, as disseminators of sustainable development who collaborate with partners in local initiatives, becoming innovative tools in adopting interdisciplinary practices, transforming their campuses and surrounding areas into living labs, which permit the access to experiences with real life practices (Trencher et al. 2014; Evans et al. 2015).

In this context, the living labs become a form of HEIs, engaging in social and environmental intervention projects as establishers and monitors of experiments based on occurring daily situations, contributing to sustainable development through collaborative experiments, which increase the access to knowledge and consciousness of students, professors and the locally involved community, besides reducing the institution's ecological footprint (Trencher et al. 2014; Evans et al. 2015; Witteveen et al. 2016; Evans and Karvonen 2012; Ramos et al. 2015; Lozano et al. 2015).

According to Evans and Karvonen (2012, 5), living labs "rooted in a specific place, they offer the immediate real-world relevance sought by policymakers; data rich, they offer the promise of causal understanding and 'factual' knowledge". Therefore, living labs represent an environment of the development of innovations (Cosgrave et al. 2013; Leminen et al. 2012).

The concept of the living lab is recent, emerging in the decade of the nineties in order to describe regional areas of a small scale in order to stimulate students to deal with real-life problems (Leminen et al. 2012). This arises as practices of implementation of a program based on environmental education, which permits the students to live sustainability on campus, developing their critical thinking and adopting sustainable behaviors that are all pertinent to their reality (Azeiteiro et al. 2015; Ramos et al. 2015; Yuan and Zuo 2013).

The implementation of actions in order to achieve sustainability on HEIs campuses is a process of development and management through the efficient use of renewable resources and other sustainable practices (Bantanur et al. 2015; Yuan and Zuo 2013). The operations to achieve a sustainable campus as the environment for practical learning (living labs), are: promotion of water efficiency, reducing the consumption of water, capturing rain water and bettering the efficiency on installed campus equipment (Guerra et al. 2016; Waheed et al. 2011); energy efficiency measures, generating renewable energy and reducing energy consumption (Adomßent et al. 2014; Guerra et al. 2016; Waheed et al. 2011); and promoting the separation by type of waste, recycling as much as possible and reducing the amount of waste produced (Adomßent et al. 2014; Azeiteiro et al. 2015; Guerra et al. 2016; Waheed et al. 2011).

Apart from these, infrastructural interventions are also strategies to promote sustainability in HEIs, such as building investments, as well as investments in the environment and sustainable transportation. In addition to other installations, which serve as reducers of the ecological footprint of the institution, who promote the immersion of students and professors in a sustainable environment, operating as a living lab, socially inclusive, economically viable, and environmentally responsive, stimulating learning and collaborating to achieve the adaptation of HEIs to climate change (Bantanur et al. 2015; Guerra et al. 2016; Ramos et al. 2015; Waheed et al. 2011; Yuan and Zuo 2013).

## *2.3 Climate Change Adaptation Strategies at Universities*

Universities have been considered for centuries as liberal environments open to changes and innovation. With the growing threat and global risks of climate change and their consequences to local communities, HEIs must adapt to this pressing issue in order to create and maintain sustainability on their campuses. Climate change policies and actions are growing at all levels of government and society; however, the youth still need to be more engaged in these actions, and education is a key tool to raise their awareness about climate change and sustainable development (Senbel et al. 2014). Therefore, universities play a critical role in educating students and the society about climate change (Wachholz et al. 2014).

Universities are town-like institutions, possessing large facilities, such as housing, transportation, recreational and agricultural facilities, laboratories, offices and classrooms, consequently these institutions have high impact at the local level; "as institutions such as universities move to become more sustainable ways to measure progress are being sought such as greenhouse gas emissions and ecological footprint analysis" (Klein-Banai and Theis 2011, 857).

"Universities are uniquely poised to play a role in not only climate change research, education, and community outreach, but also in the regional and national policy-making arena", creating and disseminating knowledge that supports the construction of climate change adaptation and mitigation policies and plans (Coffman 2009, 239).

Climate change is expected to increase the ecological footprint of HEIs, therefore, in order to reduce it, universities should address matters of energy, water and land use efficiency. Additionally, managing their wastes, also enhancing social dimension, adapting to climate change (Klein-Banai and Theis 2011; Coffman 2009; Knuth et al. 2007), also influencing the communities in their surroundings (Senbel et al. 2014) through both on-campus operations and events in the community, and the engagement of policymakers (Coffman 2009; Knuth et al. 2007).

Climate change education is another fundamental element for greening higher education; it should be addressed through interdisciplinary and problem-solving teaching, which is still a challenge for HEIs; the disciplinary focus and the top-down approaches are barriers for greening the university, both the curricula and campus (Davison et al. 2013), considering that HEIs have the mission to develop future leaders capable of solving problems, multi-disciplinary thinking is required (Fahey 2012).

The increasing effects of climate change and its impacts on local communities are instigating community leaders to seek solutions of adaptation and mitigation, therefore, universities play a key role in this context being able to support these communities—especially in their surroundings—by sharing their knowledge, their technical expertise, also operating through outreach programs and partnerships (Gruber et al. 2017). Accordingly, in order to be effective, these partnerships between universities and the communities to promote climate change adaptation plans and actions must have a long-term perspective for engaging stakeholders of the university and community (Knuth et al. 2007).

## *2.4 Methods*

The COPs' declarations were organized and submitted to the *Collocations Extraction* process, creating a list of important terms for each conference, based on the frequency of which they were quoted. The main criteria for organization and analysis was the year. Initially, all of COPs' documents were downloaded, then organized in folders by decades (1990s, 2000s and 2010s). The files collected were submitted to the *Collocations Extraction* process, using the method entitled *Named Entity Recognition*, developed by Ceci et al. (2012).

The *Collocations Extraction* process provides a list of terms representative of each conference, displaying its frequency in the files and the correlation among the terms (i.e. which one is connected to the others). Then, after evidencing the most frequent terms in the COPs' documents by decades, the correlation among the terms "education", "knowledge", "research", "capacity building", "training", "innovation", "learning", "awareness", "sustainability", "sustainable development", "climate change", and "development", were established. These terms were selected due to their relation to the aim of this paper, which seeks to understand the urge for education and more specifically actions from higher education institutions towards more sustainable development.

## 3 Results and Discussion

### *3.1 Overview of the 22 Conferences of the Parties*

The COPs are the supreme body of the United Nations Framework Convention on Climate Change (UNFCCC), responsible for the annual meeting of UNFCCC at global conferences with the objective of maintaining and making decisions in order to promote the effective implementation of the UNFCCC (UNFCCC 2017a).

The UNFCCC arises in the context of increased global awareness of the greenhouse gas concentration in the atmosphere caused by human activities (Earth Negotiations Bulletin, 1995). Its objective is to "stabilize greenhouse gas concentrations at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system (…), such a level should be achieved within a time-frame sufficient enough to allow ecosystems to adapt naturally to climate change, in order to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner" (UNFCCC 2017b). In this regard, it is the responsibility of the COPS to promote the exchange of information of Parties on measures taken to address climate change and its impacts, and to prepare periodic reports with this information.

The first COP took place in Berlin (Germany) in 1995, discussing the start of negotiation processes, encouraging international cooperation between developed and developing countries (Earth Negotiations Bulletin 1995; UNFCCC 1995). As for the second COP (Geneva in 1996), it was responsible for the establishment of the Geneva Declaration to create a document with legal obligations in order to reduce gas emission (Earth Negotiations Bulletin 1996; UNFCCC 1996).

The third COP was responsible for one of the most significant UNFCCC events to date—the signing of the Kyoto Protocol in 1997, setting greenhouse gas emission reduction targets for more developed countries (UNFCCC 1997). As for the next COPs, they discussed the implementation of the Kyoto Protocol, land use management, and technology transfer and knowledge creating and dissemination (UNFCCC 1998, 1999, 2000, 2001).

The following conferences also addressed issues of clean development mechanisms, technology transfer, clean energy and knowledge needed to adapt to climate change in less developed countries, in addition the need for adaptation based on institutional agendas and stakeholder involvement beyond governments (i.e. the private sector, civil society organizations, and HEIs) (CETESB 2017a).

It is important to highlight the importance of COP 16 (Cancun—2010), which established the Technology Executive Committee, responsible for taking actions around research and development of technologies for adaptation to climate change (CETESB 2017b). Thus, COP 20 (Lima—2014) also noted the participation of universities and other stakeholders needed to adapt to climate change through parallel events, involving discussions among academics, scientists, companies and politicians based on the impacts of extreme weather events and actions to adapt and mitigate to climate change (CETESB 2017c).

The most recent COPs (21 and 22) in 2015 and 2016 are also responsible for reaffirming the need for research, capacity building, learning, education and dissemination of information for adaptation to climate change (IISD Reporting Services 2015; UNFCCC 2016). Article 12 of COP 21 confirms the need for parties to invest in education to adapt to climate change, reaffirming that "Parties shall cooperate in taking measures, as appropriate, to enhance climate change education, training, public awareness, public participation and public access to information, recognizing the importance of these steps with respect to enhancing actions under this Agreement" (IISD Reporting Services 2015, 17).

In a general context, the COPs are responsible for the insertion of the adaptation and mitigation theme in the international scenario, addressing issues of reduction of greenhouse gas emissions, land use management, sustainability and the need for research, information gathering, capacity building and education.

### *3.2 Priority Terms: Text Mining Analysis of the COPs' Documents*

Through the process of text mining it was possible to identify the most frequent terms cited in the COPs. By far, the most frequent term is development, followed by research, climate change, United Nations, Kyoto protocol, training, capacity building and knowledge; what illustrate the need for more education when it comes to climate change (Fig. 1).

It is possible to observe that in the 1990s, the most frequent words were development, however, all the most frequent terms had a relative decline since the first COP (in 1995) to 1999 (Fig. 2).

Thus, the tag cloud with the most frequent terms of this period (1990s), provides a better picture. The most frequent terms in the period was development, research, training, responsibility, awareness, education, knowledge, indicating the urge for more research, training and education for sustainable development and climate change. Developing knowledge, gathering data and disseminating awareness and education about sustainability matters and climate resilience throughout the society (Fig. 3).

In the 2000s, the term development kept its position as the most frequent term; however, by the end of the decade there were greater balance among the frequency of the terms (Fig. 4).

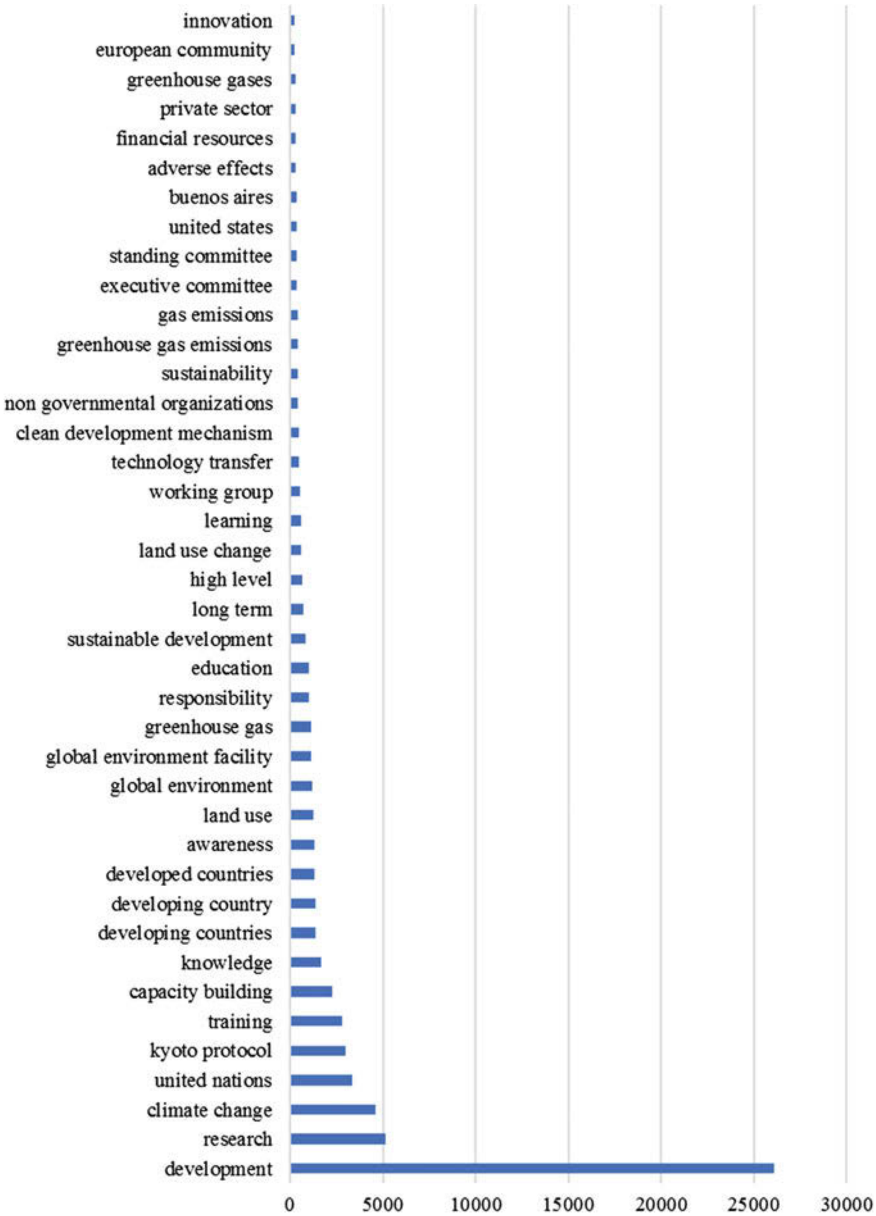


**Fig. 1** Most frequent terms in the COPs' documents (1995–2016)

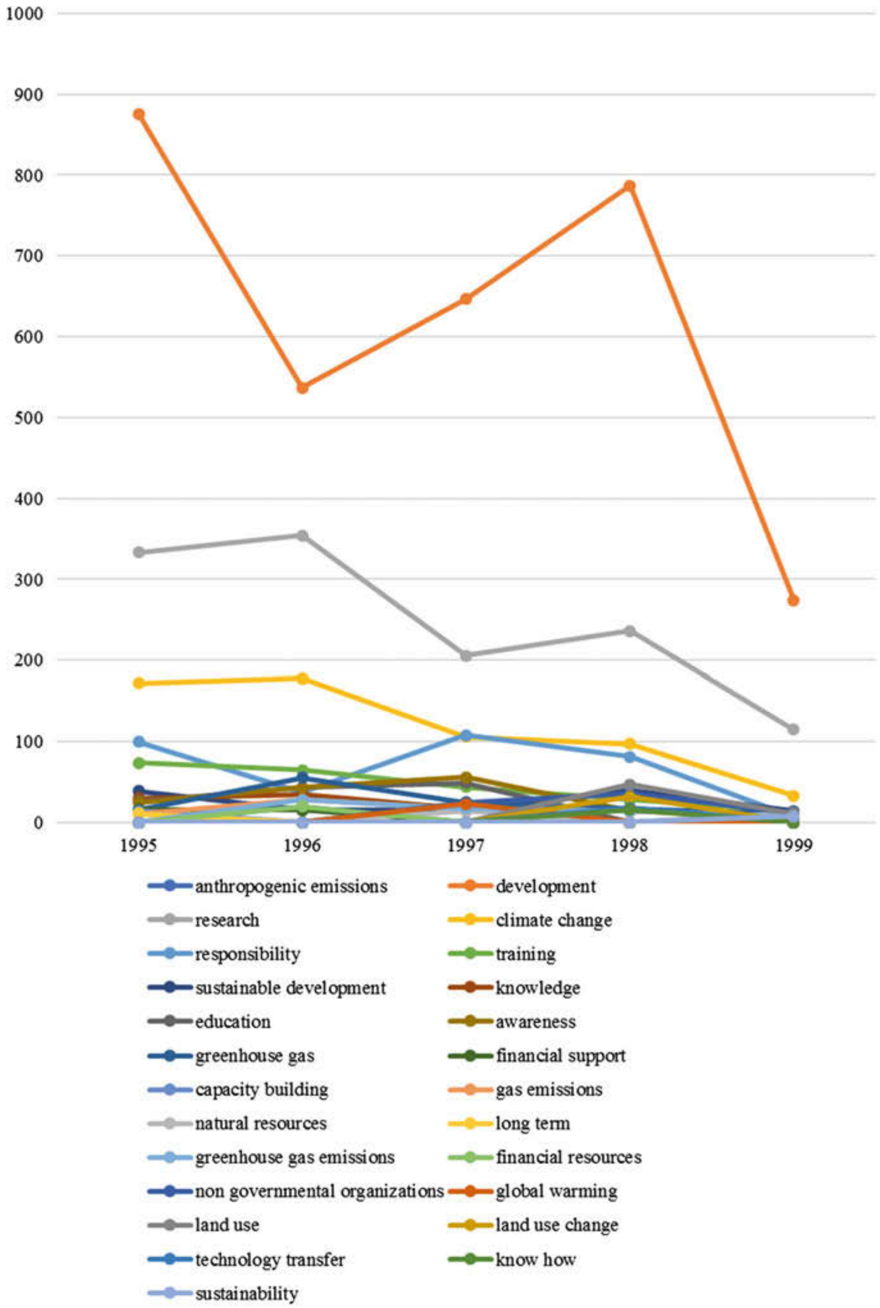


**Fig. 2** Most frequent terms in the COPs' documents in the 1990s


**Fig. 3** Tag Cloud with the most frequent terms from the 1990s COPs (without development)

Considering the terms without the word "development", in the begging of the decade there were a great urge for capacity building, research, climate change, training and land use. By the end of the decade—and apart from development—training was the most cited term. What reinforce the urge for greater capacity building at all levels of the society (Fig. 5).

Accordingly, the tag cloud for the 2000s, highlights the importance of development, research, land use, training, awareness, learning, education, capacity building, and so on; once again reinforcing the urge for a stronger commitment to education, knowledge creation and dissemination and capacity building (Fig. 6).

Finally, at the 2010s, development keeps its position as the most frequent term (Fig. 7).

Analyzing the conference terms without the word "development", demonstrates a higher equality in the use of the terms. It is also noticeable that the terms research, knowledge, capacity building, training, and education still among the most frequent (Fig. 8).

The same observations can be drawn when analyzing the most frequent terms displayed in the tag cloud of the most frequent terms from the for the 2010s' COPs; evidencing the importance of development, knowledge, research, training, education, and awareness, also indicating the need for long term precaution (Fig. 9).

With the presentation of the most frequent terms by decade (1990s, 2000s and 2010s), and with the identification of some relevant terms according to their frequency in the COPs' documents and their relevance for this paper (aiming to identify the urge for more actions from HEIs).

Thus, these terms ("education", "knowledge", "research", "capacity building", "training", "innovation", "learning", "awareness", "sustainability", "sustainable development", "climate change", and "development") were analyzed separately,

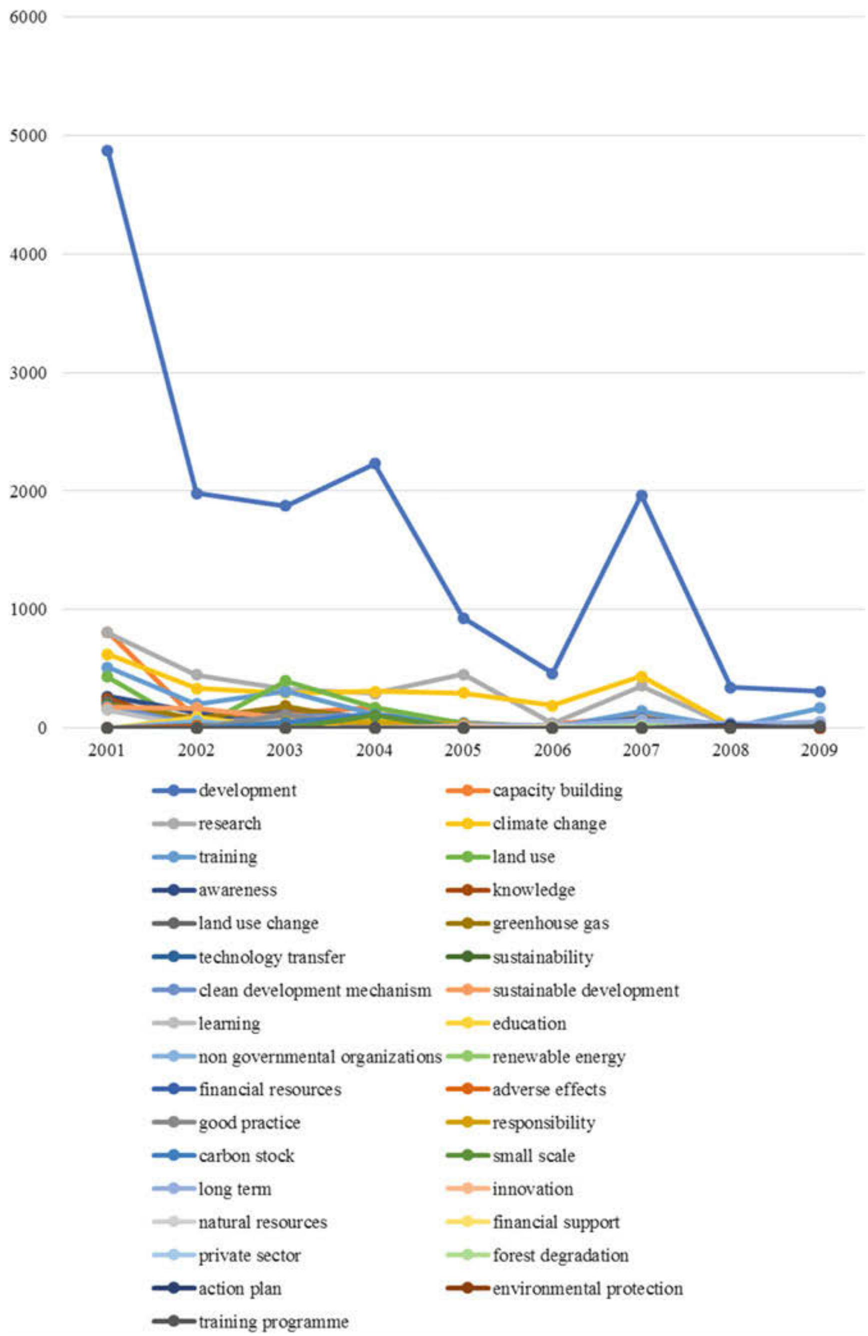


**Fig. 4** Most frequent terms in the COPs' documents in the 2000s

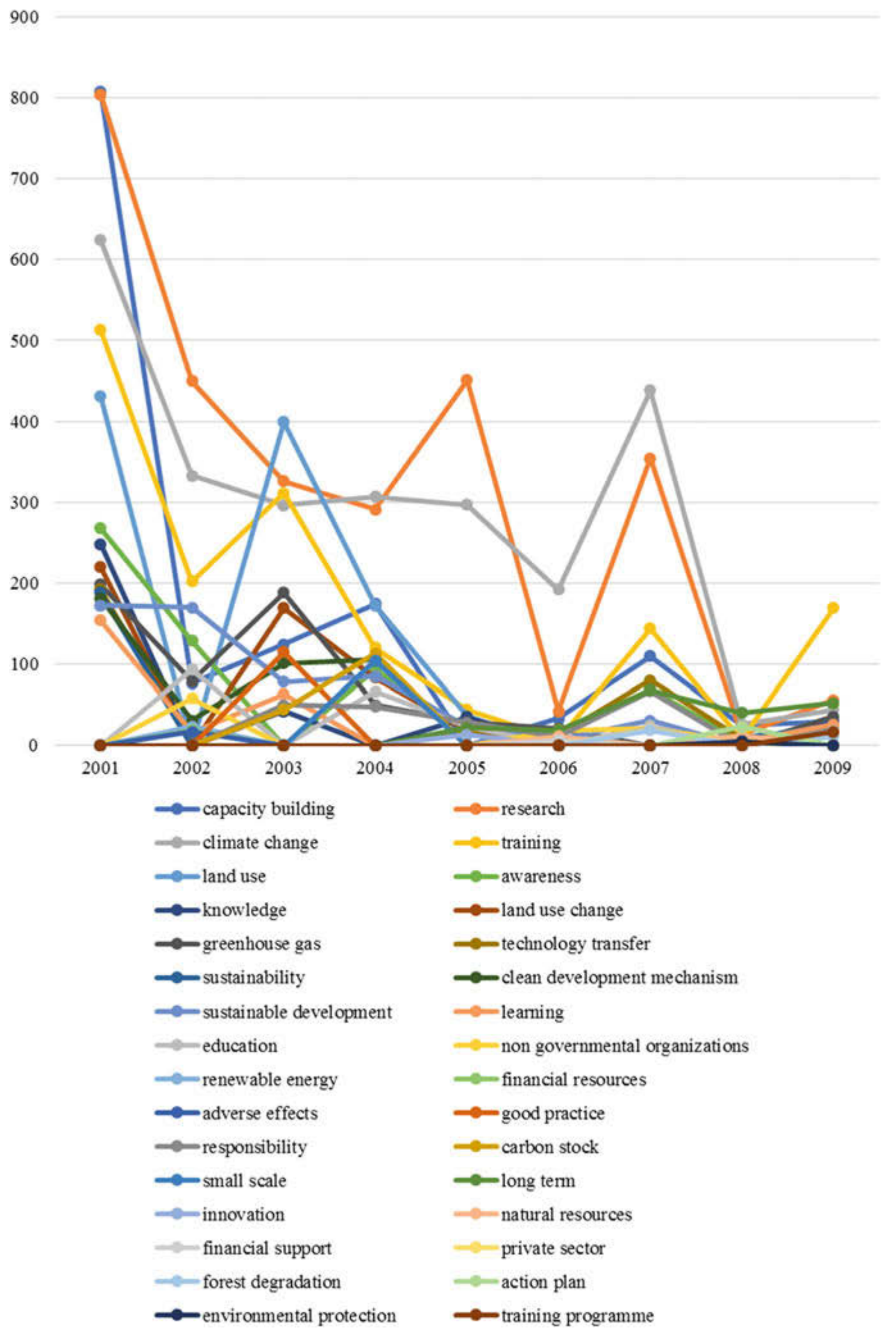


**Fig. 5** Most frequent terms in the COPs' documents in the 2000s (without the word development)


**Fig. 6** Tag Cloud with the most frequent terms from the 2000s' COPs (without development)

with the terms they correlate with in the COPs' documents. For instance, when it comes to the COPs, the term education appears strongly correlated to awareness, training, climate change, research, knowledge, development, and public awareness and participation. These also indicate the need for massive knowledge creation and dissemination, also engaging civil society in the process (Fig. 10).

The term knowledge correlates with development, climate change, awareness, training, research, education, and so on. This shows that there are a need to provide and disseminate knowledge on climate change, sustainable development, innovation, land use, gas emission, renewable energies, as well as to promote awareness, education, build capacities, and transfer technologies (Fig. 11).

When it comes to research at the COPs, the term correlates with development, training, climate change, awareness, knowledge, education, capacity building, innovation, local government, and public awareness (Fig. 12).

Regarding capacity building, the COPs relate the term with development, climate change, sustainable development, research, training, awareness, knowledge, technology transfer, private sector and civil society (Fig. 13).

The term training correlates with climate change, education, awareness, development, research, sustainable development, among others (Fig. 14).

The term innovation presents few correlations, relating to development, training, climate change, research, knowledge, sustainable development, technology information, needs and development, adverse effects, renewable energy, energy efficiency, private sector and joint research (Fig. 15).

Learning correlates with climate change, knowledge, greenhouse gas. Training, sustainability, good practice, and technology transfer (Fig. 16).

Awareness seems to be an important term, which establishes several correlations. For instance, it relates to climate change, education, training, action plan,

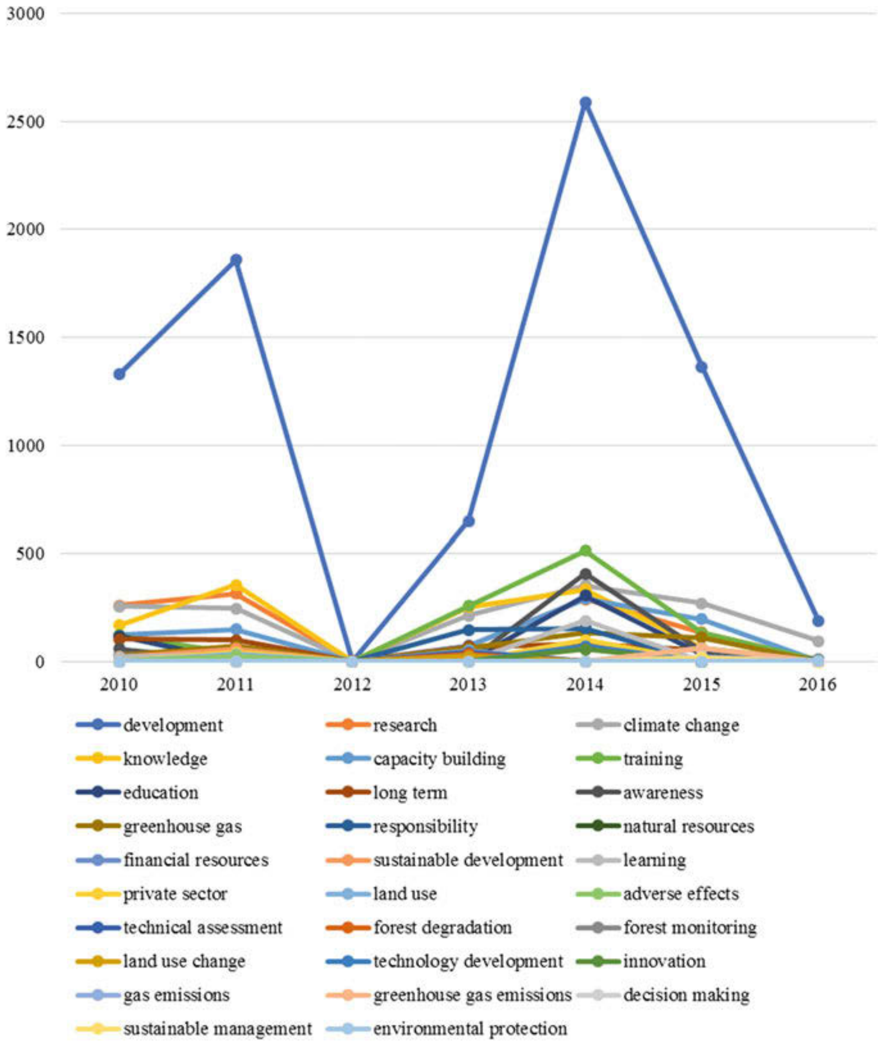


**Fig. 7** Most frequent terms in the COPs' documents in the 2010s

development, public awareness, research, knowledge, capacity building, learning, and sustainable development (Fig. 17).

Sustainability relates with development, civil society, climate change, training, awareness, research, education, and learning (Fig. 18).

Sustainable development also presents several correlations, especially in development, climate change, awareness, greenhouse gas, education research,

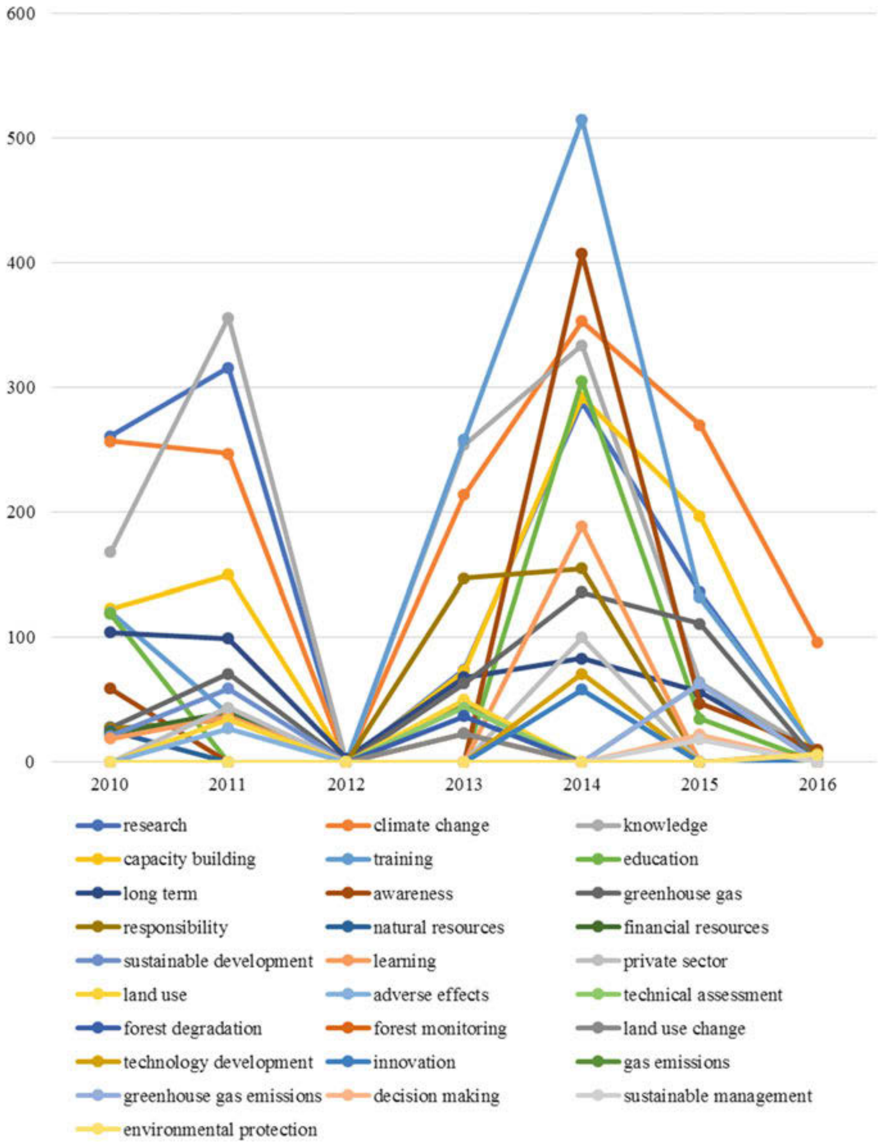


**Fig. 8** Most frequent terms in the COPs' documents in the 2010s (without the word development)

training, knowledge, data collection, policy makers, and capacity building (Fig. 19).

The correlations established with climate change are: development and sustainable development as the paths to be achieved through training, research, education, awareness, knowledge, capacity building and innovations, as a result of the


Fig. 9 Tag Cloud with the most frequent terms from the 2010s' COPs (without development)


Fig. 10 Correlated terms to: "education"

adverse effects of climate changes and greenhouse gas emissions. Thus, requiring financial support, the engagement of stakeholders and the development of action plans (Fig. 20).

Finally, the most frequent term at all COPs, development correlates in the documents with some challenges such as climate change, greenhouse gas emissions, fossil fuels, adverse effects and land use, but also with some paths to be achieved such as: sustainable development, clean development mechanisms, action plans and early warming. Also relating to the possibility of tools to overcome


**Fig. 11** Correlated terms to: "knowledge"


**Fig. 12** Correlated terms to: "research"

these challenges (i.e. research, training, awareness, education, innovations, technology development and transfer, knowledge, and multi-stakeholders approach) (Fig. 21).

These analyses demonstrate that terms related to the goals of higher education institutions (i.e. education and research, but also outreach) are at the core of the debates at the COPs, from education to innovation, to research, to learning, to capacity building, to awareness, to knowledge, and so on. Thus, the COPs also call for a sustainable development, which would be achieved by engaging civil society,


**Fig. 13** Correlated terms to: "capacity building"


**Fig. 14** Correlated terms to: "training"

creating and disseminating knowledge, building capacities, developing technologies and transforming them into innovations, engaging the private sector, raising funds to finance the process. The objective of which being to promote a sustainable and resilient society to climate change, not only in the short term, but also in the long term.


**Fig. 15** Correlated terms to: “innovation”


**Fig. 16** Correlated terms to: “learning”

## 4 Conclusions

HEIs have a vital role in transforming society towards sustainability, through education, research and outreach, training professionals, disseminating knowledge and promoting local development. One of the initiatives taken by these institutions is the insertion of the academic community in projects that increase local communities’ cognitive capacities, awareness and resilience, increasing their ability to promote sustainable actions to solve problems. In this regard, by greening their campuses and transforming them into living laboratories, HEIs creates environments propitious for innovations and practical learning towards sustainability.

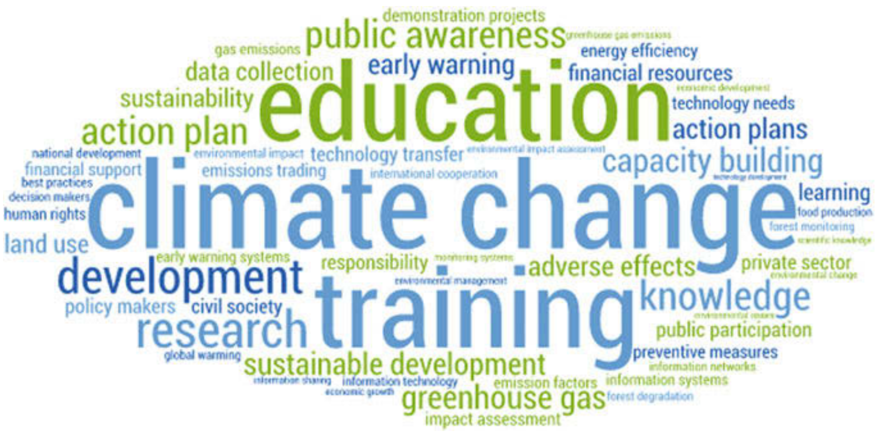


**Fig. 17** Correlated terms to: "awareness"


**Fig. 18** Correlated terms to: "sustainability"

With the increasing challenges of climate changes, it is essential that HEIs insert adaptation into their institutional agenda for sustainability. With the role of creating and disseminating knowledge, raising awareness, and building capacity, HEIs becomes an extremely important tool. Education is thus an essential means in raising awareness among students and society for strategies to adapt to climate change and mitigate its effects, also answering to the sustainability challenges.

The COPs still fail to explicitly recognize the participation of HEIs in climate change adaptation by not having specific terms (such as HEIs and universities) in their reports. Even so, the COPs recognize the need for research, innovation,


Fig. 19 Correlated terms to: "sustainable development"


Fig. 20 Correlated terms to: "climate change"

technology transfer and knowledge dissemination, capacity building and education to deal with climate change and sustainable development.

As living laboratories, HEIs demonstrate their influence in the study of real-life situations geared to the adaptation of climate change. Therefore, allowing the academic community to become a skilled participant with a critical sense of conflict resolution in the formulation of sustainable policies to collaborate locally, regionally and even in a global context. This, ultimately, shall improve the sense of community and promotion of strategies to mitigate the environmental, economic and social changes brought about by climate change.

Fig. 21 Correlated terms to: "development"

Collaboration between HEIs contributes to the promotion and dissemination of knowledge, research, expertise and experiences on sustainability and global climate and environmental changes. Therefore, stablishing a global networking system among universities and other stakeholders may favor the process towards adaptation and mitigation of global challenges such as climate change.

Finally, future studies could use the methods implemented in this research in other areas, for example, using text mining to analyze the sustainable development goals and the main trends emerging from them. Thus, the trend terms of the COPs identified in this study could be used in future studies.

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## Author Biographies

**Issa Ibrahim Berchin,** Researcher at the Research Center for Energy Efficiency and Sustainability (Greens).

**Sthefanie Aguiar da Silva,** is an undergraduate student of International Relations at Unisul. She is a junior Researcher at Greens.

**Flávio Ceci,** is a Professor at Unisul, where he is also the coordinator of the Undergraduate Program in Information Systems, and the coordinator of the Specialization in Database Brazil.

**George Mathew Gabriel,** is an undergraduate student of the Department of German and Russian Studies, at the College of Charleston. He is a researcher at Greens.

**José Baltazar Salgueirinho Osório de Andrade Guerra,** is a professor at the master program in Administration and in the master program in environmental sciences at Unisul. He is the director of Greens. Fellow at the Cambridge Centre for Environment, Energy and Natural Resource Governance (C-EENRG), Department of Land Economy, University of Cambridge, United Kingdom.

# Use of Multicriteria Decision Aid Methods in Evaluating the Millennium Development Goals (MDG) and Post-2015: Alternative for Effective Implementation of Sustainable Development Goals (SDG)

**Noemi Bonina, Marcelo J. Meiriño, Mirian Picinini Méxas and Marcelo Contente Arese**

**Abstract** The Millennium Development Goals (MDG) represents a global initiative endorsed by country governments. Its agreement established eight main objectives that would enable nations to work strategically to act in global challenges. Therefore, this work aims to use a multicriteria decision aid method to evaluate the MDG, using as datum a group of guiding indicators set by Brazilian Government as targets to be achieved by the country. TOPSIS was the multicriteria decision aid method chosen for its evaluation since it allows the search for similarities between the criteria, in order to reach the ideal solution. The verification of the technique consistency for customs and practices which involved decisions in public administration level was attested by finding ways and possibilities of

N. Bonina (✉)
School of Engineering, Federal Fluminense University, Niterói Rio de Janeiro, Brazil
e-mail: noemi_alice@yahoo.com.br; noemibonina@gmail.com

N. Bonina
Faculty of Business Administration and Accouting, Federal University of Rio de Janeiro, Av. Pasteur, Rio de Janeiro, Brazil

M. J. Meiriño · M. P. Méxas · M. C. Arese
School of Engineering, Federal Fluminense University, Rua Passo da Pátria, 156 - Sala 329 - Bloco "E" - Escola de Engenharia, Bairro: São Domingos, Niterói, RJ CEP: 24.210-240, Brazil
e-mail: marcelojm@id.uff.br

M. P. Méxas
e-mail: mirian.picinini@gmail.com

M. C. Arese
e-mail: marceloarese@hotmail.com



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evaluating the MDGs having a group of indicators in a way that the results can collaborate with the 2030 agenda, or post-2015 proposed future challenges. The implementation of the SDG will advance to the extent that mature evaluation mechanisms are used to help governments measuring the proposed objectives for the 2030 agenda.

**Keywords** MDG · Global commitments · TOPSIS · SDG

## 1 Introduction

The intensification of the relations and interdependencies between the countries recognized through globalization processes, which flows intensely in contemporary times, predicts that the possibilities for promoting and building paths to sustainable development will be guided by practices and decisions aimed at generating results through global commitments countries.

The United Nations Organization, through the United Nations Development Program (UNDP), promotes actions that seek to unite world leaders in order to establish an agenda of minimum global commitments for the promotion of human dignity (Brasil 2014; Rezende 2008; Souza 2015).

The reports issued in recent years by UNDP suggest that,

> development is related, first and foremost, to the possibility of having people living the kind of life they have chosen, while having the provision of the tools and opportunities to make their choices. (Veiga 2010, p. 81)

As a continuation of the work that has been developed by the UN since its establishment in the post-Second World War, the world began to work towards a joint strategy to combat the historical enemies of humanity, such as "poverty and hunger, gender inequality, transmissible and preventable diseases, destruction of the environment and precarious conditions of life" (Brasil 2014, p. 12).

In the year of 2000, the Millennium Development Goals (MDGs) was released by the UN, a global initiative signed by governments in more than 180 countries. The initiative aimed to promote development for the next 15 years. The deadline was estimated until December 31st, 2015 (UNDP 2016; Souza 2015).

In that year the UN released eight goals that would enable nations to work strategically in order to promote development starting with indicators that would guide government action within the framework, such as the macro understanding of an MDG.

Along with the establishment of the marks, the institution of the indicators represented benchmarks to quantify the progress so that they could be measured in the quest to overcome challenges and advance in the practical efforts to apply and fulfill each MDG.

Furthermore, building indicators serves as the basis for evolving perspectives for the global promotion of sustainability, supported by global initiatives and commitments.

Some indicators were adjusted so that they could be better adapted to the reality of each country, among these cases we can have a glance at the Brazilian reality (BRASIL 2014). The marks were achieved positively, according to UNDP (2016), although some have been achieved only by some countries. However, as Souza points out (2015: 549), "in any case, global mobilization around the MDGs has made considerable progress in many dimensions of social development".

Fifteen years later, the United Nations has made a positive contribution to the fulfilling of the MDGs and advanced oh the perspective of the continuation of the global development, releasing a post-2015 agenda for the next years, in other words, the sustainable development promotion agenda up to 2030, represented by the Sustainable Development Goals (SDG). According to UNDP (2016), the 17 SDG and 169 related marks were built on the basis of the MDGs and the perspective of work continuity to overcome the new challenges.

The UN highlights the importance of the MDG implementation process,

> UN documents stress that the Millennium Development Goals process was a success, attributing this to the combination of economic growth, better policies and global commitment to the MDGs, pointing to the rapid reduction of extreme poverty (Gallo and Setti 2014, p. 485).

In this sense, starting from the understanding that governmental actions are fundamental to the achievement of objectives of this type and that many factors contribute to increase the importance and complexity of decisions that culminate in the achievement of established marks, the use of quantitative methods for evaluation of indicators can represent significant advances for the public administration, since they enable a more robust reading of the results and collaborate in a more effective way with the decisions in this field.

The use of multicriteria decision support methods in the case of strategies where uncertainties need to be addressed and decisions are efficiently supported (Krohling and Campanharo 2009; Krohling and Souza 2011; Lima Júnior and Carpinetti 2015), can collaborate towards the work of governments, such as enabling the MDGs to be assessed in the light of their set of indicators in order to advance the decisions to be taken so the post 2015-agenda can be continued.

In this scenario, tools that allow a holistic assessment and at the same time speed up the decision making (Costa and Duarte Júnior 2013) can be useful for a faster evolution towards the achievement of marks.

So, the objective of this study is to test the use of a multicriteria method to evaluate the Millennium Development Goals (MDGs) established by the UN in 2000, in the light of a set of guiding indicators of actions that Brazil has determined as marks to be achieved within the possibilities of the country, respecting the scope of the MDGs.

The research conducted for the development of this article brings the following question to the fore: How to make it possible to evaluate the MDGs in the light of a set of indicators?

In order to develop the study, the MDGs were delimited considering the group that presented consistent measurement throughout the studied period, based on the information collected in the 5th Brazilian MDG monitoring report (Brasil 2014). The six measurable MDGs and the indicators considered in this research are presented in Table 1.

The innovative contribution of the proposal is to use the current measurable indicators related to each MDG to provide its evaluation through the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), which will make it possible to hierarchize the alternatives, establishing a systematic analysis reducing the subjectivity inherent in the decision-making process for the actions that will be chosen in future decisions.

Next, the Sect. 2 presents the multicriteria analysis and the TOPSIS method. The Sect. 3 deals with the application of the multicriteria method in ordering the MDGs. Finally, Sect. 4 shows the final considerations of the work.

## 2 Multicriterial Analysis of Decision Supporting

The multicriteria approach arises in the context of the analyzes intrinsic in Operational Research modeling with the objective of supporting decisions in environments with complex problems and whose solution is analyzed by several criteria and variables (Costa and Duarte Júnior 2013; Hein et al. 2015).

The complex decision can be characterized by some factors, as pointed out by Costa and Duarte Júnior (2013),

> This type of decision, called a complex decision, can be characterized, among other aspects, by (1) the variety of criteria used for its solution, (2) difficulty in measuring certain criteria, mainly qualitative criteria, and (3) difficulty in defining the criteria or available alternatives. (Costa and Duarte Júnior 2013, p. 519).

Multicriteria decision methods, or Multiple Criteria Decision Aid (MCDA), represent a set of tools that create models to assist decision makers in uncertainty and complexity environments (Meyer and Roubens 2005). According to Lima Júnior and Carpinetti (2015), these methods aim at the development of decision models for solving problems in the most varied areas of knowledge.

According to Table 2, there are studies in the literature that report the uses of the MDCAs in a simple way or in a comparative way, considering the context of the problems, including some that figure in the governmental decision-making spheres.

**Table 1** Millennium development goals (MDG) delimited for research and indicators

| MDG | Indicators |
|---|---|
| End poverty in all its forms everywhere and end hunger, achieve food security and improved nutrition and promote sustainable agriculture | al Percentage of the population living on less than US$ 1.25 PPC per day |
| | a2 Percentage of the population living on less than R$ 70 per month |
| | a3 Percentage of national income held by the poorest 20% |
| | a4 The percentage of national income held by the richest 20% |
| | a5 Gini index |
| | a6 Rate of occupation of the working age population (in%) |
| | a7 Percentage of the employed population living on less than US$1.25 PPC per day |
| | a8 Percentage of the employed population living on less than R$ 70 per month |
| | a9 Percentage of the employed and formal population living on less than R$ 70 per month |
| | a10 Percentage of self-employed and unpaid workers without contribution to social security in the employed population |
| | a11 Percentage of formal workers in the employed population |
| Ensure inclusive and quality education for all and promote lifelong learning | b1 Schooling rate in primary education of the population aged 7–14 years (in%) |
| | b2 Schooling rate in secondary education of the population aged 15–17 years (in%) |
| | b3 Schooling rate in higher education of the population aged 18–24 years (in%) |
| | b4 Schooling rate of the population aged 0–6 years (in%) |
| | b5 Age adequacy rate for the attended series of students aged 9–17 years (in%) |
| | b6 Literacy rate of the population aged 15–24 (in%) |
| | b7 Percentage of population aged 15–24 with at least complete primary education |
| | b8 Percentage of the population aged 15–24 with at least complete primary education |
| Achieve gender equality and empower all women and girls | cl Ratio between schooling rates in elementary education of women and men |
| | c2 Ratio between schooling rates in high school for women and men |
| | c3 Ratio between schooling rates in higher education of women and men |

(continued)

**Table 1** (continued)

| MDG | Indicators |
|---|---|
| | c4 Percentage of women in non-agricultural salaried employment |
| | c5 Occupancy rate of mothers with ore or more children from 0 to 6 years of age who do not attend school or day care (in%) |
| | c6 Percentage of women employed in domestic employment |
| | c7 Percentage of domestic workers with pension contributions |
| Reduce child mortality | dl Child mortality rate (less than 5 years old) |
| | d2 Child mortality rate (less than l year old) |
| Combat HIV/AIDS, malaria and other diseases | el HIV/AIDS detection rate (total and under 5 years) |
| | e2 Sex ratio of detected cases of HIV/AIDS (total and 10–19 years) |
| | e3 Coefficient of AIDS mortality |
| Ensure environmental sustainability | fl Proportion of population with access to drinking water |
| | f2 Proportion of population with access to sanitary sewage |
| | f3 Percentage of urban population living in inadequate housing |

*Source* By the authors

Given the variety of existing multicriteria methods, the choosing of the method used in this study was determined after the consideration of some factors: the need for ordering alternatives, the ease of applying the method, the possibility of using linear weight in the analysis, besides the simplicity in the development of the method.

The TOPSIS Method (Technique for Order of Preference by Similarity to Ideal Solution) was chosen, since it is a simple and easy to apply tool for the ordering of the MDG indicators, which can enable analyzes of the indices achieved in a deeper and more robust way, to advance the decisions needed so the post-2015 challenges are achieved.

## 2.1 *The TOPSIS Method*

The TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) proposed by Hwang and Yoon (1981) is a method that has been widely used to sort preferences, throughout the evaluation of the performance of alternatives through similarity with the ideal solution (Hein et al. 2015; Krohling and Souza 2011; Lima Júnior and Carpinetti 2015).

**Table 2** Multicriteria Methods

| Approach | Technique | Escope | Proposed by |
|---|---|---|---|
| Simple | TOPSIS | Application of the technique for decision making | Krohling and Souza (2011) |
| | | Assessment of environmental impacts | Hein et al. (2015) |
| | | Use of TOPSIS for asset pre selection | Costa and Duarte Júnior (2013) |
| | | Choose route of public transport bus lines | Godinho and Miranda (2014) |
| | | Reversal of ranking in TOPSIS method | Aires and Ferreira (2014) |
| | AHP | Selecting suppliers by using a Custom method | Alvim et al. (2015) |
| Combined | *Fuzzy*-TOPSIS | Define strategy to combat the oil spill in the sea | Krohling and Campanharo (2009) |
| | | Adoption of TOPSIS and Fuzzy—TOPSIS for selection of suppliers | Lima Júnior and Carpinetti (2015) |
| | AHP-TOPSIS | Proposition of indicators for the monitoring and evaluation of the regulation on food recollection in Brazil | Mello et al. (2015) |
| | | Choice of priority projects for the transportation infrastructure in Brazil | Silva and Netto (2010) |
| Combined Simple | AHP-TOPSIS | Monitoring and evaluation of regulations on food withdrawals | Mello (2015) |
| | TOPSIS | Evaluation of the financial performance of technology companies | Bulgurcu (2012) |

*Source* Adaptaded by Lima Júnior and Carpinetti (2015)

The general process of TOPSIS is to calculate the distance to the ideal point, both positive and negative. It is necessary to quantify the relative importance of the criteria, in addition to not needing any specific method to determine the weights. Normalization can be linear or vector. Another advantage is that it can be used for a large number of alternatives and criteria, using objective and quantitative data. As a final result, TOPSIS performs the general ordering of alternatives (Alvim et al. 2015).

The application of the method is described in a series of successive steps, in which a spreadsheet can be used as a basic tool for its development.

The stages are described below, as Costa and Duarte Júnior (2013) points out:

*Step 1: Construct the decision matrix*

The decision matrix must be assembled initially a x c, where "a" are the alternatives and "c" the criteria. From there, the steps suggested by the TOPSIS method are started.

$$M = \begin{array}{c c} & \begin{array}{cccccc} C & C_2 & \ldots & C_j & \ldots & C_m \end{array} \\ \begin{array}{c} A_1 \\ \vdots \\ A_i \\ \vdots \\ A_1 \end{array} & \begin{bmatrix} m_{11} & m_{12} & \ldots & m_{1j} & \ldots & m_{1m} \\ \vdots & \vdots & & \vdots & & \vdots \\ m_{i1} & m_{i2} & \ldots & m_{ij} & \ldots & m_{im} \\ \vdots & \vdots & & \vdots & & \vdots \\ m_{n1} & m_{n2} & \ldots & m_{nj} & \ldots & m_{nm} \end{bmatrix} \end{array} \tag{1}$$

$$\widetilde{\mathrm{W}} = \left[\widetilde{\mathrm{W}}_1, \widetilde{\mathrm{W}}_2, \ \ldots, \widetilde{\mathrm{W}}_{\mathrm{m}}\right] \tag{2}$$

*Step 2: Calculate the normalized matrix*

The normalization of the decision matrix can be done in several ways (Costa and Duarte Júnior 2013; Lima Júnior and Carpinetti 2015). In this work linear normalization was used, according to the formula below:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum x_{ij}^2}} \tag{3}$$

In which $x_{ij}$ represents the score of the j-th criterion for the i-th data source

*Step 3: Calculate the matrix with the weights*

Multiply the normalized matrix by the respective weights of the criteria. The definition of weights is performed according to perceptions of value of the decision maker or a group of decision makers. In this work, we chose to use linear weight.

$$v_{ij} = w_{ij} r_{ij} \tag{4}$$

In which $W_{ij}$ is the weight defined for each attribute or criterion.

*Step 4: Identification of the ideal solution (PIS) and the ideal solution (NIS)*

In this step, the best levels are determined, which represents the ideal solution ($S^+$) for each of the analyzed criteria. The same is true for the worst levels, which represents the anti-ideal solution ($S^-$). The following equations were used:

$$S^{+} = \{ (maxv_{ij}|j \in J), (minv_{ij}|j \in J')\} \tag{5}$$

$$S^{-} = \{ (minv_{ij}|j \in J), (maxv_{ij}|j \in J')\} \tag{6}$$

In which $J$ and $J'$ represent the criteria set.

*Step 5: Calculate the distances between the ideal positive situation and each alternative ($D^{+}$) and the negative ideal situation and each alternative ($D^{-}$)*

The separation measure is calculated for each alternative in relation to the ideal and anti-ideal solution. These Euclidean distances between each alternative and its positive ideal solution ($D^{+}$) and its anti-ideal solution ($D^{-}$) are calculated as follows:

$$D_i^{+} = \sqrt{\sum_{j=1}^{n} \left[ v_{ij}(x) - v_j^{+}(x) \right]^2} \tag{7}$$

$$D_i^{-} = \sqrt{\sum_{j=1}^{n} \left[ v_{ij}(x) - v_j^{-}(x) \right]^2} \tag{8}$$

*Step 6: Calculate the similarity to the positive ideal position*

Finally, we arrive at the coefficient C, or the result of the approximation of the ideal situation ($C_i$), and the definition of the ordering of the alternatives, through the equation:

$$C_i = \frac{D_i^{-}}{D_i^{+} + D_i^{-}} \tag{9}$$

The alternatives are sorted in descending order according to the values of the approximation coefficient, defined in the interval [0,0,1,0]. The nearest alternatives of 1.0 are considered to be the best.

## 3 Application of the Topsis Method in the Ordination of the MDG

The application of all steps of the TOPSIS method was modeled through a computational app.

The decision matrix M, in Table 1, is composed by 34 alternatives and 7 criteria. The indicators are the alternatives and have been subdivided into categories that

**Table 3** Categorization of MDG

| Indicators | MDG |
|---|---|
| a1, a2, a3, a4, a5, a6, a7, a8, a9, a10, a11 | MDG 1 |
| b1, b2, b3, b4, b5, b6, b7, b8 | MDG 2 |
| c1, c2, c3, c4, c5, c6, c7 | MDG 3 |
| d1, d2 | MDG 4 |
| el, e2, e3 | MDG 6 |
| fl, f2, f 3 | MDG 7 |

*Source* Elaborated by the authors

represent the indicators associated with each MDG (Table 3). Criteria AI1 to AI7 consist on the annual indices according to the methodology used TOPSIS.

The decision matrix was normalized as seen in Table 2.

To verify the technique's effectiveness for ordering the MDG indicators, those were categorized, as shown in Table 3 to facilitate the result's reading.

The indicators presented orbited between classifications of outcome indicators and impact indicators, in which,

> Outcome indicators: express, directly or indirectly, the benefits of implementing the government program or initiative being evaluated. Impact indicators: Comprehensive and multidimensional indicators that measure the effects of medium and long-term government strategies (Mello 2015, p. 90).

The indicators are key elements in achieving the MDG, as well as facilitating the scenario's projection to build a cycle of management of government initiatives to promote the implementation of programs and public policies in line with the global commitments assumed.

Using the Eq. (1) it was possible to create the decision matrix M which corresponds to the performance of the alternatives, as can be observed in Table 4. In this table, the indicators represent the evaluated alternatives and the annual indices correspond to the criteria used.

So that the comparison between the alternatives is significant, normalization is performed in order to transform the data into a common scale, as shown in Table 5. The basis for calculating the results was the Eq. (3).

Considering that all the indicators, given the development context that surrounds the theme, need to be evaluated linearly, the same weight for each index was considered in the calculation of the weighting (Table 6). Weights with values of $w_i = 1$ were used.

The results presented in Table 6 were based on Eq. (4).

Table 7 shows the results of the calculation of the ideal solution (PIS) and the anti-ideal solution (NIS), using Eqs. (5) and (6). The assessment regarding PIS and NIS is carried out considering the impacts that each index has in relation to the expectation shown by the indicators.

**Table 4** Decision Matrix M

| Indicators | Year l | Year 2 | Year 3 | Year4 | Year5 | Year 6 | Year 7 |
|---|---|---|---|---|---|---|---|
| | Index | Index | Index | Index | Index | Index | Index |
| al | 12.000 | 9.700 | 8.000 | 6.700 | 6.000 | 4.700 | 4.700 |
| a2 | 9.000 | 7.300 | 6.700 | 5.600 | 5.400 | 4.600 | 4.500 |
| a3 | 2.600 | 2.800 | 2.900 | 3.000 | 2.900 | 3.100 | 3.100 |
| a4 | 62.300 | 6.200 | 61.000 | 60.400 | 59.500 | 58.800 | 58.300 |
| a5 | 0.581 | 0.569 | 0.566 | 0.560 | 0.552 | 0.543 | 0.539 |
| a6 | 61.200 | 62.200 | 62.700 | 63.000 | 62.900 | 63.600 | 63.800 |
| a7 | 7.200 | 5.800 | 4.800 | 3.900 | 3.300 | 2.400 | 2.300 |
| a8 | 5.200 | 4.200 | 3.900 | 3.100 | 2.900 | 2.300 | 2.110 |
| a9 | 0.500 | 0.300 | 0.200 | 0.200 | 0.100 | 0.100 | 0.100 |
| a10 | 29.300 | 28.000 | 28.000 | 26.800 | 26.200 | 25.000 | 24.300 |
| a11 | 45.400 | 46.100 | 46.700 | 48.000 | 49.500 | 50.600 | 51.900 |
| b1 | 95.200 | 95.200 | 95.800 | 96.300 | 96.300 | 96.600 | 96.900 |
| b2 | 45.600 | 47.300 | 48.900 | 50.600 | 51.700 | 53.800 | 54.300 |
| b3 | 11.000 | 11.000 | 11.700 | 13.200 | 13.800 | 14.500 | 15.300 |
| b4 | 39.800 | 42.700 | 42.700 | 45.700 | 47.100 | 48.000 | 48.900 |
| b5 | 73.400 | 75.600 | 76.300 | 77.700 | 76.500 | 76.300 | 75.900 |
| b6 | 96.600 | 96.900 | 97.100 | 97.600 | 97.800 | 97.900 | 98.100 |
| b7 | 72.000 | 73.900 | 75.500 | 77.200 | 78.400 | 80.500 | 81.300 |
| b8 | 61.400 | 64.100 | 66.300 | 68.600 | 70.300 | 72.500 | 73.400 |
| cl | 1.010 | 1.010 | 1.010 | 1.010 | 1.010 | 1.010 | 1.010 |
| c2 | 1.240 | 1.260 | 1.220 | 1.240 | 1.260 | 1.260 | 1.240 |
| c3 | 1.300 | 1.290 | 1.320 | 1.330 | 1.330 | 1.350 | 1.380 |
| c4 | 46.600 | 46.900 | 46.800 | 47.100 | 46.900 | 46.600 | 47.200 |
| c5 | 44.100 | 45.200 | 46.100 | 45.900 | 46.200 | 46.100 | 46.200 |
| c6 | 17.300 | 17.300 | 17.200 | 16.900 | 16.500 | 15.900 | 17.000 |
| c7 | 29.000 | 27.600 | 28.300 | 29.300 | 30.200 | 29.900 | 30.800 |
| dl | 26.100 | 25.000 | 23.700 | 22.700 | 21.600 | 20.500 | 19.600 |
| d2 | 22.500 | 21.500 | 20.400 | 19.600 | 18.600 | 17.700 | 16.800 |
| el | 19.800 | 19.300 | 18.900 | 18.400 | 20.100 | 21.000 | 20.600 |
| e2 | 5.300 | 4.300 | 4.200 | 3.500 | 3.400 | 3.600 | 3.600 |
| e3 | 6.400 | 6.100 | 6.000 | 5.900 | 5.600 | 5.800 | 5.800 |
| fl | 81.000 | 81.700 | 81.800 | 82.800 | 82.800 | 83.700 | 84.300 |
| f2 | 66.400 | 67.000 | 67.800 | 68.800 | 72.000 | 71.800 | 71.200 |
| f3 | 45.600 | 44.200 | 43.400 | 42.300 | 39.600 | 33.900 | 40.700 |

*Source* Elaborated by the authors

**Table 5** Normalized Matrix

| Indicators | Year 1 Index | Year 2 Index | Year 3 Index | Year4 Index | Year5 Index | Year 6 Index | Year 7 Index | Average |
|---|---|---|---|---|---|---|---|---|
| al | 0.0462 | 0.0381 | 0.0303 | 0.0251 | 0.0224 | 0.018 | 0.0173 | 0.0282 |
| a2 | 0.0347 | 0.0287 | 0.0254 | 0.021 | 0.0201 | 0.0177 | 0.0166 | 0.0234 |
| 33 | 0.01 | 0.011 | 0.011 | 0.0112 | 0.0108 | 0.0119 | 0.0114 | 0.0111 |
| a4 | 0.2401 | 0.0243 | 0.2312 | 0.2263 | 0.2218 | 0.2258 | 0.2147 | 0.1977 |
| a5 | 0.0022 | 0.0022 | 0.0021 | 0.0021 | 0.0021 | 0.0021 | 0.002 | 0.0021 |
| a6 | 0.2358 | 0.2442 | 0.2376 | 0.2361 | 0.2345 | 0.2442 | 0.235 | 0.2382 |
| a7 | 0.0277 | 0.0228 | 0.0182 | 0.0146 | 0.0123 | 0.0092 | 0.0085 | 0.0162 |
| a8 | 0.02 | 0.0165 | 0.0148 | 0.0116 | 0.0108 | 0.0088 | 0.0078 | 0.0129 |
| a9 | 0.0019 | 0.0012 | 0.0008 | 0.0007 | 0.0004 | 0.0004 | 0.0004 | 0.0008 |
| a10 | 0.1129 | 0.1099 | 0.1061 | 0.1004 | 0.0977 | 0.096 | 0.0895 | 0.1018 |
| a11 | 0.175 | 0.181 | 0.177 | 0.1799 | 0.1845 | 0.1943 | 0.1911 | 0.1832 |
| bl | 0.3669 | 0.3737 | 0.3631 | 0.3609 | 0.3589 | 0.3709 | 0.3569 | 0.3645 |
| b2 | 0.1757 | 0.1857 | 0.1853 | 0.1896 | 0.1927 | 0.2066 | 0.2 | 0.1908 |
| b3 | 0.0424 | 0.0432 | 0.0443 | 0.0495 | 0.0514 | 0.0557 | 0.0563 | 0.049 |
| b4 | 0.1534 | 0.1676 | 0.1618 | 0.1713 | 0.1756 | 0.1843 | 0.1801 | 0.1706 |
| b5 | 0.2829 | 0.2968 | 0.2392 | 0.2912 | 0.2851 | 0.293 | 0.2795 | 0.2882 |
| b6 | 0.3723 | 0.3804 | 0.368 | 0.3657 | 0.3645 | 0.3759 | 0.3613 | 0.3697 |
| b7 | 0.2775 | 0.2901 | 0.2861 | 0.2893 | 0.2922 | 0.3091 | 0.2994 | 0.292 |
| b8 | 0.2366 | 0.2516 | 0.2513 | 0.2571 | 0.262 | 0.2784 | 0.2703 | 0.2582 |
| cl | 0.0039 | 0.004 | 0.0038 | 0.0038 | 0.0038 | 0.0039 | 0.0037 | 0.0038 |
| c2 | 0.0048 | 0.0049 | 0.0046 | 0.0046 | 0.0047 | 0.0048 | 0.0046 | 0.0047 |
| c3 | 0.005 | 0.0051 | 0.005 | 0.005 | 0.005 | 0.0052 | 0.0051 | 0.005 |
| c4 | 0.1796 | 0.1841 | 0.1774 | 0.1765 | 0.1748 | 0.1789 | 0.1738 | 0.1779 |
| c5 | 0.1699 | 0.1774 | 0.1747 | 0.172 | 0.1722 | 0.177 | 0.1701 | 0.1734 |
| c6 | 0.0667 | 0.0679 | 0.0652 | 0.0633 | 0.0615 | 0.0611 | 0.0626 | 0.064 |
| c7 | 0.1118 | 0.1084 | 0.1073 | 0.1098 | 0.1126 | 0.1148 | 0.1134 | 0.1111 |
| dl | 0.1006 | 0.0981 | 0.0898 | 0.0851 | 0.0805 | 0.0787 | 0.0722 | 0.0864 |
| d2 | 0.0867 | 0.0844 | 0.0773 | 0.0734 | 0.0693 | 0.068 | 0.0619 | 0.0744 |
| el | 0.0763 | 0.0758 | 0.0716 | 0.069 | 0.0749 | 0.0806 | 0.0759 | 0.0749 |
| e2 | 0.0204 | 0.0169 | 0.0159 | 0.0131 | 0.0127 | 0.0138 | 0.0133 | 0.0152 |
| e3 | 0.0247 | 0.0239 | 0.0227 | 0.0221 | 0.0209 | 0.0223 | 0.0214 | 0.0226 |
| fl | 0.3121 | 0.3207 | 0.31 | 0.3103 | 0.3086 | 0.3214 | 0.3105 | 0.3134 |
| f2 | 0.2559 | 0.263 | 0.2569 | 0.2578 | 0.2684 | 0.2757 | 0.2622 | 0.2629 |
| f3 | 0.1757 | 0.1735 | 0.1645 | 0.1585 | 0.1476 | 0.1494 | 0.1499 | 0.1599 |

Fonte: Elaborated by the authors

**Table 6** Normalized and Weighted Matrix

| Indicators | Year l | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 |
|---|---|---|---|---|---|---|---|
| | Index | Index | Index | Index | Index | Index | Index |
| al | 0.0462 | 0.0381 | 0.0303 | 0.0251 | 0.0224 | 0.018 | 0.0173 |
| a2 | 0.0347 | 0.0287 | 0.0254 | 0.021 | 0.0201 | 0.0177 | 0.0166 |
| a3 | 0.01 | 0.011 | 0.011 | 0.0112 | 0.0108 | 0.0119 | 0.0114 |
| a4 | 0.2401 | 0.0243 | 0.2312 | 0.2263 | 0.2218 | 0.2258 | 0.2147 |
| a5 | 0.0022 | 0.0022 | 0.0021 | 0.0021 | 0.0021 | 0.0021 | 0.002 |
| a6 | 0.2358 | 0.2442 | 0.2376 | 0.2361 | 0.2345 | 0.2442 | 0.235 |
| a7 | 0.0277 | 0.0228 | 0.0182 | 0.0146 | 0.0123 | 0.0092 | 0.0085 |
| a8 | 0.02 | 0.0165 | 0.0148 | 0.0116 | 0.0108 | 0.0088 | 0.0078 |
| a9 | 0.0019 | 0.0012 | 0.0008 | 0.0007 | 0.0004 | 0.0004 | 0.0004 |
| a10 | 0.1129 | 0.1099 | 0.1061 | 0.1004 | 0.0977 | 0.096 | 0.0895 |
| a11 | 0.175 | 0.181 | 0.177 | 0.1799 | 0.1845 | 0.1943 | 0.1911 |
| b1 | 0.3669 | 0.3737 | 0.3631 | 0.3609 | 0.3589 | 0.3709 | 0.3569 |
| b2 | 0.1757 | 0.1857 | 0.1853 | 0.1896 | 0.1927 | 0.2066 | 0.2 |
| b3 | 0.0424 | 0.0432 | 0.0443 | 0.0495 | 0.0514 | 0.0557 | 0.0563 |
| b4 | 0.1534 | 0.1676 | 0.1618 | 0.1713 | 0.1756 | 0.1843 | 0.1801 |
| b5 | 0.2829 | 0.2968 | 0.2892 | 0.2912 | 0.2851 | 0.293 | 0.2795 |
| b6 | 0.3723 | 0.3804 | 0.368 | 0.3657 | 0.3645 | 0.3759 | 0.3613 |
| b7 | 0.2775 | 0.2901 | 0.2861 | 0.2893 | 0.2922 | 0.3091 | 0.2994 |
| b8 | 0.2366 | 0.2516 | 0.2513 | 0.2571 | 0.262 | 0.2784 | 0.2703 |
| cl | 0.0039 | 0.004 | 0.0038 | 0.0038 | 0.0038 | 0.0039 | 0.0037 |
| c2 | 0.0048 | 0.0049 | 0.0046 | 0.0046 | 0.0047 | 0.0048 | 0.0046 |
| c3 | 0.005 | 0.0051 | 0.005 | 0.005 | 0.005 | 0.0052 | 0.0051 |
| c4 | 0.1796 | 0.1841 | 0.1774 | 0.1765 | 0.1748 | 0.1789 | 0.1738 |
| c5 | 0.1699 | 0.1774 | 0.1747 | 0.172 | 0.1722 | 0.177 | 0.1701 |
| c6 | 0.0667 | 0.0679 | 0.0652 | 0.0633 | 0.0615 | 0.0611 | 0.0626 |
| c7 | 0.1118 | 0.1084 | 0.1073 | 0.1098 | 0.1126 | 0.1148 | 0.1134 |
| dl | 0.1006 | 0.0981 | 0.0898 | 0.0851 | 0.0805 | 0.0787 | 0.0722 |
| d2 | 0.0857 | 0.0844 | 0.0773 | 0.0734 | 0.0693 | 0.068 | 0.0619 |
| el | 0.0763 | 0.0758 | 0.0716 | 0.069 | 0.0749 | 0.0806 | 0.0759 |
| e2 | 0.0204 | 0.0169 | 0.0159 | 0.0131 | 0.0127 | 0.0138 | 0.0133 |
| e3 | 0.0247 | 0.0239 | 0.0227 | 0.0221 | 0.0209 | 0.0223 | 0.0214 |
| fl | 0.3121 | 0.3207 | 0.31 | 0.3103 | 0.3086 | 0.3214 | 0.3105 |
| f2 | 0.2559 | 0.263 | 0.2569 | 0.2578 | 0.2684 | 0.2757 | 0.2622 |
| f3 | 0.1757 | 0.1735 | 0.1645 | 0.1535 | 0.1476 | 0.1494 | 0.1499 |
| Peso | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

*Source* Elaborated by the authors

**Table 7** Ideal and Anti-Ideal Solution + Impacts

| Impacts | (+) | (+) | (+) | (+) | (+) | (+) | (+) |
|---|---|---|---|---|---|---|---|
| Alternatives | Year l | Year 2 | Year 3 | Year4 | Years | Year 6 | Year 7 |
| PIS | 0.3723 | 0.3804 | 0.3680 | 0.3557 | 0.3645 | 0.3759 | 0.3613 |
| NIS | 0.0019 | 0.0012 | 0.0008 | 0.0007 | 0.0004 | 0.0004 | 0.0004 |

*Source* Elaborated by the authors

**Table 8** Distances in relation to each alternative ($D^+$ e $D^-$)

| Alternatives | $D^+$ | $D^-$ |
|---|---|---|
| al | 0.9039 | 0.0767 |
| a2 | 0.9164 | 0.0616 |
| a3 | 0.9491 | 0.0272 |
| a4 | 0.4968 | 0.5541 |
| a5 | 0.9728 | 0.0036 |
| a6 | 0.3481 | 0.6281 |
| a7 | 0.9356 | 0.0438 |
| a8 | 0.9442 | 0.0334 |
| a9 | 0.9762 | 0 |
| a10 | 0.7091 | 0.2678 |
| a11 | 0.494 | 0.438 |
| b1 | 0.014 | 0.9622 |
| b2 | 0.4745 | 0.5033 |
| b3 | 0.849 | 0.1283 |
| b4 | 0.528 | 0.45 |
| b5 | 0.2159 | 0.7606 |
| b6 | 0 | 0.9762 |
| b7 | 0.2079 | 0.7707 |
| b8 | 0.2978 | 0.6818 |
| c1 | 0.9682 | 0.0081 |
| c2 | 0.9659 | 0.0104 |
| c3 | 0.965 | 0.0113 |
| c4 | 0.5077 | 0.4685 |
| c5 | 0.5197 | 0.4565 |
| c6 | 0.8089 | 0.1673 |
| c7 | 0.6844 | 0.292 |
| dl | 0.7498 | 0.2278 |
| d2 | 0.7815 | 0.1959 |
| el | 0.7803 | 0.1961 |
| e2 | 0.9382 | 0.0383 |
| e3 | 0.9186 | 0.0576 |
| fl | 0.1493 | 0.8271 |
| f2 | 0.2836 | 0.6935 |
| f3 | 0.5558 | 0.4217 |

*Source* Elaborated by the authors

**Table 9** Sorting alternatives

| Alternatives | Coeffient C | Ordination |
|---|---|---|
| al | 0.078173978 | 23 |
| a2 | 0.062998776 | 24 |
| a3 | 0.027867904 | 29 |
| a4 | 0.527250416 | 9 |
| a5 | 0.003735386 | 33 |
| a6 | 0.643395302 | 8 |
| a7 | 0.044684266 | 26 |
| a8 | 0.034116829 | 28 |
| a9 | 0 | 34 |
| a10 | 0.27414329 | 17 |
| a11 | 0.494356839 | 11 |
| bl | 0.985610199 | 2 |
| b2 | 0.514739583 | 10 |
| b3 | 0.131314956 | 22 |
| b4 | 0.460113029 | 14 |
| b5 | 0.778870828 | 5 |
| b6 | 1 | 1 |
| b7 | 0.787590713 | 4 |
| b8 | 0.695976458 | 7 |
| cl | 0.008271597 | 32 |
| c2 | 0.010675745 | 31 |
| c3 | 0.01153559 | 30 |
| c4 | 0.479936916 | 12 |
| c5 | 0.467648514 | 13 |
| c6 | 0.171411186 | 21 |
| c7 | 0.299019678 | 16 |
| dl | 0.233014144 | 18 |
| d2 | 0.200407749 | 20 |
| el | 0.20086706 | 19 |
| e2 | 0.039254322 | 27 |
| e3 | 0.058977287 | 25 |
| fl | 0.847071839 | 3 |
| f2 | 0.709786047 | 6 |
| f3 | 0.431428066 | 15 |

*Source* Elaborated by the authors

The results of the calculations of relative proximity to the ideal solution are presented in Table 8. Equation (7) was used to calculate the separation measure—or Euclidean distance—$D^+$, in other words, the distance between $S^+$ and the score of each indicator on each index. The separation measure $D^-$ was calculated using Eq. (8), representing the distance between $S^-$ and the score of each indicator in each index.

Finally, using Eq. (9) and the values of $D^+$ and $D^-$, we arrived at the calculation's result of the coefficient C, presented in Table 9, which allows the observation of the ordering of the indicators. The ranking of the ordering occurs according to the descending order of the ideal solution (Bulgurcu 2012).

Sorting allows you to assess some relevant information. For example, when considering the first 10 indicators as hierarchical, it appears that indicators in category b predominate, appearing in positions 1, 2, 4, 5, 7 and 10.

Category b represents the indicators associated with MDG2—Achieving universal primary education (Table 1). These results corroborate the survey presented in the 5th Brazilian MDG monitoring report (Brasil 2014), in which the improvement.

## 4 Conclusion

Discussions based on the use of the TOPSIS technique have allowed useful tools to be followed to monitor and support decision-making on issues at the governmental level, such as the global commitments made through the Millennium Development Goals.

The verification of the technique's consistency for practices involving decisions at the public administration level was attested through the searching of means and possibilities to evaluate the MDGs in the light of a set of indicators, so that the results can collaborate with the challenges proposed by the 2030 or by the post-2015 agenda.

The TOPSIS technique was proved possible to the used example, in addition It is a technique of simple computational implementation. The presented order suggests that the results corroborated with the government's desire to achieve the established goals.

In addition, progress towards the achievement of the Sustainable Development Goals (SDG), which represent the sequencing of initiated actions through the launching, monitoring and evaluation of the MDGs, implies on the decision upon actions involving sustainable practices in approaching different areas of knowledge.

The robustness of the created foundations to achieve the MDGs goes through its phase of consolidation and progress so that it is possible, then, to comply with the SDG through the 2030 agenda.

Thus, in order to transcend the MDGs, it is necessary to learn from its implementation process and seek to consistently evaluate past actions to provide the continuity of the proposed actions for the future. Checking this MDG assessment in the light of a set of indicators, using tools to support multicriteria decision-making, suggests that the possibilities of reducing subjectivity in decision making can be a viable path for advances in government practices and actions.

Therefore, it is suggested, as recommendations for the future work, the improvement upon the studies about the possibilities of the using of the multicriteria methods in order to carry out evaluations and analyzes that involve objectives and goals that represent governmental commitments assumed at a global level.

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# Recommendations for Preparation of Anthropogenic Greenhouse Gases Emission Inventory for University Campuses

**Rogerio Fonseca Santovito and Alex Kenya Abiko**

**Abstract** Most of the greenhouse gas emissions that contribute to global climate change come from urban areas, and cities are at the forefront of low-carbon initiatives, playing a crucial role into mitigating global climate change. In this context, comprehensive sustainability education is paramount for success in the adoption of sustainable development practices. The role of a Sustainable Campus, as a field for research and experimentation, is already recognized by initiatives such as the *International Sustainable Campus Network*, the UNEP *Global Universities Partnership on Environment for Sustainability* and others. A ground rule for those initiatives is the establishment of a campus-wide inventory of GHG emissions. Nevertheless, existing guidelines commonly refer to the Campus inventory in broad terms, without offering any specific and detailed methodology on how to calculate the emissions generated from the campus operation. Based on literature review, surveys and workshops, this research offers recommendations to prepare the campus inventory, based on the widespread standard Greenhouse gas Protocol for Cities GPC. Some relevant emissions sources, specific to University Campuses, are identified. It is expected that, with the proposed recommendations, the resulting inventory will allow a better visualization of GHG mitigation opportunities.

**Keywords** GHG inventory · Sustainable campus · Neighborhood
Urban sustainability

## Context

Extreme climate changes are increasingly affecting populations worldwide, and anthropogenic GHG emissions play a relevant role in this problem. The increase in urbanization rates and the demographic changes of cities adds more complexity to

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R. F. Santovito (✉) · A. K. Abiko
Departamento de Engenharia de Construção Civil, Escola Politécnica,
University of São Paulo, Av. Prof. Almeida Prado, Trav.2, Nº 83,
Edifício de Eng. Civil, Cid. Universitária, São Paulo CEP: 05508-070, Brazil
e-mail: rogerio.santovito@usp.br

A. K. Abiko
e-mail: alex.abiko@usp.br



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combating the causes of these climatic changes. Although climate change mitigation is a global process, usually initiated on a country scale, many mitigation actions must be conducted by cities, considered the main arena for sustainable development actions.

In recent decades, the *sustainable development in the built environment* discussion has focused mostly on the topic of *green buildings*, with emphasis on pioneering initiatives of energy-efficient buildings and environmental efficiency of buildings and its operations. However, many areas of urban sustainability development still need to be considered, such as the role of cities and the development of metrics in a neighborhood scale, to promote the concept of *sustainable urban development*.

Urban emissions of GHG in cities of emerging economies are already converging with those of developed countries (World Bank 2014, 13). Although there is no evidence of a consensual percentage's of this contribution, mainly due to comparability issues with existing city-level GHG inventories, is now notorious that cities worldwide play an important role in achieving carbon reduction targets. The recognition of the importance of cities has triggered several initiatives by local authorities, centered on decarbonization or on achieving low levels of carbon emissions.

In the case of Universities, it is important to have a clear vision of the emissions that occur within the campus boundaries, because of their operation and the activities that occur within their geographical and administrative boundaries. In this sense, the use of a neighborhood scale is important, not only for greater speed of implementation of mitigation actions, but also on the engagement of communities in low-carbon projects.

Universities, because of their scale, have the potential to easily demonstrate principles of sustainable development in its operations on the campus and can be a model for society. Beyond the expertise in education and research (themes that are out of scope of this paper), the development of mitigation actions in a University campus can bring practical insights for the development of urban level actions in scale of neighborhoods in cities, for example in redevelopment projects of neighborhoods.

Universities or higher education institutions (HEIs) worldwide have already mobilized at different levels and ways to incorporate the principles of sustainable urban development in their operations. Currently there are specific networks of HEIs for exchange of experiences and, specifically, to provide tools and information about the amount of GHG emissions resulting from their operations.

However, the references used for calculation of GHG inventories of HEIs are standards established for other contexts, such as countries (IPCC 2006) or cities (Fong et al. 2014). Because of different approaches in relation to the definitions of emission sources and scope of the inventory, emission factors to be used, and how to obtain activity data, such references often result in inventories that, apart from problems of comparability, do not indicate clearly the possible opportunities for mitigation actions.

## 1 Characteristics of the Academic Community

The HEIs seek to gather in a suitable environment, human and material resources for the development of their activities, that is, build, transmit and disseminate knowledge and experience to their students and to the community in which it is inserted, providing a good level of learning and professional preparation. As a result, what we have is the development of the whole society and evolution of knowledge, leading to new frontiers of knowledge and human progress.

Generally, we can say that the development of education activities occurs through a process where it is essential the participation of the teacher, the student and the community, and where the absence of one harms everyone else, preventing a quality end-result. We can verify the interrelation among the participants of this process, because while the professor conveys his knowledge to the pupil, he also learns from it, since the quest for learning by the student makes the teacher active to acquire better knowledge.

On the other hand, it is in the community that the student will acquire his practical experience, where he will see how in practice, his theoretical knowledge acquired in school banks will apply. That way the students interacts with the community when they apply their knowledge and the community interacts with it to the extent that it provides a semi-controlled experimentation field, essential for effective consideration and consolidation of the teachings.

With respect to the relationship between community and teacher, it is important to realize that the community supports students and future teachers. In addition, the community shall convey to the professor their needs, concerns and problems, which in turn research, interprets and elaborates studies, which will serve to develop new knowledge that will return to the community.

There is an increasingly awareness of the meaning of the conditions of the physical environment for the development of teaching and research activities. Teachers, students and community, interact and share experiences, and this whole process ends up happening in the field of human relationships. This trait carries expectations specific to each one of the participants, teacher, student and community, difficult to evaluate, but important to achieve a high level of educational and research performance.

In this sense, there are two basic types of expectations: one purely academic, related specifically to the teaching and research activities; and other concerning the conditions of living where the activities occur, especially concerning the conditions of the physical and urban environment. Using as a benchmark research conducted within the Polytechnic School of USP, the National Clearinghouse for Educational Facilities and at the University of Georgia, we can synthesize the expectations of each of the involved in this process, as follows.

**Expectations of the Teachers** In addition to the financial issues, the teacher seeks to connect the educational entities that have enabling environment for your intellectual development, where the contact with teachers and students of good academic level is constant. The learning environment is important and so, the workplace must bring out the end to which it is intended and be a source of pride for everyone. Laboratories and appropriate classrooms, well maintained, for the exercise of the teaching and research, should support this entire environment. The supporting infrastructure must be organized and effective, as well as complementary services, such as meals, libraries, bookstores, etc. Building infrastructure should be properly maintained and your architecture should provide a pleasant environment and suitable for study and reflection. Aspects of safety, health, comfort and well-being are also important.

**Student Expectations** Under the academic aspect, students expect to find teachers and colleagues of good learning intellectual level, which provide adequate preparation for professional life. Students' expectations with respect to the physical environment virtually matches the ones of teachers.

**Expectations of the Community** The community expects that the institution provide excellent learning, which is a place of dissemination of academic knowledge and ideas aimed at the well-being and development of the human being. Items such as safety and health must be properly resolved. The environment and resources should be appropriate for the intended purpose and with enough infrastructure.

From simple operations, which were based mainly on the knowledge of teachers and few physical resources, the HEIs as an education sector evolved into great teaching complexes requiring knowledge and skills specific to their management and operation. Unsurprisingly, the higher the prestige achieved by the institution, the greater the expectations with respect to the physical environment in which these activities occurs. The excellence of a teaching and research institution happens when activities-end and middle activities interact with each other, each contributing in their specialties.

Nevertheless, according to Sayce et al. (2005), RICS (2011), RICS (2013), although the sustainability topic has been somehow incorporated into the curriculum of higher education courses, increasingly the real estate industry recognizes Sustainable Development as an issue of mandatory competence for future professionals. This would favor the incorporation of sustainability aspects into curricula of higher education courses, either through specific self-contained modules, or by updating the course curricula and incorporating interdisciplinary sustainability issues.

On the other hand, however, the concept of Sustainable Urban Development applied to University campus can be wide-ranging, and lack theoretical consensus. Often, therefore, there is the adoption in courses of several complementary definitions, as well as environmental practices already established prior to the emergence of this discussion. In that sense, one can assume that *"... programme core knowledge and competencies must be defined with reference to market needs."* (D'Arcy and Taltavull 2009).

In order to address the sustainable urban development topic in higher education, the authors conducted a survey applied to students and alumni of MBA-level courses related to real estate, aiming to identify students' perceptions of education for Sustainable Real Estate Development (Santovito 2013). Participants were asked about how they see involvement of real estate companies into Sustainable Development practices, and their opinions about delivery formats of educational content, able to stimulate meaningful learning situations. The survey was designed after Biasutti and Surian (2012), Rieckmann (2011), Hayles (2010), and included the alumni respondents from MBA courses related to real estate, urbanism and construction engineering, from years 2009–2013, in total of 53 valid participants. Survey results indicated:

> *That the definition for the concept of Sustainable Development varies greatly among the alumni;*
>
> *That the concepts of Sustainable Urban Development has highly affected their current professional activity;*
>
> *That the concept of Sustainable Urban Development has highly affected the business of the company for which the respondents work, in terms of changes of the competencies needed for professional performance.*

One can see from this discussion the importance of sustainable urban development in HEIs. The performance in activities aimed at the comfort, health and hygiene, creating suitable environments for the practice of teaching and research, the provision of services such as maintenance, new deployments, inputs and control spending, improving conditions in buildings, renovations and etc., shows the high degree of involvement with teachers, students, employees and community.

## 2 Sustainable Campus

Cities are at the forefront of low carbon initiatives, playing a crucial role in the global climate change mitigation and helping countries to achieve the sustainable development goals of the UN. In this context, education for global sustainability is paramount to success in adopting sustainable development practices. This is valid not only for educational practices developed in universities, but also to managers of the Campus and their practices in the operation of the campus. The scientific literature on the subject and sites of universities offer a substantial range[1] and increasing examples of how a college campus is a living laboratory for developing sustainable interventions in the practices of the operation of the campus.

Education for sustainable development is often isolated from the research and not always is likely to be linked to sustainable campus operations. In 2009, McMillin and Dyball has already warned that most universities dealt with the issues of sustainability of a compartmentalized way, education for sustainability being limited to specific courses. Currently, however, believes that universities can optimize your role as agents of change in relation to sustainability, adopting a systemic and holistic approach to sustainability. This approach explicitly binds

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[1]As an example, the International Journal of Sustainability in Higher Education, ISSN: 1467-6370, has since 2000 offered a specific forum for the dissemination of contents of this nature.

research, educational activities, operational and disclosure and involves students in each one of them. On this aspect, Moreira (2006) has stated that by encouraging a collaboration space within the curriculum, so that students, academics and managers can reflect critically on the performance of the University in relation to sustainability, many positive benefits result, in addition to providing meaningful learning experiences for students.

Based on recent literature on the subject, means that in General, higher education institutions are prepared to play a significant role in the search for a more sustainable future. Atherton and Giurco (2011), offers in your research several practical guidelines for universities wishing to an organizational transformation towards sustainability, with a focus on how to involve staff and students and to turn this commitment into tangible actions, goals and objectives.

Küçüksayraç et al. (2017) present an analysis based on case studies, reflecting on how universities can act as intermediaries in the delivery of the HEIs community (and for the construction industry), sustainable solutions for design, construction and operation of sustainable neighborhoods. In this article, it is stressed the need for innovative learning approaches and partnerships as ways to strengthen the capacity for achieving the goals of sustainable development.

In General, the role of a Sustainable Campus as a field of research and experimentation is already recognized by many initiatives such as the *International Sustainable Campus Network*, the *UNEP Global Universities Partnership on Environment for Sustainability*, the *American College and University President's Climate Commitment (ACUPCC),* in addition to numerous initiatives taken individually by the institutions.

## 3 UN-Global Universities Partnership on Environment for Sustainability (GUPES)

Released in June of 2012 by the UNEP-Tongji Institute for Environment and Sustainability (Shanghai), the GUPES is one of the main programs for sustainable education of the UN-Environment's Environmental Education and Training Unit (EETU). The GUPES was the result of a consultative forum organized by the UN and its partners, to deliberate on ways to stagger the United Nations involvement with universities. The goal is to promote the integration of environment and sustainability issues in teaching, research and community engagement, University management, including improvements in environmental sustainability, infrastructure facilities and University operations. The aim is to increase the involvement and participation of students in sustainability activities, through conferences and other events. Currently there are 790 institutions listed as members,[2] which only 10 are from North America, which seems to favor the ACUPCC.

[2]According to the listing available at: http://gupes.org/index.php?classid=3459

Beyond your expertise in education and training on issues of sustainable development, the GUPES has an important performance in collaboration networks, encouraging and participating in regional and sub regional networks of higher education about the environment and sustainability, whether established in terms of continents, regions of UNEP, as well as North-South cooperation and South-South. Establishes links with other initiatives still in higher education for sustainability globally and acknowledge Excellence programs. Under this research theme, the product of this collaboration that highlight is the "**Greening Universities Toolkit V 2.0**" (GU-Toolkit), with your last issue published in 2014. During the workshop in Tongji University, Prof. Dr. Jiang Wu, Vice President of Tongji University and Rector of the ESDI described the GU-Toolkit as an initiative in the creation of a network of universities with a focus on maintenance not only of an environment of sustainable construction, but also in creating a mindset of sustainable development on students. The GU-Toolkit search provide the University community, faculty, staff and students, a range of strategies, tools and resources, extracted from the literature, global case studies and practice designed to inspire, encourage and support the Universities to develop and implement their own transformation strategies for the establishment of Sustainable Campus.

Specifically on GHG Inventories, subject of this thesis, the GU-Toolkit makes several mentions of the inventory as a basis for the recognition of the current state of the emission of the institutions, but does not offer any detailed and specific methodology for the establishment of this inventory. On the contrary, the GU-Toolkit indicates the guidelines developed by AASHE for getting data from Scope 1, Scope 2 and Scope 3, mention the *Campus Carbon Calculator* tool developed by the University of New Hampshire, UNH (both described in detail below) to support the preparation of inventories.

The GU-Toolkit considers a climate action plan assuming the necessary policies, governance and administrative structures, should be started with the development of a GHG inventory. If the focus of the emissions is limited to the scope 1 and 2, including reference to billing data to utilities (energy, water, etc.) and measurement or simulation of fugitive emissions of GHGS, such as refrigerants used in air-conditioning systems or the methane produced by farm animals if any on campus.

According to GU-Toolkit (UNEP 2014), compensation of emissions (*emissions offsets*), such as planting trees and the renewable energy credits, must also be included in the inventory. It is understood that the inclusion of Scope 3 emissions requires a significantly more detailed data collection. Thus, in the GU-Toolkit, it is considered more practical to start the scope 3 with a small number of high-visibility examples (such as purchases), instead of trying to assess the emissions of all goods and services purchased by the University. This approach of scope 3, specific actions and high visibility, is also recommended by Atherton and Giurco (2011).

## 4 ISCN-GULF Sustainable Campus Charter

The network *International Sustainable Campus Network* (ISCN) is a global forum to support colleges, universities and corporate campus in the exchange of information, ideas and best practices for achieving sustainable campus operations, and promote the integration of sustainable development issues in research and teaching. Currently, more than 50 institutions from 15 countries on six continents are represented on the network as a member of the ISCN.[3] ISCN members include the majority of the members of the World Economic Forum GULF (Global University Leaders Forum), with which the ISCN collaborated in the development of the **ISCN-GULF Sustainable Campus Charter**. The 'Charter' (or 'Letter') was developed as a compromise to support universities in setting targets and reporting on sustainable development goals the campus and performance, according to the principles of the ISCN. The three principles, with which the signatories commit themselves, are[4]:

Sustainability aspects must be an integral part of the planning, construction, renovation and operation of buildings on campus, in respect for nature and the community;
To ensure the sustainable development of campus over the long term, strategic planning, your strategic plan and the establishment of goals throughout the campus should include environmental and social objectives;
Installation and operation of the campus, research and education must be connected in order to create a "living laboratory" for sustainable development.

The ISCN is positioned as a support network complementary to existing networks, and offers opportunities for collaboration between institutions, supporting international and national networks that want to commit to ongoing actions and regular and public reporting on sustainability on campus. On the specific theme of this thesis, the establishment of GHG inventories for the operation of sustainable campus, the ISCN Charter makes no specific mention, in addition to considering the inventory as an integral and fundamental part of a sustainable development strategy. It is mentioned also by supporting the AASHE, the *Campus Carbon Calculator* tool developed by the University of New Hampshire, UNH, as support for the preparation of inventories.

[3]The University of São Paulo is listed as a member of ISCN. Listing available in http://www.international-sustainable-campus-network.org/membership/iscn-member-directory Access in April 2017.

[4]freely translated from on http://www.international-sustainable-campus-network.org/charter-and-guidelines Access in April 2017.

## 5 American College and University President's Climate Commitment (ACUPCC)

The ACUPCC was an initiative started by 12 Presidents of American institutions, within the framework of the *Association for the Advancement of Sustainability in Higher Education* (AASHE), in addition to support in implementation by the American NGO Second Nature.[5] After several planning sessions and discussions on the role of higher education institutions in the fight against climate change, was formed the ACUPCC and, in December 2006 were sent invitations for participation to about 400 representatives from educational institutions, and in June 2007, the initiative was officially launched at the first Climate Leadership Summit, with 284 signatories American institutions. Currently, the initiative is called simply for "Carbon Commitment", and has over 595 signatory institutions,[6] which undertake to develop actions to achieve climate neutrality. As a tool to support these institutions, is used mainly to reporting platform maintained by Second Nature, and the tool for preparation of inventories *Campus Carbon Calculator* developed by the University of New Hampshire.

## 6 Campus Carbon Calculator (CCC)

The NGO Clean Air-Cool Planet and the Sustainability Institute at the University of New Hampshire, UNH, were the original developers of the Campus Carbon Calculator tool (CCC). The initial development was based on a design of the UNH *entitled Greenhouse Gas Emissions Inventory* (inventory of greenhouse gas emissions), 1990–2003, and in the work of the IPCC reports on the achievement of national inventories (IPCC 2006). Started as a spreadsheet tool Microsoft Excel-based, customized to account for the main emission sources, including energy production on campus, purchased electricity, transport, waste, agriculture and soft drinks. Your use spread and grew from a few dozen early adopters, the almost 200 users during the first year. Today, thousands of American institutions use the tool to monitor their institutional emissions of greenhouse gases, including more than 90% of US colleges and universities that publish their emissions.

In 2014, the Sustainability Institute of UNH took over ownership of the tool and developed the **Carbon Management and Analysis Platform—CarbonMAP**, a web platform that includes the **CCC Inventory** module, through which it is possible to calculate the greenhouse gas emissions of University campus. The web platform to replace the Excel version of the tool in the near future. In addition, there is a version of CCC to Canadian institutions, in line with the American version.

[5]"Second Nature" is a nonprofit public benefit corporation of "Commonwealth of Massachusetts".

[6]More detailed information on the signatories is available in: reporting.secondnature.org.

In this version, the emission factors were reviewed. The heat content, carbon content and potential of global warming have changed for consistency with the American version. Canada data is also updated regularly.

Methodologically, the CCC (either in your EXCEL version, either in the web version), is based on national inventories of the IPCC methodology, published in 2006. As already discussed, building inventories for towns also used originally on the IPCC 2006 and was later replaced by more specific methodologies, to culminate in the establishment of the specific methodology of the GPC. It is desirable that the same evolution for the methodological reference used currently in inventories to university towns.

## 7 GHG Inventories at Higher Education Institutions

Approaches based on scales of neighborhoods are considered as important as the sectoral initiatives, being the ideal arena to put into practice many sectoral initiatives (such as energy efficiency actions). As an example, many pilot actions were developed in China, both in cities such as in districts: more than 160 pilot cities used the WRI GPC to access their GHG emissions, and some of them were able to develop some scale inventories of neighborhoods, like the test methodology. In addition, the neighborhood scale-based approaches are relevant not only for the implementation of innovative actions on a smaller scale, but also for the renovation of the city and as an arena easier to get the engagement of the community.

Within the framework of the HEIs, many universities, such as the National University of Singapore NUS and the Tongji University, develop actions on their campus, aligned as sectoral initiatives within municipal programs to combat climate change. The campus, in these cases, contributes to the city serving as a laboratory for new environmental solutions.

## 8 Recommendations

Based on what could be observed through the analysis of available inventories of American and European institutions, two references are key in the study of the theme: the **Campus Carbon Calculator (CCC)** and, to a lesser use, the **Greenhouse Gas Protocol for Communities (GPC)**. Although various institutions to this day have used both tools, both are incomplete for direct application in university towns, especially:

Due to the scope approach, once the scale of neighborhoods makes it essential to include the scope 3 in the emissions inventory (indirect emissions);
The scale of neighborhoods makes the adoption of specific emission factors for the area studied more complex;

It is imperative to obtain data from the specific activity of the HEI campus, which are specific and not typical of other neighborhoods.

Using this references, it was possible to come up with a series of recommendations, to be observed when developing GHG inventories for HEIs. These recommendations should be observed when one wants to measure the GHG emissions of a HEI campus, situated in a geographically defined area and with clear administrative boundaries.

## 9 Inventory Limits

As initial recommendation, the campus managers must define with great clarity the inventory boundaries criteria. There are basically four boundaries to be defined: geography, time, gases and emission sources.

## 10 Geographical Area

In principle, any geographical limit can be used for inventory. However, if the purpose of the establishment of the inventory is to perform an effective emissions management, with definition of mitigation strategies and actions, it is important that the geographical range align with the scope of campus. The procedure of data collection activity is also facilitated when administrative hierarchies match, avoiding double command or overlapping responsibilities.

## 11 Time

An inventory can be developed considering different time metrics, such as fiscal, academic year or calendar year. It is important to define a standard period for all inventories of the same kind, whether of cities or college campus, follow the same timeline. This is especially important to institutions of higher education, because there are common periods where the use of the campus is minor, such as holidays. Although the GPC reference do mention the possibility of using any time reference, it is recommended the use of calendar year for the reporting of emissions of cities. As the inventory accounts for all emissions that occurred in a period of 12 months, any seasonality is incorporated in the period, either fiscal or calendar year school year. The recommendation found in existing methodologies is just that it is adopted the same criterion for the inventories of cities or campus are comparable. Thus, it is recommended to use the calendar year as the basis of the inventory.

## 12 Gases

The Kyoto Protocol regulates the main greenhouse gases and families of gases, and determines specific targets for the reduction of GHG emissions. Some of the inventories of GHG emissions for cities, and some of that could be analyzed for campus academics focus on the $CO_2$, leaving other GEE out of inventory. However, the non-$CO_2$ GHGS contribute with up to 40% for global warming, and the inventories should not omit them. It is recommended that the GHG inventory of IES be aligned to the GPC, which includes all gases of the Kyoto Protocol, using the Global warming potential factors of IPCC to calculate $CO_2$ equivalents. Consideration of all the GEE does not change due to the nature of the activities covered by the inventory (University campus), nor by the desired range (neighborhoods).

## 13 Scope

In the currently existing GHG inventories for cities, it applies three levels of detail, or scopes. The inclusion of a specific emission source in each scope may vary according to each reference used, leading to problems of comparability. To avoid this, the use of the same reference (in the case of cities, the GPC) is essential. The activities resulting from the operation of the campus generate GHG emissions within the physical boundaries of the campus, but also generate indirect emissions outside the physical limit, the geographic campus. To prepare the calculation of emissions resulting from the operation of the Campus, it is necessary to initially establish a classification in emission scopes, based on limits set for the inventory. As already said, to standardize the reporting of emissions and enable comparability between inventories in cities, the GPC establishes a frame of reference of three scopes. Making the analogy of this methodology to the case of the University campus, we have that:

Scope 1: activities in emission sources that occur within the campus are defined as Scope 1. Scope 1 emissions also are sometimes referred to as "territorial", because necessarily occur within the bounds of geography of the campus.
Scope 2: emissions arising from the use, on the edge of campus, network utilities, such as electricity systems, heating systems, chilled water or steam, supplied by a network that may or may not cross the boundaries of geography of the campus.
Scope 3: all other emissions that occur outside the boundaries of the campus, but they are caused by activities that occur on campus, for example, purchasing paper, waste incineration and air travel.

Almost all calculations of inventory that could be found for universities focus solely on emissions from Scope 1 (for Stationary Energy and Transport) and sometimes include emissions from Scope 2 (for waste treatment that occurs outside the perimeter of the campus). Under the aspect of the use of scopes, it is understood that the inventories for cities that use the methodology GPC, and intended for campus, may share similar principles in the definition of limits, emission sources and scopes. A key point of difference between a GHG accounting on the scale of the City and on the scale of neighborhood (case of University campus) is the understanding of the breadth of scope. While for cities an activity can be classified as "inside the perimeter" neighborhood-scale, this same activity can be classified as "outside the perimeter", passing therefore to integrate the Scope 2 or Scope 3. This means that emissions from scope 2 and 3 in inventories of University Campus may account for a larger percentage than in cities.

## 14 Emission Sources

Emissions sources can be seen as a group of activities that, by the nature of their operation, emit GHGS and should, therefore, be accounted for. The main inventory methodologies currently consider the same emission sources, diverging only in relation to sectors and subsectors, and the way in which the sources of emission are considered in each scope. Illustrative of this is the comparison between the emission sources considered in the GPC and those used by the IPCC (2006). Based on the discussions in the workshops and inventories available to North American universities,[7] one can relate as emission sources usually included in GHG inventories for University campuses:

## 15 Heating and Cooling Systems

Central facilities or physical plants on college campuses are essential to provide heating and cooling at the campus. In North America, the heat distribution systems, steam, hot water or cold across a campus are highly variable and require extensive maintenance on the part of the staff of the University. In Brazil, heating systems are not usual. Combined heat and power (CHP), also known as cogeneration, combining electrical and mechanical equipment in an operating system that is designed to convert the energy of fuel into electricity and useful thermal energy. Several universities use CHP systems, ranging in size from 150 kW to 500 MW, depending on the technology employed. Carbon emissions are typically reduced by 30% when CHP overrides the power generation central station.

[7]At the present stage of the research, these were the main emission sources that could be identified specifically for university campuses, based on literature and workshops.

## 16 Sources of Direct Transport

The opportunity for the use of alternative energy sources is well suited to supply the fleet vehicles on campus. The campuses offer a niche market for alternative fuel vehicles, because fleets are generally supplied in a single place, and the range of travel is limited mainly to the outskirts of campus. Promote actions to improve efficiency in the use of fuel in existing vehicles also contributes to reduce emissions on campus.

## 17 Refrigerants

There are many types of refrigerants that act as GEE. The degree to which these substances destroy the ozone layer and contribute to global warming is variable and specific to each climate and location. However, it does not matter whether an institution decide to use HFCs instead of CFC to cool your structure, the actual environmental impact is the amount of these refrigerants and not necessarily its quality.

## 18 Fertilizers

Management of fertilizer used on a large scale for lawns, athletic fields and farming fields inside the campus can contribute to reduce the amount submerged under the ground of nitrous oxide, a powerful greenhouse gas.

## 19 Purchased Electricity

Although the universities are not directly responsible for emissions from purchased electricity, one can argue that is a University consumption, therefore being considered in scope 2 indirect emissions category in the existing inventories. In fact, the factor that can significantly influence the global GHG emissions of the University is the source of energy used to generate the purchased electricity. The two main components of electricity at the University are how it is created and how it is transmitted, and both must be assessed and included in the inventory.

## 20 Transport

Students who do not live in homes owned by the institution on the campus, and therefore, make daily trips to the campus, are a significant majority of the student population at USP. The transport sector is responsible for a large percentage of carbon dioxide emissions, with motor vehicles accounting for most of the emissions. The data set used to calculate these emissions should reflect daily emissions, produced by users of the University (students, faculty, and staff) on their daily driving to and from campus. To estimate the emissions from commuting to a University, it may be necessary, for example, to collect data in terms of number of users, the number of trips per week, the number of weeks applicable per year, the percentage of users who use bicycle, bus and ride to the campus and the average distance travelled for each commuting method.

## 21 Air Travel

In the environment of universities, unlike common neighborhoods, it is usual that faculty, staff and students, carry out a lot of air travel, for example on account of congresses, serving the University administrative, or teachers coming from outside the country to develop activities on campus. These trips indirectly contribute to the concentration of GHG emitted by a University. However, there are many challenges in obtaining this type of information, being that universities do not normally have purchasing systems, and centralized travel miles in flight records are rare (most of the data are kept for billing purposes and include only monetary values and not quantities of air miles traveled). However, this is an important source of GHG emissions and a frequent activity of a campus, so should not be omitted from the inventory.

## 22 Solid Wastes

If a product is not recycled, it can go to landfill, be composted or incinerated, for example. A waste management strategy can help reduce emissions by decreasing the amount of methane in landfills and emissions from incinerators. For that, a comprehensive waste management plan should be devised in conjunction with the emissions management plan.

## 23 Wastewater

Water tends to be a matter disputed nowadays, mainly because universities can be located in cities where water scarcity is a problem. Wastewater treatment is also is an expensive option and requiring treatment in large plants and employment of complex technology. Once universities have a large water consumption, this issue should also be addressed in the GHG inventory.

## 24 Final Considerations

Universities have the potential to demonstrate sustainable principles in their operations on campus and can be a model of sustainable development for society. The lessons learned when developing environmental sustainability actions in college campus can provide a roadmap for city managers follow when developing specific local actions in their cities, especially when these occur at the scale of neighborhoods. A first crucial step in this process is the execution of an inventory of greenhouse gas emissions.

However, all currently existing guidelines refer to the inventory in general terms, without offering any specific and detailed methodology on how to calculate the emissions generated by the operation of the Campus, in range of neighborhoods. Unfortunately, different calculators and tools for emission inventory are currently in use by universities around the world, many of these developed solely to reflect the particular conditions of the sponsoring institution, which complicates studies for consistency and comparability. Typically, these calculators are simply tools based on a methodology originally developed for the countries, reflecting the specific characteristics of an operation on campus.

The development of methodologies for GHG inventories, specific to the case of University campuses, allows mitigation actions be taken more efficiently, increasing the visibility of actions and allowing the inventory to be used more effectively as a management tool of the Campus' Sustainability.

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# Part II
# Case Studies and Examples of Campus Greening Initiatives

# Universities as Sustainable Actors: A Case Study of the Environmental Plan of the University of São Paulo (USP) with Emphasis in the Actions of the Sustainable Building Working Group (WG)

**Mariana Auad Proença and Roberta Consentino Kronka Mülfarth**

**Abstract** The Universities have been acting in an impactful way in the implementation of sustainable actions within university campuses and as living labs for the universities, communities and cities. This paper presents a case study based on the Environmental Plan of the University of São Paulo (USP) with emphasis in the actions of the Sustainable Building Working Group (WG), as well as an overview of Sustainability Plans developed by universities in big centers worldwide. It is important to highlight how the universities are introducing sustainable issues inside campuses through the development of environmental plans by contemplating social, economic and environmental fields of sustainability. Some projects implementations and results demonstrate how environmental plans are important to promote better understanding on the importance of the environmental preservation and the construction and refurbishment of buildings through sustainable actions based on the environmental comfort of their users. Finally, through the case study of University of São Paulo (USP), this paper aims to serve as a base guide to anyone interested to know how environmental plans are being structured and implemented in universities.

**Keywords** Sustainability · Eco campus · Universities · Environmental plan

M. A. Proença (✉)
Architecture and Urbanism Faculty, University of São Paulo,
Rua do Lago, São Paulo 03178-200, São Paulo, Brazil
e-mail: marianaproenca.arq@gmail.com

R. C. K. Mülfarth
Department of Technology in Architecture, Architecture and Urbanism Faculty,
University of São Paulo, Praça Do Relógio 109/Bloco K Sala 309,
São Paulo 005508-050, Brazil
e-mail: rkronka@usp.br



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## 1 Introduction: Sustainability or Environmental Plan Inside the Eco Campus Context

Nowadays, the sustainable development through the preservation of the environment and the conservation of the natural resources have become even stronger since that the natural resources have become scarce and the quality of life has become delicate. According to Kronka Mülfarth (2006) "over the past decade, the issues of sustainability has come to the fore and its principles are being incorporated by all actors in society reinforcing the need to promote deep structural changes in search of greater social equality, enhancement of cultural aspects, greater economic efficiency and less environmental impact on the equitable distribution of raw materials, ensuring the competitiveness of man and cities". Some ideas and actions to achieve a more sustainable environment started to be implemented in 1972 at the first version of The United Conference on Environment and Development (UNCED) held at Stockholm, Sweden. But, it was at its second meeting held in June 1992 in the city of Rio de Janeiro that the sustainable development was recognized as an important concept to be put into practice (Tauchen and Brandli 2006). Moreover, the universities around the world started to appear playing an important role, while promoting and implementing sustainable practices and also through the conception of the environmental policies.

Currently, sustainable issues are being considered in many areas of interest. One of them is recognized as Eco Campus, which has been addressed in the university context. The Eco Campus can be understood by its two strands. The first one is applicable in a practical form through the rebuild of the interactions between societies, encompassing economy, environmental, research, education and social aspects, by seeking the respect of life and preserving the resources of our planet. The second strand highlights the important role that universities are taking while addressing the sustainable issues by searching alternatives of rethinking and implementing lines of action related to these issues (König 2015).

Universities in big centers of the world are developing Environmental Plans as a practical form of structuring and application of the Eco Campus concepts. The main objective is to reinforce the role of universities as experimental living labs, as well as a vehicle of communication among other universities, the community and local governments, seeking to form better citizens compromised with the environment conservation.

The structures of the Environmental Plans are based on the needs of each university related to the implementation of sustainable actions driven by guidelines, objectives, indicators and targets. The Plans essentially propose a "zero carbon" campus model, but also focus on the buildings and their environmental impacts, the campus urban planning and the interaction of sustainability at levels of teaching, researching and culture. The implementation of these actions has been made by students, teachers and employees and in some cases involving the participation of the community and local governments.

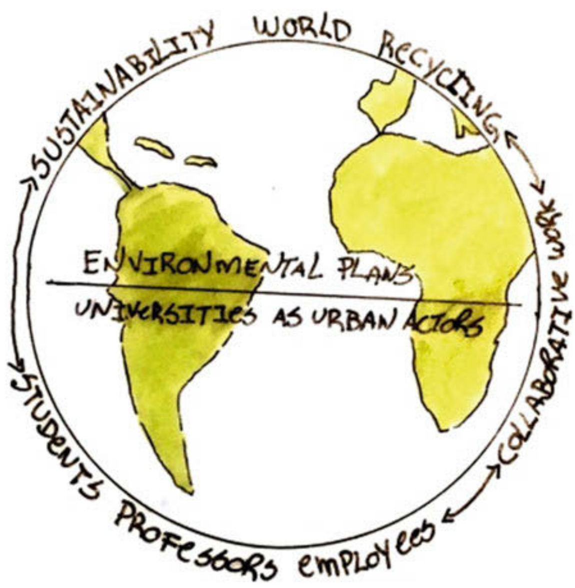


**Fig. 1** Collaborative work towards a more sustainable environment. Material developed by the authors, 2017

It's important to highlight the main role that Universities are taking as sustainable actors either through the introduction of the environmental issues into the high education or through the Plans, where actions are being implemented. Moreover, universities actions serve as an example for other universities, communities and the cities. The Fig. 1 illustrates that these Plans are developed through a collaborative work among students, professors, employees in some cases with the community and local governments towards a more sustainable environment.

Based on that, this paper will present a case study of the Environmental Plan of the University of São Paulo (USP) with emphasis in the actions of the Sustainable Building Working Group (WG), as well as an overview of Sustainability Plans developed by universities in big centers worldwide with the purpose of demonstrating as an example the development and design of an Environmental Plan.

## 2 An Overview of Sustainability Plans

As mentioned before universities around the world started to appear playing an important role, which consist according to Romero and Kronka Mülfarth (2017) "in their primary function of knowledge construction, has a duty to strengthen their roles as an intermediary between local government and society, not only in promoting discussion, but also as an important agent towards these changes". To put this role in practice universities in big centers of the world, organizations or governments are developing sustainability or environmental plans that seeking for goals that will promote environmental, community, social, and financial sustainability.

Moreover, as reported by Johnson et al. (2004) "Sustainability Plans can help identify what resources are necessary to sustain projects, encourage the development of partnerships, and support collaboration. Whatever the understanding of sustainability (different organizations' or governments' interpretation of sustainability will vary according to their priorities), sustainability plans are an important tool not only for diagnosis, but also to identify actions in pursuit of more sustainable benchmarks. Moreover, for universities, sustainability plans are important to not only organize actions, but also to establish goals".

Many universities in big centers worldwide are developing their sustainability plans based on concepts to achieve a healthier and resilient future through criterions that will "guide projects and plans in teaching and research to achieve goals in sustainability" (Romero and Kronka Mülfarth 2017).

Following are some examples of sustainability plans for Harvard University, City University of London and Polytechnic of Milano.

## 3 Harvard University

> The Harvard Sustainability Plan is the University's roadmap for building and operating a healthier, more sustainable campus community. The Plan aligns Harvard's decentralized campus around a holistic vision and sets clear University-wide goals and priorities based on the innovations and solutions that have been developed at our individual Schools and departments (Harvard 2015).

The Sustainability Plan of Harvard has been developed by a collaborative work among faculty, students, facilities, and operations experts along with the Harvard office for sustainability management. The Plan was defined concerning five topics, listed below, which are then analyzed according to three categories.

TOPICS

*Emissions and energy*: greenhouse gas emissions; energy reduction; and renewable energy.

*Nature and ecosystems*: landscape operations; campus design; conservation and education.

*Campus operations*: new constructions; building operations; transportation; climate preparedness and campus resilience; and procurement.

*Culture and Learning*: research and teaching; governance; external partnerships; communications; and community action.

CATEGORIES

*Goal*: University-wide resource reduction goals with a specific target within a set timeframe (Harvard 2015).

*Standard*: Operational standards to facilitate alignment across the University, ensuring that a consistent approach is being implemented. Standards are designed to allow flexibility for how they are implemented by individual Schools and administrative departments (Harvard 2015).

*Commitment*: A statement of commitment or recommendation for future research in areas where there was not enough information to set a specific numeric goal standard (Harvard 2015).

## 4 City University of London

> As a leading global university, committed to academic excellence, we have an important role to play in promoting sustainability, both locally and globally. We aim to fulfil this role by reducing our carbon emissions, ensuring that our facilities are built to the highest sustainability standards and reinforcing our commitment to behavior change and Education for Sustainable Development (City University London 2015).

Based on the principles mentioned above, an Environmental Management System was established through the Environmental Sustainability Policy that is accredited to ISO14001. The performance evaluation is based on nine key environmental aspects, listed below.

*Energy*
*Water consumption*
*Waste*
*Construction and maintenance*
*Transport and travel*
*Purchasing and procurement*
*Sustainable food*
*Biodiversity*
*Stakeholder engagement*

## 5 Polytechnic of Milano

> Città Studi Campus Sostenible is a project promoted by the Politecnico di Milano (POLIMI) and Università degli Studi Milano (UNIMI). The project aims to transforming the whole campus neighborhood into an urban area which can serve as an urban model in Milano with respect to life quality and environmental sustainability. The project is open to the participation and support of researchers, students and all campus citizens (POLIMI ISCN-GULF Sustainable Campus Charter Report 2014).

The main idea of the project is to create a living lab campus by promoting sustainability based on the following goals: *"test innovations developed by scientific research; to promote life style transformation and more livable spaces; to become a positive example for the entire city; to cope with the international network of sustainable campuses"*. And furthermore, a website was developed to organize technical meetings (thematic tables), encompassing students, academics and technical staffs for sharing proposals, ideas, and case studies through a collaborative work.

The project initially was structured focusing in four main themes: *people; energy; environmental; and mobility.* After that, in 2013 two new themes were created in addition: *city; food and health.* It's important to highlight that the sustainability themes were guided by the "ISCN-Charter principles and helped in organizing the management of the whole process and structuring the ISCN-report" (POLIMI ISCN-GULF Sustainable Campus Charter Report 2014).

The five themes eventually structured by three principles, are listed below:

THEMES
*People and City: users, participation and identity/transferring research from labs into urban life*
*Energy: energy efficiency and renewable energies*
*Environmental: environmental quality*
*Mobility: transport terms accessibility and sustainable mobility*
*Food & health: sustainable lifestyle and sociocultural topics*

PRINCIPLES
*Building and their sustainability impacts*
*Campus-wide planning and target settings*
*Interaction of research teaching, facilities and outreach*

## 6 The Case Study: The Environmental Plan of the University of São Paulo (USP)

The University of São Paulo (USP) was founded in 1934 and is consisted of 42 units distributed in campuses of eight cities of the state of São Paulo. Its quality as university is expressed as follows:

> The talent and dedication of the faculty, students and staff have been recognized by different world rankings, created to measure the quality of universities from a variety of criteria, particularly those related to scientific productivity (USP 2017).

For over 20 years the University of São Paulo (USP) has been introducing and developing sustainable actions. In 2009, a Working Group (WG) was created to implement an environmental management system based on the National Solid Waste Policy (NSWP). And, in 2012 the Superintendence of Environmental Management was founded with the main objective to promote the importance of environmental sustainability followed by the basics principles:

- To develop actions for the conservation of the natural resources from the university;
- To promote health and safety of the environment inside campuses;
- To promote the rational use of the resources and to teach based on the sustainability;
- To transform the University in a sustainable model for society.


**Fig. 2** Sustainable timeline activities and actions. Material developed by the Superintendence of Environmental Management (2016)

After the creation of the Superintendence of Environmental Management a great number of sustainable activities and actions were published. The Fig. 2 illustrates a time line of all these sustainable activities and actions.

In 2014 a new management was created inside the Superintendence of Environmental Management by taking as goals:

- To reduce the carbon emissions from university campuses;
- To emphasize the role of the university as a living labs for the cities;
- To improve the sustainable actions into three spheres: actions inside USP; from USP to other Brazilian universities and from USP to the cities.

Based on that, in the same year of 2014 the Environmental Plan of the University of São Paulo (USP) was formulated and the Plan was structured placed on four phases:

- ***First phase: definition of the Sustainable Policies:*** it was concluded in November 2015 and developed through eleven thematic policies (administration, greenhouse gas emissions, energy, water, mobility, fauna, green areas, environmental education, land use, waste and sustainable buildings). This phase is complemented by the policy of management. For each one of the thematic policies were established Workings Groups (WG) structured by the faculty and technical people that had worked to develop this document based on: Subject and Implementation; General Provisions; Definitions; Principles; Goals; Guidelines; Management Tools; Administration Tools and Financial; Responsibilities and Prohibitions.
- ***Second phase: definition of the Environmental Management Plan:*** The second phase was structured by the Environmental Management Plan of each policy established by actions, goals and guidelines and it was concluded in

2016. The thematic plans were developed by a specific working group (WG) formed by students, professors and employees.

- ***Third phase: definition of the Environmental Master Plans with the 11 Thematic Chapters:*** Based on the second phase each campus will develop a master plan taking into account all the local ecological and urban diversity. This phase is planned to be finished in 2018.
- ***Fourth phase: sustainable programs of each school or department:*** All the actions and activities that will be defined by each school or department will be assisted by the Environmental Plan of USP and their phases.

The Fig. 3 illustrates all the phases of Environmental Plan of USP.

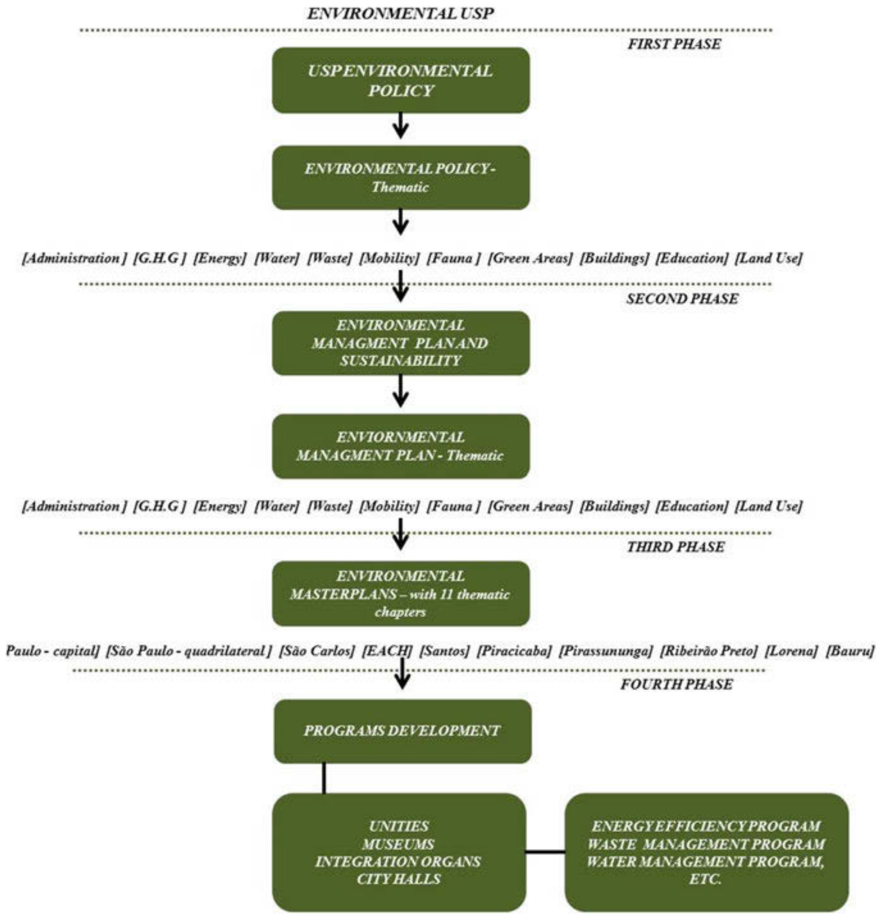


**Fig. 3** Diagram of the fourth phases of the environmental plan of the University of São Paulo (USP). Material developed by the authors, 2017

It's important to feature that concurrently of the Environmental Management Plan another two projects were developed.

***The GAIA (temporary name) platform***: a web database that will share information about the consumption of water, waste and energy, (also all the data from environmental plan) from each one of the unities of the campuses.

***The PAP (people learning participating—PLP)***: a program that promotes the sustainable education inside the campuses.

After the implementation of the Environmental Plan of USP some projects and actions have been implemented inside the campuses, as the Pilot Project called BOSSA, which is nowadays developing a research of post-occupancy of office buildings and their performances inside the campus of São Paulo. Furthermore, the Environmental Plan of USP was awarded excellence in 2016 by the International Sustainable Campus Network (ISCN),[1] in the category Planning and Management Systems for Campus.

It's important to highlight that all the development and implementation of an Environmental Plan is based on a collaborative work and has the main purpose to serve not only as a reference for other universities, but also to the city. If they can apply all the projects and actions inside the university it will be possible to be applicable in an urban vision: the cities.

In conclusion of this section on the Environmental Plan of the University of São Paulo, it had the intention to present the composition of this plan and a preview of what each of its phase represents. Moreover, this section aimed also to demonstrate that a university can be an example of a living lab to other universities, community and to the city in searching for a more sustainable environmental.

In the sequence it will be described the structure of the Sustainable Buildings Working Group (WG).

## 7 The Environmental Management Plan of Sustainable Buildings: The Performance of Sustainable Buildings Working Group (WG)

As described before, the Environmental Plan of the University of São Paulo (USP) has 11 thematic policies, and for each of them the Environmental Management Plan (Thematic) was developed by a specific working group (WG). For this chapter the Sustainable Buildings WG was selected to emphasize the work that was developed up to the conclusion the Environmental Management Plan of

[1]International Sustainable Campus Network (ISCN): "The International Sustainable Campus Network (ISCN) provides a global forum to support leading colleges, universities, and corporate campuses in the exchange of information, ideas, and best practices for achieving sustainable campus operations and integrating sustainability in research and teaching". (Extracted from: https://www.international-sustainable-campus-network.org/ Last access: 2017).

Sustainable Buildings. In addition, the sustainable buildings WG is serving as an example of an applicable methodology for the other WGs.

The sustainable buildings WG has the main purpose to promote the sustainability either into the new buildings of the campus, or prioritizing the refurbishment, retrofit and renovation of the existing buildings, at the same time preserving the natural resources such as the water, energy, etc. For achieving this main purpose some concepts were established, such as: *the development of an USP constructive environmental performance certification; the establishment of benchmarks for the evaluation of thermal efficiency, natural lighting, acoustics and energy and also the durability of materials used in construction; the use of operational instruments with national and international technical standards (USP Environment Management Plan, Sustainable Buildings Chapter,* 2016*).*

The development of the Sustainable Buildings Management Plan was made through a collaborative work formed by selective group of students, professors, employees and within the Superintendence of Physical Space, known as SEF.

To a better understanding of how the Plan would be structured, at first an analysis of the Thematic Policy of Sustainable Buildings was made, being composed of: *Subject and Implementation; General Provisions; Definitions; Principles; Goals; Guidelines; Management Tools; Administration Tools and Financial; Responsibilities and Prohibitions (USP Thematic Policy of Sustainable Buildings* 2015*).* Subsequently a survey of sustainable plans was made, considering specific universities around the world that are developing and implementing sustainable actions in their campuses and also for complementing some national and international laws and standards which were used as a reference for the definition of the actions, indicators and targets.

The Building chapter of the Environmental Management Plan was basically structured through four general objectives:

- ***First general objective***: *Building requalification; identify the necessity of buildings requalification for a better environmental performance.*
- ***Second general objective***: *Design; develop projects for new permanent and temporary buildings of high performance and environmental quality.*
- ***Third general objective***: *Construction; accomplishment of constructive processes of low environmental impact.*
- ***Fourth general objective***: *Post-occupancy of campuses buildings*; *Implementation of routine maintenance, use and operation of buildings for high performance and environmental quality.*

Some specific objectives complemented by actions, indicators, goals and members in charge were developed for the four general objectives. Regarding actions and goals, deadlines were defined that were specified as short, medium and long term, while for the indicators two types related to the quantitative and qualitative aspects were established. Furthermore, a method for ranking the actions was developed considering the prioritization of their implementation and their specific objectives. To conclude, for the members in charge, was selected a group formed by: *The City Hall of the campus, the Superintendence of Physical Space—SEF, the Superintendence of Environmental Management—SGA, the Center for Cultural Heritage—CPC, the Directorates of Units and Museums, the Maintenance Teams and Museums, as well as the occupants of the buildings.*

Aiming to facilitate the reading of the structure described above and for helping the ones of the sustainable buildings WG in charge to implement these actions, a table was composed gathering all the related content. Such a table was also conceived to serve as a base guide for putting into practice all these concepts established. The Fig. 4 illustrates a diagram of the table structure.

It is important to emphasize that this thematic environmental management plan will also allow contemplating research activities through the development of master and doctoral projects that will help in the implementation of the objectives, actions and goals stipulated for this Plan.

An additional aspect to be pointed out is about the importance of having this plan as a reference guide for the refurbishment and construction of new more sustainable buildings through the achievement of satisfactory environmental performance. Actually, the guide is supposed to be a reference not only to the university, but also for other universities and inside an urban view, such as the city.

Regarding the Environmental Management Plan, two important aspects must be emphasized:

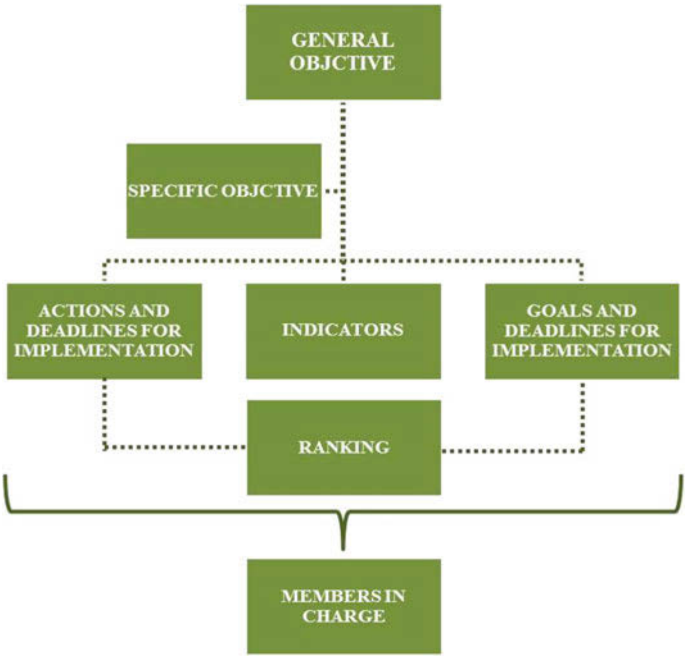


**Fig. 4** Diagram of the structure developed for the table. Material developed by the authors, 2017

- The focus on the buildings maintenance: this aspect will be developed by prioritizing the so called passives ways of analyses, that is, through considering the study of acoustics, natural ventilation, natural lighting and processing of data measured in the spaces. It is important to point out that these analyses can serve as an excellent form of evaluation and comparison of the buildings conduct, seeking for improvement of its environmental performance.
- The environmental education of the buildings users: this aspect involves a better exploitation of the spaces and the resources of natural ventilation and lighting, as well the use of energy and water. To achieve a satisfactory environment performance of the buildings, it is also important to evaluate the perception of the users, by taking into account the consistent and conscious occupation of the spaces.

In conclusion, this section has described the work developed by one of the eleven WGs that are part of an Environmental Plan, having the purpose to implement sustainable actions inside the university.

## 8 Implementations and Results: The Development of Pilot Projects as a Strategy of the Environmental Policies

As mentioned before, the Environment Plan of USP at its the second phase has established the Environmental Management Plan of each area of activity, which is composed by: *management, greenhouse gas emissions, energy, water, mobility, fauna, green areas, environmental education, land use, policy management and sustainable buildings.* All of these thematic plans were developed by a specific working group formed by students, professors and employees, having been structured a methodology of application to stipulate their actions, goals and guidelines. It is important to highlight that the WGs have taken the work developed by the Sustainable Buildings Working Group as the main reference.

Alongside to the thematic environmental management plans, some pilot projects have been developed inside of various campuses of USP as a strategy of the environmental policies. Such projects are as follows:

- Law Faculty of USP: Living Coverage, which consists in the revitalization of the rooftop of the Law Faculty building by enabling different types of use.

This is the first building in the city to use native plants for the green rooftop and its being an example for other buildings.

- Campus of Pirassununga: Project Bike Path/"Let's Go by BiKe" it is a project still in operation. It has been established for promoting the bike use through sharing them and by seeking for a more sustainable displacement. The main goal in the future is to extend this idea to the community.

This project is for stimulating students to use bicycle and inspiring the community.

- Campus of Ribeirão Preto: Genetic Bank/Institutionalization of the Bank in vivo of Genetic Diversity of USP/RP through academic-scientific and university extension activities. This project aims at supporting a proposal for the management of the in vivo Genetic Diversity, academic-scientific and university extension bank, to evaluate the functional state of the USP-PR Forest through ecological diagnoses. Moreover, this project aims to encourage actions to be made connecting the internal and external community;
- Campus of São Paulo: this lies of the development of the Olympic Radius—CUASO and the CienTec Technology Park. The basic aim is to promote outdoor environmental education activities, with focus on of the scholastic public in the basic education level.

Nowadays several education activities are being managing through the CienTec Technology Park by promoting the use of outdoor spaces as a way to expand teaching and researching practice.

- Campus of São Paulo: the BOSSA—CUASO project was developed to evaluate the behavior of the users of the campus by taking into account the perceptions of the environmental comfort, such as the usual practice of natural ventilation and lighting and also the use of the air conditioning into the administrative spaces of the existing buildings. It is important to point out that this project is based on the Environmental Policy of USP of Sustainable Buildings that has as one of the main focuses the education of the users. The project also envisage to extend these actions through the students at the didactic spaces.

This project is helping users to understand how they can achieve a satisfactory quality of the work environment. Furthermore it allows for introducing studies of measurement to help in collecting data to achieve a better performance for the buildings.

- Superintendence of Environmental Management (SGA) Electronic Magazine—USP: it consists of the Environmental Public Policy Magazine of the SGA on environmental topics. The basic aim is to contribute for elaboration and implementation of the public environmental policy in Brazil;
- Campus of São Paulo: the CEPEUSP - Performance Project—CUASO is related to the installation of water saves mechanisms, seeking for the conscious consumption of water, therefore reducing and by the assistance the costs management of the project.

This project is important for improving the conscious use of water inside campus.

- Campus of São Paulo: Shared Bike—CUASO, it is being developed with the purpose to facilitate the access inside the campus through sharing the bikes, and also the integration between the Butantã subway Terminal and the surroundings.

This project aims to stimulate the use of bicycles inside campus through the installation of 10 bike stations making available about 100 bicycles.

Finally, it is important to emphasize once again how universities are acting as sustainable urban actors through the implementation of environmental plans and how these plans are becoming practice. It is believed that once these ideas and conceptions are applied inside university it is possible to foreseen its extension to the cities, therefore reinforcing the important role that universities can take for promoting the sustainable development.

## 9 Conclusion: Universities as Sustainable Actors

The universities have been acting in an impactful way either in the implementation of sustainable actions within university campuses or as living labs for other universities, communities around and cities. Related to these aspects, this article aimed to demonstrate that Environmental Plans are being developed with the purpose of dealing with the environmental issues and also by structuring their actions to be implemented.

As a study case, the Environmental Plan of the University of São Paulo (USP) was chosen to be described as an example of how universities in big centers of the world are developing their sustainable actions. It is important to emphasize that this Plan has been implemented since 2014 and has already had some results through pilot projects, by research and the dissemination of issues that can impact in a good way the implementation of their actions. Also, it was described the performance of the Sustainable Buildings Working Group (WG) at the development of the Environmental Management Plan of Sustainable Buildings by demonstrating the structure established for the thematic chapter through a collaborative work among students, professors, employees.

Finally, through the case study of University of São Paulo (USP), one concludes that the Environmental Plan of USP with focus at the Environmental Management Plan of Sustainable Buildings may serve as a base guide to anyone interested to know how environmental plans are being structured and implemented in universities. Also, it is important to emphasize that based on the concrete results presented in this article, it is wind up that the environmental plans are indeed an efficiency form to promote, develop and put into practice the sustainable actions that universities are dealing as a way to achieve a more sustainable environment.

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## Author Biographies

**Mariana Auad Proença (M.Sc. Student)** Master's degree student at School of Architecture and Urbanism of University of São Paulo (FAU-USP) and Bachelor's degree (2010) in Architecture and Urbanism at Mackenzie Presbyterian University (FAU-Mack). Member of Sustainable Building Working Group at Superintendence of Environmental Management of USP (SGA-USP), contributing to the development of sustainable policies of the University. Attended on WC2 University Network (World Cities World Class) Summer Symposium Berlin, representing USP at the Eco campus Group (2016). Currently attending the Latitudes Global Studio, a cooperation project between School of Architecture and Built Environment of University of Westminster and FAU-USP. Emphasis on architecture and urbanism fields, focusing on sustainability in the built environment, eco-campus, hospitals, landscaping and interior design.

**Prof. Roberta Consentino Kronka Mülfarth (Ph.D.)** is Associate Professor at School of Architecture and Urbanism of University of São Paulo (FAU-USP) since 2006. Ph.D. (2002) in Urban Environmental Structures at the same institution, a Master's Degree (1998) in Energy at the Postgraduate Interunit Program of University of São Paulo and a Bachelor's Degree in Architecture and Urbanism (1994) at FAU-USP. Technical Adviser at the Superintendence of Environmental Management of USP (SGA), and Coordinator of the development of Environmental Policies of USP and Sustainable Building Working Group at Superintendence of Environmental Management of USP (SGA-USP). Member of the WC2 University Network (World Cities World Class), representing USP at the Eco campus Group. Member of ISCN Advisory Committee (International Sustainable Campuses Network) since 2016. Experience in architecture and urbanism fields, focusing on Environmental Comfort and on researches related to environmental performance of built environment.

# Evaluation of Environmental Impacts from a Molecular Evolution Laboratory's Waste Management System—A Brazilian Case Study

**Beatriz Vieira Freire and Ana Paula Bortoleto**

**Abstract** This study proposes an integrated waste management system to a university laboratory aiming: (i) waste prevention as the precursor activity; (ii) to distinguish not hazardous chemicals waste and enable recycling, and; (iii) to recycle solvents. The main objective is to decrease negative environmental impacts caused by studies conducted in this type of laboratory. A life cycle assessment was conducted to infer these impacts. Material consumption data were collected on site while recent studies were used for environmental impacts. Two scenarios were evaluated: (1) the current situation, where ethyl alcohol is recycled, chemical waste is incinerated and non-hazardous waste is landfilled; (2) a future scenario, where waste prevention is implemented; ethyl alcohol, gloves, plastic pipette tips and tubes are recycled; chemical waste is incinerated, and; paper waste is composted. The second scenario decreased considerably the environmental impacts and suggested that there is a potential for plastic waste recycling, yet it is necessary an economic evaluation to determine its feasibility. The pursue of waste prevention through new initiatives (e.g. electrical hand dryers) may also represent another gain on environmental and economic impacts. This methodology proved to be effective in achieving its purpose and it can be used to improve waste management in similar situations. Yet, the importance of this study relies on the inclusion of waste prevention as a first step to improve the current waste management system and also by including the assessment of its environmental impacts as a way to effectively decrease them. It important to highlight that is a type of waste common in most of the universities.

**Keywords** Life cycle assessment · Recycling · Non-hazardous waste
Molecular biology research

B. V. Freire (✉)
Bioscience Institute, University of
São Paulo, Rua do Matão, nº 101, São Paulo 05508-090, Brazil
e-mail: beatriz.freire@ib.usp.br

A. P. Bortoleto
Department of Sanitation and Environment, University of Campinas,
Avenida Albert Einstein, nº 951, Campinas, São Paulo 13083-852, Brazil

 
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# 1 Introduction

Universities are important places to develop innovative solutions to society's problems not only by researching but also by designing new management policies. These innovative practices can be served as examples or pilot experiments to be lately implemented or replicated in urban areas. Thus, the universities' environmental management policy pose as an opportunity to contribute to sustainable development by encouraging environmental responsibility and by promoting individuals' behavior change towards the environmental conservation (Conto 2010; Cortese 1997). In this context, research laboratories are a case for environmental management. In these places, different types of experiments are conducted and each of them generated several waste categories usually each one in small quantities (Conto 2010; Schultz 2009). Consequently, waste management becomes complex due to the lack of standardization procedures.

An example of an environmental management in universities laboratories is the sustainability plan promoted by the University of California Santa Cruz. The plan includes initiatives of waste reduction and recycling of some specific laboratory's items: plastic pipette tips boxes, tubes and nitrile gloves. The gloves are recycled through a Kimberly-Clark program. In Brazil, a great initiative is the chemicals' recycling program promoted by the Chemical Institute at the University of Sao Paulo. These chemicals are recovered by distillation, decreasing the number of new chemicals purchase and waste incinerated (Di Vitta et al. 2006).

Another initiative is the Harvard University Green Lab program. They implemented sustainable practices and technologies by considering the unique conditions in each individual laboratory. For example, the program includes initiatives regarding energy saving and waste reduction; waste segregation is encouraged through local campaigns to improve recycling rates and local composting of organic matter, and an online list of laboratory's equipment and supply was made available to researchers and students to promote sharing and reusing. However, the program does not include the waste directly generated by the conducted experiments.

Laboratory waste is mainly constituted by gloves and other plastic disposable materials (i.e. pipette tips). In the same way, as in hospitals, they are usually discarded as hazardous waste since they may have entered in contact with hazardous chemicals or pathogens. However, as argued by Pereira (2011), single-use materials are directly responsible for various environmental impacts. One way to decrease these impacts is to implement waste segregation prior to disposal. It is estimated that 85% of medical waste is recyclable while only 15% are hazardous (Toledo and Demajorovic 2006). In the case of research laboratories in which these materials do not have contact with human fluids or pathogens, the percentage of recyclable waste is greater than in hospitals being limited by the hazardous reagents used in the experiments.

Thus, this study proposes an integrated waste management system (IWMS) to be implemented at the Molecular Evolution Laboratory at USP aiming: (i) waste prevention as the precursor activity; (ii) to distinguish on hazardous chemicals waste by improving segregation to enable recycling, and; (iii) to recycle solvents. The main objective is to decrease negative environmental impacts caused by the experiments developed in this type of laboratory. It is an important study because analysis the environmental impacts, and a way to decrease them, of a kind of waste very usual at universities.

To infer these environmental impacts a simplify Life Cycle Assessment (LCA) was conducted to compare the environmental impacts caused by the current waste management system (WMS) and the proposed one. LCA is a methodology normally used to infer the environmental impacts and aspects of different products by analyzing the interaction between the product and the environment in all steps of the product life cycle; since the raw material production, including the factory production, transportation, distribution, use and final disposal (ABNT 2001). When applied to WMS it analyzes the interaction of the waste with the environment, since it is discarded including possible energy or material recovery by recycling, until the final emission to the environment at a landfill or incineration, that is, all the steps related to the waste management (Konstadinos 2011).

## 2 Methodology

This study proposes an Integrated Solid Waste Management (ISWM) to a university research laboratory aiming at waste prevention as the precursor activity to decrease its negative environmental impacts. To achieve it, a waste prevention program was developed and LCA was conducted to determine these environmental impacts. Here, it was considered the following waste categories, due to quantity and frequency: (i) general: paper towel; (ii) hazardous chemicals: ethyl alcohol and chemical contaminated disposable waste (gloves, pipette tips and plastic tubes). The waste prevention program includes changes in the laboratory workflow to ensure the correct segregation of the disposable waste, to decrease the amount of them that are contaminated with hazardous chemicals; and also, initiatives to consume reduction: pipette tips reuse and the use of roll paper towels instead of multi-folded ones.

A boundary system was established considering the steps of waste generation to final disposal excluding the transportation steps (Fig. 1). The LCA was conducted for two scenarios: (1) the current waste management, where alcohol is recycled, chemical waste is incinerated and non-hazardous waste is landfilled (Fig. 2); and (2) the proposed ISWM, where waste prevention is implemented; ethyl alcohol, gloves, polypropylene pipette tips and tubes are recycled; chemical waste is incinerated, and; paper towel waste is composted (Fig. 3).

Foreground data related to material consumption was collected on site. For the hazardous waste, it was used the consumption data of 2015, and for the general waste, it was observed the consumption in one month and then estimated the total consumption in a year.

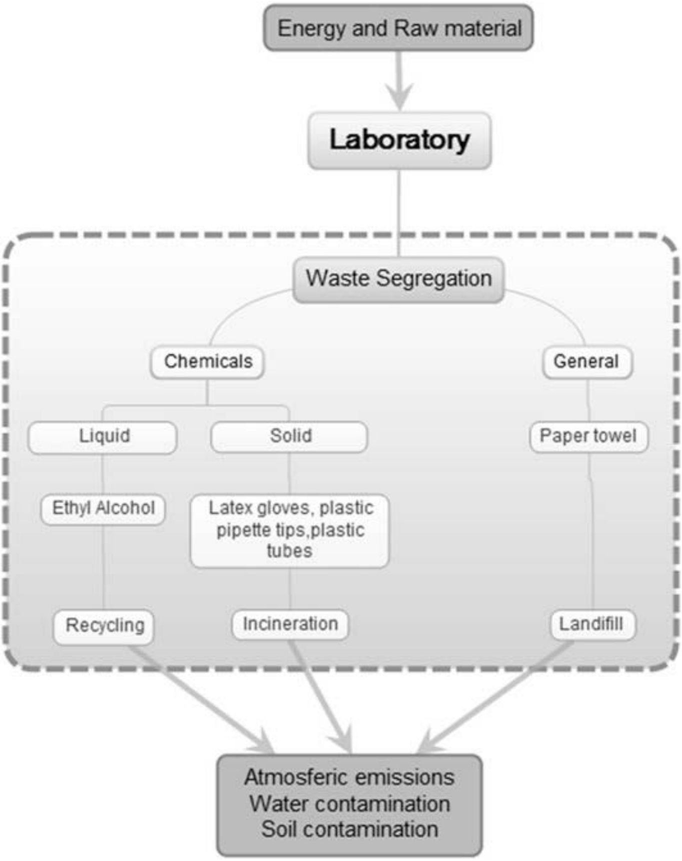



**Fig. 1** Boundary system

Yet, for the plastic waste, it was also estimated the quantity of them that did not have contact with hazardous chemicals, treated here as a plastic waste recycling potential. For this estimation, it was measured the quantity required of pipette tips and tubes for 15 laboratory procedures (Appendix), considering the analysis of one sample, and the presence of hazardous chemicals in these procedures, by consulting the material safety data sheets of each reagent. This plastic waste recycling potential applied to the total plastic wasted in 2015 gave us the information of the recycling potential of a year of research at this laboratory.

These 15 procedures are those widely used by most researchers in this laboratory for the achievement of genomic sequences, so are the ones that contribute most to the waste generation. Nevertheless, it must be considered that as the context analyzed is a research laboratory, new procedures are always being tested and implemented so the data can be different considering other years.

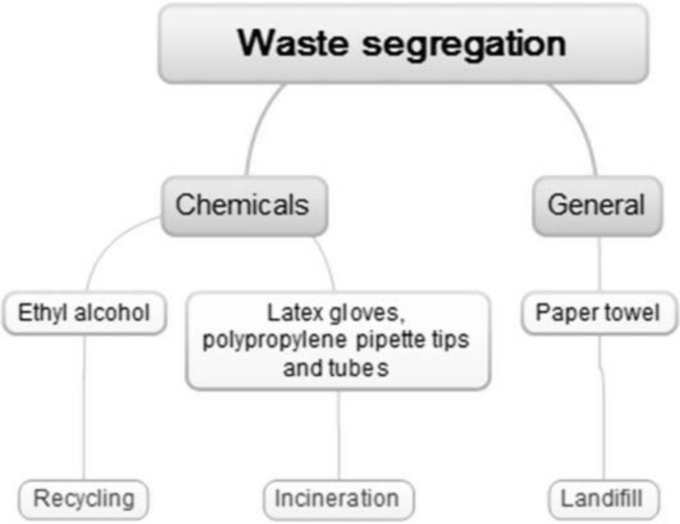



**Fig. 2** Scenario 1 waste management

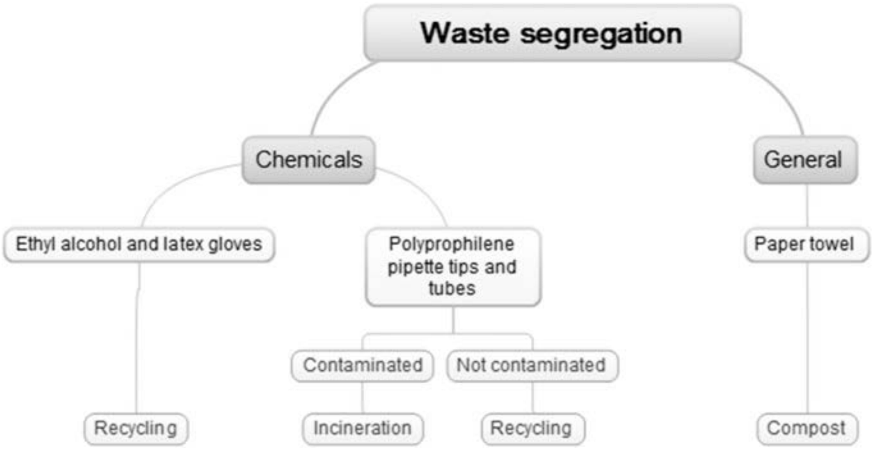



**Fig. 3** Scenario 2 waste management

Environmental impacts data, for each material production and disposition, was collected in recent LCA studies. It was analyzed the ones that are widely used in such studies (e.g. Bortoleto and Hanaki 2007), which are: human toxicity (1,4-$DB_{eq}$), climate change potential ($CO_{2eq}$), water acidification potential ($SO_{2eq}$) and eutrophication potential ($PO^{-3}_{4\,eq}$). The studies used to survey these environmental impacts, and respective LCA methodologies, are listed in Table 1. The environmental impacts reported on them are presented in Table 2.

**Table 1** Articles used to survey the environmental impacts and respective LCA methodologies

| Waste | Reference | Methodology |
|---|---|---|
| Paper towel | Madsen 2007 | CML version 2.02 |
| Polypropylene | PlasticsEurope 2014 | Eco-profile 2011 |
| | Harding et al. 2007 | CML 2 Baseline 2000 v2.03 |
| Latex | Jawjit et al. 2010, 2015 | CML 2002, Eco-indicator 99 |
| Ethyl alcohol | Ometto et al. 2009 | EDIP 2003 |

**Table 2** Environmental impacts reported on each article

| Waste | Functional unity | Climate change potential (kg $CO_{2eq}$) | Water acidification potential (kg $SO_{2eq}$) | Water eutrophication potential (kg $PO_{4eq}$) | Human toxicity (kg 1,4-$DB_{eq}$) |
|---|---|---|---|---|---|
| Papertowel | 1208 sheets | 486.77 | 4.5 | 3.2 | 839.01 |
| Polypropylene | 1 kg | 1.63 | 0.043 | 0.00118 | – |
| | | 3.53 | 0.0488 | 0.00584 | 1.87 |
| Latex | 1 ton | 169 | 1.622 | 0.208 | 38 |
| | | 6374 | – | – | – |
| Ethyl alcohol | 1 l | 0.296 | 0.0163 | – | – |

Paper towel was the only waste category that it was possible to find a complete LCA study, *cradle to grave* (Madsen 2007). From this study, it was used the data for the category of "washroom towel", for considering the most likely product used in this laboratory, and therefore the analysis includes the data for landfilling (79%) and incineration (21%) without energy recovery, USA reality. Regarding plastic waste, it was used two articles, *cradle to gate* LCA for polypropylene production (Harding et al. 2007; PlasticsEurope 2014) because the most recent one did not include the human toxicity potential impact. Concerning gloves waste only 5% of the gloves used in 2015 was nitrile ones, hence this material was not considerate here. The article chosen for latex gloves is a *gate to gate* LCA about the concentrated latex factories in Thailand (Jawjit et al. 2015), and another article (Jawjit et al. 2010), that analyzed the rubber tree plantation step. As this one is not an LCA study it was considered aside the LCA to complement the discussion. Finally, for the ethyl alcohol waste, it was not possible to find data about all environmental impacts analyzed. Most of the studies are about fuel alcohol and only analyze the climate change potential. It was chosen the data of a *cradle to grave* of fuel alcohol study (Ometto et al. 2009) produced in São Paulo state, Brazil, and the steps of distribution and use, not concerning chemical alcohol, were removed from the analysis.

Despite the missing data, the ethyl alcohol waste analysis was also done by using a database from Ecosolvent 1.0.1 software. Developed by the Swiss Federal Institute of Technology the software aim was to facilitate the decision between different solvents treatments options and gave us the information about the climate change potential of the solvent recovering process, though solvent distillation, and the alternative incineration with energy recovery (Capello et al. 2014).

## 3 Results

Table 3 presents the composition, quantification and destination on the scenarios 1 and 2 of the LCA, for the analyzed waste at a period of a year.

The Appendix presents the reagents used in all 15 laboratory procedures considered here and its classification regarding the chemical hazard of each. Of the 51 reagents, only 12 are classified as hazardous being that as two of these are volatile they do not leave hazardous waste on the plastic. Thereby barely 10 reagents would impair the plastic waste recycling resulting in a waste recycling potencial of 82% of plastic pipette tips and 48% of plastic tubes. Moreover, considering the prevention activity of pipette tips reuse only 5 laboratory procedures did not enable it which results in a reduction of 4 kg of a year waste.

## 4 LCA

Table 4 presents the environmental impacts in a period of one year considering the scenario 1, where alcohol is recycled; pipette tips, tubes and latex gloves are incinerated and paper towel is landfilled. As ethyl alcohol is recovered, its impacts are considerate with a negative value as they are interpreted as avoided impacts. Besides, that to it was considerate 95% of distillation efficiency and the sending of the remaining waste to incineration.

About the latex production is interesting to notice that the climate change potential regarding the rubber tree plantation (223.09 kg $CO_{2eq}$) is meaning higher than the other rubber production steps and environmental impacts. This occurs because the author is considering a deforestation step (Jawjit et al. 2010). Also, it is

**Table 3** Composition, quantification and destination of each waste on scenarios 1 and 2 of the LCA

| Waste | Composition | Waste/year | Scenario 1 | Scenario 2 |
|---|---|---|---|---|
| Paper towel | 100% virgin cellulose | 25,200 sheets | Landfill | Composting |
| Pipette tips | 99.9% Polypropylene | 21.62 kg | Incineration | Recycling/ Incineration |
| Tubes | | 6.16 kg | | |
| Procedure gloves | Natural latex | 35 kg | Incineration | Recycling |
| Ethyl alcohol | NA | 17 l | Recycling | Recycling |

**Table 4** Environmental impacts of scenario 1 of the LCA

| Scenario 1 | Waste/ year | Climate change potential (kg $CO_{2eq}$) | Water acidification potential (kg $SO_{2eq}$) | Water eutrophication potential (kg $PO_{4eq}$) | Human toxicity (kg 1,4-$DB_{eq}$) |
|---|---|---|---|---|---|
| Papertowel | 25,200 sheets | 10,154.47 | 94.5 | 66.75 | 17,502.53 |
| Polypropylene | 27.8 kg | 45.31 | 1.2 | 0.03 | 51.99 |
| Latex | 35 kg | 5.92 | 0.06 | 0.01 | 1.33 |
| | | 223.09 | – | – | – |
| Ethylalcohol | 17 l | −4.53 | -0.25 | – | – |

**Table 5** Environmental impacts of scenario 2 of the LCA

| Scenario 2 | Waste/ year | Climate change potential (kg $CO_{2eq}$) | Water acidification potential (kg $SO_{2eq}$) | Water eutrophication potential (kg $PO_{4eq}$) | Human toxicity (kg 1,4-$DB_{eq}$) |
|---|---|---|---|---|---|
| Papertowel | 12,600 sheets | 5077.24 | 47.25 | 33.38 | 8751.26 |
| Polypropylene | 23.86 kg | −15.62 | −0.41 | −0.01 | −17.91 |
| Latex | 35 kg | −5.92 | −0.6 | -0.01 | −1.33 |
| | | −223.09 | – | – | – |
| Ethylalcohol | 17 l | −4.53 | −0.25 | – | – |

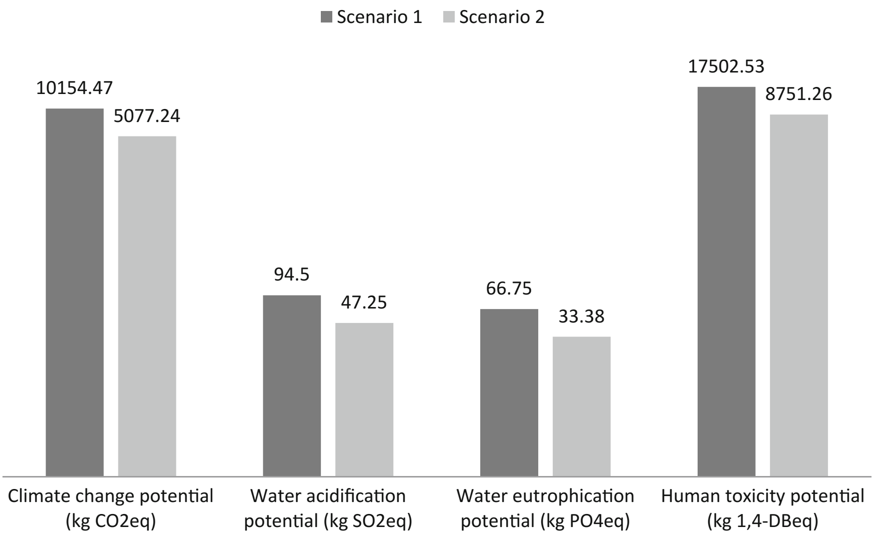
important to notice that the study used in the LCA (Jawjit et al. 2015) did not include the environmental impact of the latex transport from Thailand to Brazil.

Table 5 presents the environmental impacts in a period of one year considering the scenario 2, proposed ISWM, that considerate initiatives of waste prevention: use of roll paper towel and pipette tips reuse; alcohol, gloves and not contaminated pipette tips and tubes are recycled; chemical waste is incinerated, and paper towel waste is composted. All negative data are considerate avoided impacts.

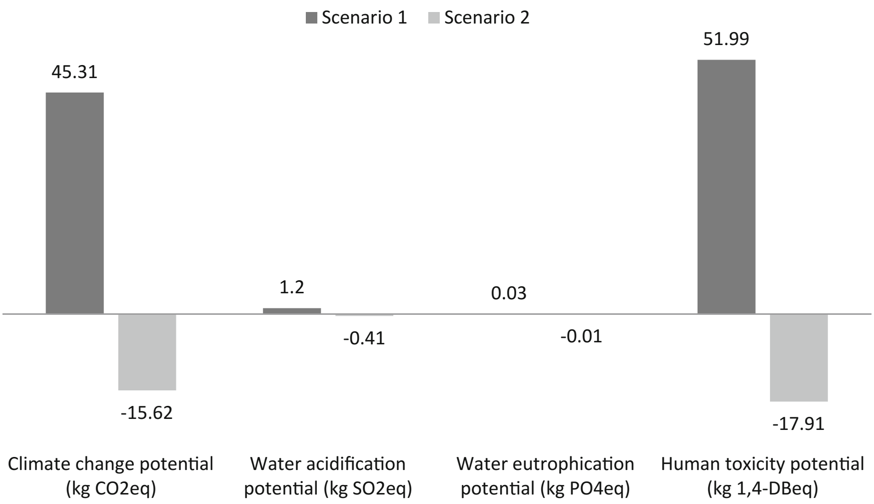
To calculate the final impacts related to polypropylene waste (pipette tips and tubes), it was considerate the amount sent to incineration for being contaminated with hazardous chemicals, plus the avoided impact related to the amount sent to recycling. Regarding the latex waste, it was considered 100% of the waste recycled, as the recycling process includes a cleaning step, but it was not possible to consider possible loss of resources caused by the recycling process.

The Graphics 1, 2 and 3 shows the comparison between the two scenarios for the wastes respectively: paper towel, polypropylene and latex.

As the ethyl alcohol waste did not have a management proposal different from the actual, the comparison of scenarios was not made. For instance, the Ecosolvent analyses showed that the distillation alternative for this waste decreases the climate change potential by 43% compared with the incineration option (Graphic 4).



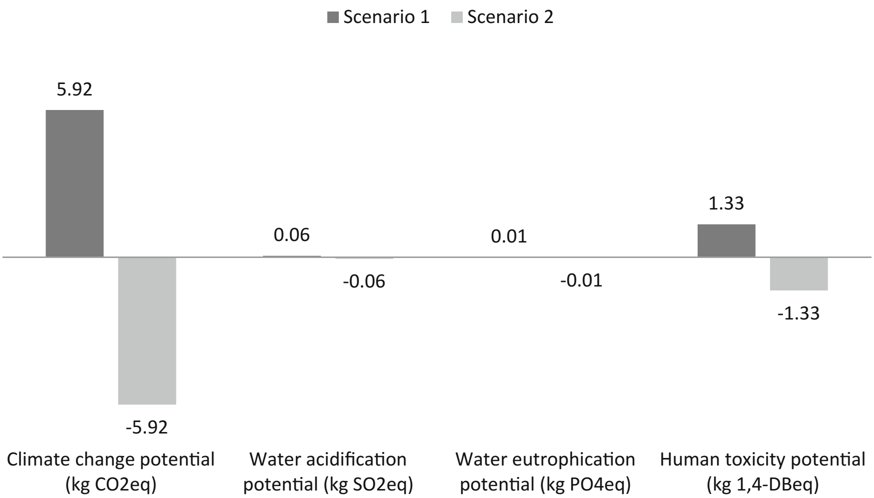

**Graphics 1** Environmental impacts related to paper towel waste in both scenarios




**Graphics 2** Environmental impacts related to polypropylene waste in both scenarios

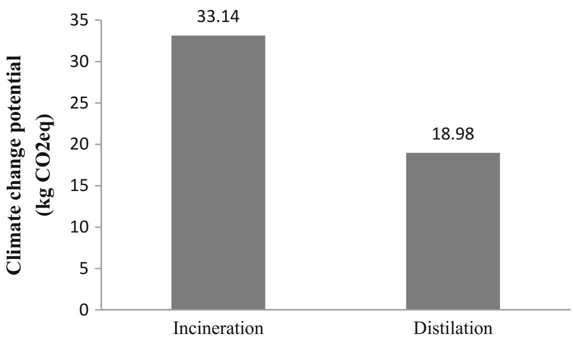
## 5 Discussion

By comparing both scenarios the second scenario decreased the environmental impacts related to the paper towel waste and avoided the impacts related to the polypropylene and latex wastes, suggesting that there is a potential for waste




**Graphics 3** Environmental impacts related to latex gloves waste in both scenarios

**Graphics 4** Ecosolvent analysis comparing climate change potential of two treatments to ethyl alcohol waste: Incineration and distillation




recycling; yet it is necessary an economic evaluation to determine its feasibility. The LCA also resulted that the human toxicity potential was the impact with higher values in both scenarios and the water eutrophication potential the lower one.

Paper towel waste was the only one that did not present avoided impacts because the composting was not considered as a recovering of resources as recycling was. It was not possible to calculate the environmental impacts of the landfill versus composting alternative, so the final data of paper towel wasted in scenario 2 considers the reduction of 50% by the substitution of multi-folded paper to roll one (USA-EPA 1997).

In relation to the viability of the paper towel composting the literature showed two limiting factors to the paper degradation and the consequent compost quality: the carbon nitrogen relation, relative to the amount of paper against food waste; and the presence of plastic in various paper towel products (Cabaraban et al. 2008). The product used in this laboratory is 100% virgin cellulose so the only limitation would be the carbon nitrogen relation. Therefore, it is interesting to analyze the Institute compost demand to find out the viability of implementing this proposed destination. Paper towel waste also presented higher impacts of all analyzed, being that the human toxicity potential was the higher potential. Madsen (2007) has reported that 98.8% of this impact is resulting from the paper pulp production, because of the PAH emission. Considering this great impact caused by the paper production, the substitution of the paper towel by other alternatives, like electric hand dryers, may represent another gain on environmental and economic impacts. Hypotheses presented in other studies concluded that the electric hand dryer has a minor environmental impact than a paper towel (Budisulistiorini 2007; Gregory et al. 2013; Joseph et al. 2015). In this way, it is also interesting to analyze the viability of this substitution in the laboratory reality.

Regarding the polypropylene waste (tubes and pipette tips) both prevention and recycling presented to be feasible only depending on orientations about the correct waste segregation to ensure that this waste did not mix to the hazardous one. Though it no analysis was made about the economic feasibility of this waste recycling which is important to implement the proposed changes. Still, the pipette tips and tubes are most of the plastic products and a waste of this laboratory, but there are other plastic products like other types of tubes, boxes, racks also made of polypropylene that can be recycled, as occurs in Harvard´ Green Labs program.

About the latex gloves waste, it was not possible to study the laboratory workers disposal behavior so it was not included a prevention possibility. Also, it can be interesting to calculate the environmental impacts with nitrile gloves to compare with the results from latex ones. The latex recycling the process proposed is not implemented in the market yet, as the nitrile gloves are, but it was considered an important future process since the environmental impacts related to the latex production.

The ethyl alcohol recycling proved to be a better treatment alternative than incineration as enables reuse, avoiding the environmental impacts related to the production of new ethyl alcohol. Yet, the software Ecosolvent considers only incineration with energy recovery, which is not the reality in Brazil. Thus, the real environmental impact of the ethyl alcohol incineration from this laboratory probably is higher than related in Ecosolvent.

## 6 Conclusion

The proposed IWMS decreased the environmental impacts related to the paper towel waste and prevent the impacts related to the polypropylene and latex wastes, suggesting that there is a potential for waste recycling.

The ethyl alcohol recovery, already practised in this laboratory, proved to be important in mitigation of the environmental impacts related to its production and incineration.

This study's limitations are mainly related to its context. A research laboratory is constantly testing new procedures, therefore, waste prevention and recycling actions need to be improved as these procedures change. Another limitation is regarding the waste transport activities which were not included on this LCA. The Latex recycling process proposed here has not implemented in the market yet. The same applies to the nitrile gloves recycling, at least in Brazil. Lastly, the lack of data made difficult to compare some end of life alternatives, for example, landfill versus composting.

This methodology proved to be effective in achieving its purpose and it can be used to improve waste management in similar situations. Steps that can be replicated in similar laboratories include: (1) use of roll paper towel instead of multi-folded; (2) analyze the processes to find possibilities of tips reuse and orientations to the laboratory workers to do it; (3) material safety data sheets survey to know the hazardous chemicals used in the laboratory processes and then know the plastic tips and tubes recycling potential; (4) analyze the possibility of solvent recovery; and (5) orientations about latex gloves reuse to decrease its demand.

Future studies should analyze the possibility of substituting the use of paper towel by electric hand dryers. Another important topic to study would be an economic assessment to evaluate the feasibility of implementing the plastic and latex recycling technology and, also, the comparison of the environmental impacts between nitrile and latex gloves. Lastly, a key step for further studies is to analyze technicians, students and researchers behavior related to prevention, recycling and littering actions to infer the real potential of waste reduction.

## Appendix

See Table 6.

**Table 6** Data survey about the hazardousness of all reagents used in 15 laboratory procedures analyzed

| Laboratory steps | Procedures | Reagents | Hazardous | Not hazardous |
|---|---|---|---|---|
| DNA extraction | Common reagents for all DNA extraction procedures | Proteinase K | • | |
| | | DTT | • | |
| | | Ethyl alcohol 70%* | • | |
| | | Tris-EDTA buffer | | • |
| | | Tris(hydroxymethyl) aminomethane | | • |
| | | Tris Hydrochloride | | • |
| | | EDTA | | • |
| | | SDS | | • |

(continued)

**Table 6** (continued)

| Laboratory steps | Procedures | Reagents | Hazardous | Not hazardous |
|---|---|---|---|---|
| | Saline extraction | Ammonium acetate | | • |
| | | Isopropanol* | • | |
| | Phenol-chloroform | Phenol | • | |
| | | Chloroform | • | |
| | | Isoamyl alcohol* | • | |
| | | Sodium chloride | | • |
| | Commercial kit "DNAZOL" | | • | |
| | QIAGEN "Easy DNA" commercial kit | Buffer ATL | | • |
| | | Buffer AL | | • |
| | | Buffer AW1 | | • |
| | | Buffer AW2 | | • |
| | | Buffer AE | | • |
| | Agencourt "DNAdvance" commercial kit | Lysis buffer | | • |
| | | BIND1 | • | |
| | | BIND2 | | • |
| | | Elution buffer | | • |
| DNA Quantification | Nanodrop | NA | NA | NA |
| | Electrophoresis | TBE | | • |
| | | Bromophenol blue, glycerol, EDTA | | • |
| | | Gel red | | • |
| | | DNA ladder | | • |
| | | Low mass | | • |
| | Qubit | HS reagent | • | |
| | | Standard buffer 1 | | • |
| | | Standard buffer 2 | | • |
| | | HS buffer | | • |
| DNA Amplification | Polymerase chain reaction | Sintetic DNA | | • |
| | | dNTPs | | • |
| | | Magnesium chloride | | • |
| | | Buffer 1 | | • |
| | | Buffer 2 | | • |
| | | Buffer 3 | | • |
| | | DMSO | • | |
| | | Polymerase | | • |
| | GE Healthcare Ready to Go commercial kit | | | • |
| | QIAGEN RepliG commercial kit | Buffer DLB | • | |
| | | Polymerase | | • |
| | | Reaction buffer | | • |
| | | Stop solution | | • |

(continued)

**Table 6** (continued)

| Laboratory steps | Procedures | Reagents | Hazardous | Not hazardous |
|---|---|---|---|---|
| Purification | Agencourt Ampure XP | | | • |
| | Thermo Fisher Scientific ExoSAP-IT™ PCR Product Cleanup Reagent | | | • |
| Sequencing | Thermo Fisher Scientific BigDye™ Direct Cycle Sequencing Kit | Buffer BD | | • |
| | | Big Dye | | • |
| Sample preparation | DNA precipitation | Sodium acetate | | • |

*Are inflammable but volatile, thus are classified as hazardous but did not leave a residue at plastic pipette tips

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# Prospects for University Territories: The Rural University of São Paulo in Pirassununga

**Fabrício Ribeiro dos Santos Godoi**

**Abstract** The specific characteristics of the university territories vary, among other determinants, according to their location in relation to the city. Most of the studies refers to the typical American, suburban or part-town campus, or the institutions located in the urban plot. The university territories situated in the rural environment, interconnected to this reality, set up a separate category, with its own specific characteristics. A particular case will be taken, the Campus Fernando Costa of the University of São Paulo in Pirassununga, a city of the state of São Paulo, as the basis for presenting some perspectives for sustainable development for this category of university territories. The Campus Fernando Costa, founded in the years 1940, has 2240 hectares, 800 of them in areas of preservation and almost 120,000 $m^2$ of constructed area. In it are courses linked to the rural environment, there are areas devoted to experimental and productive farming, besides the other structures typical of the public universities at São Paulo State (housing, restaurant, administration, academic areas). It is significant the potential of a university territory in rural environment for the experience and application of sustainable development processes. The case of USP Campus at Pirassununga is exemplary and we believe it can be useful to other institutions in rural areas, especially in Brazil and Latin America.

**Keywords** University territories · Sustainability · Rural · Brazil

## 1 Introduction

Would the university territories situated in rural areas have their own characteristics? Could these territories be privileged spaces for sustainable development? We think so, supported by MC Clelland (1988, p. 291) and in this paper we will present some experiences and some potentials and prospects that this category of territory possess.

F. R. S. Godoi (✉)
Instituto de Arquitetura e Urbanismo—Universidade de São Paulo,
Avenida Duque de Caxias Norte, nº 225—Jardim Elite, Pirassununga, São Paulo, Brazil
e-mail: fabricio.godoi@usp.br



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The methodology is a case study, the "campus Fernando Costa" of the University of São Paulo (USP), in the city of Pirassununga, in the interior of São Paulo. In another work (GODOI 2017) we have done comparisons with other university territories in rural areas, also in Brazil, which allows us to highlight the general aspects of this case study.

We will begin with a brief contextualization, presenting the university and the campus, in addition to conceptualizing what we call university territories in rural areas, essential condition for the eventual reproduction of experiences or identifying potentials in other cases in the same category.

Next, we will present the actions carried out, the possibilities and limitations, setting up the heart of this work. The main themes relate to the preservation of biomes, mobility and circulation, energy generation, water supply, soil use and sustainability in buildings. Some attempts at generalizations are offered, before final considerations.

Before, however, we would like to discuss the concept of rural university territories very briefly. The term University territories includes "campus", nomenclature emerged in the United States, but with worldwide widespread significance, well described by Dober (2000): Integrated constructions and fields in green areas of pleasant visualization, well defined physically and with a specific sense of place and productive in encouraging fortuitous and synergistically interaction between individuals who share the use of this place. "University territories" also includes the other names, which extrapolate or reduce the term "campus", such as University towns, university pole or university grounds. It also includes campus extensions, such as some "farms" that shelter the teaching of agrarian sciences. When we cut that broad term (university territories) with the adjective "rural", we refer to those devoted to the teaching of agrarian sciences, located outside the urban environment (or on the margin of this), and must necessarily simulate the conditions found in agrarian practice. This results in extensive territories, with considerable diversity of usages and relatively low constructive density. A category of territories different from the typical structures described by Dober.

It is great the potential of these rural university territories for experiences in sustainability, in addition to the possible experiences in urbanized areas or in buildings, which can also be applied in examples such as ours, it is also possible to carry out experiences of different scales, with diversified materials and even in greater harmony with the natural environment.

## 2 Contextualizing the University of São Paulo in Pirassununga

The University of São Paulo is the largest public university in the country. It has more than 90,000 students, being approximately one-third are graduate students, and 6000 faculty. It is an autarchy of the state of São Paulo, with high financial autonomy, guaranteed by the fixed pass of a percentage of state taxes. It is a university organized in schools, institutes, colleges and central organs, which have relatively high autonomy to develop their academic activities (USP 2015).

USP is distributed in several cities in the state, although most units are located in the capital, in the place known as "Cidade Universitária Armando de Salles Oliveira" and in other historical or newer locations. Within the state, there are seven campuses. The Ribeirão Preto campus and São Carlos campus are more diversified and the others have some level of specialization. In the area of agrarian sciences, there are two campuses: Piracicaba and Pirassununga. Both are located in adjacent locations of the urban plot, possessing vast areas where the activities inherent in teaching, research and extension of the agrarian sciences can be fully developed (USP 2015). This paper will refer more specifically to the "Campus Fernando Costa", as it is called the campus located in the city of Pirassununga. The main differences of Piracicaba ("Campus de Luis de Queiroz") are: the area (Pirassununga is three times larger than Piracicaba), the urbanization (Piracicaba has 2.5 more built area than Pirassununga) and population (Piracicaba has two Times the population of Pirassununga). The sustainable experiences in Pirassununga campus are different from the other ones USP campuses. These experiences, understood as a whole, are unique in the country and are grounds for closer analysis.

USP in Pirassununga owns 2240 hectares and almost 120,000 m$^2$ of built area (the data is from 2017, from the campus prefecture.). On this campus are offered four undergraduate courses, linked to the Agrarian sciences (veterinary medicine, zootechnics, food engineering and biosystems engineering) and seven graduate programs, also linked to this field of knowledge. They are more than 2000 students and 130 faculty, organized in two colleges, being one of them wholly located on campus (FZEA 2013).

The first schools of agrarian sciences are founded in the United States, from the Hatch Act of 1887, which was destined for federal funds for certain schools that inaugurated experimental farming stations (Turner 1987, p. 129). Among the seminal experiments, the most prominent ones are the projects and works of Frederick Law Olmsted and after his office, managed by his son. Between the decades of 1860, before the Hatch Act itself, and 1890, Olmsted was engaged in the planning of more than 30 plans of university territories. Its influence was decisive for the projects of this category of territory in that country (Turner 1987, p. 140). It comes from him the first lesson for planning these territories, in a deeply democratic view, as quoted by Turner (1987, p. 143):

> you must embrace in your ground-plan arrangements for something more than oral instruction and practical demonstration in the Science of agriculture… you must include arrangements designed to favorably affect the habits and inclinations of your students, and to qualify them for a wise and beneficent exercise of the rights and duties of citizens and of householders.

In Brazil, almost simultaneously appears the first high school of agriculture, but the first successful institution, which continually offered courses until today, formed its first class in 1895. The professional organization, however, appears only in 1910 (Godoi 2017, p. 68).

The existence of the campus in Pirassununga dates back to the old Practical School of Agriculture, Fernando Costa, founded in 1945, it had as a function to form field workers, so that Brazilian and Paulista farming became technologically more advanced and for the country man to leave his condition as ignorant, as people without access to education. The political project that supported this transformation was defeated, after the death of its creator (which gives name to the school and the campus, Dr. Fernando Costa). With this, the school has become a professional education institute, focused on the technical training of medium-level workers, still in the farming area. The link to the university arises in this period and gradually, the place will become an effectively university territory, with higher-level courses and research development (Godoi 2017, p. 91). Today, the previously presented figures put the campus in evidence: not only by their super barking dimensions, but also for their importance to the institution.

## 3 The Case of Sustainable USP in Pirassununga

The first aspect we will emphasize is about the preservation of forests and landscapes on the inside of the campus. Internal legislation (USP 2012) determined the preservation of 800 hectares, including the Permanent Preservation Areas (apps, in Portuguese), which in Brazilian federal legislation are already protected, in addition to dense arboreal masses and connecting corridors. The integral preservation of the areas containing riparian forests is essential to ensure soil quality and ensure the longevity of the agricultural system (Momoli 2011). Brazilian legislation provides for the preservation of 30 m from the margins in small watercourses, as is the case of the water system on the campus in Pirassununga. Some of these areas were not effectively protected, but internal legislation triggered local initiatives for this protection to be effective. Moreover, the connecting corridors between the different apps and the remaining tree masses, of forestry character, are important to sponsor the surviving of fauna and flora. Although discussions on the width of the corridors are not conclusive, their importance is proved (Castellón and Sieving 2006). The legal device made the prediction and assured that connectivity.

Another important aspect is to perceive the diversity of soil usage over time. The original biome of the campus is the Atlantic Rainforest, more specifically the Semideciduous Seasonal Forest (MMA 2006). However, the landscape is quite modified by men. The remnants of the original coverage are only part of the areas determined for preservation. Part of these preserved areas are modified by men and must be recomposed over the years. The surrounding areas are occupied by the activities typical of the Paulista farming system: Pastures for cattle, buffaloes, equines, goats and sheep, installations for other creations (poultry, rabbit keeping, etc.) and agricultural crops, in rotation systems such as maize, sorghum, sugar cane. Finally, the system of circulation and infrastructure: roads, posts and networks, water nets. This diversity of uses creates a typical and very rich landscape, which is quite positive. There is a continuous planning work in these territories so that each productive area has the most suitable destination, considering the pedological characteristics and proximity to the related didactic installations.

Another aspect we intend to demonstrate, with regard to the legal preservation of forests and landscapes on campus, is related to the enjoyment of their landscaped potentials by the population. The Atlantic Rainforest is a biome that has significant landscaped potential, thanks to the vast diversity of Fauna and Flora (Mantovani 1993). The less impacting alternative to the use of this potential is sustainable tourism, which in the case of natural areas encourages productive usage of inappropriate areas for farming and should be carried out on a small scale, as teaches Swarbrooke (2000). There is also the concern for the impacts of this tourism priority, in front of the market interests, as indicated in Hall and Lew (1988). The interventions carried out on the campus fully satisfy these premises. Pre-existing paths and service routes were used to create a system of ecological trails, which can be traveled on foot or with bikes. These trails were flagged, according to an attractive visual communication project. The signal of flags was constructed with recycled material. Complementing the proposal, the dissemination of the trails system is part of an environmental education process, which provides users with the qualities and specificities of each landscape. It is also worth remembering that this achievement was conceived by administrative officials of the campus and made financially viable with resources from environmental fines, directed by the municipal representation of the judiciary.

The second aspect that we shall emphasize is concerning the circulation and mobility on campus. Some characteristics of the place should be taken into consideration: the large dimensions of the campus; its geomorphological characteristics (gentle undulations) and the concentration of didactic and administrative activities in three regions, distant between each other from 3 to 5 km. These routes were overcome primarily with the use of private cars and secondarily with the public transportation of the university, which is free and relatively sufficient attendance. On other USP's campuses, the free internal transportation has also been offered for decades, aiming at the mobility of students in a fragile economic situation. Active mobility, by hiking or bicycles, has already been observed before the new actions (although it has not been measured). The following detailed actions were carried out, with the intention of broadening these modes of circulation, more sustainable in all aspects and object of experiences at various universities around the globe (Van Heeke and Sullivan 2014; UESSEX 2014; UNAM 2017; UAM 2017).

The construction of roads detached paths for bikes (bicycle paths) was the first action for the incentive of active mobility. According to the Brazilian transit manuals, the detached paths routes for bicycle traffic must have 1 m wide in each direction. The roads built on campus are three meters, aiming at shared use with long-distance runners. This share has been shown effective and have not been counted conflicts (accidents) due to shared usage. For treating a campus in the rural environment, with a large area for infrastructure deployment, it is possible and desirable that comfort.

Deployed in phases, the cycle system is not yet complete. The third phase will be built in 2017, interconnecting the first two phases. There will still be a fourth stage, which when completed totals nearly 6 km of bicycle paths. However, a very important detail of the construction of bicycle routes is that they have made use of constructive techniques considered sustainable. The pavement was constructed with mixture of asphalt pavement recovered and heated asphalt mixture (Lopes 2015). The lighting was accomplished with LED light fixtures powered by photovoltaic plates, which shows sufficient (Zukauskas et al. 2002) and imposes smaller impacts, since the system consumes only the energy that produces most of the time, composing a virtually autochthonous model. In addition to the physical infrastructure has also been operationalized a bicycle lending system, located next to the campus portals, for document carriers attesting to the university. The system is recent: it was inaugurated in April/2017. Those responsible for the control intend to extend the public user in the future, also allowing campus visitors to loan bicycles.

Therefore, the system composed of the track cycle with lane for corridors (active mobility), constructive material with lower environmental impact (paving), intelligent lighting (led with photovoltaic plates) and bicycle loan, can be considered a exemplary sustainable mobility system. The increase in the use of the system has yet to be measured, but empirically it is already remarkable.

The third aspect we present is concerning the generation of electricity. It is intended, on this campus, to create a pole of alternative experiences of energy generation. Currently almost all the energy consumed on campus is conducted by electrical system, with the supply of the same carrier that provides for the city. The exceptions are punctual: for heating there is a boiler and some gas spots. We already cited the photovoltaic plates on the bicycle path. There is a higher seasonal demand in heat periods for cooling environments. It is therefore important that other sources serve the system, both to reduce costs, and to maintain some control over the supply, to be used strategically in sensitive locations (such as cold chambers with long-lasting or slaughterhouse heating experiments, for example).

Independent actions arising from professors' research have been concentrated on an axis, so that there is synergy in the initiatives and in the future the campus has a "sustainable energy axis". One of the actions is the installation of a solar plant, which concentrates the solar energy reflected by a field of mirrors, which will generate energy for the replacement of a boiler, which is currently powered by firewood. The project coordinated by prof. Celso Lins Oliveira, from Laboratory of Energetic Efficiency and Process Simulations (LEESP, in Portuguese), started at 2010 and it is called "Solar-Hybrid Micro-turbine Systems for Cogeneration in Agro-Industrial Electricity and Heat Production (SMILE)". Another independent action is the construction of a model biodigester for the Laboratory Multiuser of Swine. Animal wastes were not treated according to best practices, since the laboratory is very old (built in the Decade of 1940) and for financial contingencies few updates were constructed over time. However, motivated by the sustainable vision that currently permeates—say, since it does not guide—the decision-making bodies preferred to resolve the environmental problem in the best possible way: reducing the volume of waste, leading them to a power generation system. The efficiency of this system is proven by other experiences (Santos et al. 2015) and its environmental effectiveness can be meaningful (Jesus and Barbosa 2009).

The fourth aspect is referring to the supply of potable water. The state of São Paulo has recently experienced a major water crisis, exacerbated by the poor management of the reservoir system (Coutinho et al. 2015). In the city of Pirassununga and particularly on the campus of USP the same crisis fell. The existing system was composed of a source (in two dams), with reservoirs totaling approximately 1,650,000 L. With the crisis, the system reached the minimum levels and it was necessary to make a partnership with the municipality of the city to guarantee the supply. To avoid future problems, a new supply station was built, interconnected to new reservoirs with 1,400,000 L, which guarantees the supply for a week. Important to emphasize that USP has already owned consumption reduction programs and on campus the distribution was already supervised to avoid losses. This aspect of sustainability on campus is especially important, as in addition to the consumption of more than 2000 people daily, there is also the consumption of the herds.

The last aspect we would like to quote has gained minor advances. The new buildings advocate sustainable systems such as rainwater reuse for irrigation (Liang and Van Dijk 2011 point the benefits) and installation of photovoltaic boards. However, the construction market in the city of Pirassununga is unsophisticated, limiting the possibilities for adopting alternative constructive systems and diversified materials. The provision of trained workforce for alternative or more sustainable constructive systems is not available in the city. In the case of public works, it is necessary to respect the best efficiency in the use of (public) money. Alencastro et al. (2014) Demonstrate the difficulty of public power in adopting the sustainability criteria. Its study refers to the federal government, which has a much larger structure and diversity than a university campus located in a relatively small town of the interior of a state.

In each of the presented aspects, it can be stated that the campus has advanced in terms of sustainability. However, it would be possible to apply other initiatives that would deepen the experience. The integrated planning of the Territory is the most obvious of these initiatives and only in April 2017 began the process of the first territorial director plan of the campus, addressing the entire property. This is a recent improvement in soil management and the consequent optimization of its use, especially in areas not occupied with academic or research activities. It is necessary, however, that the ongoing planning that exists in the protected Territories is integrated with the integral planning, which begins. Programs for reducing individual mobility, with the improvement of the attendance of public transportation, are also on the agenda, awaiting the feasibility.

But the largest potential in terms of sustainability of the campus is the possibility of reaching the self reliance of water supply and energy production. The first is practically a reality and the next step would be to carry out a supply exchange with the municipality, enabling the sale of the campus surpluses to the city. The second is still a distant idea: in addition to the expansion of the systems of biodigesters and solar energy, other arrays can be installed. Possibility as the exploitation of the wind potential can be adopted (as São Paulo [Estado] 2012).

Finally, the thematic cutout that could further advance in experiences on this campus is the architecture and construction. The new buildings must be sustainable, adopting simple technologies, since most of the building are relatively small, including the provision of training for the local labor and thus leading the idea of sustainability to the city.

There are, logically, difficulties and limitations. The integral planning of the territory involves large amounts of organs and decision instances, only recently assembled. With regard to soil usage, the need for frequent changes in soil use, due to new experiments, gives little margin to the best handling. Large distances impose high costs for mobility and circulation, generating, for example, unsustainable public transportation intervals. Finally, the implantation of small buildings, whose constructions are contracted through price disputes (according to Brazilian legislation), hinders the implantation of sustainable ideas in civil construction. About the pre-existing buildings, the difficulty is even greater: these are works of the 1940 years, some of them of architectural and historical interest, whose retrofits would have unviable costs for the university's financial condition, which lives its biggest crisis (Righetti 2017).

Therefore, from the aspects presented, the first ones (preservation, mobility, generation and distribution of water and electricity) succeeded and resulted in benefits for the campus, while the latter, concerning the sustainability of buildings, did not advance sufficiently.

## 4 Possible Generalizations

We advocate the dissemination of the previously substantiated sustainable experiences in the idea of Ribeiro (1969), that universities should anticipate social transformations, to be converted into an instrument of overcoming national delay, contributing to these transformations of society.

All the successful aspects of sustainable initiatives presented in this work can be replicated in other locations and institutions, also in the rural environment, with some caveats. The availability of extensive areas and the sparse occupation of the territory, characteristics typical of this typology of university territories, create a similar geographical context. The idea of replication is also extensible to another kind of territories, possibility also raised by Ruschensky and Silva Medeiros (2016) and Tauchen and Brandli (2006).

Firstly, with regard to the preservation. The preservation of the areas of permanent protection (according to Brazilian law) and the surrounding areas, which favours the diversity of the landscape, the implantation of green corridors and infrastructure for the enjoyment of the landscape. These initiatives do not require large investments and the normative may be internal to the university institution. It is therefore an initiative that can be adopted immediately, with positive results and gradual implantation, as financial resources are available.

Secondly, with regard to mobility and circulation. As we have seen, the adoption of active mobility programs is not new in university territories. The system of bicycle paths composing routes, with the loan of bikes, plus the offer of spaces for long distances corridors, is paradigmatic with respect to a healthier lifestyle (Cooper and Leahy 2017). Even better if they are built and illuminated with sustainable systems.

Thirdly, with regard to the self-reliance in water supply and electricity production. Here resentment flow the geographical differences affecting university territories. In the Brazilian cases we studied in other work (Godoi 2017), the initiatives presented here could be applied, but with limitations. The alternative generation of electric energy is more spreadable: in campuses with herds, the implantation of bio-digesters is possible; on campuses of tropical locations, the use of solar energy is more indicated; in others, it may be wind power and we also find the chance to use water energy (which is not possible in Pirassununga). In relation to water supply, local experiences can hardly be applied in other locations. The geographical specificities and availability of springs enable the proper provision and allow the construction of a fairly generous reserve system for the USP campus in Pirassununga. What can be widespread in this regard is the caution to cope with future times, which can be calculated in cases of territories that have historical rainfall data.

Finally, what should be incorporated in the experience presented is the ongoing action of planning. Because it is still incipient, the perception of the actions presented in this work seems less impacting. Important aspects, such as the issue of solid waste, could also be innovative. In short, the innovations performed on this campus are generalizable, but in full views could be even more relevant.

## 5 Final Considerations

We are aware that this study has limitations on which we should be attentive to: it was conducted from a case study, even though it was complemented with benchmarks from another work. There are enormous variety in the typology "rural University territories" and the proposed generalizations may not apply to all cases. Some of these actions are still very recent and there is no data availability, so we infer some empirical assumptions.

These are the possibilities of disseminating the sustainable experiences of this case study, summarized in: 1-proposals for the preservation of the environment; 2-proposals for mobility; 3-proposals for generating and distributing energy and water. Specifically for the studied campus, it is important to develop new ways of addressing sustainability in buildings, which is the aspect that has greater potential for new experiences.

Considering these limitations and possibilities, we understand that the experiences presented in this paper, when viewed together, are a great approach to the theme for other campuses with rural characteristics. This category of territories can and should be paradigmatic in sustainability initiatives, and thus being able to start their practices from this example and innovating with creativity, exploring the unique characteristics of each locality. Therefore, this article is included among those that form a "field of possibilities", created by the plurality of actions, projects and ideas for a greater relevance of the environmental issue in university campuses.

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## Author Biography

**Fabrício R. S. Godoi** holds a master's degree in architecture and urbanism from the Instituto de Arquitetura e Urbanismo of the Universidade de São Paulo (IAU/USP) and is the architect responsible for the USP Campus Fernando Costa in Pirassununga/SP, Brazil, for seven years. He is also a professor of Architectural Design, at the Centro Universitário Fundação de Ensino Octávio Bastos, in São João da Boa Vista/SP.

# Universities in Transition to Sustainability: Challenges and Opportunities for the Campus of the University of Brasilia in Planaltina

**Marcelo Bizerril**

**Abstract** A significant expansion of Brazilian public higher education occurred in the last decade. It is necessary to analyze the performance of sustainability within new federal university campuses to identify successful cases that may influence the university system as a whole. The present study is important because it addresses the case of a campus with the potential to be a reference on sustainability in Brazil, but it still faces obstacles and challenges to reach this condition. The Faculdade UnB Planaltina (FUP) is one of the three new campuses of the University of Brasília, and presents potential for sustainability given its location, courses, faculty profile and organizational structure. This study analyzes the performance of FUP in the field of sustainability from the seven dimensions of university activities proposed in the literature on sustainability in higher education: education, research, outreach, campus operations, on-campus experiences, Institutional framework, assessment and reporting. The campus's strengths are research, outreach, participation in management and the Institutional Pedagogical Political Project that reflects the intentionality of the campus in relation to sustainability. However, it is necessary to continue to strengthen sustainability in the curriculum and implement an environmental management system.

**Keywords** Education for sustainable development · Expansion of higher education · Social responsibility · Sustainable university

## 1 Introduction—Contextualization and Objectives

According to data from the Ministry of Education, since 2003, and especially since the Restructuring and Expansion of Federal Universities Program (REUNI) started in 2007, 14 new federal universities and more than 100 new campuses were created

M. Bizerril (✉)
Faculdade UnB Planaltina, University of Brasília, Área Universitária n.1,
Vila Nossa Senhora de Fátima, Planaltina-DF 73.345-010, Brazil
e-mail: bizerril@unb.br



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in Brazil. This process of creating federal universities' campuses outside of large urban centers expanded the number of municipalities served by universities from 114 in 2003 to 237 by the end of 2011. The expansion promoted an increase of approximately 70% of the attendance enrollments in the federal network higher education (Brasil 2010; Nogueira et al. 2012).

The impact of this investment in the country's development is still being studied and is not conclusive (Nogueira et al. 2012; Mancebo 2015). However, the expected renewal of higher education may not be occurring to its full potential if the new campuses do not change the university culture. Instead, they run the risk of reproducing the large-scale historical limitations of Universities, especially in terms of pedagogical practices, management and the conditions of access and permanence of students in higher education.

Many of these characteristics of universities are related to obstacles in the implementation of a culture of sustainability described in the literature. Examples of these obstacles include: personal resistance to change and innovation (Lozano 2006; Ćulum 2014); the institutional and systemic barriers to change (Harris and Crane 2002); the limited and compartmentalized perception of the concept of sustainability by managers (Wright and Horst 2013); difficulties in conducting participatory processes in the institutionalization of sustainability (Disterheft et al. 2014); the rigidity and traditionalism of Higher Education Institutions, in which the Cartesian and Newtonian models of thought predominate, which relegate the teaching and learning processes to mechanical actions that do not meet the skills needed for sustainability (Lozano 2006; Lotz-Sisitka et al. 2007; Segalàs et al. 2012; Lozano et al. 2014; Ćulum 2014).

Considering the theoretical set developed in the last decade (Lozano 2006; Alshuwaikhat and Abubakar 2008; Karatzoglou 2013; Lozano et al. 2014; Amaral et al. 2015; Bizerril et al. 2015 and many others), it can be concluded that the Sustainable University is expected to perform consistently and consciously in the following dimensions:

- *Education*: the presence of inter- or trans-disciplinary approached to sustainability in different disciplines and curricula, including in teacher training programs, seeking the promotion of sustainability values such as critical thinking and complex vision, conviction and skills to act as future professionals and citizens committed to sustainability.
- *Research*: the existence of structures and financial support for the production of knowledge and technology on sustainability based on complex and trans-disciplinary thought.
- *Campus Operations*: allowing for the presence of sustainability in the daily functioning of the university, including management and efficiency in the use of water, energy, waste and gases, as well as transport and accessibility, and access to quality food.
- *Outreach*: strengthening the integration of the university with society (other universities, governments, businesses, schools, civil society organizations and the local community) in promoting sustainability.

– *Assessment and reporting*: implementing an environmental management system among several that may be available, as well as the internal and external dissemination of the results of this monitoring.
– *Institutional framework:* including sustainability in policies, missions and other official documents.
– *Sustainability experiences on campus:* promoting the existence of working groups, facilities and other permanent sustainable practices with the academic community; maintaining an environment of respect in relations between students, faculty and staff; carrying-out democratic management that enables participation in decision-making.

Brandli et al. (2015) and Leal Filho (2010) considered that the implementation of sustainability practices in Brazilian universities does not seem to be sufficiently satisfactory or comparable with other universities, such as those in Europe. In fact, sustainability has been receiving increasing attention from managers of higher education institutions worldwide given its direct implication with university missions in terms of teaching, knowledge production and engagement with society. However, the transition from higher education institutions towards Sustainable Universities (SU) is necessarily a process that suggests profound changes in the traditional way that the university operates. The new Brazilian campus experience offer the opportunity to create new university cultures. That is why they can play the role of driving the transformation of universities to meet the demand of sustainability. In this sense, it is necessary to analyze the performance on sustainability of the new federal university campuses to identify successful cases that may influence the system as a whole. The present study is important because it addresses the case of a campus with the potential to be a reference of campus sustainability in Brazil, but still faces obstacles and challenges to reach this condition.

Faculdade UnB Planaltina (FUP) is one of the four campuses of the University of Brasilia, located 40 km from the federal capital of Brazil. At eleven years of age, the campus presents potential for sustainability given its location, courses, teachers' profile and organizational structure (Bizerril 2013).

This study analyzes the sustainability performance of FUP from the seven dimensions described above. It seeks to identify how FUP has been taking the path to becoming a SU, what advances have already been made, and what characteristics of the campus promote this process. At the same time, the paper also identifies which aspects are not well advanced and the obstacles that remain.

## 2 Sustainability in FUP

This is an exploratory study based on the analysis of institutional documents and participant observation. The author is a professor and current director of the campus, allowing for such access. The main documents analyzed were the Institutional Pedagogical Political Project, the campus regiment and the FUP web site (www.fup.unb.br). The campus performance was analyzed from each of the seven dimensions of sustainability in universities.

## 2.1 Institutional Framework

The campus has not signed any of official agreements on sustainability nor does it formally participate in institutional forums in this issue. However, the Institutional Pedagogical Political Project is categorical in affirming the institutional commitment to sustainability by including the five pillars that make up the FUP missions, as seen in the section:

> The FUP's mission is to guide ethical and citizen intervention, scientifically and socially reflected in the spheres of education, research and extension for the theoretical and methodological development that contribute to the resolution of socio-environmental problems (Universidade de Brasília 2012, p. 10).

This document clearly reflects that the campus' compromise to sustainability is in line with the main and current recommendations of the international literature for an effective and complex performance as a Sustainable University, when it states that the campus must:

(a) Consider the academic environment as a structure that promotes the culture of sustainability;
(b) Consider the university environmental management as an ongoing educational process of principles and practices of sustainability, with permanent pedagogical intent that is experiential, informal and extracurricular;
(c) Ensure the acquisition of values, knowledge, skills and sustainable attitudes towards critical and complex environmental knowledge for the academic community;
(d) Be an example of and testimony for sustainability through the establishment of internal environmental programs at the campus and in the context of their community and territorial scope;
(e) Adopt continuous improvement strategies of Campus environmental performance;
(f) Integrate environmental knowledge and principles of sustainability into teaching activities, research projects and university extension;
(g) Conduct research and studies that contribute to increasing knowledge about sustainable development;
(h) Develop permanent mechanisms for the continuing education of staff, teachers, students and graduates (Universidade de Brasília 2012, p. 10).

## 2.2 Education

FUP offers four interdisciplinary degrees: Bachelors in Education of Natural Sciences; Bachelors in Rural Education; Bachelor of Environmental Management and Bachelor of Agribusiness Management. All of the programs have a strong identity with the theme of sustainability, however its presence in the depth of the curriculum varies between courses. There is only one internal study on environmental issues out of all offered courses on campus within the four programs, developed by Layrargues and Dourado (2011). The authors analyzed 226 different subjects and verified that, among them, 17% present environmental issues as fundamental, whereas 23% insert environmental issues as inserted peripherally, and in 60% it is altogether absent.

There are few sustainability courses that are common across all four programs Nor are there studies on pedagogical approaches of the disciplines in order to assess the degree of development of key competencies for sustainability, such as critical thinking, complex perspectives, openness to interdisciplinarity, innovation, cooperation and teamwork, as well as the ability to adapt technologies and methodologies to different contexts, make and implement decisions, communicate and promote interaction between institutions and people.

There are two regular spaces for the exchange of pedagogical experiences, such as the Graduate Collegiate and the Pedagogical Conversations seminars, coordinated by the Education and Language area of FUP. Both are held monthly. Another possibility is the Socializing Experiences Seminar first held in 2015 and again in 2017 when it became a periodical activity. There are two institutional programs of teacher training (PIBID/CAPES), the PIBID "Diversity" and PIBID "Science Education", which can also be oriented to the promotion of Sustainability.

## *2.3 Research*

The five postgraduate programs in operation are also interdisciplinary: Materials Science (PPGCIMA), Environment and Rural Development (PPGMADER), Environmental Sciences (PPGCA), Public Management (PPGGP) and Science Education (PPGEC), the last in partnership with other units of the central campus 'Darcy Ribeiro'. Two programs are especially dedicated to sustainability, one focusing on the ecological approach to sustainability (PPGCA) and the other more focused on the socio-environmental approach (PPGMADER). The PPGCA was created from the separation of an original proposal of PPGMADER which had a more transdisciplinary character and therefore more in line with the guidelines of education for sustainability, but that was not feasible at the time. The other three programs do not have a particular focus on sustainability, but they often approach it from environmental education (PPGEC), sustainable purchasing management (PPPGGP) or environmental innovation (PPGCIMA).

In 2011, an analysis of 119 research projects registered in FUP indicated that for each ten research projects, approximately seven of them did not consider environmental issues, in two of them environmental issues were peripheral, and one held environmental issues as central (Layrargues and Dourado 2011). Despite this statement, a more current analysis is necessary when considering the recent emergence of groups, centers and research programs related to sustainability such as the Center for Studies, Research and Extension in Agroecology and Sustainability (NEPEAS), the Metropolis Observatory, the Rural Education

Observatory, the Observatory of the Movement for Social Technology in Latin America, the Laboratory of Environmental Nanosciences and the aforementioned PPGCA.

## 2.4 Campus Operations

In daily campus management it is clear that despite the efforts made, none of the major aspects related to resource use is sufficiently organized as a sustainability policy. For example, there is no automatic light control system. Nevertheless, water faucets have automatic control taps in the bathrooms, and one sees some control in use in gardening and maintenance on the campus, however, there is no rainwater harvesting system or water reuse for irrigation or for use in toilets. This is particularly worrying at a time when the entire region of Brasília is experiencing a water rationing process due to the low water level in the Federal District reservoirs. Given the growth of the city, water management will be a recurring and crucial issue in the region.

There is a chemical waste collection system for laboratories, and selective collection of solid waste is being implemented throughout the campus, coordinated by FUP's Environmental Advisory. Professors of the Sustainability Nucleus of UnB produced a diagnosis of waste production on the campus, which served as basis for preparation of the selective collection project. Currently the campus has an adequate amount of selective collection bins available in all environments. Recyclable garbage is collected and stored in containers in order to be collected weekly by a trash cooperative. A project still under development aims to compost all of the organic garbage produced on campus, including the university restaurant.

Food is provided by a university restaurant and a snack shop, however there is no university control over, for example, the option for agro-ecological food or locally produced by family farming, as there are no sustainable purchasing strategies.

There is bus transport from the center of Brasilia to the campus that runs through the four campuses of the University of Brasilia. Despite this, there continues to be an increase in the number of cars in the parking lots, although there is some effort of the academic community to practice a ride culture. Although most students and staff reside in the surroundings of the campus, the occurrence of bicycles is very low, which may be related to the absence of bike lanes in the city of Planaltina.

One potential silver-lining is the fact that the campus has an area of 29.5 hectares that shelters vegetation of cerrado (regional biome with savannah-like vegetation) with high plant and animal diversity. The campus is surrounded by an urban Ecological Park, the Sucupira Park, and the Ecological Station of Águas Emendadas, of 10 thousand hectares, which is one of the main areas of cerrado conservation in the Federal District. This presents a challenge and also an opportunity to apply for resources that could build sustainable architecture and urbanism. This would help to develop campus physical structure in line with the conservation of this natural environment. In 2017, the academic community on campus is being invited to participate in the discussion of such possibilities through the preparation of the campus' Master Plan.

In 2016 an electronic information system (SEI) was implemented throughout the University, however no studies were yet performed on the environmental impact of the SEI in the reduction of paper consumption.

### 2.5 Outreach

Layrargues and Dourado (2011) verified that there was a balance between the 15 extension projects registered in FUP at the time of their study. Exactly one third of them belonged to each of the three classes of occurrence of the environmental issues defined by authors: high, medium and low. As in the case of research projects, it is necessary to seek an update on these data in view of the campus growth in recent years and the establishment of laboratories and long-term projects such as the InovaCerrado Project, the Parque Sucupira Project, and the Research Laboratory in Social Sciences, Qualitative Methods and Social Mobilization (LaPCIS).

Since the beginning of its operation, FUP has been notable for the strong outreach action, being the second unit with the largest number of extension projects in the whole university. But the bureaucratic requirements have reduced the number of officially registered projects. There is little integration between projects and also a reduced cooperation with companies, producers and schools regarding the potential associated to sustainability.

Currently, the extension has been strengthened through the support of the structure and support team, in addition to the creation of a campus extension board and the expansion of participation in the organization of the campus outreach actions. As a result, the number of projects increased to 33 in 2017, of which 9 were directly related to sustainability.

Another strong point is the existence of a formal Community Council that includes representations from various sectors of society. However, the council's activities are still incipient, with few meetings a year and few concrete actions.

### 2.6 Assessment and Reporting

An annual reporting management tool has been improving since a few years ago; however, it does not address sustainability as a specific point. Thus, there are no indicators or monitoring of sustainability actions.

### 2.7 Sustainability Experiences on Campus

A highlight of the campus is the aforementioned contiguous area of native cerrado vegetation that provides an improved quality of life, as evidenced by the climate and the presence of various birds, as well as pave the way for teaching, research and extension in contact with nature. The cerrado is also present in the green areas of the campus between the buildings. This enables educational and sensorial experiences in the natural environment.

The most obvious sustainability actions in the daily life of the campus are the projects that collect cooking oil for soap production, the agroecological product fair, the practice of selective collection, and several lectures and debates on environmental issues.

The culture of participation is one of the hallmarks of FUP (Bizerril 2015). As a way to enable participation in management, at least twice a year a meeting is held with all teachers and staff, and another with students, to evaluate and plan aspects of campus management. Teachers, staff and students participate as advisors in the monthly meetings of the FUP Council. It is here where, besides the talking points of the day-to-day bureaucratic management, strategic planning discussions are generate that relate to sustainability issues as a mission of the FUP.

## 3 Conclusions: Challenges and Opportunities for the Campus

The analysis presented in this paper is based on the perspective of a single campus teacher, who is currently the campus director. This may have generated limitations and bias in describing some of the aspects considered on campus sustainability, but it did not prevent the study from providing a good overview of campus performance.

The campus' strengths are research, outreach, participation in management and, above all, the Institutional Pedagogical Political Project. This project reflects the intentionality of the campus in relation to sustainability and is in line with the main and current recommendations of the international literature for an effective and complex performance as a Sustainable University. However, it was recommended that the campus expands spaces for pedagogical discussion, implements an environmental management system, invests in sustainable buildings and strengthens sustainability experiences on campus. All of these actions are based on strengthening the participation of the community council which is made up of members from Planaltina.

In order to do so, it is necessary to mobilize the diversity of knowledge and skills of staff, teachers and students in order to guide the conduct of the academic community towards sustainability. Two actions with strong mobilizing power are the preparation of the Master Plan of the FUP and the revision of the campus regiment (in progress since 2017). We believe that these two actions, involving the spatial planning and formalization of rules and missions with a view to the future of the campus, can result in significant impacts to strengthen the practice of sustainability since conducted through successful participatory processes.

It is recommended to expand the analysis on the performance of new campuses regarding sustainability in order to map the actions that can influence the university system as a whole. The FUP experience can be seen as a stimulus for other new campuses on the path of transition to a sustainable university.

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## Author Biography

**Marcelo Bizerril** is Associate Professor at the University of Brasilia (UnB), with a doctorate in Ecology from the University of Brasilia, and a post-doctorate in Policy and Management of Higher Education from the University of Aveiro (Portugal). Over the last two decades, he has been developing a research program on sustainability in formal and non-formal Environmental Education Programs, Science Teaching, and Higher Education Administration. He is a researcher in the Postgraduate Programs in Environment and Rural Development (PPGMADER) and Science Education (PPGEDUC) of UnB. Currently, he is the director of the University of Brasilia in Planaltina-DF (Faculty UnB Planaltina), a position he has held between 2007 and 2012.

# UFRJ Campus: A City of Innovative Mobility

**Richard M. Stephan, Carlos Levi and Pablo Benetti**

**Abstract** In 2009, the general development plan for the Federal University of Rio de Janeiro (Plano Diretor UFRJ 2020 in Portuguese) was approved for the period between 2009 and 2020. A significant effort was made to incorporate in-house innovative solutions as much as possible. Such strategy was supposed to (1) directly benefit the University with solutions created within its own research programs; (2) serve as a privileged showroom of its potential contributions to the community; and (3) pioneer applications that may be adopted in urban areas in the near future. UFRJ's main campus is located in an island, with an area of circa 5.2 km$^2$, 5 km in length and 1 km in width. Its daily population is estimated in 60,000 persons, including students, faculty, technical, administrative and support workers, and visitors. More than 25,000 vehicles circulate every day along its main avenues. Besides the university buildings and installations, 15 other research centres are also located in the campus. These features provide the ideal conditions for UFRJ's main campus to become a lively and efficient laboratory of a smart city of the future. The synergy generated by the interdisciplinary and multidisciplinary knowledge can be maximised by turning the Plano Diretor UFRJ 2020 into reality. Based on such premises, an occupation plan was conceived. The main idea was to transform the

R. M. Stephan (✉) · C. Levi · P. Benetti
Federal University of Rio de Janeiro, P.O. Box 68504,
Rio de Janeiro 21941-972, Brazil
e-mail: richard@dee.ufrj.br

C. Levi
e-mail: levi@laboceano.coppe.ufrj.br

P. Benetti
e-mail: pablobenetti@gmail.com

 
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University Campus in part of the city creating urban spaces, integrating internal disciplinary areas and the University with the urban fabric nearly. Unfortunately, due to recent political unrest and a deep economic crisis that currently plague Brazil, the implementation of a significant part of the plan has been postponed. Nevertheless, the internal mobility project, featuring a Magnetically Levitated (MagLev) vehicle is going forward. This paper describes the development of the project, known as MagLev-Cobra, since the proof of its concept in the year of 2000, until its final implementation, due to 2020. The frame of technology development, established by NASA and known as Technological Readiness Levels (TRL's), will be used as reference. The cooperation between various university departments and companies, some of them spin-off incubated companies, will be stressed, as an example of the positive impacts from cooperative work in research, teaching, innovation and technological development.

**Keywords** Cities of the future · Magnetic levitation · Transportation
Green energy

## 1 Introduction

The main campus of the Federal University of Rio de Janeiro is located in an island with approximately 5.2 km$^2$. In 2009, the occupation of this space has been planned as an example of a city of the future, profiting from the knowledge generated by the research carried out in the academic activities. The result is summarized in the so called Plano Diretor 2020 (UFRJ 2009). Figure 1 depicts a global view of the proposed study.

In this figure, crossing the island, along the central avenues and indicated in dashed purple color line, it is possible to recognize a MagLev line. The plan is to use the project of a magnetically levitated (MagLev) vehicle, developed at the university and named as MagLev-Cobra, to offer the internal mobility inside the campus and, in the future, connecting the campus with the city. Presently this MagLev system runs in an experimental line 200 m long. The present paper will describe this development and the future steps for its implementation.

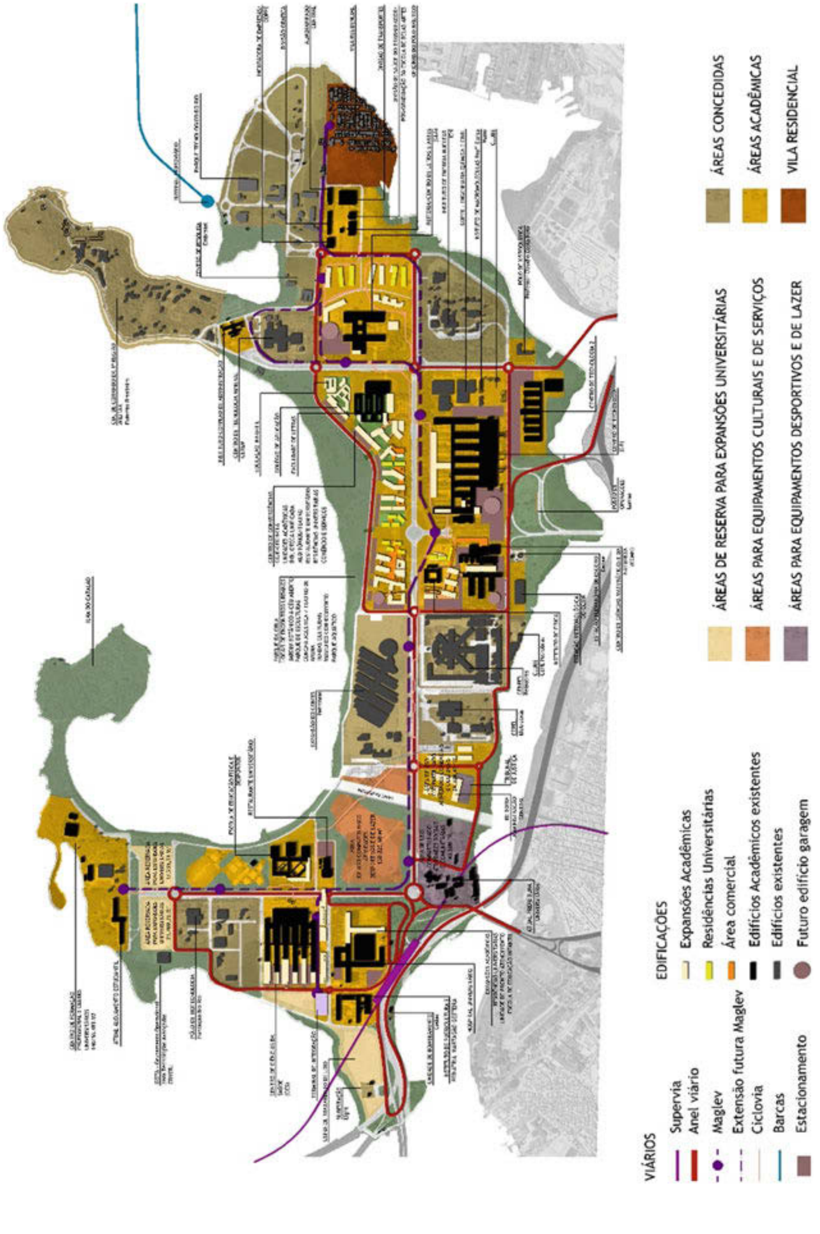


**Fig. 1** Occupation plan of the Federal University campus in Rio de Janeiro

## 2 UFRJ General Development Plan (Plano Diretor UFRJ 2020): A Short Description

The UFRJ General Development Plan for 2020 is based on the idea that the University must be fully committed to research and to finding innovative solutions. Therefore, the University must make explicit these values by incorporating pioneering technical advancements and transformational policies within its own campus.

From an urbanistic and architectural point of view, the influence from the Modern movement of the 1940s and 1950s is clearly noticeable all throughout the campus of UFRJ in the form of its wide open spaces and in its semi-monumental buildings. However, this model of urban occupation has not favored much academic integration and articulation between the different academic centers and schools of UFRJ. This goes directly against the current tendency in scholarly research based on intense exchange and integration between the different areas of scientific knowledge.

To cope with such a legacy, the General Development Plan for UFRJ focuses on improving internal mobility. In the paper, we present the MagLev project as a key component of the intra-campus transport system proposed in the UFRJ General Development Plan. Because of its pioneering and innovative features, and the fact that it has been fully developed by UFRJ researchers, the MagLev project is the ideal embodiment of the values expressed in the UFRJ General Development Plan.

## 3 The Challenge and the MagLev-Cobra Solution

Nowadays, a great part of the world population lives in big cities. Therefore, non-polluting, environmental friendly, energetically efficient public transportation is a social, technical, political and economic priority.

Subways are still considered a paradigm. Nevertheless, underground construction costs in the order of US$ 100 M/km turn this option extremely expensive and time consuming. The MagLev-Cobra technology offers a quicker solution by at least 1/3 of the price.

MagLev-Cobra is a vehicle with multiple short units, allowing curves of 50 m radius, ramps of 15% and velocities up to 70 km/h. When these short units are connected, the vehicle resembles a ‘snake’ or ‘cobra’ in Portuguese.

The levitation technology is based on the properties of High Temperature Superconductors (HTS) and the magnetic field of Nd–Fe–B magnets. These materials were made available at the end of last century and until today there is no such system in commercial use.

A linear motor gives the traction. Since this propulsion method only needs electric energy, which is mainly generated by hydro power plants in Brazil, the MagLev-Cobra has low polluting effect. Due to the low noise emission level, the vehicle can run inside cities on elevated structures. Moreover, the energy consumption and the maintenance costs are lower than that of a LRV (Light Rail Vehicle) since no mechanical contacts and rotational parts are necessary.

The proposed vehicle gives a futuristic view along its way, matching high technology, modern design, environmental restrictions and social requirements.

Maglev-Cobra technology is summarized in Fig. 2. The vehicle is traveling on an elevated line and does not disturb the city life. In the center, is the secondary of the Linear Induction Motor (LIM) used for traction. To the right and left of the linear motor, are the lines of permanent magnets. The highlight shows the cryostat (high quality thermos bottles) inside of which are superconductors cooled with liquid nitrogen at minus 196 °C, providing a levitation height of the order of 1 cm.

In summary, being electrically driven and completely independent of friction, wheels, rails and trucks, this medium speed (<70 km/h) vehicle offers the following advantages, when compared with conventional LRV (Light Rail Vehicles) or Metros:

- Silent
- Non-polluting
- Lighter
- Operational radius of 50 m
- Operational ramps of 15%
- Lower construction costs due to the reduction of tunnels (Metro) or expropriation and interference areas (LVR)
- Estimated lower maintenance and operational costs due to no contact, lower friction and energy consume.

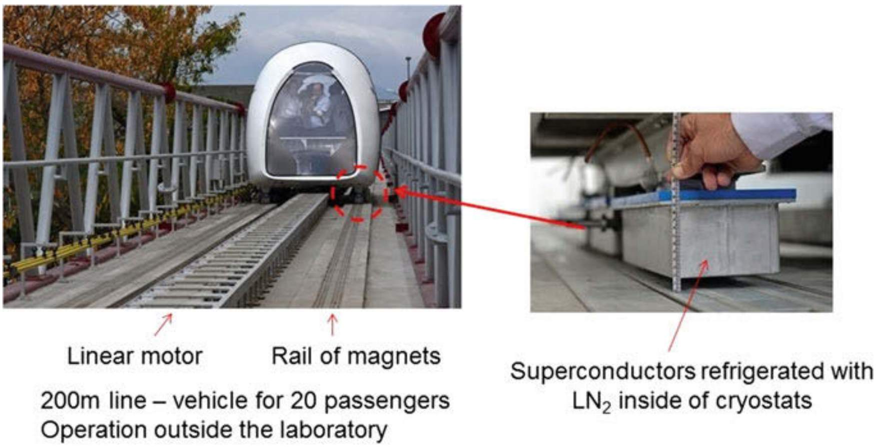


**Fig. 2** Graphical abstract of the MagLev-Cobra project (Stephan et al. 2017)

## 4 Magnetic Levitation Methods and MagLev in the World

There are three main levitation methods applied to MagLev transportation systems: Electromagnetic (EML), Electrodynamic (EDL) and Superconducting (SML). EML and EDL are based, respectively, on unstable attractive and repulsive forces and are applied since the sixties of last century. The method used in MagLev-Cobra (SML) is relatively new ($\sim$1990) and is based on stable forces between superconductors of type II and rare earth permanent magnets.

Besides that, the MagLev technology has two main groups: High-Speed MagLev (TAV) and Urban MagLev (Schach et al. 2006; Liu et al. 2015; Han and Kim 2016). Figure 3 shows the location of projects with full scale or, at least, laboratory prototypes able to transport people all over the world.

There are two other projects using the same levitation technique (SML) of MagLev-Cobra: historically the first in China, Chengdu (Wang et al. 2003), and another in Germany, in Dresden (Schultz et al. 2005). They are still inside laboratories and carry just one or two people, respectively.

It is also worth noting that four projects are already deployed in commercial operation: a high-speed, in Shanghai, China, and three urban, in Nagoya, Seoul and Changsha. All of them employ EML technology. A fourth urban EML line, 10.2 km long, will start operation in December this year in Beijing (Rail News 2017).

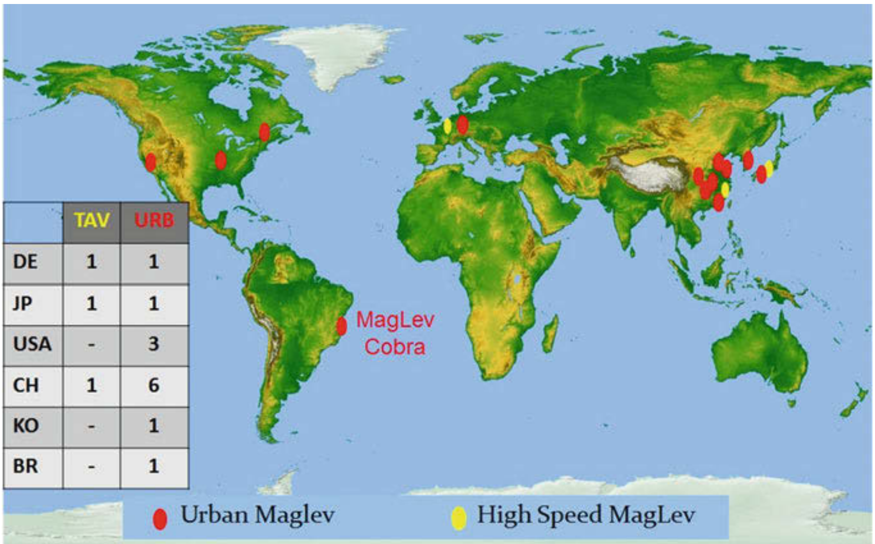


**Fig. 3** MagLev projects in the world (Stephan et al. 2017)

## 5 Comparison of the Magnetic Levitation Methods for Urban Transportation

Table 1 presents the main urban MagLev deployments in the World, highlighting the country, the owner, the levitation method, the type of traction and some observations regarding the length of the track. The projects in commercial operation are indicated in italic.

The EDL method is appropriate for high speed operation, since the levitation is based on repulsion forces that increase with velocity and are big enough just up a certain velocity. For instance, in the high speed MagLev project in Japan, this velocity is in the order of 100 km/h. There is an effort in USA to apply the EDL technology for low speed MagLev, but Table 1 confirms that the majority of projects apply EML. Therefore, the following paragraphs will focus on the comparison between SML and EML.

Figure 4 compares the infrastructure of the urban MagLev projects operating commercially with the MagLev-Cobra elevated line that has a willowy engineering construction, due to the lower total weight of the SML vehicle.

Figure 5 compares the levitation equipment necessary for the EML technology with the levitation method (SML) of the MagLev-Cobra project.

**Table 1** Urban MagLev projects in the world (Stephan et al. 2017)

| Country | Project | Levitation | Traction | Details |
|---|---|---|---|---|
| USA | AMT | EML | LIM | Geórgia—ODU (1 km) |
| | GA | EDL-PM | LSM | Califórnia (500 m) |
| | MagneMotion | EML-PM | LSM | Massachusetts (30 m) |
| Japan | *HSST-Linimo* | *EML* | *LIM* | *Nagoya (9 km), since 2005* |
| China | *State-owned* | *EML* | *LIM* | *Changsha (18.5 km), since 2016* |
| | *State-owned* | *EML* | *LIM* | *Beijing (10.2 km) up December 2017* |
| | State-owned | EML | LIM | Shanghai (1.7 km) |
| | State-owned | EML | LIM | Tangshan (1.5 km) |
| | State-owned | EML | LIM | Zhuzhou (1.5 km) |
| | Jiaotong Uni. | **SML** | LIM | Chengdu (45 m) |
| South Korea | *KIMM* | *EML* | *LIM* | *Incheon Airport (6.1 km), since 2016* |
| Germany | IFW | **SML** | LIM | Dresden (80 m) |
| Brazil | UFRJ/COPPE | **SML** | LIM | Rio de Janeiro (200 m) |

LIM—Linear induction motor; LSM—Linear synchronous motor
PM—Permanent magnet
EML—Electomagnetic Levitation
EDL—Electrodynamic Levitation
SML—Superconducting Magnetic Levitation


**Fig. 4** Comparison of the elevated lines of the EML urban MagLev projects in commercial use and the MagLev-Cobra (SML) elevated line: slimmer structure

**Fig. 5** Comparison of the equipment necessary to achieve EML (left side) with the cryostats necessary for the MagLev-Cobra (SML) project (right side): simpler and more robust

**Table 2** Comparison of EML and SML methods for Urban MagLev

| | EML | SML (MagLev-Cobra) |
|---|---|---|
| Civil engineering construction | ☹ | ☺ |
| Levitation: weight/ simplicity | ☹ | ☺ |
| Cost of rails | ☺ | ☹ |

The simplicity of the SML method, that uses superconductors inside of cryostats above magnetic rails in a stable configuration, is evident in comparison with the EML method that needs huge electromagnets, power electronics actuators, feedback control and backup power supply to stabilize a naturally unstable system.

The main disadvantage of the SML method is the cost of the permanent magnets. In fact, the refrigeration of the superconductors with liquid nitrogen requires special attention in the SML method, but this challenge is under control due to high quality cryostats, that keep the liquid state for 24 h, and the automation of the filling process, that must be carried out every day. These considerations are summarized in Table 2.

## 6 The Development of a New Engineering Product

The development of any new engineering product can be generally divided in four steps:

Step 1: Proof of concept
Usually a small scale prototype consolidates this step. Universities are probably the best place for this initial development.
Step 2: Functional prototype
Here a full scale prototype must be constructed and many engineering problems are already faced: the product design, the construction methods, the industrial partners, the financial support. This phase is prone of possibilities for patent applications.
Step 3: Operational tests
The full scale prototype is not enough. The operational characteristics must be known and well tested. In other words, the equipment must be certified. In the specific case of a transportation vehicle, safety issues are a main concern: what happens if there is a brake failure, if there is a short circuit, if there is a storm, if the door does not close or open, if there are too many passengers, and many other questions.

Step 4: Industrialization
Finally, the series production and commercialization can start. This last step represents a big challenge and by no means a trivial one. Usually it begins with a first product. The man force, the money, the difficulties, everything increases at each step.

## 7 The Development of the MagLev-Cobra Project

The origin of the MagLev-Cobra Project can be traced back to the year 2000. At the 16th International Conference on Magnetically Levitated Systems and Linear Drives, MAGLEV'2000, Rio de Janeiro, the paper "The Brazilian Project for a Superconducting Magnetic Levitation Train" announced the basic concept of the proposal (Nicolsky et al. 2000). Following this initial step, a small scale prototype, in closed loop 30 m long trajectory, was constructed and reported in MAGLEV'2002 (Nicolsky et al. 2002) and MAGLEV'2004 (Stephan et al. 2004). The full scale prototype, still operating inside the laboratory hangar, was finished in 2011 and reported in MAGLEV'2006 (Stephan et al. 2006), MAGLEV'2008 (Stephan et al. 2008) and MAGLEV'2011 (Stephan et al. 2011). Three years of intensive work led to an operational prototype, constructed in the University Campus, a 200 m long line, with the capacity to carry 20 passengers presented on the last day of the 22nd MAGLEV Conference in Rio de Janeiro, in 2014. After this conference, another year of improvements was necessary to open this test line for regular visits every Tuesday (Stephan et al. 2016). Since then, more than 9000 passengers had the opportunity to travel inside the MagLev-Cobra vehicle. Some data of this experience are summarized in Table 3. The next step is the construction and operation of the first certificated and final use product, the 5 km long system inside the university campus described previously.

**Table 3** Main characteristics of the MagLev-Cobra experimental line

| | |
|---|---|
| Capacity | 20 passengers = 5 pass./$m^2$ |
| Cruise speed | 10 km/h |
| Line extension | 200 m |
| Declivity | 1% |
| Traction | Linear induction motor—short primary |
| Vehicle external dimension | H = 2.8 m; W = 2.3 m; L = 6 m |
| Levitation force per cryostat | 250 kgf |
| Total number of cryostats | 24 |
| Liquid nitrogen consumption per day | 480 L $\sim$ 80 US$ |
| Electric energy consumption per round trip | 0.1 kWh |

## 8 NASA's Technology Readiness Levels

The readiness evaluation of a technology is established more accurately by NASA in 9 levels (USA 2011a, b), as shown in Table 4. The correspondence of this classification with the 4 steps above mentioned can be established, for the MagLev-Cobra technology.

*Step 1* [TRL 1–2–3] (2000–2006) was concluded in 2006. A small scale prototype that run in a 30 m long closed loop track (Stephan et al. 2005).

*Step 2* [TRL 4–5] (2008–2012). The gap of two years between these steps is due to difficulties to raise funds. In fact, US$1 M were necessary for this part, approximately 10 times more than the money applied in step 1. It consists of a 12 m long line to verify the technical characteristic of the system. The vehicle is a full scale module inside the laboratory (Sotelo et al. 2014).

*Step 3* [TRL 6–7] (2014–2016). Based on the experience of step 2, the next move tested the operation of the vehicle in everyday use. For that, a line of 200 m connecting two units of the Federal University of Rio de Janeiro has been constructed (Stephan et al. 2015).

*Step 4* [TRL 8–9] (starting in 2017). After the improvements that will result from the experience of step 3, the technology will be mature for the construction of the first product (the 5 km line inside the university campus) and the commercialization.

Figure 6 summarizes this evolution and correspondent TRL evolution (Stephan 2017)

**Table 4** Technology readiness levels

| | |
|---|---|
| TRL1 | Basic principles observed and reported |
| TRL2 | Technology concept and/or application defined |
| TRL3 | Proof of concept validation |
| TRL4 | Validation in laboratory environment |
| TRL5 | Validation in a relevant environment |
| TRL6 | Validation in a relevant final environment |
| TRL7 | Validation in an operational environment |
| TRL8 | "Mission qualified" trough test and demonstration |
| TRL9 | "Mission proven" trough successful mission operations |

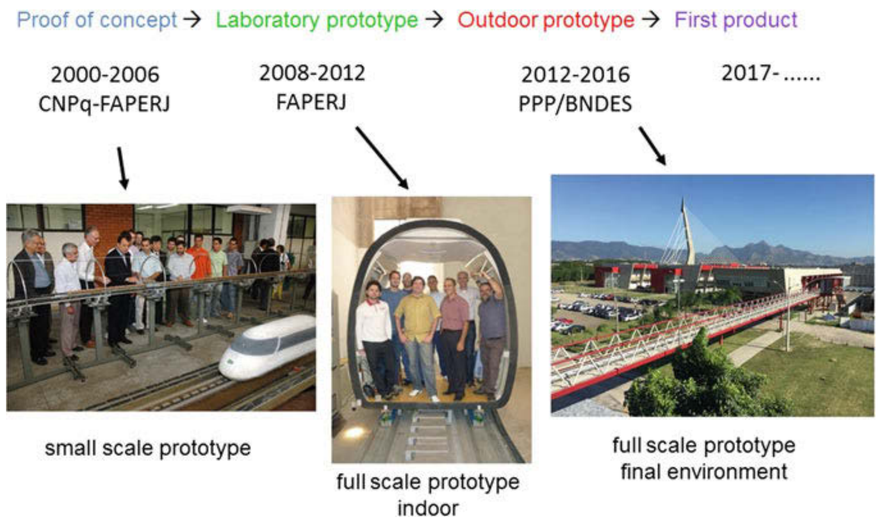


**Fig. 6** The development of the MagLev-Cobra project according to NASA's TRL. (Stephan et al. 2017)

## 9 Conclusion

MagLev-Cobra is a promising technology for Urban Transportation. Moreover, this project unfolds many opportunities, for instance: the production of rare earth magnets; the production of superconductors; the development of power electronic converters and linear motors; the magnetic bearings technology and the production of Light Rail Vehicles. The real scale prototype is a life laboratory for research and development works. The project has already received support from the Civil, Mechanical, Chemical, Materials, Transportation, Naval, Energy and Industrial Engineering Departments, besides the Physics and Architecture schools. Four spin-up companies, grounded by former students, took part of the project. With the weekly operation of the MagLev-Cobra experimental line in the campus of the Federal University of Rio de Janeiro, it will be possible to fulfil the requirements necessary for the construction of the line inside the UFRJ campus and to boost innovation and creativity.

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# Turning Waste into Power: Michigan State University's Anaerobic Digester

**Wolfgang Bauer**

**Abstract** As part of its ambitious Energy Transition Plan towards 100% renewable power Michigan State University (MSU) built an anaerobic digester facility in 2013. Annually it consumes approximately 22,000 metric tons of organic waste, predominantly food waste from the MSU cafeteria system and animal excrements from the MSU farms, and turns them into biogas and digestate. The digestate is a high quality organic fertilizer and replaces chemically produced fertilizers for MSU's farm fields, which saves money at the same time that it conserves valuable resources. The biogas is combusted in high efficiency reciprocating engines and produces a constant electric power of 300–500 kW. The digester facility also serves as a living classroom for a wide variety of student groups: it hosts thesis projects for graduate students and senior undergraduate students in bio-systems engineering and other engineering and agriculture disciplines, it serves as a laboratory for regularly scheduled undergraduate classes, and it is a popular destination for K-12 school field trips. Thus the MSU anaerobic digester facility serves the entire sustainability education and outreach spectrum, in addition to its sustainability scholarship, research, and practical application purposes.

**Keywords** Sustainability · Renewable power · Waste reduction
Biogas · Education

## 1 Introduction: Sustainability at Michigan State University

Michigan State University was founded in 1855 as the premier Land Grant University, is one of the 62 members of the Association of American Universities, and is generally recognized as one of the top-100 universities in the world.

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W. Bauer (✉)
Department of Physics and Astronomy, Michigan State University,
426 Auditorium Road, Suite 412, East Lansing, MI 48824, USA
e-mail: bauerw@msu.edu



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Its contiguous campus has a size of 21 $km^2$, of which 8.1 $km^2$ are developed and occupied by 545 buildings, 103 of which are used for instruction. The campus serves over 50,000 students and employs almost 12,000 faculty and staff members.

In 2009, recognizing the long-term problems of global warming, environmental damage, resource depletion, and sustainability, MSU assembled a leadership team to develop a long-term energy transition plan, and the current author was a member of this team. MSU's Board of Trustees adopted this plan in April of 2012 (MSUETP 2012). At the core of this plan are the triple mandates to improve the physical environment, to increase research in renewable energy, and to cement MSU as an educational leader in sustainability. The plan establishes a long-term vision of a transition to 100% renewable energy and intermediate term concrete goals of greenhouse gas emission reductions and renewable energy contributions by target dates of 2015, 2020, 2025, and 2030. These are summarized in Table 1.

Operating under the boundary conditions of cost, capacity and reliability, health and environmental impacts, MSU subsequently started to invest in a large number of high-impact energy and sustainability projects. Some of these projects address the energy and resources demand side via the Spartan Energy Treasure Hunt, participation in the US Department of Energy's Better Building Challenge, construction of a new central MSU data center with power utilization effectiveness of $PUE < 1.3$, an aggressive revamping of the campus steam traps, replacement of incandescent light bulbs with LED lighting, and many others.

Other projects address the emission of green house gases, first and foremost among them the replacement of coal as the primary fuel source for the campus power plant with natural gas, which is saving an annual emission of over 250,000 metric tons of carbon dioxide. Yet other projects are dedicated to the resource conservation, repurposing, and recycling, among them the construction of the state-of-the-art campus recycling center and surplus store. And finally, there is an array of projects designed to included renewable energy resources into the campus power and heat generation portfolio, such as a 11-MW solar array which was completed in December 2017, the vertical geothermal array used to heat the College of Nursing building, and the south-campus anaerobic digester.

It is important to realize that sustainability does not necessarily have to imply giving up financial benefits in order to conserve resources or energy. Instead, all of the above projects carry with them monetary savings and position MSU to be in a better financial position. This fiscal year between 6 and 7% of the entire power and water operations budget will be returned to general funds, allowing MSU to keep

**Table 1** Goal timetable of the MSU energy transition plan

| | % Campus renewable energy | % Greenhouse gas emission reduction |
|---|---|---|
| FY2015 | 15 | 30 |
| FY2020 | 20 | 45 |
| FY2025 | 25 | 55 |
| FY2030 | 40 | 65 |

tuition low. In fact, we claim that financial sustainability and environmental sustainability need to be coupled tightly. Otherwise environmental sustainability efforts do not make a lasting contribution and are doomed to fail in the long run. Bauer et al. (2016) give an overview of these sustainability projects and their impact on teaching/learning and scholarship, but here we wish to focus on the digester project.

## 2 MSU's South-Campus Digester Facility

In August 2013 MSU officially opened the South Campus Anaerobic Digester (SCAD) facility. The anaerobic digestion process uses microbes like those found in the digestive tract of farm animals to convert organic materials into biogas. The relevant biochemical reactions proceed in the absence of oxygen, which makes them anaerobic. Biogas is a mixture of predominantly methane ($CH_4$) and carbon dioxide ($CO_2$), typically in a 60/40 mixture. Biogas can be turned into electricity and heat by using it to fuel high-efficiency internal combustion engines that drive generators.

The main component of the MSU anaerobic digester facility is an aboveground 1700 $m^3$ steel tank where the blended feedstock is homogenized and kept at a temperature of approximately 38 °C, optimal for the digestion process. Two large submerged hydraulically powered mixers are used to make sure the blended feedstock does not separate and form a solid top layer, which would prevent the biogas from escaping and would shut the digestion process down. The system is designed for a 25-day retention time, during which the feedstock develops biogas (Fig. 1).

The biogas powers a 450 kW combined heat and power system, the heart of which is an internal combustion engine. A small fraction of the electricity generated by the engine and the electrical generator it drives is used to supply the mechanical and electrical systems of the digester facility, and a small fraction of the heat generated by the engine is used to heat the feedstock and the digester content to the optimal operating temperature.

The remaining digestate is a liquid-solid mixture organic fertilizer, which can be spread on crop fields and contains all of the essential nutrients for plant growth. This contributes to making the MSU farms more sustainable, because they require significantly less chemically produced fertilizers. Noteworthy is also that field application of this fertilizer emits significantly less odor as compared to conventional manure spreading techniques, because the biogas with trace aromatic compounds has already been captured in the process.

The majority of the world's biogas producing anaerobic digester systems uses energy crops such as corn as the main organic feedstock. In order to generate enough feedstock for a facility of the scale of our digester one typically needs to harvest approximately 100 hectare of energy crops. This is an excellent way to generate electricity and biofuels and is significantly more efficient (Bauer 2013, 2015) than using corn for bioethanol production purposes (Pimentel and Patzek 2005;


**Fig. 1** MSU south campus anaerobic digester. The large tanks in the background are the digester and digestate storage tanks; the lidded containers in the foreground are used for feedstock delivery

Liska et al. 2009). On the other hand, growing energy crops for biogas production only partially eliminates the problem of land use (Searchinger et al. 2008) for energy production, the famous "food vs. fuel" dilemma. This is of particular concern when replacing fossil fuels with biofuels for transportation purposes (Ohlrogge et al. 2009). MSU's digester facility, by contrast, uses only animal excrements and organic food waste products as feedstock. In this way the digester facility completely sidesteps the "food vs. fuel" debate. It also keeps food waste out of the landfill, which makes another significant contribution to sustainability and reduction of greenhouse gas emissions. This is because organic waste decaying in landfills emits methane into our atmosphere, which is a much more potent greenhouse gas (by a factor of 20–50) than the carbon dioxide resulting from the combustion in the reciprocating engine of our digester facility.

## 3 Food and Animal Waste at MSU

MSU has one of the largest residence hall systems in the United States, housing 14,500 students on campus. The 10 campus dining halls provide an average of 35,000 meals per day to students, faculty and staff. Several hundreds of tons of

**Table 2** MSU South Campus Anaerobic Digester Feedstock

| Feedstock | TS (%) | Planned | | 2014 | | 2015 | | 2016 | |
|---|---|---|---|---|---|---|---|---|---|
| | | (tons) | (%) | (tons) | (%) | (tons) | (%) | (tons) | (%) |
| Dairy manure | 12 | 7000 | 43 | 16,000 | 67 | 9525 | 43 | 10,554 | 52 |
| Fruit and vegetable | 11 | 3900 | 24 | 2900 | 12 | 2900 | 13 | 0 | 0 |
| Fats, oil and grease | 20 | 5000 | 30 | 4400 | 19 | 3730 | 17 | 4747 | 23 |
| Cafeteria food waste | 10 | 750 | 3 | 430 | 2 | 440 | 2 | 513 | 3 |
| Milk process waste | 12 | | | | | 5475 | 25 | 4444 | 22 |
| Packing material | 90 | | | | | 60 | – | 34 | – |
| Glycerin | 15 | | | | | | | 88 | – |
| Total | | 16,650 | | 23,730 | | 22,070 | | 20,380 | |

organic waste per year are resulting from food preparation waste and post-consumer waste, i.e. table scraps, as well as food, which was prepared but not eaten, and which has to be discarded.

Fruit and vegetable from MSU as well as large grocery chains in the community are other organic waste products, which normally would end up in landfills, but which provide very valuable digester feedstock. Of particular high energy content are fats, oils, and grease, which are waste products from restaurant operations.

Michigan State University's College of Agriculture has teaching and research centers for beef cattle, beef cow-calf, dairy, horse, poultry, sheep, and swine. Each of these centers house hundreds of farm animals, which produce manure in copious quantities. The manure, in particular from the dairy operation, provides the bulk of the feedstock for the digester, approximately half of the total input tonnage. Table 2 shows the initially planned input quantities for the digester, as well as the actual annual numbers for 2014–2016. The entry row for 'milk process waste' is a good example for how the feedstock input into the digester can be and is dynamically adjusted as a function of available organic waste supplies.

## 4 Sustainability Education at the MSU Digester Facility

Absolutely essential for a university environment is that a state-of-the-art facility is not just used as a piece of infrastructure, but instead also finds purpose in research and teaching. The wide variety of research projects includes several Master's and Ph.D. thesis projects, predominantly in the Biosystems and Agricultural Engineering department of the College of Agriculture, which is also the MSU department operating the digester facility.

The digester facility also serves as a living classroom of practice for the entire spectrum of K-16 education. In the school systems of the surrounding communities the digester facility serves as popular field trip destination, where school children can get a first-hand impression of the practical implementation of sustainability.

A large variety of undergraduate classes take advantage of the on-campus digester facility as well. In the College of Natural Science there is a Freshmen Seminar on Green Chemistry. In the Lyman Briggs College there is a Senior Seminar on Renewable Energy (LB 492). In the Department of Crop and Soil Science there are classes on BioEnergy Feedstock Production (CSS 200, CSS 467). And of course the Department of Biosystems and Agricultural Engineering makes extensive use of the digester facility, using it for classes on Engineering Analysis of Biological Systems (BE 230), Biomass Conversion Engineering (BE 468), Biosystems Design Techniques (BE 485), and Biosystems Design Project (BE 487).

## 5 The Future of Anaerobic Digestion

Collecting food waste provides significant logistical challenges, and not all of these are solved at the present time. For example, food service personnel occasionally throw rubber or latex gloves into the collection bins for food preparation scraps, which constitute a significant contamination. Trying to collect post-consumer table scraps can also lead to serious contamination due to silverware being discarded into the collection bins by mistake. Better training is part of the answer, but automated pre-processing systems of the food waste are also contemplated at present. Once these problems are solved we should be able to double the volume of organic food waste collected from our cafeterias and keep more organic material out of the landfills.

In order to solve the steady rise of greenhouse gases in our atmosphere (Keeling 1960) and associated climate problems without a reduction in prosperity a large combination of approaches and technologies is needed (Pacala and Socolow 2004). Anaerobic digestion of biomass, both from energy crops and from organic waste, can make a very significant positive difference. MSU will work on research to advance the state of the art in this field, and MSU is also committed to continue and expand the work in sustainability education on the use of anaerobic digestion.

In particular in the Brazilian context we can envision the use of anaerobic digesters to help with the problem of raw sewage entering waterways, as well as using bagasse for biogas production. Bagasse is what remains of sugarcane after the juice, which is used for gasohol production (Gomes da Silva et al. 1978), has been extracted. Currently bagasse is incinerated for electricity and heat production (Macedo et al. 2008). However, use of digesters may yield higher power output while dramatically reducing PM 2.5 and soot emissions. First conversations about a pilot plant are in progress.

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### Author Biography

**Wolfgang Bauer** is a University Distinguished Professor at Michigan State University (MSU). He received his Ph.D. in physics from the University of Giessen in Germany in 1987. After a one-year postdoctoral appointment at the California Institute of Technology, he joined the faculty at MSU in 1988, with a dual appointment at the National Superconducting Cyclotron Laboratory. From 2001 to 2013 he served as chairperson of the Department of Physics of Astronomy, and in 2009 he became the Founding Director of the Institute for Cyber-Enabled Research. He has consulted on energy issues for hedge funds and oil companies, and he is co-owner of several companies in the renewable energy sector. He is the author of three introductory physics textbooks, which have been translated into German, Korean, Portuguese, and Spanish languages. His current position is Senior Consultant in the Office of the Executive Vice President, which he has occupied since 2013.

# Teacher Training in Environmental Education and Its Relation with the Sustainability Culture in Two Undergraduate Degrees at USP

**Rosana Louro Ferreira Silva, Denise de La Corte Bacci, Isabela Santos Silva, Diego de Moura Campos, Lillian da Silva Cardoso, Livia Ortiz Santiago and Daisy Pinato**

**Abstract** This study is part of a larger interdisciplinary research on environmental education (EE) in teacher training degrees of São Paulo University, including two undergraduate degrees and two researches institutes. The present research considers students as the subject of investigation and their socio-environmental perceptions. This data are hard to find at the University of São Paulo, drawing attention to the

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R. L. F. Silva (✉)
Department of Zoology, Biosciences Institute, University of São Paulo,
Rua Do Matão, Travessa 14, 101. Cidade Universitária,
São Paulo CEP 05508-090, Brazil
e-mail: rosanas@usp.br

D. de La Corte Bacci
Department of Sedimentar and Environment Geology,
Geosciences Institute University of São Paulo, Rua Do Lago 562.
Cidade Universitária, São Paulo CEP 05508-080, Brazil
e-mail: bacci@usp.br

I. S. Silva · D. de Moura Campos · L. O. Santiago
Biosciences Institute, University of São Paulo, Rua Do Matão,
Travessa 14, 101. Cidade Universitária, São Paulo CEP 05508-090, Brazil
e-mail: ss.isabela@gmail.com

D. de Moura Campos
e-mail: diego.moura.campos@gmail.com

L. O. Santiago
e-mail: livia.o.santiago@gmail.com

L. da Silva Cardoso · D. Pinato
Geosciences Institute University of São Paulo, Rua do Lago 562.
Cidade Universitária, São Paulo CEP 05508-080, Brazil
e-mail: lillian.cardoso@usp.br

D. Pinato
e-mail: daisy.pinato@usp.br



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potential that researches like these have for contribuiting to develop of more robust environmental culture. The driving question in the context is: How pre-service teachers in biological sciences and geosciences identify their qualification in environmental education and sustainability culture? Data were collected with an online survey, divided into three sections: EE in the undergraduate degree; EE in the everyday; and EE on the campus. The questions were organized with 19 multiple choice questions and 6 open-ended questions about their EE knowledge, values and action or projects participation. 118 students participated and based on personal identification of one's own gender, we have, 65.3% female, 33.9% male and 0.8% identified as others. The results indicated that the dimensions of EE knowledge, values and means of participation were imbalanced in both courses. Students considered themselves environmentally educated but their environmental performance is steal weak, far from sustainability purposes. Data also indicated that university extramural activities are essential in the environmental education process involving students that can develop the desire and the capacity for lifelong learning. EE in the curriculum at universitary courses and improve students participation in reaserch projects are also important to foster better learning opportunities to their students.

**Keywords** Environmental education · Higher education teacher training
Sustainability · Curriculum greening

## 1 Introduction—EE and Sustainability in Higher Education

In this chapter we will present partial results of the research project "Environmental Education in the University of São Paulo undergraduate teaching degrees: courses, interdisciplinary practices and the construction of sustainability culture. *Funded by USP/Santander Grandes Temas, grants 2016*. The research seeked out the cathegorization of EE disciplinary and interdisciplinary practices in teaching degree undergraduated courses. As well as the identification of the formative processes perceived by the students, being this the analytical object of the present work from two undergraduate programs.

The importance of working with issues related to environmental education in higher education began to be institutionalized in 1986, when SEMA (Special Secretariat for the Environment) organized the first seminar called "University and the Environment" in Brasilia, DF. From that seminar, several other meetings were held on the theme in Brazil, highlighting: the importance of the University's participation in the formulation of solutions, within an interdisciplinary perspective on the environmental issue; The need for ethical-political reflection at university; The discussion about theoretical and methodological assumptions and their correlation with action strategies for solving environmental issues; The politics of environmental education based on the theme "University facing Brazilian Environmental Policy" (BACCI; SILVA; SORRENTINO 2015).

The Treaty of Environmental Education for Sustainable Societies and Global Responsibility, signed during the RIO 92, emphasized the importance of mobilizing higher education institutions for teaching, research and extramural activities (outreach) in environmental education.

In Brazilian context, and according to the National Policy for Environmental Education Law nº 9795/99 (Brazil 1999), Environmental Education will be developed as an integrated, continuous and permanent educational practice at all levels and modes of formal education. EE in higher education curriculum is optional and can consider methodological approach.

The national curriculum guidelines for Environmental Education, published in 2012, reaffirms the focus on methodological aspect:

> *Art. 16*. The insertion of knowledge concerning Environmental Education in the curriculum of Basic Education and Higher Education may occur: I - by transversality, through themes related to the environment and socio-environmental sustainability; II - as content of components already included in the curriculum; III - by the combination of transversality and treatment in the curricular components. *Single paragraph*. Other forms of insertion can be admitted in the curricular organization of Higher Education and in Technical Professional Education of Medium Level, considering the nature of the degrees …..

Considering world demands on sustainability knowledge, these issues are being gradually incorporated into university education, through different forms of professional development competence, specially in teaching degree courses. The current guidelines of the Ministry of Education address universities as sustainable educational spaces, where pedagogical practices are concrete references to socio-environmental sustainability. Thus, sustainability is an orientation to be internalized by the actions of teaching, researches, extramural projects and campus management (Silva et al. 2016).

The ACES Network (Curriculum Greening Network of Higher Education) was founded between 2001 and 2004. As part of their commitment to sustainable development, the "greening" of curricula is a major objective of universities worldwide. Ninety five universities from 35 countries took part in the 2010 version of Green Metric: 18 from the Americas, 35 from Europe, 40 from Asia and 2 from Australasia. In 2016 the ranking ranked 515 universities from 75 countries around the world, including USP. This network is committed to promoting the training of future professionals to social and environmental issues and changes to sustainability. A conceptual matrix concerned with the construction of plural theoretical language which respects the different cultural realities and their essentially interdisciplinary character was elaborated.

Silva et al. (2016) cite in their work the definition of the ACES Network (Network of Curriculum Greening of Higher Studies) on the process of curricular greening:

> […] training of professionals committed to the permanent search for the best possible relations between society and nature, taking into account the values of justice, solidarity and equity, applying universally recognized ethical principles and respect for diversity (ACES Network, 2000 *apud* Silva et al. 2016).

In this context, the construction of the sustainability culture did not come only from its participants' conception about the socio environmental theme (Fracalanza et al. 2005), but also comes from the motivation and training receiving within the university environment.

The importance for the theme is highlighted at the UI GreenMetric World University Ranking, an initiative of Universitas Indonesia launched in 2010 to measure campus sustainability efforts. It aims to provide the current condition and policies related to Green Campus and Sustainability on Universities all over the world as a result of an online survey. Are intended to be relevant to university leaders and stakeholders, more attention will be given to combating climate change, energy and water conservation, waste recycling, and green transportation. Such activities will require change of behavior and provide more attention to a sustainable environment. As well as economic and social problems.

Education is one of the criteria that was added in 2012 UI GreenMetric and represents 18% of the total score. According to the website "this criteria is based on the thought that university has an important role in creating a new generation concerned with sustainability issues". Some indicators are: number of courses related to environment and sustainability offered, total research funds dedicated to environmental and sustainability research, number of scholarly publications on environment and sustainability published, number of student organizations related to environment and sustainability and existence of a university-run sustainability website.

Despite the importance of these criteria, it would also be important to think about indicators related to curriculum and training from an environmental education perspective in every courses. We believe that to construct a culture of sustainability, socio-environmental training must be present in all degrees and do not only those dedicated to specific training in the environment. Levy and Marans (2012) state that to transform sustainable culture, action is necessary in three fronts, viz., Education and training, engagement, and monitoring and evaluation. Socio-environmental issues are emerging in the current population situation and the university has a central role in the possibilities of changes through its education-research-service axis, that is, through education, scientific production and community service programs that extend to the entire university community and even beyond its borders.

Our research adressed an initial diagnosis regarding the panorama of environmental education in teaching degree. This data are hard to find is scarceat the University of São Paulo, drawing attention to the potential that researches like these have for contribuiting to develop of more robust environmental culture.

According to Souza (2016)

> Education for the environment in higher education institutions (HEI) needs to strike a balance between professional qualification for work and the training of citizens aware of their rights and duties towards society. The market needs more and more qualified professionals in the environmental area and society as a whole needs these professionals to be well-formed and embed in it as critical citizens in search of the common good and social-environmental justice.

The processes of greening curriculum have an important educational dimension that resides, in ethical, aesthetic and moral aspects in all levels and environmentally oriented institutions. The university is one of the institutions that tends to respond to social demands. The current guidelines of the MEC presents universities as sustainable educational spaces, that is, they have the pedagogical intentionality to be concrete references of socio-environmental sustainability (Trajber and Sato 2010). Carvalho et al. (2012) understand that sustainability is an orientation for internalize by the teaching, research, extramural and management actions of the campus.

The present investigation context is about a public university with eight *campi* and a university community of around 120,000 individuals, including employees, students and professors. We emphasize that the University of São Paulo has been planning its Environmental Education Policy, within the context of the university's environmental policies, which has as one of its guidelines to promote the socio-environmental dimension in all USP's degrees curriculum and teaching programs, as an integrated, transversal, interdisciplinary, continuous, permanent educational practice. In addition, it has carried out initiatives that involve the socio-environmental training of different segments, such as employees (Sudan et al. 2015).

In this sense, teacher training courses have a fundamental role, although in these courses the presence of the environmental dimension is still incipient (Thieman et al. 2014). The research questions dealt with in the present chapter is: How pre-service teachers in biological sciences and geosciences identify their qualification in environmental education and sustainability culture during undergraduation?

It is highlighted the need for initiatives that recognize the transversality and collectivity of the environmental issue. Sorrentino and Nascimento (2010) discusses that the training processes in institutions of higher education can play two roles: the first, being to educate the institution itself, so that it incorporates the environmental issue in its daily life, crossing the axes of education—research and management, in order to make the institution environmentally friendly; And the second is to contribute to the environmental education of society, through a management project aimed at the greening of the country and educational actions are compromised.

## 2 Critical Environmental Education

Wals et al. (2014) points out that EE research offers insights into how to engage people with environmental issues through participation and action. According to the authors:

> Today much of the EE research focuses on investigating the conditions and learning processes that enable citizens, young and old, to (i) develop their own capacity to think critically, ethically, and creatively in appraising environmental situations; (ii) make informed decisions about those situations; and (iii) develop the capacity and commitment to act individually and collectively in ways that sustain and enhance the environment.

The present research uses the concept of Critical Environmental Education. Different of a traditional and behavioural view, the educational processes must go towards a reflexive and participatory attitude towards the consolidation of a sustainable society, based on not only technical assumptions, but also political, ethical and ideological (Silva and Campina 2011). EE aims not only at the rational use of natural resources, but also a citizen participation in discussions and decisions on the environmental issue (Reigota 1995). Carvalho (2004) considers that in critical EE, the change of individual behaviors is replaced by the construction of a citizen culture and the training of ecological attitudes, which supposes the creation of a sense of ethical and social responsibility.

Thus, we take into account the dimensions of the educational praxis: concepts, values, and participation (Carvalho 2006). In this way, we seek to identify *what students of two undergraduate degree, in "Biological Sciences" and "Geosciences and Environmental Education", identify in their qualification, understanding a broad perspective of training that involves teaching, research and extramural projects, and how this is reflected in means of participation on Socio-environmental issues at the university.*

The critical thinking of EE is based on the guiding principles of the *Treaty on Environmental Education for Sustainable Societies and Global Responsibility,* such as: "Education is the right of all; we are all learners and educators"; "Environmental education, whether formal, non-formal or informal, should be grounded in critical and innovative thinking in any place or time, promoting the transformation and construction of society" and "Environmental education is not neutral but ideological. It is a political act".

Considering these principles, we work in a perspective that starts from a premise that understands education as an element of social transformation, based on dialogue, the exercise of citizenship and the strengthening of the subjects (Silva and Campina 2011). The critical strand of environmental education, as described by Sauvé:

> … insists, essentially, on the analysis of the social dynamics that lie at the basis of environmental realities and problems: analysis of intentions, positions, arguments, explicit and implicit values, decisions and actions of the different protagonists of a situation. (Sauvé 2005, p. 30)

The concept of action associated with environmental education emerged in opposition of the type of teaching that is only intended to raise awareness and provide information. This concept involves developing abilities to work with critical thinking, reflection and participation in a democratic society. In this context, the school environmental focuses which begins to engage with its community (Copello 2006).

The teaching of science and geography has, historically, a greater responsibility on the socio-environmental training of students in relation to formal education (Bortolozzi and Perez Filho 2000). It is noted that Institutes and Colleges that are associated with the Environment Biological, Agrarian Sciences and Forestry Engineering propose a curriculum with greater availability of Environmental Education and Environmental Education courses, neglecting other licentiate degrees that are also qualified to act at formal education. We now understand the need to integrate all areas in the construction of a sustainable culture and awareness in our society (Haigh 2005).

According to Tilbury (2011), the transformation of a university to sustainability requires a realignment of all activities with the reflexive and critical paradigm, which can support the construction of a sustainable future. The author stresses the need for the involvement of different groups, such as employees and students, so that it is possible to change the culture of university institutions. In order to give meaning to these changes, it is necessary to search for interdisciplinary, participation and in-depth pedagogical processes, as well as the opening of institutional limits to the community.

## 3 Methodology

A questionnaire containing twenty-five questions (nineteen multiple choice questions and six open questions) was constructed based on other existing instruments, such as the document "Sustainability Here and Now: Brazilians from 11 capitals talk about the environment, consumption habits and recycling" (MMA 2010) and the *Plataform informação, sensibilização e avaliação da sustentabilidade na universidade* (Universidade Autônoma de Madri; Universidade de São Paulo 2016). The five axes of identification of the culture of sustainability in universities suggested by Levy and Marans (2012) were also used, which are: knowledge of the case (e.g. the reason to recycle); Knowledge of the procedure (e.g. how to recycle on campus); Social incentives (e.g. social incentive programs for recycling); Material incentives (e.g. direct material gain in return for positive sustainable actions); "Prompts" (e.g. materials that constantly remind people of the actions they must take to promote sustainability).

The questionnaire was formulated and answered through the *Google forms* platform, made available by email to the students of the two degrees during the period of October 2016.

Eighty-four answers were obtained from undergraduate students of the Institute of Biosciences (IB-USP), 64% of respondents being women. Most students (52%) have studied for a minimum of three and a maximum of five years at IB and 77% attend baccalaureate and licentiate degrees. At the Institute of Geosciences, twenty-one answers were obtained, with the majority studying from one to two years at the University (52%), 64% of the respondents are also women and they are all exclusively licentiate students.

## 4 Results and Discussions

When we asked about the presence of Environmental Education (EE) in the degree of Biological Sciences, 57% identified the presence in their graduation. Forty-eight students who considered having EE in the curriculum, twenty nine (51.8%) indicated access to EE in courses, thirteen (23.2%) in extramural programs and twelve

(21.4%) identified EE transversally in undergraduate subjects not necessarily related to EE (Fig. 1).

The data were different to the Licentiate degree in Geosciences with the presence of environmental education being practically associated only with the disciplines with very little attention being to extramural projects and without any indication of transversality, as can be seen in Fig. 2.

It was observed a predominance of the environmental approach in the two teacher training degrees, both in Biological Sciences and in Geosciences. It was noticed as difference between the two degree that in the Biological Sciences the subjects of Environmental Education are optional and in the Geosciences are mandatory disciplines of the curricular grade.

Another relevant point aimed to identify whether the approach of the most present disciplines and/or training practices would be related to the different dimensions of the educational praxis: knowledge, values and participation.

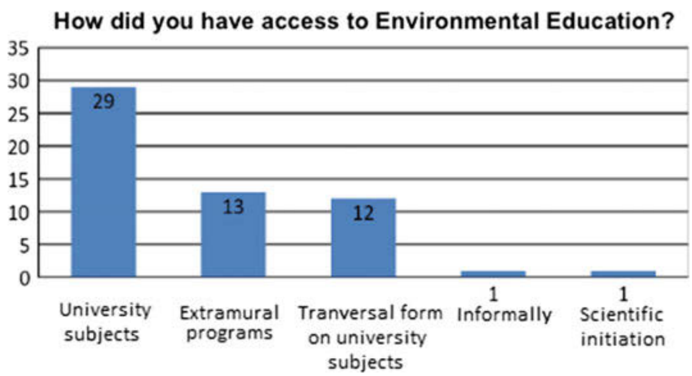
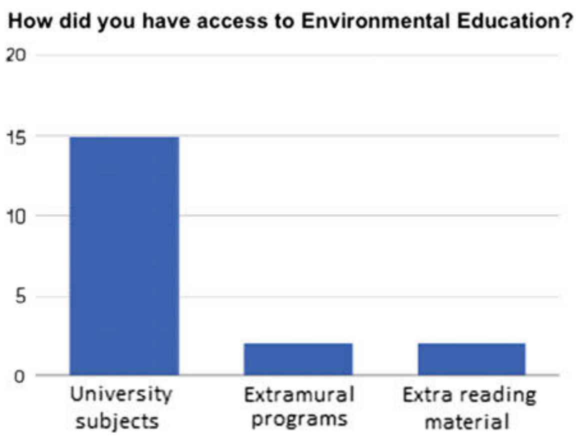



**Fig. 1** Biological sciences students' perceptions about their access to environmental education at university

**Fig. 2** Biological sciences students' perceptions about their access to environmental education at university



The question allowed more than one answer and it included the definition according to Carvalho (2006):

> "Knowledge": the apprehension of environmental complexity through our efforts to understand the patterns of interaction with nature that leads us to the necessary dialogue of knowledge, which demands of us the consideration of the other constitutive dimensions of human practice, subjectivity, values and the political dimension; "Values": the idea of an essence or a human nature is no longer accepted. In this context, references to human behaviors are sought in the natural characteristics of living beings in general and of humans in particular. The ethical question began to focus, therefore, on the attempt to outline values that would enhance this natural existence; "Participation": the political dimension of education that is concretized by human praxis, through the collective participation of individuals to build the ideal of citizenship and a democratic society, unveils the contradictory and dialectical character of the educational process.

The data of the Biological Sciences degree presented an emphasis on knowledge, followed by means of participation and values (Fig. 3), showing that there is not yet a balanced qualification in terms of the three approaches in this licentiate degree. However, in the Geosciences degree, students' perception is that there is a balance of these three dimensions (Fig. 4).

Forty-nine percent of students from the Biological Sciences degree consider themselves well or well-informed about environmental issues. Most students (68%) consider themselves environmentally educated. Along with the question followed the definition of "environmentally educated": "that is, it believes that it was educated to act with" ethical, aesthetic and moral values around environmental care in social practices and individual orientations and theoretical- Practical to act in an environmentally responsible way from their area of action "(Carvalho et al. 2012)."

However, although they consider themselves environmentally well educated, only 36% of Biological Sciences students and 29% of Geoscience students

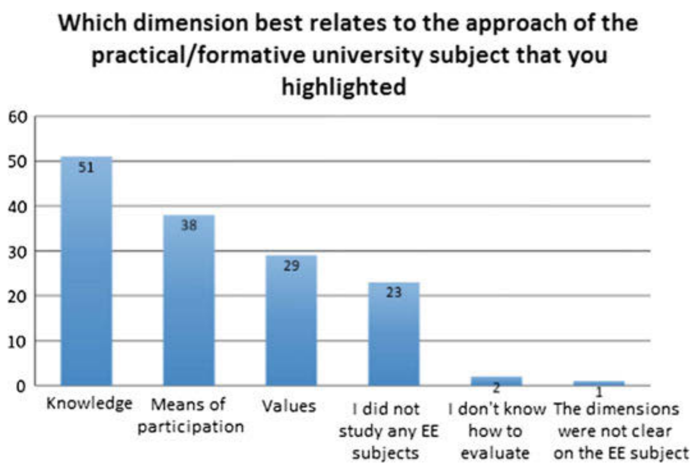



**Fig. 3** Description of dimension approached by university courses based on Biological Sciences student's perceptions

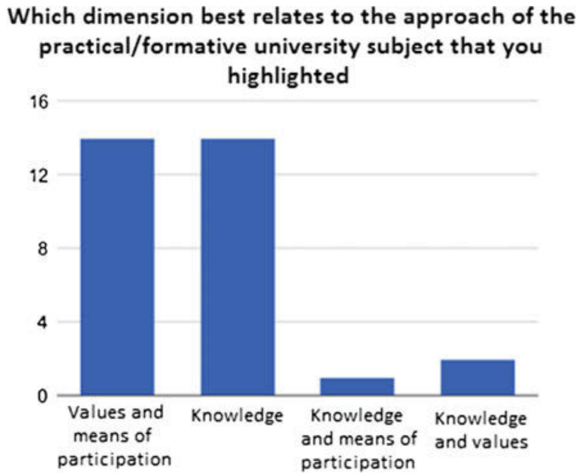



**Fig. 4** Description of dimension approached by university courses based on geosciences student's perceptions

evaluated their commitment to the socio-environmental situation of the campus as good or excellent. The question "Do/ did you participate in or promote any kind of socio environmental activity on your campus?" (Fig. 5), allowed more than one answer, and most students said they had not been involved with the topic so far. Those who responded having participated in/promoted any socio-environmental activity said that they did it through disciplines, open events or study/research groups and campus extramural programs.

According Disterheft et al. (2015), participative processes in higher educations need an interdependent with structural institutional conditions and the persons engaged. The authors highlight the importance of participative processes in sustainability in higher education:

> Despite relying strongly on a given context that is different in each university, participatory processes can offer different kind of positive outcomes and benefits for the academic community and their efforts in fostering sustainable development. These can be, among others, a better quality of dialogue, a higher awareness for sustainability and empowerment (Disterheft et al. 2015).

It was identified a strong influence of the Internet as a source of information acquisition on the environmental theme (36.7%), followed by Education Institutions (28%) (Fig. 6). Concerning the difficulties faced for participation in socio-environmental actions, "lack of time" and "lack of institutional support" were the most cited in both degrees. Figure 7 presents these data from Biological Sciences students.

According to Chauí (2003), higher education needs changes in the curriculum: reducing the number of classes and increasing the time for reading and research; implanting new disciplines; assuring students of the contact with classical issues interrelated with contemporary debates. According to Freitas and Souza (2011), "the university often considers only scientific knowledge as valid and true, knowledge arising from society and other social groups ends up being disqualified

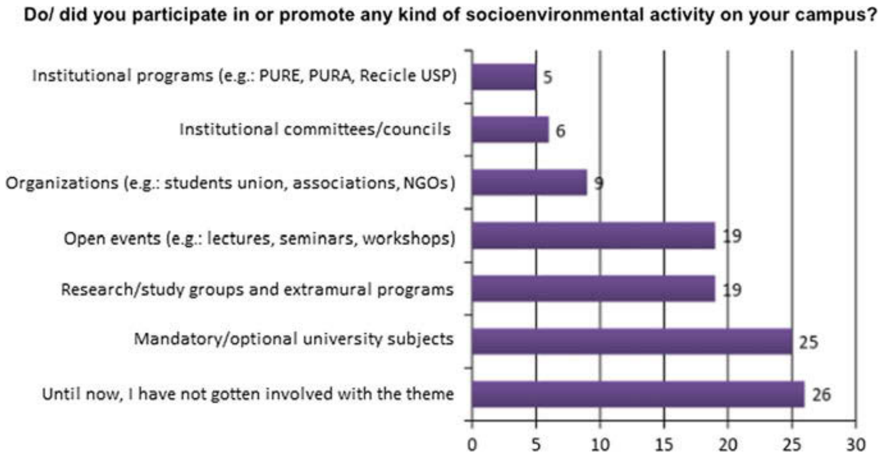



**Fig. 5** Answers to the question: "Do/did you participate in or promote any kind of socio environmental activity on your campus?" from Biological Sciences students (The question allowed more than one answer)


**Fig. 6** Answers to the question: "Where do you find places for information and discussions on social and environmental issues?" (The question allowed more than one answer)

by the group that holds the academic knowledge". Such practices hinder the relation between scientific knowledge and popular knowledge, where extramural programs represents a way of encouraging the inclusion of other cultures and other visions in the university environment.

Within the Biological Sciences degree, fifty students (33.3%) identified that the socio-environmental training comes from participation in university extramural

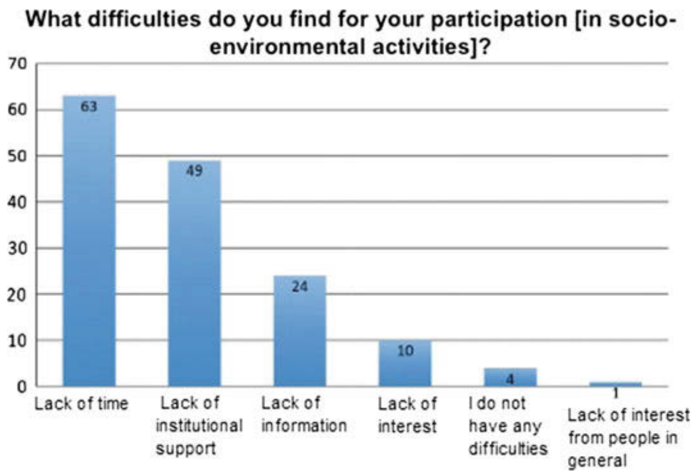



**Fig. 7** Answers to the question: "What difficulties do you find for your participation [in socio-environmental activities]?" (The question allowed more than one answer)

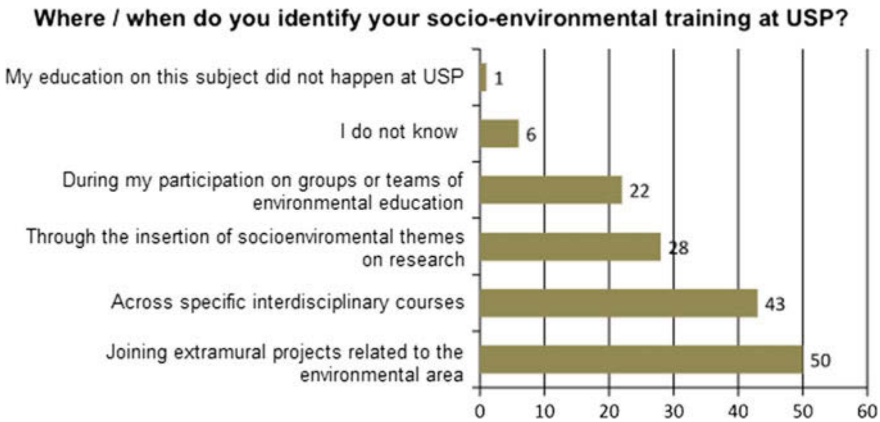



**Fig. 8** Answers to the question: "Where/when do you identify your socio-environmental training at USP?" (The question allowed more than one answer)

projects, 43 students (28.6%) in specific elective disciplines or interdisciplinary practices, and 28 (18, 6%) in socio environmental topics within university scientifical production (Fig. 8), emphasizing the importance of the triad that supports the university—teaching, research and extramural—to qualify teachers in EE. This result corroborates the work of Pavesi (2007) "The policies that regulate and promote the articulation of extramural programs with education represent a key factor in the greening of professional training, insofar as it relies heavily on dialogue with the community with the purpose of understanding their languages, values and needs".

Many students cited extramural projects such as the Environmental Biology Commission, described in Macedo et al. (2016), the Biology Station and the Thematic Week of Biology-USP, as important factors in the socio-environmental qualification.

It possible to see from the questionnaire that although students consider themselves well informed about environmental issues, most of them assess their commitment to social and environmental issues on *campus* as regular and poor. The majority (58%) say that they do not participate or promote socio-environmental actions. Thus, there is a gap between knowledge and participation in actions to promote a more sustainable society, proposed by the Critical EE. Even at the courses highlighted as related to EE by students, it appears not to emphasize on the participation and citizenship of sustainability, and thus, the political dimension of EE is imbalanced in relation to other dimensions of educational praxis (knowledge and values).

## 5 Conclusion

University of São Paulo, as an exponent in Brazilian higher education and responsible for the training of hundreds of educators annually, needs to participate actively in the movement of curriculum greening that are occurring in others universities of the world. In order to follow this demand, it has to happen not only in the educational range as demonstrated in this work, but also stimulating research in environmental education and university extramural actions that permeate an environmental theme, since we understand the University as an important agent in the process of social change.

Among other aspects, the results indicated that the dimensions of knowledge, values and means of participation were not in equilibrium on student training. The preliminary results demonstrated that even though there are few EE subjects in curriculum, they were recognized by students as an important contribution to their degree. EE is also present in different extracurricular projects mentioned as essential to encourage sustainability culture. In this situation, we expected that the project contributes to USP's EE Policy Management Plan, for a curricular reform/reconstruction and to promoting new ways for citizens/professionals to identify, problematize and to act on socio-environmental challenges. This would lead to the improvement of the culture of sustainability on *campus* and the creation of subsidies for teacher and student training.

The University, as a professional training center, by responsibility not only enable its students to understand the environmental theme, but also prepare them to act in the transformation of the environment around them, especially through teaching. Therefore, proper training of people as environmental educators becomes a necessity for undergraduate licentiate degrees. Moreover, as universities also represent a model by the rest of society, in this context, identifying the status of curriculum greening produces data for the creation of educational policies.

Souza (2016) points out that different elements related to economic and social factors have created obstacles to the incorporation of environmental knowledge into the training of professional-citizens who are able to comprehend and renounce current socio-environmental problems. This way, leaving environmental education in higher education often reduced to a general process of awareness of citizens and the incorporation of environmental knowledge into a slight capacity for specific problems in which environmental complexity remains fragmented.

The results in course of teacher training of biological science and geosciences demonstrate that there was a distance between students considering themselves as environmentally educated and their socio-environmental performance. Concerning the difficulties faced for participation in socio-environmental actions, "lack of time" and "lack of institutional support" were cited in both degrees, which demonstrates the need to institutionalize environmental education in the curriculum not only for contents, but also for interdisciplinary socio-environmental practices. This way, the curricular environmental movement is an attempt to modify society through the Higher Education Institutions (HEI) on a global scale (Capdevila et al. 2002; Skeaff 2014; Xiong et al. 2013).

This research is insert in a broader project, related to environmental education in the University of São Paulo and the existence of a culture of sustainability in its campuses. It will complemented with ongoing studies on the perception of teachers and coordinators on the insertion of the thematic in their units, as well as with students from other undergraduate courses, particularly teacher training. Beside this, it is important to compare these results with other teacher training courses in the Brazil and in others universities around the world.

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# Inclusion of Sustainability in Higher Education Institutions: A Comparative Study of São Carlos School of Engineering—University of São Paulo and the Leuphana University of Lüneburg

Érica Kamimura Nishimura and Tadeu Fabricio Malheiros

**Abstract** This work consists of conducting a comparative analysis of sustainability integration in Leuphana University of Lüneburg and São Carlos School of Engineering EESC/USP. The importance of this paper is to highlight the fundamental role of sustainability in Higher Education Institutions and how is the development of this issue in different contexts (territorial, economic, politic, social and environmental). As an introduction to the topic, there was a discussion about some basic concepts that are often used but also misunderstood, such as the connection between "Environmental Education" and "Education for Sustainable Development" (ESD). In addition, there was an analysis of the important role of higher education in sustainable development. The comparison between universities was carried out investigating the national scenario in each of them, their history of sustainability, and other specific themes such as the signing of international agreements and/or declarations about ESD, participation in international membership association, debate and/or implementation of Local Agenda 21, existence of sustainability policies, responsible groups for the sustainability, areas of focus on sustainability in the Higher Education Institution, analysis of sustainability tools and indicators used by both universities, the sustainability projects on campuses, education and research, extracurricular student organizations focused on sustainable development and the communication with stakeholders.

**Keywords** Higher education for sustainable development · Sustainability assessment tools · EESC · Leuphana

É. K. Nishimura (✉) · T. F. Malheiros
Department of Hydraulics and Sanitation, University of São Paulo,
Avenida Trabalhador São-carlense, 400, 13.566-590 São Carlos, SP, Brazil
e-mail: erica.k.nishimura@gmail.com

T. F. Malheiros
e-mail: tmalheiros@usp.br

 
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## 1 Contextualization

Since 1970, debates related to the sustainable development became more frequent with the search for a more balanced lifestyle in all social segments.

In this context, Higher Education Institutions (HEI) show their relevance and the urge to occupy a leadership role.

This change and adequacy purpose of HEI is aligned to the Education for Sustainable Development concept, which indicates the commitment with sustainability in all ways, such as the need for discussion, education and research, operational activities in the campus and management of sustainable programs organized by students, professors and society.

The main difference between Education for Sustainable Development (ESD) and Environmental Education is that Environmental Education focus on environmental issues, while EDS focus on three pillars of sustainability: environment, social and economic issues.

One of the key factors for a higher sustainability performance of HEI is networking and information sharing. The interaction between universities is also important because different contexts result in different approaches, and the diversity is beneficial to solve problems and to improve the sustainability in HEI's.

From the previous justifications and due to the importance of ESD, the objective of this paper is to analyse sustainable activities developed by two HEI: São Carlos School of Engineering (EESC)—Brazil and Leuphana University of Lüneburg—Germany.

## 2 Methodology

The presented work is a correlational study that uses quantitative and qualitative information to characterize the role of both universities on sustainability issue.

The methodology was organized in three parts: the first was a characterization of Brazil and Germany and an evaluation of both universities. The second was an analysis of some particularities of EESC-USP and Leuphana. The last part was discussion and conclusion.

All the information used in this paper was taken from Nishimura and Malheiros (2015).

The main limitation of this study was the information source.

Because of the specificity of the case study, there was a lack of papers and scientific researches, which caused the need for using other information sources, as the news from institutions, universities and governments websites.

## 3 Characterization

- **Brazilian scenario**

In dealing with development and national mobilization for Environmental Education, Brazil had specifics actions but not a wide integration system, according to Leme (2008). Some of the national developed programs are:

- National Policy of Environmental Education,
- National Program of Environmental Education and
- other programs as “consolidation of environmental education in Brazil”,
- “continuing education of teachers and students” and
- “training of environmental educators”.

Brazilian Constitution of 1988 also lights up the need to promote the “Environmental Education in all school levels and public awareness of the need to preserve the environment” (Brazil 1988).

According to Brazilian Ministry of the Environment (2005), Brazilian guideline for the United Nation Decade of Education for Sustainable Development (2005) was:

- management and planning of environmental education,
- training of environmental educators,
- communication for environmental education,
- inclusion of environmental education in educational institutions, and
- monitoring and evaluation of policies,
- programs and projects of environmental education,
- however, it was not found any document with Brazilian results.

- **German scenario**

The German educational system has a consolidated education for sustainable development. One of the first and most important accomplishments in national trajectory of sustainable development of HEI was the COPERNICUS Letter.

According to “UNI 21: Hochschulbildung für eine Nachhaltige Entwicklung” elaborated by German Federal Ministry of Education and Research (BMBF 2004), the German government indicated some topics as sustainable lifestyle and consumption, fair economy in a global context and environmental education to be investigated by HEI.

In 1998, it was elaborated guidelines for “Education for Sustainable Development” by Bund-Länder Commission for Educational Planning and Research (Bund-Länder-Komission BLK).

In the same year, BLK listed five main characteristics of Education for Sustainable Development:

- interdisciplinarity and focus on resolution of problems,
- research of environmental groundings,
- benchmark between HEI, industries, markets, governments and citizens,

- improvement of efficiency processes and
- dissemination of Education for Sustainable Development for all of the HEI's stakeholders.

In dealing with United Nation Decade of Education for Sustainable Development, Germany had an active participation through the elaboration of the Hamburg Declaration in 2003, the National Action Plan for UN Decade, and the UNESCO Chair in Higher Education for Sustainable Development.

According to the "UN DECADE WITH IMPACT—10 years of Education for Sustainable Development in Germany" (German Commission for UNESCO 2014), German performance was excellent, however, it is known that this was only the first step toward sustainability.

- **EESC-University of São Paulo scenario**

The São Carlos School of Engineering (EESC-USP) is one of the five research and teaching institutes of University of São Paulo (USP) at São Carlos campus, and it had 3910 students in 2015.

In 2015, EESC had three main institutional programs for sustainability:

- USP-Recicla (in English: USP-Recycles), that promotes environmental education, solid waste management and discussions about environmental issues;
- Permanent Program for Efficient Use of Energy (original name: PURE) and
- Program of Rational Water Use (original name: PURA).

In 2009 and 2010, USP and Autonomous University of Madrid performed an international cooperation research called "Sustainable Project", whose results were the sustainability performance benchmarking, publishment of two books ("On the way of sustainability: challenges and learning shared between the University of São Paulo and the Autonomous University of Madrid", 2010 and "Ibero-American sustainable views and experiences at universities", 2011), development of an interactive web/online platform (www.projetosustentabilidade.sc.usp.br), the elaboration of seminars, workshop and sustainability test for universities.

The University of São Paulo created, in 2012, the Superintendence of Environmental Management (original name: SGA-USP) whose principles are: developing national resources conservation actions in the University; promote a healthy environment and an environmental safety in the campus; promote resources rational use; education aiming sustainability; collaborative building of a more sustainable university to turn USP into an exemplar of sustainability for society (SGA-USP 2015).

USP has performed actions such as the creation of a 2165,98 ha Ecological Reserve, the publication of a Solid Waste Policy in 2013, and specifically, EESC campus has elaborated "Sustainable EESC" (original name: EESC-Sustentável), a program which aims to improve the sustainability in the campus.

- **Leuphana University of Lüneburg**

Leuphana University is located in Lüneburg city and had 7400 students in 2015 (Leuphana 2015a). The university was awarded with "Sustainable University" program in 2008, it was the winner of "Architecture with Energy", a competition of German Federal Ministry of Economy and Technology in 2009, and was one of the winners of International Sustainable Campus Excellence Award 2015. Leuphana had the best performance between the German universities regarding United Nation Decade of Education for Sustainable Development (Leuphana 2015b), the university was one of the COPERNICUS Alliance founding members, hosted the "Higher Education for Sustainability: Towards the World Summit on Sustainable Development 2002" and hosted the meeting of Higher Education for Sustainable Development of UNESCO.

Since 2000, Leuphana has an ecological auditory called EMAS and publishes annually the "Steps into the future" report.

## 4 Performance of EESC-University of São Paulo and Leuphana University

This topic introduces briefly the actions taken by both analysed HEI according to the following criteria.

- **Signatory of agreements**

Leuphana is signatory of six international agreements, namely:

- Halifax Declaration;
- Copernicus Letter;
- Kyoto Declaration;
- Lüneburg Declaration;
- Ubuntu Declaration and
- Rio+20 Treaty on Higher Education.

EESC-USP University is signatory of two agreements, namely:

- Magna Carta and
- Sapporo Declaration.

- **Associations and Benchmarking**

Leuphana is vinculated to:

- UNESCO Chair,
- IAU—International Association of Universities,
- GUNI—Global University Network for Innovation,
- COPERNICUS Alliance and
- The Decade of Education for Sustainable Development.

EESC-USP is a member of:

- World Cities World Class,
- G8 University Network and
- Global Universities Partnership on Environment and Sustainability (GUPES).

- **Agenda 21**

Local Agenda 21 promotes a participatory planning and has sustainability as an axis.

From 1999 to 2001, Leuphana elaborated the "Agenda 21 and the University of Lüneburg" research project which aimed to identify what the university should do to achieve the challenges of the Agenda 21. The results of this research were applied at Leuphana as the Environmental Management System and its guidelines of sustainability.

EESC-USP had some researches of Local Agenda 21, however, they were not implemented.

- **Sustainability Policies**

Sustainability Policies have high relevance because they ensure the commitment of universities about the sustainable issue.

Leuphana has the "Guidelines for Sustainability" approved by German senate in 2000, which means that the university has a legal obligation to sustainability and environmental protection. Leuphana was one of the firsts European universities to formalize under the law their sustainable obligations.

In 2015, EESC-USP had no environmental or sustainable policies; however, SGA-USP has been working on the development of them.

USP had ten working groups of Environmental Management Superintendence (USP 2014) which are elaborating the Environmental Guidelines Policy of USP.

São Carlos campus of USP, the EESC, expects to create its "Sustainability Policy" through the improvement and consolidation of "Sustainable EESC" Program.

- **Responsible Group**

It is important to have a specific responsible group for sustainability issues to improve efficiency, strategy and action plan.

Leuphana has, since 2002, the Environmental Coordination and the Environmental Working Group that are the responsible for sustainability issues on campus, however, each discussion about Education for Sustainable Development is held jointly with Faculty of Sustainability, its institutes, university managers, Center for Sustainability Management (CSM), researchers, professors and students.

The University of São Paulo has the Superintendence of Environmental Management, responsible for socio-environmental dimension. SGA is composed of 10 working groups: water and wastewater, sustainable building, environmental education, gases emission, energy, fauna, mobility, solid waste, management sustainable, usage of soil, green areas and ecological reserve groups.

Specifically in São Carlos campus (EESC), there is the "Sustainable EESC" Program that:

> Aims to promote the integration of environmental, cultural, economic and social aspects in teaching, research, extension and management of São Carlos campus.

Sustainable EESC Program is composed of university workers, professors, and students, and had in 2015 six working groups: curricular greening, sustainable purchasing, sustainable buildings and green areas, environmental education and organizational culture, communication, solid waste management and electronic management.

- **Sustainability approach**

Each university has its own approach strategy, according to its characteristics and believes that focus on specifics issues or general problems, being more conservative or challenging.

Leuphana University of Lüneburg had, in 2015, six main themes of Sustainable University: Campus life; operational optimization, campus development; Leuphana as a social actor, teaching and formation, subjects based on inter- and transdisciplinary research.

EESC, through "EESC Sustentável" has five main themes: teaching and human resources training, research and innovation, environmental management, extension for community, information and communication (Schenk and Ranieri 2014).

- **Analysis of assessment tools for sustainability**

The analysis of assessment tools for sustainability is based on the five principles of Shriberg (2002) of ideal assessment tools, which are:

(1) a sustainability tool must identify important issues,
(2) be measurable and comparable,
(3) move beyond eco-efficiency,
(4) measure processes and motivations and
(5) be comprehensible to a broad range of stakeholders.

Leuphana University had in 2015 three assessment tools for sustainability: EMAS (European Eco-Management and Audit Scheme), EMS (Environmental Management System) and the Annual Report of Sustainability—Steps into the future (original name: "Schritte in die Zukunft") which includes indicators of the "Global Reporting Initiative" (GRI), G3 version.

The assessment tools for sustainability of Leuphana were analysed according to the principles of Shriberg.

(i) Important issues

The tools of Leuphana are able to identify which issues are more relevant for sustainability, seeing that one of the eleven principles of GRI is "Materiality—The information in a report should cover topics and indicators that reflect the organization's significant economic, environmental, and social impacts or that would substantively influence the assessments and decisions of stakeholders". EMAS also indicates the necessity of identification, evaluation of environmental aspects (direct and indirect) and the need for criteria to evaluate the significance of them.

(ii) Measurable and comparable

One of the principles of GRI is "comparability—issues and information should be selected, compiled, and reported consistently. Reported information should be presented in a manner that enables stakeholders to analyse changes in the organization's performance over time, and could support analysis relative to other organizations". This principle and some of EMAS indicators guarantee both aspects (to be measurable and comparable).

(iii) Move beyond eco-efficiency

The Annual Report of Sustainability uses eco-efficiency indicators to elaborate its own evaluation of sustainability.

(iv) Monitoring processes and motivation

The Annual Report of Sustainability presents the motivations and some qualitative data while EMAS and GRI indicators presents more quantitative data.

(v) Be comprehensible

There are three of GRI principles related to the topic:

– completeness: "coverage of the material topics and indicators, and definition of the report boundary should be sufficient to reflect significant economic, environmental, and social impacts and enable stakeholders to assess the reporting organization's performance in the reporting period",
– accuracy: "the reported information should be sufficiently accurate and detailed for stakeholders to assess the reporting organization's performance",
– clarity: "information should be made available in a manner that is understandable and accessible to stakeholders using the report".

The results of EMAS are submitted to internal environmental audit, which gives credibility to them.

The USP campus of São Carlos has an Annual or Biennial Report of USP-Recicla. This document contains the performed activities of USP-Recicla at São Carlos campus, some information about solid waste generation and developed projects of the program.

EESC had some studies about sustainable indicators and tools for São Carlos campus, such as "ecological footprint", developed by Amaral (2010), elaboration of indicators based on ecological footprint and GRI by Brandão et al. (2014), and indicators of sustainability focused on the curriculum development and institutional policy developed by Calixto et al. (2014)—however, the developed researches are independent and not institutional.

USP joined the international “ProyectoRisu” project (ARIUSA 2014), which elaborated a set of sustainability indicators.

The following analysis are about the Annual or Biennial Reports of USP-Recicla.

The set of sustainability indicators of “ProyectoRisu” cannot be analysed by principles of Shriberg, due to the lack of information about its indicators (it was only found the classification of them).

(i) Important issues

The Annual or Biennial Reports of USP-Recicla present the developed activities of environmental education and solid waste, but there is not a wide discussion of sustainability on campus.

(ii) Measurable and comparable

The number of quantitative data is insufficient for comparison with other universities. The qualitative data are specific to the activities carried out by USP-Recicla in São Carlos.

(iii) Move beyond eco-efficiency

The presented data are from projects developed by students and professors within the USP-Recicla program, therefore the analysis of eco-efficiency depends on each project and its context.

(iv) Measure processes and motivation

All the projects detailed their contextualization and motivations.

(v) Be comprehensible

The achieved results are presented in the Report of USP-Recicla, and can be found on the Sustainability Project website (2015).

- **Indicators**

The characterization of sustainability indicators used by universities helps the identification of focus theme and how it is developed.

– Leuphana

The table below describes Leuphana’s indicators.

| Index of GRI-G3 indicators | | |
|---|---|---|
| Category | Aspect | Number of indicators |
| Strategy and analysis | – | 2 |
| Organizational profile | – | 10 |
| Report parameters | Report profile | 4 |

(continued)

(continued)

| Index of GRI-G3 indicators | | |
|---|---|---|
| Category | Aspect | Number of indicators |
| | Report scope and boundary | 7 |
| | GRI content index | 1 |
| | Assurance | 1 |
| Governance, commitments, and engagement | Governance | 10 |
| | Commitments to external initiatives | 3 |
| | Stakeholder engagement | 4 |
| Economic performance | Economic performance | 4 |
| | Market presence | 3 |
| | Indirect economic impacts | 2 |
| Environmental performance | Materials | 2 |
| | Energy | 5 |
| | Water | 3 |
| | Biodiversity | 5 |
| | Emissions, effluents, and waste | 10 |
| | Products and services | 2 |
| | Compliance | 1 |
| | Transport | 1 |
| | Overall | 1 |
| Human Rights performance | Investment and procurement practices | 3 |
| | Non-discrimination | 1 |
| | Freedom of association and collective bargaining | 1 |
| | Security practices | 1 |
| Social performance | Community | 3 |
| | Corruption | 3 |
| | Public policy | 2 |
| | Compliance | 1 |
| Product responsibility performance | Customer health and safety | 2 |
| | Marketing communications | 2 |
| | Customer privacy | 1 |

*Source* Leuphana (2014a)

| Index of EMAS indicators | | |
|---|---|---|
| Category | Aspect | Number of indicators |
| Energy | Electrical system | 5 |
| | Heating system | 3 |
| | Photovoltaic system | 3 |
| $CO_2$ emission | – | 2 |

(continued)

(continued)

| Index of EMAS indicators | | |
|---|---|---|
| Category | Aspect | Number of indicators |
| Transport | – | 1 |
| Water | – | 3 |
| Waste | – | 12 |

*Source* Leuphana (2014b)

– EESC-USP

There are seven indicators in the Biennial Report of USP-Recicla (2011–2013), namely:

– Audience of USP-Recicla presentation,
– Audience of educational activities for community,
– Amount of paper in selective waste collection,
– Annual estimate of recyclable waste collected by recycling collectors cooperative,
– Annual estimate of broken fluorescent bulbs sent to a specialized company,
– Number of books about environmental education, solid waste, 3-R (reduce, reuse and recycle), composting and selective waste collection at USP-Recicla's library,
– Number, description and final report of all projects realized by students and professors within the USP-Recicla program.

The table below presents the "ProyectoRisu" indicators.

| Index of "ProyectoRisu" indicators | |
|---|---|
| Category | Number of indicators |
| Sustainability policy | 15 |
| Awareness and participation | 12 |
| Social and environmental responsibility | 10 |
| Teaching and learning | 13 |
| Research and knowledge transfer | 13 |
| Urban planning and biodiversity | 7 |
| Energy | 10 |
| Water | 10 |
| Transport | 8 |
| Waste | 11 |
| Responsible hiring | 5 |

*Source* ARIUSA (2014)

- **Project on campus**

Daily actions aiming at sustainable development should not be necessarily complex and should not necessarily need a high financial, human or material investment. Many of them are simple but innovative and generate relevant results. Because of these reasons, benchmarking between universities is so important.

Leuphana was, in 2015, a partner of the bicycle-sharing project called "City Bikes"; there is also another interesting initiative, the "Fairtrade Coffee" inside the campus, which is a cafeteria that has a trading partnership that seeks greater equity in international trade. There was an area called "Leufarm", where the students could plant and care for the university garden.

Another project is "Climate-neutral Campus" that aims to reduce energy consumption and aims to consume only renewable energy sources.

USP has institutional programs such as PURA, PURE, USP-Recicla that can be found in every campus.

USP-Recicla has some successful projects in São Carlos campus, for example selective waste collection, reduction of food waste in university restaurants, distribution of plastic mugs for reducing the use of disposable plastic cups, support for events to reduce the environmental impact, creation of a composter in the campus and many other environmental education activities.

The program of São Carlos campus, "EESC Sustentável", also had in 2015 mechanisms of sustainable purchase, sustainable building, sustainable mobility, reducing of paper documents and selective waste collection.

- **Education and research**

HEIs should be aware of the need to improve the sustainability theme in their educational and research activities.

Leuphana was the first German university to establish its own Faculty of Sustainability. All the Leuphana students have sustainability classes in their first semester, the disciplines are as transdisciplinary as possible and the university was the first in the world to develop a MBA in Sustainability Management (Leuphana 2015a).

According to Mori (2014) and EESC Sustentável (2015) some examples of the introduction of sustainability theme at EESC-USP are: inclusion of environmental issues in undergraduate courses at EESC-USP, prospecting of researchers and researches of sustainability, and sustainability researches incentives through "Aprender com cultura e extensão" program.

- **Extracurricular groups of sustainable development**

Extracurricular groups are very important due to their engaging aspect and for bringing theories to practice, making learning more effective.

Leuphana had in 2015 the following extracurricular groups of sustainable development:

- “Oikos Lüneburg”: it is an international organization of discussion and elaboration of social and environmental projects.
- “23grad, Netzwerk Umwelt/Nachhaltigkeit”: it is an organization to exchange experiences. Student of environmental sciences and sustainability sciences meet ex-students and other professionals.
- “Lunatic Festival”: this group organizes a cultural festival with low environmental impact.
- “Sneep”: it is a platform and a forum for those interested in economy, social responsibility, and social-ecological economy.

There were more than 30 groups related to the social, cultural, political, economic and environmental issues.

In 2015, there were found in EESC-USP:

- “Geisa” (Group of socio-environmental studies and interventions): this group discuss and perform social and environmental interventions inside and outside the campus.
- “Projeto Rondom”: The Defense Ministry of Brazil coordinates this project. “Projeto Rondom” is a project of social integration, which involves voluntary activities to improve and help needed communities.

There were also 13 groups related to the social, environmental and cultural issues.

- **Communication with stakeholders**

The university communication with stakeholders is indispensable to develop an institutional culture focused on sustainability.

Leuphana had, in 2015, practical and efficient communication channels: Sustainability Report, EMAS Report and the university website.

EESC-USP had the EESC-Sustentável and “Projeto sustentabilidade” website and the “TV-SGA” that contains some videos related to its Environmental Management System activities.

## 5 Analysis and Discussion

In spite of the limitations about secondary data, it is possible to identify the main characteristics of the universities and their context, as discussed above and presented below.

| | EESC-USP | Leuphana |
|---|---|---|
| National scenario | Brazil:<br>– The main concept is the Environmental Education,<br>– Focus: legal basis and structural basis | Germany:<br>– The main concept is Education for Sustainable Development,<br>– Focus: implementation |
| Higher education institute | – Great international prestige as university,<br>– Decentralization of environmental education activities in the campuses,<br>– Structuring phase to the environmental education | – Better structure to the Education for Sustainable Development,<br>– Education for Sustainable Development concept is consolidated at university |
| *Global interaction* | | |
| Agreement signature | – Signatory of 2 agreements | – Signatory of 6 agreements |
| Associations and benchmarking | – Associated to 2 organizations | – Associated to 5 organizations |
| Local Agenda 21 | – There is no official activity about Local Agenda 21 | – Official implementation of a Local Agenda 21 study |
| *Management and structural issues* | | |
| Sustainability policy | – Preparation stage | – Consolidated |
| Responsible group | – Consolidation stage | – Consolidated |
| Sustainability approach | – Teaching,<br>– Research and innovation,<br>– Extension to community,<br>– Environmental management,<br>– Communication | – Life on campus,<br>– Campus development,<br>– Leuphana as a social actor,<br>– Teaching and training,<br>– Disciplines based on inter-transdisciplinary research |
| *Assessment tools for sustainability* | | |
| Analysis of assessment tools | – Lack of an official assessment tool for sustainability,<br>– Annual/biennial Report of USP-Recicla,<br>– "ProyectoRisu" | – EMAS,<br>– GRI,<br>– Annual Report of Sustainability<br>– Satisfactory performance according to the Shriberg's principles (2002) |
| Indicators | – Specific to the projects developed | – 29 From EMAS,<br>– 115 From GRI |

(continued)

(continued)

| | EESC-USP | Leuphana |
|---|---|---|
| | in USP-Recicla program | |
| *Actions* | | |
| Project on campus | – Institutional projects namely:<br>– PURA,<br>– PURE,<br>– USP-Recicla | – Direct approach to the students |
| Education and research | – Inclusion of environmental issues in the undergraduate courses at EESC-USP,<br>– Prospecting of researchers and researches of sustainability,<br>– Sustainability researches incentives | – First German Faculty of Sustainability,<br>– First MBA in Sustainability Management,<br>– Introduction to the sustainability theme for all the students |
| Extracurricular groups | – GEISA,<br>– Projeto Rondon | – Oikos Lüneburg,<br>– 23grad, Netzwerk Umwelt/Nachhaltigkeit,<br>– Lunatic festival,<br>– Sneep |
| *Communication* | | |
| Communication with stakeholders | – Digital platform | – Digital platform,<br>– Report of sustainability |

## 6 Conclusion

There is a tendency of all universities around the world to improve sustainability in their processes, but it is a complex and long-term procedure.

This article aimed to clarify the concept of sustainability and its connection with HEI, in addition to obtain a comparative analysis of education for sustainable development in Leuphana and EESC-USP.

It is important to light up the influence of national context on universities' behaviour. Germany, for example, can offer better conditions to the education for sustainable development implementation.

Despite the fact that EESC is 30 years older than Leuphana, the German university began its activities and discussions on sustainability in the 1990s through the environmental science course, while at EESC, the environmental engineering graduation began to be offered in 2003. It is necessary to light up that it is not a justification, but an input data to comprehend how sustainable development is driven in both universities.

Leuphana incorporated sustainability in all fields of activities: education, research, campus environmental performance, extracurricular activities, its relationship with community and communication. Which means that sustainability has been incorporated into the core of the institution.

EESC-USP promotes, since a long time, many activities about sustainability, but it is possible to conclude that in 2015, EESC was in the structuring stage of sustainability incorporation in an institutional domain.

According to the topic of signatory of agreements, associations and benchmarking, Leuphana had, in 2015, a better performance that can facilitate information and experiences exchange with other countries and institutions.

Sustainability policies and responsible groups support good practices of sustainable development, as seen at Leuphana. EESC-USP was in the implementation stage; therefore, it is possible to expect promising scenarios related to sustainability.

The assessment tools for sustainability facilitate to present obtained results, to analyse the goals, and to contribute to a better sustainability management on campus. The lack of tools is perceived as a potential fragility of the EESC-USP environmental management.

Another fragility of EESC-USP was the communication channels. Although there were official websites, there is a lack of communication alternatives between the university, campus users, community, other universities, industries, etc.

The wide variety of activities developed in both universities, EESC-USP and Leuphana, can inspire each other in their sustainable development processes.

The analysis of different sustainable development approaches in higher education institutions, that are immerse in distinct contexts, is complex, but it is necessary to the improvement of the issue in a global way. An important theme that should be analysed more deeply in future researches is the national context from both countries, which could embrace the social, economic, political and environmental aspects.

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# Four Years of Experience with the Sao Paulo University Medical School Community Garden

**Katia Cristina Dantas, Paulo Sergio Zembruski, Marcia Saldanha Kubrusly, Regiani Carvalho-Oliveira and Thais Mauad**

**Abstract** The School of Medicine, Sao Paulo University Community Garden (FMUSP Community Garden), formed in June 2013, occupies an area of 520 $m^2$. In the concreted area, vegetables and herbs are grown in large vessels (http://www.facebook.com/HortaDaFmusp). The garden runs on an agroecological basis using locally made compost (garden leaves and horse manure) and bio fertilizers provided by volunteers and the local restaurant (coffee powder). In the garden several herbs, medicinal plants, wild food plants and different types of seasonal vegetables are cultivated. The harvest is open for the entire community. Five medical students received financial support from the University to work 40 h per month to maintain the FMUSP Community Garden. Educational activities for the community include workshops (on medicinal herbs and wild food plants) and cooking events with students and volunteers including an elderly group, focused on healthy eating. In addition, a Ph.D. student conducted studies addressing the role of air pollution on urban gardens using the garden as an experimental site. In summary, the FMUSP Community Garden has provided sustainable, educational and research activities focused on sustainability and healthy eating in the medical campus, on a low

K. C. Dantas · R. Carvalho-Oliveira · T. Mauad (✉)
Departamento de Patologia, Faculdade de Medicina FMUSP,
University of São Paulo, São Paulo, SP, Brazil
e-mail: tmauad@usp.br

K. C. Dantas
e-mail: kadantas@usp.br

R. Carvalho-Oliveira
e-mail: regiani@usp.br

P. S. Zembruski
Assessoria Academica, Faculdade de Medicina FMUSP,
University of São Paulo, São Paulo, SP, Brazil
e-mail: paulo.z@fm.usp.br

M. S. Kubrusly
Departamento de Gastroenterologia, LIM 37, Hospital das Clinicas HCFMUSP,
Faculdade de Medicina FMUSP, University of São Paulo, São Paulo, SP, Brazil
e-mail: marcia.kubrusly@hc.fm.usp.br



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budget, for the community. We believe this paper is important because it describes how this experience has benefited many health-related professionals and complements medical teaching. The FMUSP Community Garden has shown that agriculture in large urban centers is possible. The results were very promising, involving students, staff, patients and the surrounding community.

**Keywords** Community gardens · Agriculture · Sustainability · Urban health Green campus

## 1 Introduction

The FMUSP Community Garden was formed in June 2013, motivated by the growing importance of urban agriculture and awareness of the numerous environmental and social benefits that a community garden provides. A group of 22 volunteers (employees, students and physicians from the University and Hospital) created the FMUSP Community Garden in a vacant concreted area of 520 $m^2$, Fig. 1.

In 2012, during the TEDxFMUSP (TED-FMUSP 2012 (https://www.ted.com/tedx/events/6678)), we met the founder of the group Incredible Edible, a group that works in England and Portugal. Todmorden, a small town in England, inspired our actions in this project at FMUSP. A group of Todmorden residents mobilized its inhabitants (15 thousand people) in an attempt to rescue urban agriculture in all empty spaces of the city. Currently, the city contains 40 vegetable gardens, which reinvigorated its economy through consumption and marketing of the products obtained from the plantations. Todmorden has become a tourist attraction by encouraging the planting of vegetables in various public places, such as in the hospital gardens and the local police station. The city has since adopted the policy of encouraging the creation of public gardens, which exist in all schools in the city (http://www.incredible-edible-todmorden.co.uk/ and the video in www.tedxfmusp.com.br that contains the link to YouTube).

The Edible Campus project at McGill University in Montreal, Canada, also started in a concrete area of 120 $m^2$ of campus, with volunteers from the University and non-governmental organizations. The vegetable garden started in containers (barrels of 200 l cut in half). After six months, 176 kg of food in 123 containers and 30 $m^2$ of cultivated ground was produced and donated to a community in need. The project also had environmental benefits of reducing the gardening garbage of the University through composting and reducing heat generated by concrete areas. In Brazil, there are several well-established community garden projects. Two of these projects are the Hortas Cariocas in communities in Rio de Janeiro. Additionally, the virtual group Horteloes Urbanos created in 2011 gathers the communities of eleven urban gardens in Sao Paulo. The purpose of these urban gardens was to create social and environmental education projects that bring the community together.

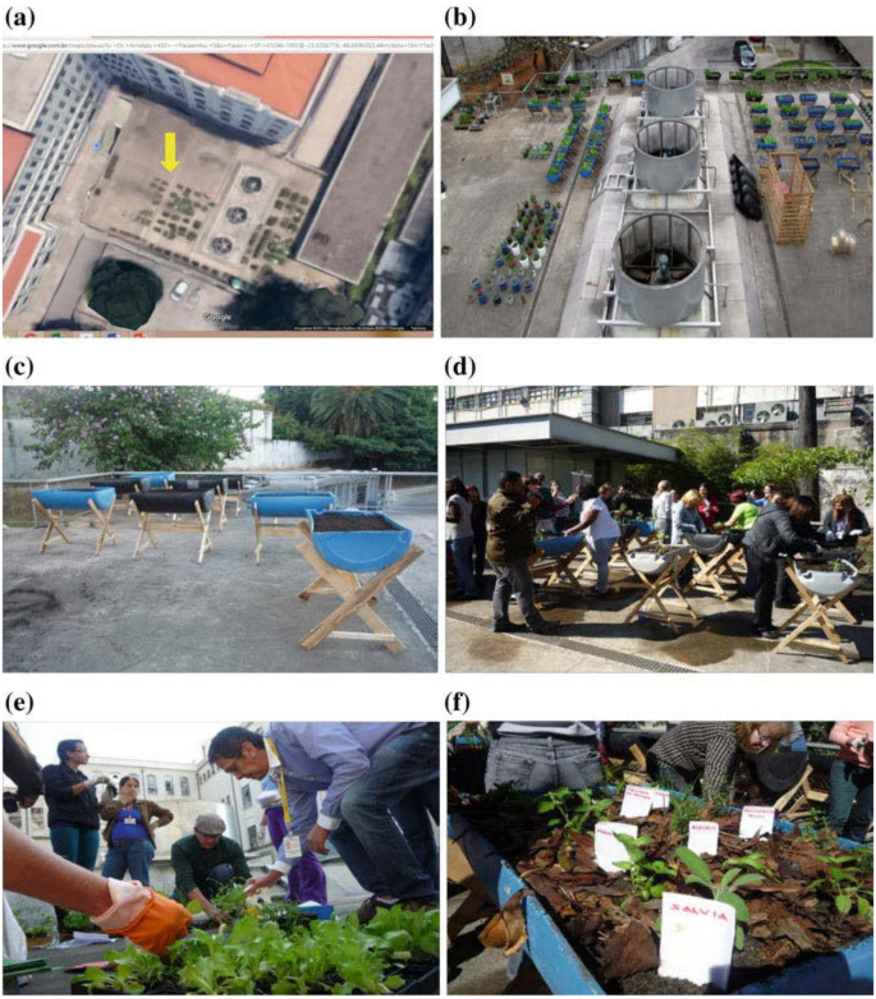


**Fig. 1** **a**, **b** Panoramic view of the FMUSP Community Garden. **c**–**f** Pictures of volunteers working at the first day of the FMUSP Community Garden

The projects described above motivated our actions in the FMUSP. The goal of our project was to bring sustainable actions within the campus. The project began by bringing barrels into an non-used and concreted space of the campus, and inviting the community to grow vegetables there. Using this empty space created a greener and cooler space in the campus and favoured integration during working time. Materials that would normally be discarded such as pallets and styrofoam boxes were used for growing plants. After four years of the installation of the garden, the former concreted area is a large, beautiful and green garden, where the medical school community can enjoy nature and collect herbs and vegetables.

## 2 Methodology

The garden occupies an area of 520 m$^2$, with good sunlight. In the concreted area, we use 200-L plastic barrels and styrofoam boxes that otherwise would be discarded to grow vegetables. We have a wood chipper donated by the Public Health School of Sao Paulo University. We used to receive horse manure from a local riding school and organic compost derived from a quick composting system from a local project developed in a Sao Paulo mall. In addition, we produce organic compost at FMUSP using the donated horse manure and garbage from pruning and care of trees and plants FMUSP campus (Fig. 2). We also built a small earthworm's farm, with a fence made of donated bamboo, for the production of humus. Earthworms were collected from the ground and from the pots.

The working volunteers gather twice a week. Volunteers group include the employees, students and, to a lesser extent, members of the outside community. During the work meetings, members perform activities related to the garden maintenance.

The irrigation of the garden is carried out with rainfall water; a collecting system was implemented in 2015, with a storage capacity of 7.5 thousand liters. Approximately 17 volunteers and students participate in shifts to take care of plants daily.

## 3 Results

The FMUSP Community Garden has been able to produce approximately 100 kg of vegetables per six months of work. The production of garden is donated to volunteers participating in the project as well as visitors. In April of 2017, the harvested vegetables were donated to an association that organized the lodging and

**Fig. 2** We produce organic compost at FMUSP used the donated horse manure and garbage from pruning and care of trees and plants FMUSP campus. The compost produced at the Medical School is set up with 70 cm-high piles


**Fig. 3** **a** Vegetables were donated to an association that organized the lodging and food for patients from other cities treated at the Teaching Hospital of FMUSP. **b–d** Undergraduate students learn to recognize plants, to cultivate, to prepare sowings, etc. Students are encouraged to recognize medicinal plants and to reflect about healthy eating habits. **e**, **f** A group of nutrition undergraduate students from Public Health at Sao Paulo University visited our garden, and collected vegetables to prepare lunch. **g** Informative Guide of Medicinal Plants

food for patients of other cities treated at Teaching Hospital of FMUSP (HCFMUSP), Fig. 3. There is funding from Sao Paulo University (USP) for undergraduate students to maintain the garden as educational activities. These students learn to identify plants, to cultivate the ground, to compost, and to perform others garden-related activities. Students were encouraged to recognize medicinal plants and to reflect on healthy eating habits, Fig. 3.

In November 2015, an event was held in collaboration with the Public Health doctors and students of the Food and Nutrition Security Discipline. A group of nutrition students visited our garden and collected vegetables to prepare a meal, which was served as a lunch for medical and nutrition graduate students, Fig. 3.

The medicinal plants of the garden aroused great interest in visitors, and two volunteers from the garden with pharmacy expertise created the "Informative Guide on Medicinal Plants", available on Facebook https://www.facebook.com/HortaDaFmusp and blog http://hortadafmusp.blogspot.com.br, Fig. 3.

A Ph.D. student used the FMUSP Community Garden to study the influence of the urban environment on vegetables. It is known that particulate matter is deposited on the surface of vegetables and that they absorb metals such as cadmium and arsenic, released mainly from motor vehicles. Therefore, to observe the effects in Sao Paulo, ten gardens in the city that contained country kale (*Brassica oleracea* L.) and spinach (*Spinacia oleracea*) were analyzed compared to a garden in a city named Piracaia (88 km of SP). This city was chosen as a control site because it has low levels of air pollution (Amato-Lourenco et al. 2016).

Several workshops were offered to the community including wild food plants, medicinal plants and aromatic herbs. An elderly group of the HCFMUSP of Geriatric Department sewed scarecrows for our garden. A hands-on cooking activity with our students and in the second one, a chef prepared a meal with the garden vegetables and herbs, focusing on healthy eating, Fig. 4a, b. In addition to the workshops, we organized markets with a focus on healthy foods and organic products. We also sold products made from plants in the FMUSP Community Garden, such as herbal vinegar, chutneys and sauces. The profits made were used to purchase seedlings and seeds for the garden, Fig. 4c.

The FMUSP Community Garden received many external visitors including pre school students, elderly groups, people interested in urban gardening, students from other universities and journalists, Fig. 4d–g.

Several TV and journal articles were written/filmed in the FMUSP Community Garden. We have a Facebook page with currently 1583 followers.

## 4 Discussion

Urban gardens are expanding in Brazil and throughout the world, providing approximately 20% of the consumed food, according to the United Nations Food (UNF) and Agriculture Organization. These data represent the resumption of activities of urban agriculture, which was very common in times of war and crisis. Vegetable gardens provide the opportunity to work, consume healthy food, and profit from the sale of produce (Alaimo et al. 2008; Hynes and Howe 2002). An increase in urban gardens is important considering that in 2050, 66% of people will be living in cities, when then the population of the planet should be close to 9 billion people. In an overburdened world, food security, water scarcity and energy will be major challenges for cities. Therefore, urban horticulture initiatives have been encouraged by governments and international organizations (http://pt.wikiversity.org/wiki/portal:agricultura_urbana).

**(a)**

**(b)**

**Fig. 4** **a**–**g** The garden received many external visitors including pre school students, elderly groups, people interested in urban gardening, students from other universities and journalists. **a** Workshops on: edible weeds, medicinal plants, aromatic herbs. **b** The first dinner was a hands-on cooking activity with our students. The second dinner was prepared by a chef using garden vegetables and herbs, which focused on healthy eating. **c** Workshops we organized at markets with a focus on healthy food and organic products. We also sold products obtained from the community garden, such as herbal vinegar, chutneys and sauces. **d** Children from the Public Health nursery, preschool students visited the garden. **e** Workshop on the preparation of scarecrows for the FMUSP Community Garden. **f** Workshop on manufacturing nameplates. **g** Workshops promoted the value of food education in medical practice, in order to promote health through changing eating habits


**Fig. 4** (continued)

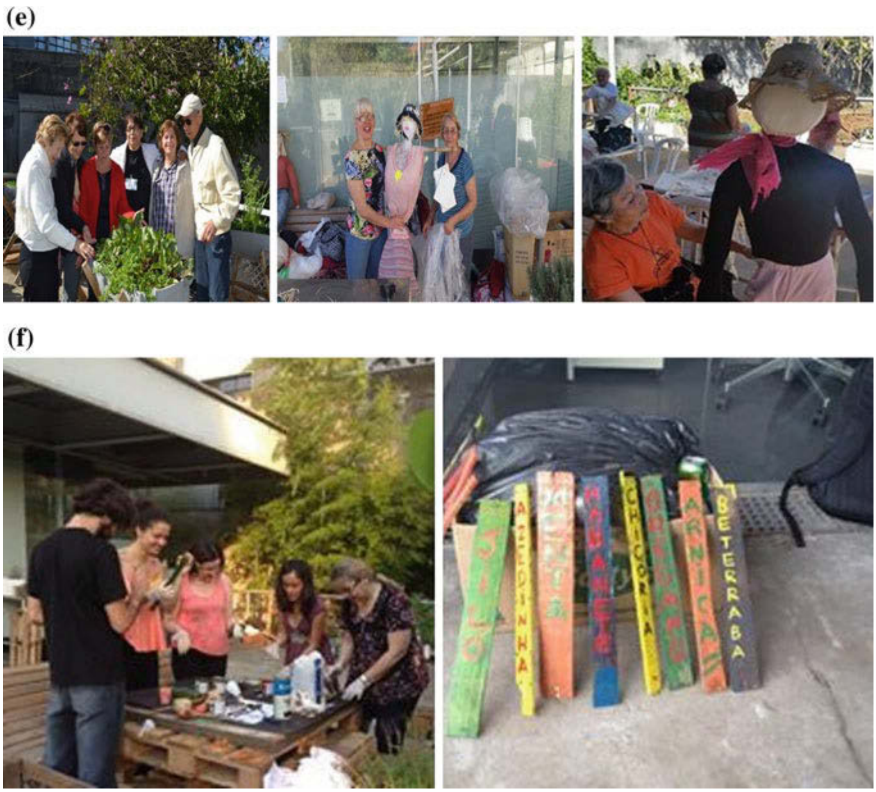


**Fig. 4** (continued)

In 2016, being concerned with future agricultural needs, the Institute of Advanced Studies gathered researchers and doctors from at USP and created the group of studies in Urban Agriculture, which collaborates with researchers from the University of Melbourne, Australia. The newly formed group discussed the role of the university and how it can provide the best techniques and information, so that society is able to source healthy food produced in an urban environment.

There is little information on how air pollution affects vegetables grown in urban gardens. Amato-Lourenco et al. (2016) evaluated the influence of atmospheric pollution on the chemical constitution of vegetables produced in urban gardens of Sao Paulo. The results showed that the traffic load is associated with the absorption of chemical elements. The greater the distance from the garden to the denser traffic lanes, the less accumulation of certain chemical elements in the plants. It was also observed that vertical obstacles appear to negatively affect absorption. The FMUSP Community Garden is in a region surrounded by buildings, which function as barriers to air pollution.

The city of Sao Paulo is a metropolis built under the “brand of progress”, where its population was proud to live, in the 70s, and is “the fastest growing city in the


**Fig. 4** (continued)

world". The map of the city of Sao Paulo began to change from 2014 due to the expansion of peri-urban agriculture in the South and Southeast. Community gardens are not official, making it difficult to compile data. The only official data are from the Secretariat of Tourism of the City Hall and the Institute Kairos that gathered information on urban horticulture in Sao Paulo. The data obtained showed that horticulturists build their plantations in unused or neglected areas, such as vacant lots or lots of electrification towers and large water pipes. The families that constitute these groups are focused on the generation of work and income.

Several countries are concerned about the overpopulation in their metropolis, predicting the necessity of food importation. The big problem lies in the quality of these foods. In China, the government has driven the demand for healthy and organic foods (Peng et al. 2015). In Australia, Melbourne has embraced urban agriculture as a new type of entrepreneurship for the marketing of healthy food. The city also seeks to improve health indicators of the population linked to heart problems and diabetes. Havana, Cuba, which is a classic example of urban agriculture, produces 70% of the food it consumes and has reduced consumption of diesel oil by 50% since 1989 and the use of insecticide and herbicide by 90% (Xianglin et al. 2015). As we observed, the motivations for the expansion of urban agriculture vary widely around the world. However, the challenges are still very similar. These challenges include formalizing certification, safety standards and addressing water scarcity in cities. These movements around the world have led to the growth of foreign trade and in particular, the agribusiness is closely linked to the expansion of urban agriculture, as the movement of the countryside migration ends up leading to professional cities or people who identify with agricultural activity.

The produce of the FMUSP Community Garden is intended for volunteers who take turns caring for the plantation. In this way, we can share records and document all learning, teaching and achievements of garden volunteers. Workshops are always related to the environment, permaculture, organic and sustainable agriculture.

Although urban agriculture has achieved great visibility in recent years, according to researchers, urban agriculture needs more efficient irrigation systems and an understanding of global climate change. The formalization of the activity is also a strong challenge, so that it can face competition for land and increase its commercial capacity. For this, it will be essential to promote cultural changes so that societies understand urban horticulture as a sustainable practice, since all the objectives of sustainable development of the UNF and Agriculture Organization (UN/FAO) by 2030 are related to the practice of urban agriculture (Hearn 2015).

The UN/FAO encourages urban agriculture as a strategy to increase city resilience and adaptation to climate change, as well as being an important element in food security for the population. The State of the World - Innovations that Nurture the Planet study, published by the World Watch Institute (WWI), estimates that among the 800 million people in the world engaged in urban agriculture, 200 million produce food to sell in markets and employ up to 150 million of people. According to the study, it was estimated that by 2020, between 35 and 40 million Africans living in cities "will depend on urban agriculture to meet their food needs (http://www.worldwatch.org/ref)". In practice, this can represent up to 40% of the recommended daily intake of calories and 30% of protein needs.

The history of urban agriculture is long and has always been related to increasing food security and fighting hunger, especially in times of war and conflict. The WWI publication shows that research conducted in 24 cities in Africa and Asia in the late 1990s revealed that, "Poor families who practiced urban agriculture ate more meals and had a more balanced diet than other people". In Kampala, the capital of Uganda, data from the 1990s indicate that children from farming families are better nourished than those who did not belong to farming families (http://www.worldwatch.org).

We believe that large cities such as Sao Paulo are becoming centers of development interventions, and planning strategies aimed at combating hunger, poverty and inequality to promote sustainability are being created. The FMUSP Community Garden has contributed to stimulate urban agriculture. Over the years, we have received many visitors to the FMUSP Community Garden.

In addition, Milliron et al. (2016) showed the nutritional benefits of a healthy diet generated by community gardens. This practice helps in the recovery of hospitalized patients by helping the patient to develop new abilities and insights that can lead to better health through behavior change.

Another study conducted at a university campus in Indonesia compared two groups of employees and volunteers: those who worked in the campus garden with the group that did not work. They assessed the quality of life, satisfaction and perception of both groups. The results showed that the groups of employees who worked in the campus garden had a higher perception of quality of life compared to the group that did not work in the garden (Tiyarattanachai and Hollmann 2016).

The implementation of the community garden in the FMUSP brought many additional environmental benefits. It reduced garden pruning rests of the FMUSP campus, which was used in composting for cultivation. In addition, the water economy was improved with the implementation of rainwater harvesting system. Free workshops offered to the general population are aimed at healthy eating and environmental education.

Despite the economic and logistic milestones achieved during these four years of FMUSP Community Garden, one important limiting factor has been the few financial resources available. The maintenance of the garden is done with donations as well as with the help of the volunteers. The number of volunteers of the FMUSP Community Garden is not enough to take care of the wide variety of vegetables, medicinal plants and others plants. If we had more financial resources and a professional helpers, we would have more time to promote educational workshops for the community. Despite these limitations, the activities developed in the FMUSP garden encouraged social engagement and solidarity in the community, resulting in improved mental health, unity and harmony between people and the environment. Especially significant for us was the improvement in the perception FMUSP students to the health benefits of community gardens.

## 5 Conclusion

The FMUSP Community Garden has shown that agriculture in large urban centers and inside an University Campus is possible. The activities in the garden involved students, staff, patients and the surrounding community. The benefits obtained from the activities developed in the FMUSP Community Garden can be seen in scientific articles (Amato-Lourenco et al. 2016, 2017), a guide of medicinal plants and activities related to environmental education and healthy food. Currently, the FMUSP Community Garden is an example for other USP units, nurseries and communities that are starting their gardens. The challenges inherent to this work were related to financial investments and volunteers engagement. In our workshops, we try to disseminate concepts and attitudes on sustainability in daily practice, such as reducing disposables waste and having a healthy diet. To expand the composting system in the FMUSP campus is would be desirable to make the campus more-sustainable in the future. This would reduce expenses from outsourced services to discard the residues from pruning and care of trees and plants of FMUSP campus. The budget saved would allow for investments in urban agriculture and healthy food education.

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# The Environmental Management Plan at University of São Paulo: A Methodology for Sustainable Buildings Policy and Its Further Developments

**Paula Lelis Rabelo Albala, Nathália Mara Lorenzetti Lima, Paula Regina da Cruz Noia, Mariana Auad Proença, Joana Carla Soares Gonçalves and Roberta Consentino Kronka Mülfarth**

**Abstract** The "Environmental Guidelines Policy", developed by the University of São Paulo (USP), pointed out the need to create an "Environmental Management Plan" to all university campuses. Thus, the Superintendence of Environmental Management assigned several Working Groups in order to elaborate the thematic chapters of this plan. Therefore, this article addresses the methodology adopted by the Sustainable Buildings Working Group (SBWG) and its further developments. The SBWG, composed by professors, graduate and postgraduate students and technical staff, framed the theoretical and practical debate towards the development of the Sustainable Buildings Policy. This policy has four general objectives: building requalification, design, construction, and post-occupancy of campuses buildings. Each general objective was then detailed into specific objectives, which in turn were analyzed in terms of necessary actions, indicators, goals and members

P. Lelis Rabelo Albala (✉) · N. M. Lorenzetti Lima · P. R. da Cruz Noia
M. Auad Proença · J. C. Soares Gonçalves · R. Consentino Kronka Mülfarth
School of Architecture and Urbanism, University of São Paulo, Rua do Lago 876, Cidade Universitária, São Paulo, SP, Brazil
e-mail: paula.lelis@gmail.com

N. M. Lorenzetti Lima
e-mail: nathalia.lorenzetti@gmail.com

P. R. da Cruz Noia
e-mail: paula.noia@usp.br

M. Auad Proença
e-mail: marianaproenca.arq@gmail.com

J. C. Soares Gonçalves
e-mail: jocarch29@gmail.com

R. Consentino Kronka Mülfarth
e-mail: rkronka@usp.br



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in charge. The heterogeneity among the SBWG members has contributed to a balanced approach between practical and organizational questions of USP and academic wills, leading to a qualitative gain in the working process. As a matter of fact, this experience evidences the great potential for University Campuses to operate as a bridge between practical and academic experiences, functioning as a real-scale sustainable project laboratory.

**Keywords** Environmental management plan · Sustainable buildings
Methodology · Higher education · University campuses

## 1 Environmental Managements Plans at University Campuses—An Overview

Since the 1960s, universities all over the world have been introducing environmental and sustainable issues in their campuses, in order to promote, to develop and to implement sustainable practices and policies (Tauchen and Brandli 2006). However, university campuses were apart of sustainability discussion until the United Nations Conference at Rio de Janeiro (Rio-92), when the international academic community has noticed the importance of being really engaged.

Recently, with growing importance on the subject, several universities distinguished as centers of excellence around the world are developing Environmental Plans as a practical form for structuring and application of the Eco Campus concept, one of the main strands of sustainability. In this context, it is important to highlight the "Global Universities Partnership on Environment for Sustainability—GUPES" program created by UNEP, which aims to promote sustainability in university campuses all over the world (UNEP 2013). As Leal Filho points out, "the implementation of principles of sustainable development as an intrinsic part of university teaching programs" (Leal Filho 2010).

Environmental Plans suggest the implementation of sustainable actions following a set of guidelines, objectives, indicators and targets. The Harvard University Sustainability Plan (Harvard 2015) the City Sustainable Campus Studies from Polytechnic of Milan (Milano 2015), the Sustainability Annual Report from City University London (London 2015) and University of Maryland Sustainability Progress Report (Maryland 2008) are some examples of these environmental plans that are being implemented. The main purpose of these Plans is to emphasize the role of the universities on seeking for a more sustainable environment through the development of sustainable actions by taking into account the concern about the consumption of energy and water, the waste management, the environmental comfort of the buildings, the sustainable urban planning of the campuses and also for serving as living labs for other universities and the cities.

For that matter, in 2014 the University of São Paulo (USP) establishes its own Environmental Policy, and in 2016, its Environmental Plan (SGA 2016).

It is important to point out that for over 20 years the University of São Paulo (USP) has been introducing and developing sustainable actions into the university. In 2012 the Superintendence of Environmental Management was created aiming to promote the importance of environmental sustainability into the university.

The Environmental Plan of the University of São Paulo (USP) was established through four phases (Romero and Kronka 2017):

- **First phase**: deals with the definition of the overall sustainable policies (administration, greenhouse gas emissions, energy, water, mobility, fauna, green areas, environmental education, land use, policy management, and sustainable buildings) and is complemented by a specific consistent policy to each theme;
- **Second phase**: consists in the definition of thematic management plans addressing actions, goals, indicators and objectives. Each one of the management plans was developed by a Working Group (WG) devoted to each thematic policy;
- **Third phase**: deals with the definition of the Environmental Master Plans covering the eleven thematic chapters for each of the campuses that constitute the university;
- **Fourth phase**: presents the sustainable programs to be developed by each school/unit or department.

These measures aim at fulfilling the exemplary duty that the University represents in society, operating in the control and legitimation of socio-environmental actions. Therefore, it is defined the importance of environmental management in this context, acting in the diagnosis, management and monitoring of the rational use of natural resources within the University.

This article focused on the theme of Sustainable Buildings. As a result of the development of the chapter on Sustainable Building of Environmental Policy at USP, the Environmental Management Plan for Sustainable Buildings was conducted by a heterogeneous work group composed by professors, undergraduate and postgraduate students and technical staff. This work was developed over a year and its results are still in process of implementation.

### *1.1 The Sustainable Buildings Working Group—Aiming a Multidisciplinary Approach*

In order to elaborate the eleven thematic chapters of the "Environmental Management Plan", the Superintendence of Environmental Management (SGA) assigned working groups to develop each one of them (SGA 2016).

Regarding this context, this paper aims to detail activities related to the group assigned to debate environmental policies, regarding campuses buildings: the Sustainable Buildings Working Group (SBWG).

The SBWG has the main objective to promote sustainability into university buildings, by prioritizing the renovation of existing buildings, construction of new buildings, as well as the preservation of natural resources. Thus, SBWG has the perspective of discussing ways to define and implement measures to ensure a sustainable production and occupancy of spaces, either by concrete interventions, or by sustainable attitudes.

In pursuance of achieving the goals mentioned above, the composition of SBWG is very heterogeneous, composed by professors, graduate and postgraduate students from different knowledge areas, and technical staff from SGA and SEF.

It is noteworthy to mention the importance of working with SEF Staff, since they are charged of all constructions, repairs or maintenance of all campuses buildings. In this context, SEF is responsible for approving and checking the progress of all constructions held on USP campuses. So, their contribution was extremely important, and has provided an approximation between measures and means adopted in theory (academic's vision) and practical issues related to construction, repairs and maintenance (practice's vision). In this way, the experience *in loco* of these professionals has contributed to the ability of SBWG to adopt measures that can actually be implemented in the daily life of the University of São Paulo.

In addition, it is important to consider that SBWG has also focused on checking the results of other working groups, in order to identify eventual overlapping issues and to align the environmental policy as a whole.

## 2 A Methodology to put the Sustainable Buildings Policy into Practice

As mentioned before, the Environmental Plan of the University of São Paulo (USP) has eleven thematic policies and to put these policies into practice an Environmental Management Plan was established for each one of them by a specific Working Group (WG). For this article it will be described the methodology developed by the Sustainable Buildings Working Group (SBWG) for the progress of the Environmental Management Plan of Sustainable Buildings that is compound of actions, goals, indicators and objectives. The SBWG is organized by a selective group of professors, technical-administrative professionals and undergraduate and graduate students of the University. And also, it is important to point out that the SBWG it is being used as an applicable methodology for the other WGs.

The first steps for the development of the Sustainable Buildings Management Plan and their objectives was based on the analysis of the Thematic Policy of Sustainable Buildings (which is composed by Subject and Implementation; General Provisions; Definitions; Principles; Goals; Guidelines; Management Tools; Administration Tools and Financial; Responsibilities and Prohibitions) and also, from the study of environmental plans that are being implemented, such as: in the University of Harvard, Polytechnic of Milan, University of London and Maryland described early at the introduction. These Plans have played an important role in designing the actions, targets and indicators for the Sustainable Buildings Management Plan.

To complement the references used for the development of the objectives national and international standards on the subject of buildings and their environmental performance were consulted, among them one can stand out*: ISO 6241: 1984 Performance standards in building - Principles for their preparation and factors to be considered* (1984)*; ABNT NBR ISO 14031:2013—Environmental management—Environmental performance evaluation—Guidelines* (2013); *ISO 13065: 2015 Sustainability criteria for bioenergy* (2015)*; ISO 50006:2014 Energy management systems—Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI)—General principles and guidance* (2014), among others. In continuing, it will be detailed the establishment of the general and specifics objectives of the Environmental Management Plan of Sustainable Buildings.

## *2.1 Establishment of General and Specific Objectives*

As brought up to discussion previously, research about Sustainable Plans developed and implemented at universities all around the word showed specific tendencies. Moreover, some national and international laws and standards were used as basic references for the definition of actions, indicators and targets.

Based on those aspects, University of São Paulo´s Environmental Policy was structured in four general objectives:

1. *Building requalification;*
2. *Design;*
3. *Construction;*
4. *Maintenance, use and operation.*

Each general objective was then detailed into specific objectives, which in turn were analyzed in terms of necessary actions, indicators, goals and members in charge. Below, we present a short description of each one, detailing their specific objectives as well:

1. *Building requalification*

The first objective evolves identifying the need for requalification of buildings for better environmental performance. From the perspective of environmental performance, post-occupation evaluation routines are fundamental for the definition of the improvement program of existing buildings. In this case, consecutive analytical studies have the role of pointing the limits of these improvements, considering construction characteristics, layout of the internal spaces, site situation and solar orientation of the existing building. In the case of historical buildings, additional constraints are defined.

Specific objectives of General Objective 1 are:

- Improve environmental comfort conditions (thermal, acoustic, luminous, ergonomic), productivity, accessibility and health inside the buildings;
- Maximize an implementation of passive ventilation and natural lighting strategies and minimize dependence on air conditioning and artificial lighting systems to create environmental comfort conditions in the interior spaces of buildings;
- Ensure the energy efficiency of the checks and verify the possibility of introducing renewable energy capture technologies and consider relevant variants that do not affect any energy performance of the building;
- Minimize or optimize water and energy consumption during the use and occupancy of buildings;
- Ensure property security in the use and occupancy of buildings;
- Ensure that project interventions for improving the environmental performance of qualifications and their energy efficiency are in accordance with the constraints of the tipping condition;
- Consider and improve relationship between ecosystem/environment and also mobility in the immediate surroundings of the building;
- Develop Energy Management System (EMS), based on the energy performance of consumption, use and efficiency;
- Establish/Define Energy Performance Indicators (EPI) based on values and measures based on results obtained through the energy efficiency, use and consumption of the editions;
- Implement the Environmental Performance Assessment System (EPAS), considering an environmental policy, objectives, goals and actions determined by the organization;
- Legislative and regulatory verification in force for the requalification of buildings.

2. *Design*

The second objective aims the design and development of permanent and temporary new buildings. Analytical studies of potential environmental performance of buildings and renewable energy play a central role in the definition of design parameters and also in the elaboration of a future USP Sustainable Building Certification.

Specific objectives connected to general objective 2 can be listed as:

- Guarantee conditions of environmental comfort (thermal, acoustic, luminous and ergonomic), productivity, accessibility and health inside the buildings;
- Maximize the implementation of passive ventilation and natural lighting strategies and minimize dependence on active air conditioning and artificial lighting systems to create conditions of environmental comfort in the interior spaces of buildings;

- Establish the potential for natural ventilation and natural lighting of buildings (where environmental performance requirements of specific uses allow for ventilation and natural lighting);
- Ensure the energy efficiency of buildings' systems, ban the indiscriminate use of artificial lighting and air conditioning systems and encourage the use of renewable energy sources in buildings;
- Establish energy performance benchmarks by disaggregated use for buildings, considering variations according to the specific climate of each campus and the requirements of thermal and lighting conditions imposed by different uses of space;
- Promote the rational use of natural resources and verify their useful life cycle (including raw materials) and industrialized products during construction, use and occupation of buildings;
- Preference for the use of materials available/produced in the region;
- Consider and improve relationship between ecosystem/environment and also mobility in the immediate environment of the building;
- Avoid negative environmental impacts of new buildings in the immediate environment, including buildings and open spaces in the neighborhood;
- Implement Manual for New Buildings, as a basic guide for the planning, practice, development, production and maintenance of new buildings;
- Create the USP certification of environmental performance of buildings ("USP Green Buildings Label");
- Develop architectural software and solutions appropriate to users' needs and expectations;
- Implement Environmental Performance Assessment (EPA) system, considering the environmental policy, objectives, goals and actions determined by the organization;
- Check existing legislation and regulations for the construction of new buildings.

3. *Construction*

The third objective considers questions related to Building Construction, focusing on the achievement of constructive processes of low environmental impact. It is important to highlight that the analysis of environmental impacts, in this case, is not only related to the construction of the building itself, but, also, to the construction site. In other words, the objective 3 establishes guidelines to build, maintain and operate the construction. Also, questions related to materials and constructive systems are also regarded.

In the case of materials and constructive systems, the understanding about environmental performance englobes issues related to life cycle analysis, durability and socioeconomic impact. Summarizing, the specific objectives of General Objective 3 are:

- Promote clean practices at construction sites, and consequently, minimizing waste generation and pollutants emissions in water, soil and air;
- Guarantee efficiency in terms of time and quality of works at construction sites;

- Promote the reuse of materials and equipment at the construction site;
- Minimize the overall environmental impact of the construction site and construction.

4. *Maintenance, use and operation*

The forth general objective aims at the implementation of routines for maintenance, use and operation of buildings in order to achieve high performance and environmental quality. A great importance is particularly placed in maintenance teams and user's education related to buildings, as the conscious use of natural lighting systems and ventilation resources, to reach environmental comfort conditions. In this regard, the Sustainable Building Chapter has a clear interface with the Education Chapter in proposing training and environmental education programs for technicians and users.

Several specific objectives are connected to the topic, mainly related to diagnosis and awareness. They can be listed as:

- Identify problems of environmental comfort, salubrity, accessibility and durability in buildings
- Aware buildings occupants about their water and energy consumption
- Instruct occupants of buildings about the potential of passive strategies of buildings and how to benefit from them in the search for better conditions of environmental comfort and health inside buildings
- Quantify of water and energy consumption of buildings
- Minimize water and energy consumption of buildings
- Promote the reduction of waste generation and the sustainable management of reminiscent waste.

There are natural overlaps between the four general objectives. Specifically *Building requalification* (Objective 1) and *Design* (Objective 2) have many overlaps, since both encompass relationships between architectural design and building systems with users, environment and local climate. In some way, if we are dealing with existing buildings and new constructions we are paying attention to the environmental performance of the building. In addition, one must also take into account the conscious use of users, it merges with one of the aspects of the Working Group on environmental education, therefore taking advantage of natural lighting and natural ventilation resources, as a passive form to get to a satisfactory environmental comfort as well as the responsible use of the electricity and water. In addition, surfacing the mobility working group, is the aspect related to access to the building as well as your proximity to public transport points, as the buses that access the campus, and the presence of bike racks, encouraging the use of sustainable means of transport.

To achieve the goals for each objective it's essential to highlight the diagnosis of the current environmental performance of buildings and how the levels of the energy and water consumption are. Although there are some campuses consumption measurements, individualized measurement of each building, as well as areas with differential consumption ensures easy control and leak detection, in addition to capturing the overuse of these sources making efficient reduction proposals being implemented according to that specific use, which converges with the measures designed in Working Group on water and effluents. Moreover, it is also important the analysis of the environmental impact and the economic, constructive and environmental efficiency of the work practices currently adopted in the campus of the University of São Paulo. This is because many common practices in the construction of buildings, not just on Campuses but also on society in general, adopt practices that go against of sustainability, generating large amounts of garbage, in addition to using water indiscriminately.

There is also a logical sequence between the four objectives, *Building requalification*, *Design*, *Construction* and *Maintenance, use and operation*. The actions, goals and indicators of each of these goals aims to surround all the major issues to be addressed about environmental management on campus, encompassing all stages of the construction lifecycle.

## 2.2 Determining Global Actions, Indicators, Goals, Deadlines of Implementation and Members

For each one of these general objectives some others specifics objectives were established taking into account that for each one of them were defined actions, indicators, goals and members in charge. To complement, deadlines were stablished for actions and goals, being specified as short, medium and long term. Regarding the general objective of building requalification the deadline was defined as variable.

Considering the deadlines, each action or goal were analyzed considering short, medium and long terms.

Short term actions and goals come from survey and monitoring of building conditions to allow the creation of manuals and training programs for occupants. So, they are focused on quantitative and/or qualitative parameters on energy and water consumption. Finally, short terms actions or goals are expected to be put in practice within 4 years.

Medium term actions are more focused in training and orientation of managers, staff and teacher on procedures for building interventions. Their target is to reach the entire USP community (students, staff and teachers) within 4–6 years.

Last but not least, long term actions are related to measurement and continuous monitoring of water and energy consumption of buildings, for example. Thus, long term actions and goals – which can be put in practice within 6–10 years—are related to the guarantee of high degree of satisfaction of the users with the buildings and diagnosis or control of energy and water consumption (Fig. 1).

**Fig. 1** Deadlines for actions and goals—summary. *Font* Authors' elaboration

| DEADLINES FOR ACTIONS AND GOALS | |
|---|---|
| cp | short term: within 4 years |
| mp | medium term: within 4 to 6 years |
| lp | long term: within 6 to 10 years |
| var | varies, depends on needs for requalification |

**Fig. 2** Indicators types. *Font* Authors' elaboration

| INDICATORS TYPES | |
|---|---|
| qt | quantitative, index calculations |
| rel | qualitative, reports |

Also, two kinds of indicators were developed: quantitative (relating to index calculations) and qualitative (descriptive reports of actions and results) (Fig. 2). It's important to highlight that for a single General Objective, the same action and indicator can be associated to more than one specific objective.

To conclude, for members in charge some the possible agents were established: The City Hall of the campus, the Superintendence of Physical Space—SEF, the Superintendence of Environmental Management—SGA, the Center for Cultural Heritage—CPC, the Directorates of Units and Museums, the Maintenance Staff and Museums, as well as the occupants of the buildings (Fig. 3).

All these conceptions and definitions were gathered in structured tables that can make easier the understanding to anyone to be in charge of the implementation. As we will detail further, such tables are also useful for putting into practice the actions of the Sustainable Buildings Management Plan.

## 2.3 *Hierarchizing Priorities*

In order to establish a hierarchy between all specific objectives, within each objective, the SBWG developed a qualitative methodology. This consists in settling five criteria and attributing different weights to each one, accordingly to their relevance to the goals and actions of each objective (Table 1).

| RESPONSABILITY | |
|---|---|
| **PREF** | USP Campus Cityhall |
| **SGA** | Superintendence of Environmental Management of USP |
| **SEF** | Superintendence of Physical Space of USP |
| **DUM** | Directorates of Units and Museums |
| **CPC** | Center for Cultural Heritage |
| **MAN** | Maintenance Staff |
| **OCU** | Occupants |

**Fig. 3** Indicators types. *Font* Authors' elaboration

**Table 1** Weighting criteria to hierarch goals and actions

| Criterion | Brief description | Punctuation | Weight |
|---|---|---|---|
| Urgency (U) | Evaluates the need of implementing a specific action or goal, according to an urgent reason, focusing on the achievement of the policy's objectives as a whole | 0—Does not apply<br>1—Low urgency<br>2—Medium urgency<br>3—High urgency | 3 |
| Safety (Sa) | Evaluates the need of implementing a specific action or goal, according to user safety reasons | 0—Does not apply<br>1—Low priority<br>2—Medium priority<br>3—High priority | 3 |
| Impact (I) | Evaluates the consequences of implementing a specific action or goal, considering the achievement of the policy's objectives as a whole | 0—Does not apply<br>1—Low impact<br>2—Medium impact<br>3—High impact | 2 |
| Scope (Sc) | Evaluates the consequences of implementing a specific action or goal, considering the benefits for the USP community | 0—Does not apply<br>1—Low priority<br>2—Medium priority<br>3—High priority | 2 |
| Cost (C) | Evaluates the costs of implementing a specific action or goal, according to an urgent reason | 0—Does not apply<br>3—Low cost<br>2—Medium cost<br>1—High cost | 1 |

*Font* Authors' elaboration

The selected criteria and their respective weights are:

As we can see at the table above, the criteria "urgency" and "safety" were considered by SBWG as the most important, and, due to that, these criteria received a maximum weight (3). In sequence, impact and scope received an intermediary weight (2). Finally, the criteria "cost" has received a minimum "weight" (1).

Thus, the final punctuation of each goal or action was defined by the following equation (Eq. 1):

$$\textbf{Final Punctuation (FP)} = \frac{\mathbf{3.U + 3.sa + 2.I + 2.Sc + 1.C}}{\mathbf{11}} \tag{1}$$

Equation 1. Punctuation Formula to hierarch goals and actions. *Font* Author's elaboration.

Hence, the higher "FP" obtained in each goal or action, the highest priority of their implementation.

In this sense, and regarding the "cost" criteria, it is noteworthy to highlight some aspects. Even if the cost of implementing goals and actions is an extremely important criterion, it was necessary to attribute a low weight in order to not disqualify priority measures due to their associated costs. To counterbalance this, its punctuation is inversely proportional in importance, when compared to other criteria. In other words, while the weight 3 has a positive meaning in all other criteria, for the Cost, the weight 1 represents the more favorable situation, in order to benefit low cost measures. Finally, in order to identify different types of costs, the SBWG create a classification, as demonstrated at Table 2.

So, after this analysis, all goals and indicators were ranked according to its punctuation, which ranges between 0 and 3. The order that all actions and goals appear in the objectives' tables is directly related to the overall importance attributed to each one of them.

One of the advantages noticed in this process is related to see the level of importance of each action or goal, independent from its deadlines (short, medium or long terms).

## 2.4 *Creation of Summary and Detailed Tables*

After all analysis, the SBWG developed two formularies for each general objective. The first one (Fig. 4) shows in a very direct manner the actions, indicators and goals for each specific objective. Also, this summary table designates members in charge of a general objective.

The second table produced by the SBWG consists in a more detailed summary for each general objective. As we can see below (Fig. 5), anyone who needs to

**Table 2** Justification of costs

| Types of costs | |
|---|---|
| rh | Human resources—hours worked |
| ee | Specialized study—analytical |
| ob | Construction services—installation/facilities |
| eq | Equipment—supply |

*Font* Authors' elaboration

| GENERAL OBJECTIVE | SPECIFIC OBJECTIVE | ACTIONS/ DEADLINES FOR IMPLEMENTATION | | | | | INDICATORS | | | | | GOALS/ DEADLINES FOR IMPLEMENTATION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A.1 | A.2 | A.3 | A.4 | A.5 | I.1 | I.2 | I.3 | I.4 | I.5 | M.1 | M.2 | M.3 | M.4 | M.5 |
| 1 | 1.1. | | | | | | | | | | | | | | | |
| | 1.2 | | | | | | | | | | | | | | | |
| | 1.3 | | | | | | | | | | | | | | | |
| | 1.4 | | | | | | | | | | | | | | | |
| | 1.5 | | | | | | | | | | | | | | | |

| RESPONSABILITY | PREF | SGA | SEF | DUM | CPC | MAN | OCU |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

**Fig. 4** Summary table for each general objective. *Font* Author's elaboration

| GENERAL OBJECTIVE | | RESPONSABILITY | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | PREF | SGA | SEF | DUM | CPC | MAN | OCU |
| 1 | | | | | | | | |

| SPECIFIC OBJECTIVES | | ACTIONS/ DEADLINES FOR IMPLEMENTATION | | | | | INDICATORS | | | | | GOALS/ DEADLINES FOR IMPLEMENTATION | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A.1 | A.2 | A.3 | A.4 | A.5 | I.1 | I.2 | I.3 | I.4 | I.5 | M.1 | M.2 | M.3 | M.4 | M.5 |
| 1.1. | | | | | | | | | | | | | | | | |
| 1.2 | | | | | | | | | | | | | | | | |
| 1.3 | | | | | | | | | | | | | | | | |
| 1.4 | | | | | | | | | | | | | | | | |
| 1.5 | | | | | | | | | | | | | | | | |

| ACTIONS/ DEADLINES FOR IMPLEMENTATION | | |
|---|---|---|
| A.1 | | |
| A.2 | | |
| A.3 | | |
| A.4 | | |
| A.5 | | - |
| **INDICATORS** | | |
| I.1 | | |
| I.2 | | |
| I.3 | | |
| I.4 | | |
| I.5 | | |
| **GOALS/ DEADLINES FOR IMPLEMENTATION** | | |
| M.1 | | |
| M.2 | | |
| M.3 | | |
| M.4 | | |
| M.5 | | |

**Fig. 5** Detailed table for each general objective. *Font* Author's elaboration

verify the meaning of each action, indicator or goals, can consult this table. Also, this form was developed to be frequently changed, in order to keep up with USP Campuses needs.

## 3 Final Remarks and Further Developments

The foregoing discussion lead us to conclude that the heterogeneity among the SBWG members has contributed to a balanced approach between practical and organizational questions of USP and academic wills, leading to a qualitative gain in the working process.

In addition, to ensure a better formulation and implementation of sustainable Buildings policy, it was remarkable the necessary interaction and discussion with other working groups, in order to identify overlaps or points in common, avoiding contradictions and creating a coherent environment policy through all areas. The interaction between various areas of the University was also of great importance to expand the applicability of the proposals and objectives set out in policy.

Another point, extremely important for several measures, is the involvement of building occupants in the process, in order to achieve sustainability, contributing to enhance the autonomy of the buildings, without relying on excessive use of air conditioning or even artificial lighting.

As further developments of this Environmental Policy of the University of São Paulo, a number of measures and projects have started to put into practice. In this manner, we can highlight the pilot project called "BOSSA", which consists in investigate post-occupation of USP's office buildings, in order to determine the conditions of work and comfort of users, and their ability to change the climatic conditions in the interior of these buildings, "educating" them according to the new guidelines. Furthermore, is intended to extend the project to the students in educational environments.

As a matter of fact, this experience evidences the great potential for University Campuses to operate as a bridge between practical and academic experiences, functioning as a real-scale sustainable project laboratory, serving as reference and experience for future projects to be deployed in the city.

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## Author Biographies

**Paula Lelis Rabelo Albala (Ph.D. Candidate)** Ph.D. Candidate at the Faculty of Architecture and Urbanism of University of São Paulo (FAU-USP), Master’s Degree (2010) at Universitat Politècnica de Catalunya (UPC), Spain and Bachelor’s degree (2007) in Architecture and Urbanism at FAU-USP. Member of Sustainable Building Working Group at Superintendence of Environmental Management of USP (SGA-USP), contributing to the development of sustainable policies of the University. Attended on WC2 University Network (World Cities World Class) Symposium, representing USP at the Eco campus Group (2016). Practitioner Architect, with experience in projects related to sustainability in Brazil, Spain and Chile. Emphasis on architecture and urbanism fields, focusing on sustainability in the built and urban environments, sustainable mobility, environmental performance, and low impact materials.

**Nathália Mara Lorenzetti Lima (Msc)** Master’s degree (2017) and Bachelor’s degree (2014) at the Faculty of Architecture and Urbanism of University of São Paulo (FAU-USP). Member of Sustainable Building Working Group at Superintendence of Environmental Management of USP (SGA-USP), contributing to the development of sustainable policies of the University. Attended on WC2 University Network (World Cities World Class) Symposium, representing USP at the Eco campus Group (2016). Emphasis on architecture and urbanism fields, focusing on sustainability in the built environment, ergonomy, environmental performance, retrofit, elderly.

**Paula Regina da Cruz Noia (Ph.D.)** Ph.D. (2017), Master’s degree (2012) and Bachelor’s Degree in Architecture and Urbanism (2008) by the Faculty of Architecture and Urbanism of University of São Paulo (FAU-USP). Exchange student with the École Nationale Superieure d’Architecture of Grenoble (2006–2007). Member of Sustainable Building Working Group at Superintendence of Environmental Management of USP (SGA-USP), contributing to the development of sustainable policies of the University. Research internship with the Universidad Nacional de Colombia (2012) and Université de Montréal (2015–2016). Practitioner Architect, with emphasis on Technology and Building Design, working mainly on the following topics: construction technology, constructive cultures, social technology, sustainability, participatory processes, housing and institutional buildings.

**Mariana Auad Proença (Msc Student)** Master's degree student at the Faculty of Architecture and Urbanism of University of São Paulo (FAU-USP) and Bachelor's degree (2010) in Architecture and Urbanism at Mackenzie Presbyterian University (FAU-Mack). Member of Sustainable Building Working Group at Superintendence of Environmental Management of USP (SGA-USP), contributing to the development of sustainable policies of the University. Attended on WC2 University Network (World Cities World Class) Symposium, representing USP at the Eco campus Group (2016). Currently attending the Latitudes Global Studio, a cooperation project between the Faculty of Architecture and Built Environment of University of Westminster and FAU-USP. Emphasis on architecture and urbanism fields, focusing on sustainability in the built environment, eco-campus, hospitals, landscaping and interior design.

**Prof. Joana Carla Soares Gonçalves (Ph.D.)** Joana Gonçalves is Associated Professor at the Faculty of Architecture and Urbanism of University of São Paulo (FAU-USP) and Head of Technology Department at the same institution (since 2015). Coordinator of the Sustainable Building Working Group at Superintendence of Environmental Management of USP (SGA-USP). Ph.D. (2003) at FAU-USP, Master's degree (1997) in Environment and Energy at Architectural Association Graduate School (AA); and Bachelor's Degree in Architecture and Urbanism (1993) at Federal University of Rio de Janeiro (UFRJ). Course Tutor at "Sustainable Environmental Design" Master Program at AA (between 2009 and 2013), Visiting Lecturer at Graduate School of Design (GSD) at Harvard University (2011), Visiting Professor at Faculty of Architecture and the Built Environment of University of Westminster (since 2015). Member of PLEA Director's Board (Passive and Low Energy Architecture). Experience in architecture and urbanism fields, focusing on Environmental Comfort and on researches related to environmental performance of the built environment.

**Prof. Roberta Consentino Kronka Mülfarth (Ph.D.)** Roberta Kronka Mülfarth is Associate Professor at the Faculty of Architecture and Urbanism of University of São Paulo (FAU-USP) since 2006. Ph.D. (2002) in Urban Environmental Structures at the same institution, a Master's Degree (1998) in Energy at the Postgraduate Interunit Program of University of São Paulo and a Bachelor's Degree in Architecture and Urbanism (1994) at FAU-USP. Technical Adviser at the Superintendence of Environmental Management of USP (SGA), and Coordinator of the development of Environmental Policies of USP and Sustainable Building Working Group at Superintendence of Environmental Management of USP (SGA-USP). Member of the WC2 University Network (World Cities World Class), representing USP at the Eco campus Group. Member of ISCN Advisory Committee (International Sustainable Campuses Network) since 2016. Experience in architecture and urbanism fields, focusing on Environmental Comfort and on researches related to environmental performance of the built environment.

# Sustainable Campus Model at the University of Campinas—Brazil: An Integrated Living Lab for Renewable Generation, Electric Mobility, Energy Efficiency, Monitoring and Energy Demand Management

**Luiz C. P. da Silva, Marcelo G. Villalva, Madson C. de Almeida, José L. P. Brittes, Jorge Yasuoka, João G. I. Cypriano, Daniel Dotta, José Tomaz V. Pereira, Mauricio B. C. Salles, Giulianno Bolognesi Archilli and Juliano Garcia Campos**

**Abstract** The aim of this article is to describe the concept of a Living Lab to be implemented at the University of Campinas through a partnership between UNICAMP and CPFL (local Utility Distribution Company). This project was recently submitted to a strategic and priority call from the Brazilian Regulatory Agency (National Electric Energy Agency—ANEEL, acronym in Portuguese). The Living Lab is divided into six subprojects integrating energy efficiency with research and development in distributed generation. These subprojects include: 300 measure points for a Power System Control Center; 400 kWp PV-Minigrid

L. C. P. da Silva (✉) · M. G. Villalva · M. C. de Almeida · J. G. I. Cypriano · D. Dotta
School of Electrical and Computing Engineering (FEEC),
University of Campinas, Cidade Universitária Zeferino Vaz,
Av. Albert Einstein 400, Distrito Barão Geraldo, Campinas, SP 13083-852, Brazil
e-mail: lui@dsee.fee.unicamp.br

M. G. Villalva
e-mail: mvillalv@dsce.fee.unicamp.br

M. C. de Almeida
e-mail: madson@dsee.fee.unicamp.br

J. G. I. Cypriano
e-mail: joao.ito@dsee.fee.unicamp.br

D. Dotta
e-mail: dotta@dsee.fee.unicamp.br

J. L. P. Brittes
School of Applied Sciences (FCA), University of Campinas, Limeira,
Rua Pedro Zaccaria, 1300 - Jd. Santa Luiza, Limeira, SP 13484-350, Brazil
e-mail: jose.brittes@fca.unicamp.br



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installation, distributed into 18 plants; Electric Mobility with a recharge facility and an electric bus; retrofit in an electrical facility as a prototype; an innovative IoT-based DMS energy management tool; and training in Distributed Generation (DG), Smart Grid and Energy Efficiency. The complementarity of the subprojects will empower the living lab in terms of innovation, research and teaching in energy management, measurement and verification, photovoltaic energy generation, electric mobility and sustainability in energy consumption at the University. All these actions comply with the ISCN/GULF Sustainable Campus Chapter policies, signed by UNICAMP a few years ago. This paper is important because it will result in a replicable model for sustainable campuses for Latin America, with a detailed step-by-step procedure covering local mini-grid EMS, IoT-educational DMS, Mobility, real-time retrofitted efficiency and institutional energy governance, which is a pioneering approach in South America.

**Keywords** Living labs · Sustainable campus · Energy sustainability
Energy efficiency

J. Yasuoka
School of Mechanical Engineering (FEM), University of Campinas,
Cidade Universitária Zeferino Vaz - Rua Mendeleyev, 200 - Distrito Barão Geraldo,
Campinas, SP 13083-860, Brazil
e-mail: yasuoka@gmail.com

J. T. V. Pereira
Interdisciplinary Centre of Energy Planning (NIPE), University of Campinas,
Rua Cora Coralina, 330 - Distrito Barão Geraldo, Caixa Postal 6166,
Campinas, SP 13083-896, Brazil
e-mail: tomaz@nipe.unicamp.br

M. B. C. Salles
Department of Energy and Electric Automation Engineering (PEA),
Polytechnic School, University of São Paulo, Cidade Universitária
Armando de Salles Oliveira, Avenida Professor Luciano Gualberto,
Travessa 3, nº 158, São Paulo, SP 05508-010, Brazil
e-mail: mausalles@usp.br

G. B. Archilli · J. G. Campos
CPFL Group, Rodovia Engenheiro Miguel Noel Nascentes Burnier,
Km 2,5, S/n - Parque São Quirino, Campinas, SP 13088-900, Brazil
e-mail: giulianno@cpfl.com.br

J. G. Campos
e-mail: julianocampos@cpfl.com.br

## 1 Introduction

Higher education institutions play an important role in developing society by training and educating new leaders, managers and entrepreneurs transforming and creating paradigms that provide a conscious future for new generations. As they have this regional and international socioeconomic influence, many universities have committed themselves to promoting sustainability regarding their activities and operations by signing national and international declarations, charters and partnerships of sustainable commitment (Lozano et al. 2013). Considering this, various academic communities are currently engaged in establishing new standards for Research, Development and Innovation (RDI), education, organizational structure, operation and infrastructure, based on sustainable development.

The aim of this article is to present a sustainable campus model to be adopted by the University of Campinas (UNICAMP) by implementing an energy efficiency and Research and Development (R&D) project promoted by the public-private partnership with *CPFL Paulista* (Local Utility Distribution Company) responding to the 001/2016 call from ANEEL, entitled "Priority Project on Energy Efficiency and Strategic R&D—Energy Efficiency and Mini Generation in Public Higher Education Institutions".

As a final result, a Living Lab will be set up for energy sustainability by integrating the creation of new technologies, products and patents in a real application context counting on the university's RDI capacity (Niitamo et al. 2006) in areas of renewable energy mini-generation, electric mobility (electric bus), energy efficiency in buildings, monitoring and energy demand management. This paper is important because it will result in a replicable model for sustainable campuses for Latin America, with a detailed step-by-step procedure covering local mini-grid EMS, IoT-educational DMS, Mobility, real-time retrofitted efficiency and institutional energy governance, which is a pioneering approach in South America.

## 2 The University

The University of Campinas (UNICAMP) is located in the state of São Paulo and has four campuses, namely: the main campus (*Cidade Universitária Zeferino Vaz*) in Campinas; the School of Dentistry in Piracicaba; the School of Applied Sciences and the School of Technology in Limeira; and the Chemical, Biological and Agricultural Pluridisciplinary Research Centre ([1]CPQBA in Portuguese). The university is made up of 24 teaching and research centres and has a vast health complex on the Campinas campus, as well as 23 centres and interdisciplinary centres, two technical colleges (*Cotil* and *Cotuca*) and many support units in a place

[1]The authors decided to leave some abbreviations in Portuguese throughout the paper to make it easier for the reader to refer to these places and groups on Brazilian websites.

where approximately 60 thousand people circulate on a daily basis (UNICAMP 2017).

All this infrastructure has led to UNICAMP being responsible for 8% of all academic research in Brazil, including 12% of postgraduate education in Brazil. There are 34,000 enrolled students (52% undergraduates and 48% postgraduates) in 66 undergraduate and 153 postgraduate programs with an annual average of 2100 thesis and dissertation defences (UNICAMP 2017). Thus, the university has become a “research factory” and an education centre for highly qualified professionals, combining teaching with research.

## 3 Commitment to Sustainability

In addition to being a national reference in research, education and development, UNICAMP signed the ISCN-GULF Sustainable Campus Charter from the International Sustainable Campus Network (ISCN) in April 2015 (GGUS 2017). The ISCN provides a global forum to support key colleges, universities and corporate campuses in exchanging information, ideas, and best practices for achieving sustainable operations in institutions and integrating sustainability into research and teaching, counting on members such as Harvard University, the Massachusetts Institute of Technology (MIT) and Yale University (ISCN Charter and Guidelines 2017).

Having signed the Charter, UNICAMP publicly committed itself to the sustainability of its objectives and alignment of its research, teaching and administrative operation following three principles set out in the charter, described in Fig. 1.

## 4 Sustainable University Management Group (GGUS in Portuguese)

Therefore, at the end of 2015, the University created the Sustainable University Management Group (GGUS) with the purpose of planning, developing, enabling and managing actions, projects and institutional programs related to socio-environmental sustainability, based on the continuous improvement and environmental, economic and social performance (GGUS 2017).

Through GGUS, UNICAMP seeks to become a reference in Sustainability and provides a benchmark for a living lab for social and environmental actions. Taking this into account, an organizational structure was created, divided into technical and administrative topics, as can be seen in the organisational chart in Fig. 2.

Technical Chambers (CTs in Portuguese) are study groups comprising faculty members and collaborators specialized in the specific subjects, subdivided into 6

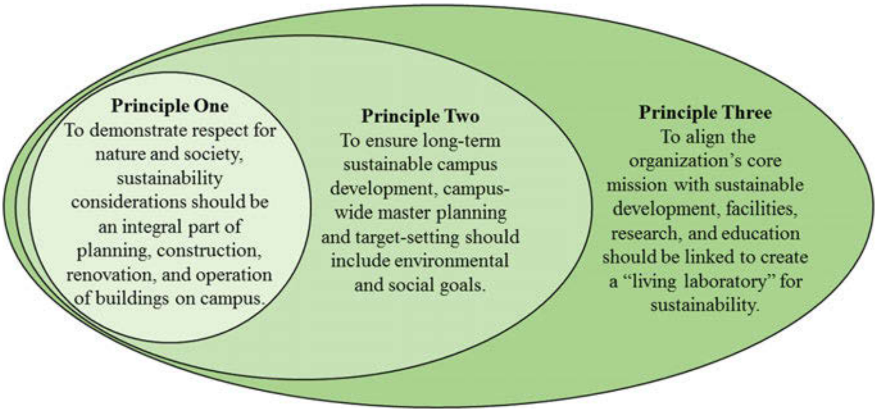



**Fig. 1** Principles of the ISCN-GULF sustainable campus charter (ISCN 2017)

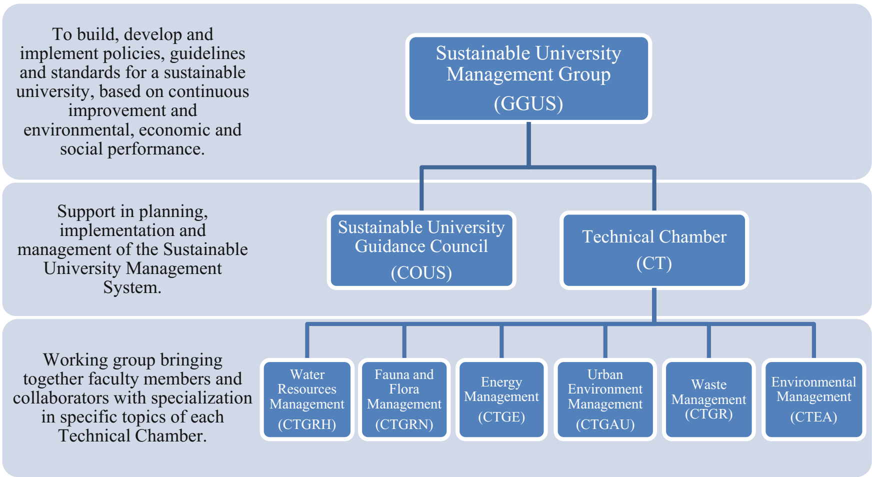



**Fig. 2** GGUS organisational chart (GGUS 2017)

major areas: water resources, fauna and flora, energy, urban environment, waste and environmental education. Based on the goals and guidelines set out by the GGUS, the CTs plan and determine their short, medium and long term activities, always operating together.

The Sustainable University (SU) model described in this article is based on energy sustainability and is led by the Energy Management Technical Chamber (CTGE in Portuguese), which is responsible for developing the Energy Management program at UNICAMP campuses. Its objective is to reduce energy consumption by developing management programs and technical procedures, improving the university's energy efficiency counting on the participation of bodies from the UNICAMP managerial and operational structure.

The Waste Management Technical Chamber (CTGR in Portuguese) is closely integrated with the CTGE as it is important to properly dispose of any waste in the energy efficiency and retrofit activities (exchanging old equipment for more modern and efficient apparatus). This technical chamber is currently one of the most structured, managing various chemical, biological and hospital waste and treatments, as well as standardising and raising awareness of the program which has a differential by separating this waste.

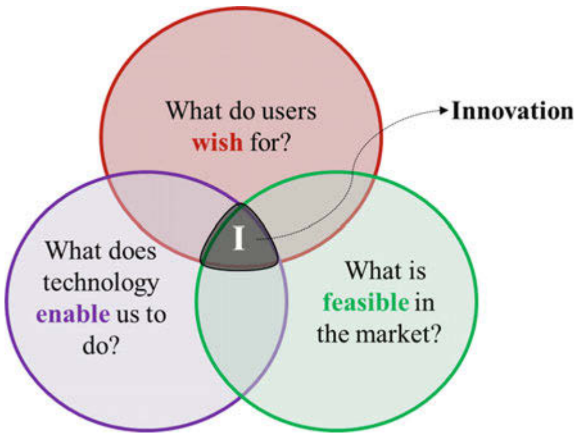
## 5 Living Laboratories

Among the principles described in the "Sustainable University" Charter is the term "living labs", which consists of an open innovation ecosystem through the integration between users, academia and the market (private companies). This new way of generating innovation and products aligns technical and scientific possibilities (research) with the users' desires and the market feasibility of implementing them.

Thus, the knowledge generated will be used, according to the current needs in the regional environment of the living lab, financed by a public-private partnership with real applications and tests. The diagram in Fig. 3 exemplifies this integration and where innovation is located.

Energy sustainability will be the basis of the living lab implemented and will include six subprojects (described in the next topic) which will enable the interoperability of different systems, helping innovation and implementation to take place more quickly.

**Fig. 3** Living lab concept diagram



# 6 The Project

Having the aim of developing and putting sustainability into practice in the academic culture of UNICAMP, the 001/2016 call from ANEEL, entitled "Priority Project on Energy Efficiency and Strategic R&D—Energy Efficiency and Mini Generation in Public Higher Education Institutions" is a clear opportunity whereby the university can put this major plan into practice.

The "UNICAMP Sustainable University" project is a long-term project and will be carried out based on a series of initiatives. However, through this call, UNICAMP will have the opportunity to carry out energy sustainability projects, defined through goals and guidelines from the Energy Management Technical Chamber (Fig. 4).

The project will consist of: photovoltaic energy micro-generation with various generation plants spread around the main campus; electric mobility by electric bus, mapping the socio-environmental impacts of using this technology; retrofit and sensors for energy efficiency; energy monitoring and network evaluation; and finally, knowledge compiled in programs, courses, lectures, booklets and books (Fig. 5).

## *6.1 Subproject 1—Mini-Centre Operation of the University's Power System*

This subproject aims to implement a smart mini-centre for data consumption and power system operations for the main UNICAMP campus (*Cidade Universitário Zeferino Vaz)* by installing electronic meters in all the consumer units (faculties, institutes, laboratories, interdisciplinary centres, administration, etc.) to monitor the


**Fig. 4** Corporative structure

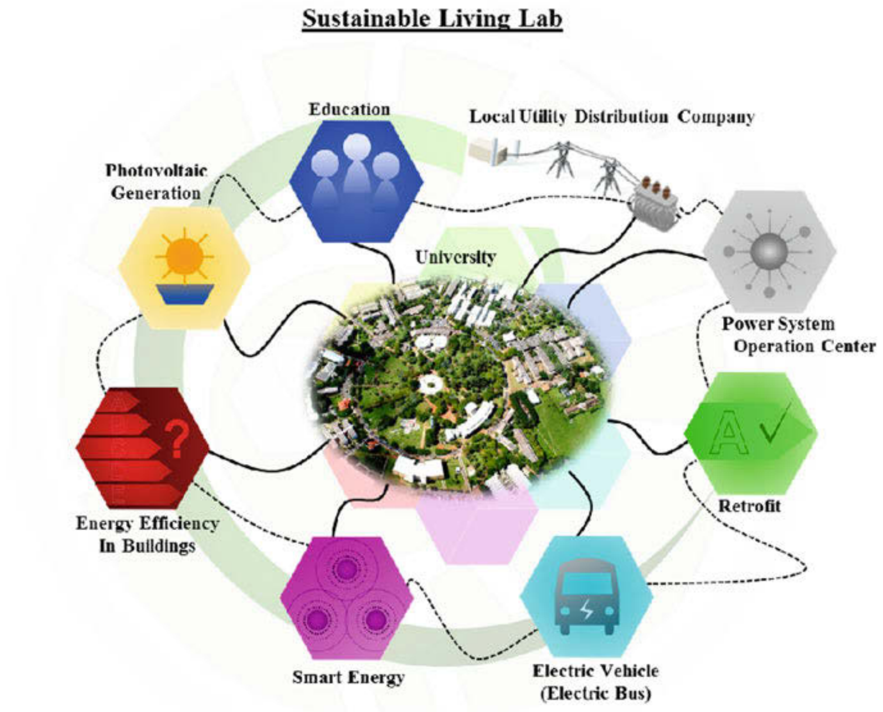



**Fig. 5** Integration of the projects

actual consumption of each consumer. Currently the university is a free consumer and only has the interface measurement with the network of the utility, and therefore does not have much knowledge about the internal losses of its distribution network.

It is widely known that power consumption without due monitoring and financial accountability is the greatest incentive for inefficiency and irrational use of electricity. Therefore, in order to fulfil the goals towards developing a Sustainable Campus, it is a priority for the university to build a data centre for measuring consumption. It should also take advantage of this opportunity to build a hardware and software infrastructure which can use network analysis and optimization tools, aiming at efficiency gains both from the consumption point of view, as well as the most suitable operation, planning and maintenance of the electrical grid.

Any energy efficiency project depends on sound information to succeed. Implementing this project will continuously and permanently provide information in real time on the energy consumption in the *Barão Geraldo* Campus. This subproject is vitally important for all initiatives to be implemented at the

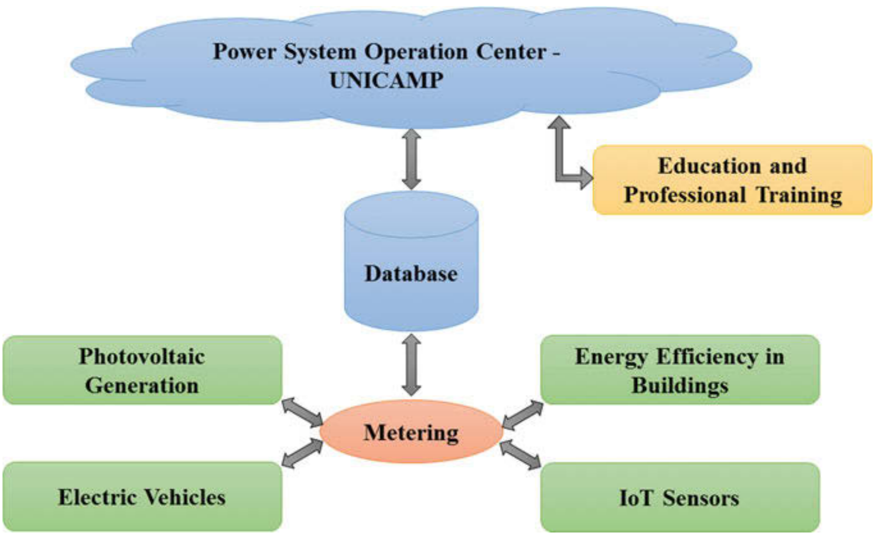



**Fig. 6** Communication structure between projects

university in the area of energy efficiency and energy conservation. It will also be a living lab to develop research on the topic of power system operation centres (Fig. 6).

## *6.2 Subproject 2—Photovoltaic Microgeneration*

Installing renewable microgeneration at UNICAMP is an important initiative to reduce the cost of power purchases at the university, encourage and disseminate the area of photovoltaic generation in Brazil and set up a living lab for research, education and training technicians and specialists in photovoltaic power generation. It will be installed in various parts of the campus, such as at faculties, institutes, administrative buildings and car parks, micro-generation plants with power ranging from 7 to 80 kWp (kilowatt peak), totalling 534 kWp of installed capacity.

The photovoltaic generation living laboratory will be able to: assess the use of crystalline photovoltaic modules using double-glass technology and compare their performance with conventional modules; carry out studies concerning solarimetry, solar radiation modelling, photovoltaic module modelling and energy simulation methodologies and evaluate the performance of photovoltaic systems; create a computer simulator to evaluate the performance of photovoltaic systems, having mini-aeration systems implanted on the campus as a validation laboratory; develop equipment to plot IV curves for testing photovoltaic systems and solar plants (Fig. 7).

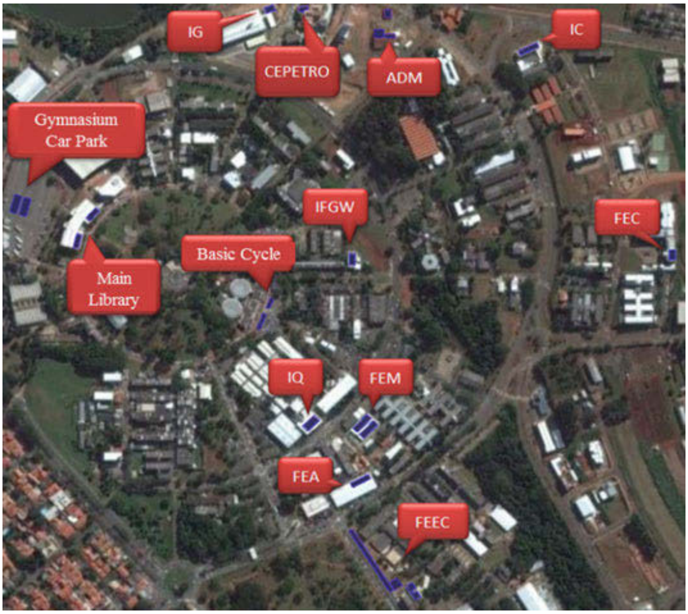



**Fig. 7** Photovoltaic microgeneration

### *6.3 Subproject 3—Electric Mobility*

Mobility is fundamental in terms of developing cities, connecting distant places and allowing for social and environmental encounters of people who live or visit cities. This subproject proposes to implement electric mobility in the campus' circular transportation system, i.e., to introduce electric buses to the university, as well as to build a research and innovation infrastructure considering this topic.

Currently, the *Barão Geraldo* Campus offers a circular transportation system to its students, faculty members and employees, including four microbuses with internal combustion engines. This project will replace one of the microbuses by an electric microbus, which will circulate daily on routes already stipulated. Therefore, a comparative analysis can be made of the socio-environmental, technical and economic impacts using this technology in urban environments (Fig. 8).

### *6.4 Subproject 4—Energy Efficiency in Buildings*

Power consumption in Brazilian Federal Universities is the third largest expense for these institutions on a yearly basis (ANEEL 2017), most of which is used for air conditioning. Air conditioners account for the highest percentage of consumption in


**Fig. 8** Electric bus route

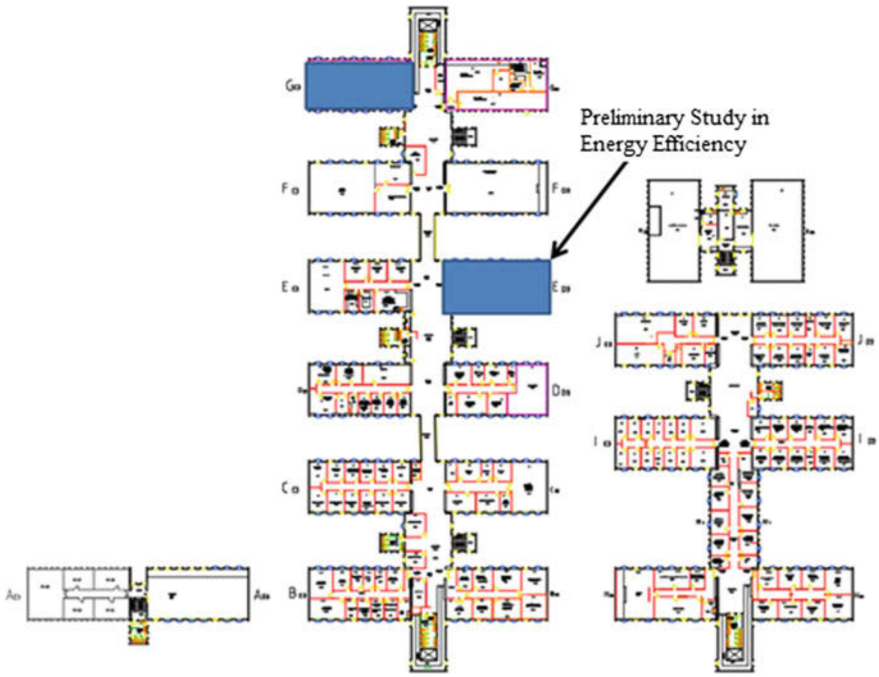



**Fig. 9** School of Mechanical Engineering blueprint

electric energy bills in buildings, from 35 to 60% depending on the technology, size, different attributes of the installed place and the energy regime.

This project will improve energy efficiency by exchanging 166 air conditioners in the School of Mechanical Engineering buildings, as a pilot project. Real time energy consumption monitoring (integration of subproject 1—monitoring mini-centre), measuring the temperature and noise of indoor environments and continuous evaluation of efficiency will be carried out (Fig. 9).

### 6.5 Subproject 5—Smart Efficiency

This subproject aims to develop a tool for Energy Management at Unicamp, integrating supply and demand with the concept of Smart Efficiency of the behavioural elements, supporting management and energy efficiency programs monitored in real time. It will be implemented using a pilot test in the School of Mechanical Engineering with low cost market hardware and free software, based on Arduino with radio frequency.

In the proposal, in addition to objectively maximising the efficiency of the installation, the aim is to also continuously and subjectively maximise the efficiency for its users, monitoring the conditions that ensure continuous improvement of the rational use of electrical energy. Therefore, it is a new frontier for Energy Efficiency, Subjective Efficiency, i.e., which reduces loss resulting from an increase in user perception, improving the use of equipment, systems and utilities in general that consume electrical energy, rationalizing their use and not causing damage to their personal and/or functional well-being.

This is due to the continuous monitoring of internal conditions (thermal mapping, humidity, lighting, gas, presence, etc.) and the environment of the building, as well as electrical magnitudes connected to important equipment, which, after being processed, are communicated through an interactive interface with the user(s), instructing them on the best ways to consume electrical energy, giving suggestions about saving energy by changing habits, maintaining the level of thermal comfort, lighting and ventilation (Fig. 10).

### 6.6 Subproject 6—Teaching and Professional Training

Having the objective of improving and training future professionals by disseminating technical and academic knowledge gained from this Sustainable University project in energy efficiency, photovoltaic mini-generation, electric mobility and energy monitoring and management, a subproject was created responsible for joining the results and knowledge acquired by all the previous subprojects and transforming them into courses, lectures, training sessions, educational materials and instruction booklets. The aim is to instruct other public-private institutions when implementing sustainability in their management and operations, ensuring the growth of the country towards technological and sustainable competitiveness.

This initiative ensures that energy efficiency, energy conservation and distributed generation are disseminated to the university's internal and external community. Courses will have a differential in terms of integrating theoretical knowledge with practical applications within the living lab's own infrastructure, enabling students to experience market realities and acquire new skills.

For the administrative technicians and the external community outside the university, training and development courses will be created in the outreach modality.

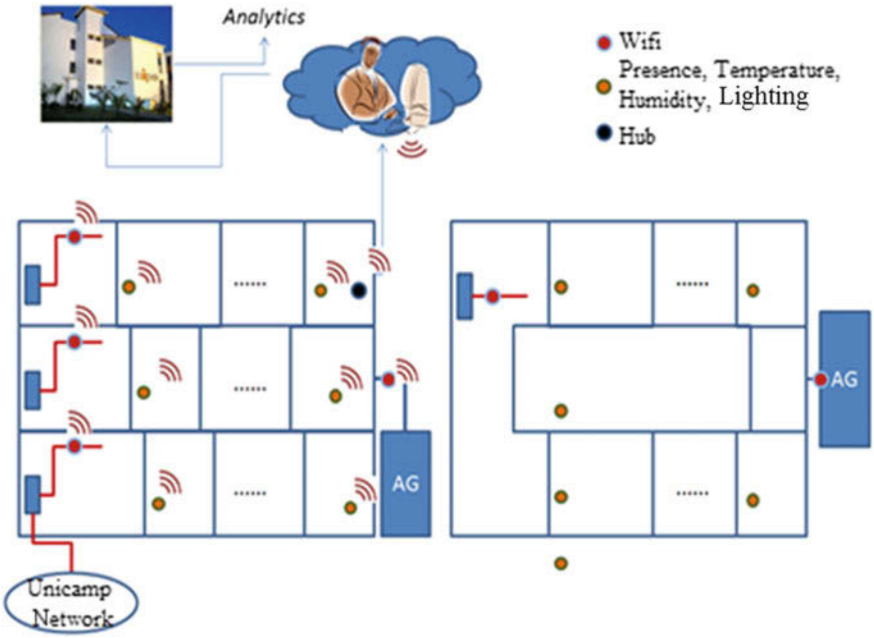



**Fig. 10** Communication structure of (internet of things) IoT sensors

Furthermore, short lectures will be given to ensure the knowledge gained is disseminated. Therefore, it is expected that at the end of the project we will have many courses and training sessions for different levels of education, such as postgraduate studies, high school, etc.

As a final result, by implementing the R&D and Energy Efficiency subprojects, integrated with the bibliographic material provided by this subproject, we will have a book on methodologies to set up sustainable campuses, which can be used as a reference for educational institutions in Brazil, extending to the whole community of Latin America (Fig. 11).

## 7 Expected Results

As cited in Jorge et al. (2015) and Figueiró and Raufflet (2015), the obstacles in terms of implementing sustainability in Higher Education institutions and in education are: the resistance to change concerning the existing Cartesian model; a lack of support from the university administration; a shortage of academic professionals specialised in sustainability and a lack of funding.

For this sustainability project, all the items pointed out as difficulties will not be decisive in terms of beginning the implementation of the Sustainable Campus,

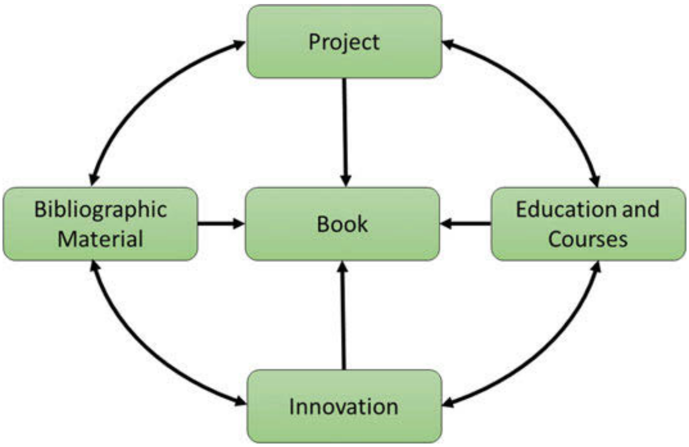



**Fig. 11** Knowledge flow

as after signing the ISCN/Gulf Sustainable Campus Charter and creating the GGUS (Sustainable University Management Group), the administrative and Cartesian resistance is lower.

On the other hand, the public-private partnership will allow for an initial contribution of funding to implement the six subprojects, creating a solid infrastructure to continuously develop sustainability.

Regarding the specialization of professionals, it is expected that this project will begin by training future multipliers of the knowledge gained, educating in total 1350 undergraduate, and postgraduate students, as well as outreach and technical and administrative staff in 11 courses, divided into: the introduction and project sizing in photovoltaic energy; energy efficiency and energy management; electric mobility; energy sustainability; and distributed generation. The whole project will be carried out with the participation of 14 university lecturers who hold Ph.D.s from the University of Campinas (School of Electrical and Computer Engineering, School of Mechanical Engineering and Interdisciplinary Centre of Energy Planning), 6 Ph.D. students, 6 Master's students and 9 undergraduate students doing scientific projects.

The project was institutionally formatted to develop an Integrated Energy Management System for a Sustainable Campus, i.e., a platform that will guide energy governance actions at UNICAMP with assertive actions to reduce consumption, adopt energy management methodologies, provide support to the criteria of expanding units, educational campaigns, systematically implementing IoT (Internet of things), finding partners for projects concerning progressive Energy Efficiency until the whole campus is covered, radar of sustainable and efficient technologies, building energy labelling program and many other possibilities.

This platform connects the monitoring systems installed in each consumer unit with the subprojects of electric mobility, photovoltaic generation, IoT sensors of maximising energy efficiency in environments and energy efficiency programs inside the campus, so that data and information can be collected. Later on, these data can be analysed to produce guidelines related to the conscious consumption of energy, expansion plans and contracting energy, asset management, training and continuing education in energy sustainability.

In the first three years, this sustainability model proposed for UNICAMP through public-private partnership will be able to: reduce up to 50% of losses in the distribution system of the university and transformers, scaling and planning the consumption of each institution; cut down on the consumption of 1066 MWh per year due to the photovoltaic mini-generation (850 MWh per year) and energy efficiency in the air conditioning at the School of Mechanical Engineering (216 MWh per year); reduce 64.8 tons of $CO_2$ per year including an electric bus in the internal urban mobility fleet; reduce 43.41 kW of demand during the peak period; and publish a book about energy sustainability in universities.

## 8 Conclusion

This paper presents the concept of a Living Laboratory for University campus. The complete model for the implementation and management of efficient electric energy consumption can be used by other type of people concentration (like villages, condominiums, small towns, etc.). The model could also be replicated with minor adaptations to cities in general. It offers a place to test technology and impacts in society development that would be very difficult to test separated from each other.

Electric energy is an input that includes almost all vital character of the society and at the same time becomes more and more critical regarding its availability, economic and environment costs. On the other hand, universities, as research and education centres with enormous capacity in replicating knowledge and human behaviour, should take the lead in proposing technologies and models for the rational use of electric energy.

The limitations of this work are related to the implementation of the control centre to analyse the huge volume of data and manage to act in the most efficiency direction.

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# 14 Years of History on Sustainability: Waste Management FMUSP/IMT/SVOC

**Fabio Luiz Navarro Marques, Arlete Araújo Saraiva, Adilson Caetano Cesário Chaves, Ana Maria Gonçalves da Silva, Edite Hatsumi Yamashiro Kanashiro, Eduardo Pompeu, Gabriela Hase Siqueira, Joana Sueli Maziero Bernardo, Lilian Apolinário, Maria Carmen Arroyo Sanchez, Maria Inês Calil Cury Guimarães, Thais Mauad, Felipe Neme Souza and José Otávio Costa Auler Jr.**

**Abstract** High regulation in environmental protection and sustainability was established in Brazil around 2003. From that time, the board of directors of the Faculty of Medicine, Tropical Medicine Institute, Death Verification Service, and Medical Investigation Laboratories, of the University of São Paulo created the **Waste Management Committee** to organize and implement actions to comply with Brazilian legislation. This paper outlines the main actions taken by the Committee and Board of directors of the institutions, presenting it in ages. During the first five years were developed works to know the passive/regular discharge of infectious agents, chemicals, radioactive compounds, recyclable and common garbage. From this data, were constructed stations for provisory disposal, transportation flow and general rules were established, and training was given to staff and students. During the following five years, or in the second phase of actions

F. L. Navarro Marques (✉) · A. A. Saraiva · E. Pompeu · L. Apolinário
M. I. C. C. Guimarães · T. Mauad · F. N. Souza · J. O. C. Auler Jr.
Faculdade de Medicina FMUSP, University of São Paulo,
Avenida Dr. Arnaldo 455, Sao Paulo, SP 01246-903, Brazil
e-mail: fabio.marques@fm.usp.br

A. C. C. Chaves
Faculdade de Medicina FMUSP, Serviço de Verificacao de Obitos da Capital SVOC,
University of São Paulo, Avenida Dr. Enéas de Carvalho Aguiar 250,
Sao Paulo, SP 05403-000, Brazil

A. M. G. da Silva · E. H. Y. Kanashiro · M. C. A. Sanchez
Instituto de Medicina Tropical IMT-USP, University of São Paulo,
Avenida Dr. Enéas de Carvalho Aguiar 470, Sao Paulo, SP 05403-000, Brazil

G. H. Siqueira · J. S. M. Bernardo
Laboratorios de Investigacao Medica LIMs, Faculdade de Medicina,
Hospital das Clinicas HCFMUSP, University of São Paulo,
Avenida Dr. Arnaldo 455, Sao Paulo, SP 01246-903, Brazil



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plans, efforts were focused on improving the management of the process and increasing the gathering of recyclable materials. Now, in the third phase, actions have been developed aiming to eliminate devices that use mercury and mercury vapor lamps from FMUSP building; furthermore, composting of food and garden material is in the evaluation process. These actions gave to FMUSP two Prize Friend of the Environment (2010 and 2016), offered by Health Secretary of São Paulo State, and these experience will be shared in this paper. However, it is necessary to have in mind that this work was done under Brazilian regulations, but certainly, it can be adjusted to all countries.

**Keywords** Waste management · Residues policies · Health service
Research laboratories · Anvisa

## 1 Introduction

For a long time, the discussion about waste and environmental contamination was focused on manufacturer companies, but not on the users and consumers. For example, electronics industries follow the rules to produce and dispose of their wastes. The same was not true for the users/consumers that needed to replace the old products by a new one, and they do not have technical information about how to discard it in a correct form. A similar process happened with mercury vapor lamps, medicines, etc. At least in Brazil, the problem is unsolved, and unusable materials, like TV, lamps, medicines, food, etc, are placed in the same container, for general waste collection.

At the similar level, procedures for the disposal of wastes in the universities and research centers were not well established or standardized, mainly for the complexities and diversity of these materials. For example, in one unique laboratory can be generated wastes composed of animal tissues, infectious materials, chemicals, and radioactive materials, in a separate form or, frequently, such as a mixture of them.

To organize the management and wastes disposal in research centers and hospitals, in 2004, the Resolution ANVISA RDC 306 was published, giving technical information about the Management of Residues in Health Institutions (Agência Nacional de Vigilância Sanitária [ANVISA] 2004). In 2005, the complementary Resolution CONAMA 358 established the rules for treatment in the final disposal of residues from Health Institutions (Conselho Nacional do Meio Ambiente [CONAMA] 2005). Finally, in 2010, the Law 12,305 was approved, establishing the National Solid Waste Policy (Congresso Nacional 2010). There are other laws, rules and protocols are complementary to that one.

Based on these laws, the action plans related to the management of waste produced in the institutions were established in Faculdade de Medicina (FM = Faculty of Medicine), Instituto de Medicina Tropical (IMT = Tropical Medicine Institute), Serviço de Verificação de Óbitos da Capital (SVOC = Death Verification Service), and Laboratórios de Investigação Médica (LIMs = Medical Investigation Laboratories). These four institutions will be named through text as Medicine Building Complex.

The importance of this paper is to describe our achievements in the management of waste, resulting in a well-established routine that becomes a model for other Brazilian institutions. However, it is necessary to have in mind that this work was done under Brazilian regulation, and can be necessary to adaptation for developing it in other countries.

## 2 Faculty of Medicine, Tropical Medicine Institute, Death Verification Service and Medical Investigation Laboratories in Numbers

The Medicine Building Complex is located in a central region of São Paulo city and comprises a total area of 51,000, 22,935 $m^2$ of constructed area, 51 laboratories and 5700 people, considering students, professor and staff. These people mean a population bigger than 1480 cities in Brazil.

The main activities in the institutions are teaching, and research focused on health and biology, responsible for the generation of a complex type of residues and rejects, such as biological, infectious, chemical and radioactive, in their different degree of dangerous, food, garden components, and recyclables.

## 3 Action Plans on Residues Policies

In 2003, the boards of the directors of FM-USP, IMT-USP, SVOC-USP, and LIMs-HCFMUSP organized a working group, named **Health Care Waste Management Committee**, to comply with the new rules to coordinate the handling and final destination of residues generated in the Medicine Building Complex. The Committee was composed of administrative staff, biomedical, chemist, pharmacist, physics with radiological protection specialization, veterinarian, and physician. The committee was in charge of studying the characteristics of the residues, such as the kind and amount, and organizing the flow for collection and correct disposal, as well as to make continuous improvement in the process, as a way to:

- Minimize the effect of waste on public health, such as disease transmission (e.g., HIV/AIDS, hepatitis B, and hepatitis C) and injuries caused by sharps.
- Prevent risks to waste-handling staff.
- Reduce the environmental impact caused by pollution resulting from improper disposal of waste, including contamination of grounds, water, and air.
- Reduce costs by correct waste handling.

- Facilitate resource recovery of useful products (reduce, reuse, recycle).
- Prevent and control breeding of insects, rodents, and other pests.
- Reduce nuisances (e.g., smell).
- Prevent animal and human pollution.
- Improve on aesthetics and ensure the institution have a beautiful environment.

## *3.1 From 2003 to 2010*

The first action established by work group was to know about residues generated daily in the institution, as well as to find and classify the waste stored for a long time in different places of the buildings. During this action, it was collected about two tons of chemicals, biological and decayed radioactive material, which was sent to appropriated final disposal. The second action was to define a provisory place to receive, store and organize waste for adequate disposal.

After these two emergency actions, a list of key points to be solved was established. The first one was the planning and construction of a waste storage building (Fig. 1), in agreement with health and environmental legislation (ANVISA 2004; CONAMA 2005), and construction policies for São Paulo city. After 12 months, since the initial project, a building with an area of 75.6 m$^2$, divided into six rooms: chemical storage, radioactive decay (class C), chemical waste (class B), infectious waste (class A1–A4), refrigerated chamber (dead animal and tissues—class A2), and non-contaminated/non-recyclable waste (class D), was ready.

The second point was the preparation of documents, in three different formats and complexity, as detailed below, which was done together with the building construction:


**Fig. 1** Installation for storage wastes before final destination at Medicine Building Complex. The chemical storage room is not shown (Faculty of Medicine—USP 2017)

- **The Health Service Waste Management Plan** is the most important document since it is an official document established by ANVISA RDC 306, in which are described information about the institution (geographic localization, area, constructed area, the board of directors, number of employees, etc.). It also contains the actions for management of waste in all its stages, from generation, segregation, packaging, storage, transport, treatment and final disposal, including issues concerning the health and safety of the worker, data from the establishment, indicators, and activities of the Plan. The final document was submitted to Health Surveillance Agency (ANVISA) in 2007, and an actualization of data is done each five years.
- **The Guidance Booklet For Waste Disposal** was done for wide dissemination among the members of the institution. The main objective was to raise awareness about the impact and the risk of improper handling of the wastes, as well as give a general guide for correct disposal. A review is in progress (2017) adding new rules and knowledge acquired during the last ten years.
- **The Standard Operating Procedures** (SOP) for wastes disposal were prepared in parallel, with the booklet. They aimed to detail the steps of collection, storage, and disposal of each type of waste and were distributed for laboratories coordinators, not for the public. They were reviewed in 2013 and 2017, for exchange or inclusion of procedures. Together with these documents, identification tags were prepared for each class of residues, to identify the user, material, risk, etc.

The third, and maybe the most important point for the success of all actions, was the training of staff. The Committee requested the laboratories' coordinators to indicate one employee, to act such as the bridge between workers in the laboratories (students, employees, and professors) and the "Waste Committee." Selected professionals were then trained to implement the waste management policy within the respective laboratory.

## *3.2 From 2010 to 2016*

After the consolidation of the hazardous waste management plan and the increase of collaborators in the work group, new actions were incorporated into the plan. In this step, we focused on daily consuming material in research laboratories and home, but with some chemical risk for people and environment.

A widespread material, Styrofoam containers, composed of expanded polystyrene or EPS takes 150 years to disappear from the environment, and it is one significant contaminant in river and oceans, with high impact in the life of water's animals (Ivar do Sul and Costa 2014). In our institution, since 2013, all material considered not contaminated by chemical, infectious agent or food, are considered for reuse in laboratories or our community market garden. The excess is sent to recycling companies that destine the product to be used in houses or edifices build (Souza et al. 2017).

Lamps based on mercury vapor are frequently used in research institutions, commercial places and at home, due to their low energy consumption. However, mercury is a dangerous chemical compound with high risk to human health. Frequently, these lamps are disposed of in a general garbage container, where they can be broken and release metal vapor to environmental (Hu and Cheng 2012; Nance et al. 2012). Since 2013, all lamps out of use in the institution are collected, stored and sent to a company that has a technology to extract the mercury component for the further final destination.

Disposable batteries are composed internally of heavy metal like lead, cadmium or mercury, among other material, with high potential for contamination of the environment (Zahir et al. 2005; Barrett et al. 2012; Recknagel et al. 2014). In 1999, the resolution CONAMA nº 257/99 was published, giving orientation for adequate disposal or recycling for this material (CONAMA 1999), and, in 2008, was established the level of heavy metal in this device (CONAMA 2008). Before 2016, we had an unofficial program to collect batteries. In 2016, an official program was established, and the material began to be measured before being sent to appropriate disposal (recycling). The same happens with radiological films, which are impregnated with silver (Muhamedagic et al. 2009). This noble material is recovered from the film by a specialized company; furthermore, the plastic component, after chemical decontamination, is sent to recycling.

Electronic devices are selective collected and sent to a cooperative for recycling. Computers and their components are forwarded to an appropriate program in the university, where students work to repair and to update the equipment for donation to low-income institutions.

Finally, reverse logistic, that means, to give back to the producer the used material, has been adopted in a few cases, such as printer cartridge. However, it is not an easy task, once many products are manipulated or transformed during the use, not allowing their return.

A protected area for recycling material was not planned in the first project of the waste disposal building. However, this extra space became necessary due to the amount of material received/collected. A project for building this space was approved, and after the construction, actions will be done to increase the amount of recycling collection.

### *3.3 From 2017 to 2020*

Actions started in 2010 and in progress, have been focused on the treatment of part of our residue or elimination of dangerous products, such as those containing mercury.

The action plan in charge is to turn the Medicine Building Complex into a mercury-free space, in agreement with Minamata Convention on Mercury (United Nations Environment Programme 2013). The actions involve exchange all lamps of mercury vapor by LED lamps, exchange all mercury thermometer by electronic ones, elimination of all mercury sphygmomanometer.

A second plan, under discussion and analysis, is to treat part of our non-recyclable waste, composed of tree pruning material and garden grass. In 2013, a restaurant started to operate in the Faculty of Medicine building and food was included as non-recyclable waste. Our project is to try to transform 100 tons/year of non-recyclable waste, in composting for further use in the garden and the community market garden. At this point we are planning the best process for composting, a practice used in several universities (McEachren et al. 2004; Boyd 2013).

## 4 General Evaluation and Results

### *4.1 General Evaluation*

Although this work had been done under Brazilian regulations, certainly it can be adjusted to all countries, since following the three statements:

- Unconditional support of program demands, but based on priorities and availability of resources;
- In the formation of a multidisciplinary and committed team with the project;
- The convincing of workers and students of the importance of the process, based on the examples that the members of the committee give to their peers and on the presentation of quantitative and qualitative results.

After 14 years working together, the committee is respected by direction board, by employees and students. Health São Paulo State Secretary recognized the actions, through two awards "Amigo do Meio Ambiente" (Friend of the Environment) 2010 and 2016 (Fig. 2).

### *4.2 Collecting Dangerous Material from Research Laboratories and not Recyclable Material from Areas of Cohabitation and Garden*

The first synergic effort was done to attend the laws and to collect dangerous products generated at the laboratories. Officially data started to be collected in 2006. Chemicals were generated in small quantities, at a median of four tons at first five years, growing to seven tons in the last five ones. Infectious products have been in a constant level about 100 tons/year. Non-recyclable materials were constant until 2015 but in 2016 the amount grow-up from 50 tons to about 100 tons. The increase can be explained by measurement logistic, once until 2015, measurement was done one week/month and medium for the month was calculated. From 2016, measurement has been done daily, giving more accurate results (Fig. 3).


**Fig. 2** Pictures of awards Friend of the Environment 2010 and 2016 (Faculty of Medicine—USP 2017)

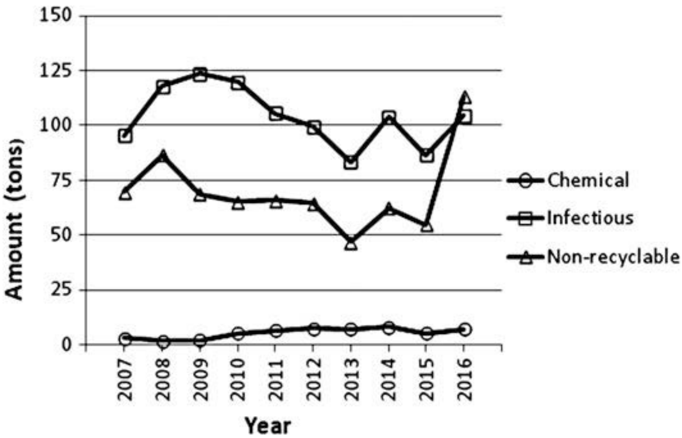


**Fig. 3** The amount of wastes collected and sent to a final destination in the complex of Faculty of Medicine—USP, from 2007 to 2016

## *4.3 Collecting Recyclable Materials and Non-controlled Dangerous Material*

Although the collection of recyclable material had been made before, just from 2011 it began to be measured (Table 1). During 2013 and 2014, there was a decrease in the collection, due to changes in the logistic operation with recyclable

**Table 1** Amount of collected recyclable material and non-controlled dangerous material, since 2011

| Year | Recyclable (kg) | Mercury lamps (units) | Battery (kg) |
|---|---|---|---|
| 2011 | 24,905 | – | – |
| 2012 | 14,922 | – | – |
| 2013 | 5846 | 4297 | – |
| 2014 | 9385 | 3469 | – |
| 2015 | 10,550 | 2982 | – |
| 2016 | 19,023 | 4068 | 295 |

material, but after the installation of a new eco point in 2015, this has grown again. The same situation is related to mercury lamps, although they had been collected before 2013, just in that year, the registration started. Disposable batteries started to be measured just in 2016. X-ray films have been collected and have been stored since the amount is too small to be sent for recycling.

## 5 Conclusion

Since the creation of the committee, 14 years ago, a long way has been traveled to achieve a level of excellence in waste management. Success was achieved by three main factors: a group of professionals, with different technical backgrounds working with motivation and interest in common well-being. The unconditional support of the institution's management, providing financial resources and administrative support; and adhesion of students and workers to the process, which recognized the efforts of the committee and the management, through the actions and results that were observed.

The new challenge for the waste committee is to move towards sustainability, seeking to promote actions (practical or educational) aimed at increasing understanding of how to avoid waste of materials in research laboratories, including water and electricity consumption, by the simple reorientation of personal habits. It should also be a focus, transferring the lessons learned to the wider community, encouraging our 5700 students and workers to transform their homes and neighborhood, using our institutional example as a model.

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# How Reliable Is the Temperature Information of Street Thermometers? A Simple Case Study in São Paulo City

**Jonas Guitart Guimarães de Arqueros e Ribeiro, Humberto Ribeiro da Rocha, Helber Custódio de Freitas and Arthur Henrique Bussinello**

**Abstract** The public information of real time weather in urban places, especially air temperature and humidity, is generally acquired *in locus*, that is, using local instrumentation, and has also to inform in a convenient and easy way the passerby people, usually displayed in vertical boards of street clocks. These devices seldom use accurate sensors and are placed in vulnerable conditions which include the influence of buildings, trees, wires, vehicles, animals, people etc. This work envisages to discuss how reliable are the temperature data available in the street clocks for passers-by users. We questioned the accuracy of the temperature shown in street thermometers at the USP campus, in São Paulo, Brazil. Data was taken during February to April 2014 using an experimental approach that compared the temperature displayed in boards of street clocks/thermometers to a reference air temperature measured in the adjacencies. The board temperature was generally warmer at daytime (mean deviation of 2 °C) in a site not shadowed by surrounding buildings, with extremes that reached about 8 °C, and less in a partially shadowed site. The deviations were larger with clear sky conditions, although the background with diffuse solar radiation was sufficient to show substantial daytime warming. Likewise, at night the board temperature appeared to be colder (mean deviation of about −1.5 °C).

## 1 Introduction

Usually the information of weather forecast in street boards encompasses a set of meteorological information, such as air temperature, relative humidity, wind and rainfall, often supposed to be valid for a small region centered in the city. The weather forecast is the elaboration of complex analysis in meteorological institutions that use numerical computational prediction, satellite information and ground

J. G. G. de Arqueros e Ribeiro (✉) · H. R. da Rocha · H. C. de Freitas · A. H. Bussinello
Departamento de Ciências Atmosféricas,, Instituto de Astronomia, Geofísica e Ciências Atmosféricas (IAG), University of São Paulo, São Paulo, Brazil
e-mail: jonas.ribeiro@usp.br



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climate station data observed in previous hours/days. Differently, the public information of local and real time weather in urban places, especially air temperature and humidity, is generally acquired *in locus*, that is, using local instrumentation, and has also to inform in a convenient and easy way the passerby people, usually displayed in vertical boards of street clocks. These devices seldom use accurate sensors, and rather use small electronic thermometers (e.g. thermistors) embedded in large metal boards, and placed in vulnerable conditions which include the influence of buildings, trees, wires, vehicles, animals, people etc. This work envisages to discuss how reliable are the temperature data available in the street clocks for passers-by users. We noticed how scarce the information of such assessment is, and in turn how important it ought to be in order to prevent bad quality information to whom may eventually needs it in societal environment.

We worked on a simple case study at the USP campus (Universidade de São Paulo, São Paulo city, Brazil), where the information of temperature is available for passers-by in several street clocks deployed in sparse places, shown in vertical boards of street clocks on the sidewalk. We argued about the quality of the temperature data provided to users, with the hypothesis that existing devices potentially have several limitations, that may result in partial reliability only. We discussed the results of a simple investigation, by comparing the temperature information shown in two street thermometers, at distinct places and different adjacent conditions, and compared to a reference air temperature simultaneously measured.

## 2 Materials and Methods

We made two experiments during February to April 2014, each in a specific street clock/thermometer, both located at the Cidade Universitária Armando Salles Oliveira (CUASO) or the USP campus in São Paulo city. The experiments aimed to compare the temperature data acquired in the street thermometers (hereafter referred as board temperature) to the air temperature measured with an automatic weather station (referred as the reference), displaced about 3 m apart. The reference was measured with a multivariate automatic weather station WXT 520 (Vaisala, Helsinki, Finland), which measured air temperature (accuracy ±0.3 °C), atmospheric pressure, relative air humidity, horizontal wind speed and precipitation, acquired every 2 s and registered the 2 min mean using a CR1000 data logger (Campbell Scientific, Utah, USA). We took digital photographs of the temperature shown on the board with a digital camera placed aside. The images captured the visual information displayed on the board and were converted to digital records using automatic algorithm that kept the values at 4 min time intervals. Converted data was partly discarded due to differences in sun brightness, that overshadowed the image on the board, and that was not automatically adjusted with the camera. The reference and board temperature data were finally organized as synchronized time series with a 4 min time step.

We ran two experimental sites, the first located in the sidewalk in front of the *Information Center* building (Praça Reinaldo Porchat), near the campus gate P1 (Fig. 1), here referred as site 1. The second was near the entrance of IPEN (Instituto Nacional de Pesquisas Energéticas), at the sidewalk of Av. Prof. Lineu Prestes, referred as site 2 (Fig. 1). The vertical board of the street thermometers was aligned at azimuth zenith angles of approximately 37° and 38°, respectively (Fig. 2), a condition that is does not minimize fully the incidence of direct solar radiation. The devices were near sidewalks covered with concrete pavements at streets covered with asphalt. Site 2 was partially covered with grass at the adjacencies of the sidewalk (Fig. 2). Site 1 was placed in a shadow-free environment, and Site 2 was partially shadowed in the afternoon.

We estimated the cloud cover fraction during the range of measurements to help discussing its likely control on the patterns of temperature. The cloud cover data was taken at the Cientec Meteorological Climate Station about 10 km distant of the sites (R. Miguel Stefano, São Paulo, Brazil), that we hypothesized as useful for our analysis using data on a mean hourly basis.

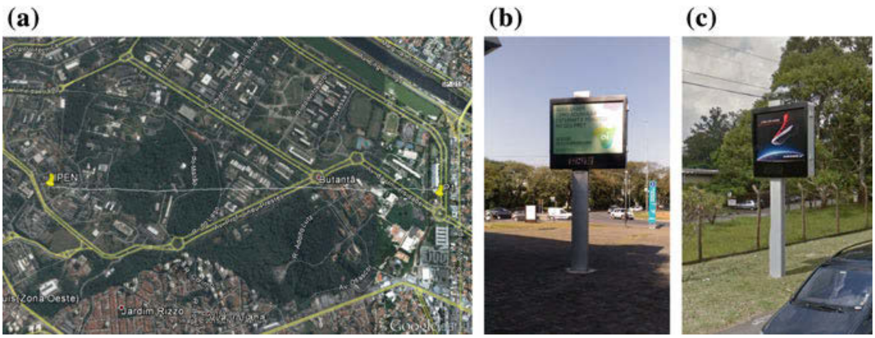
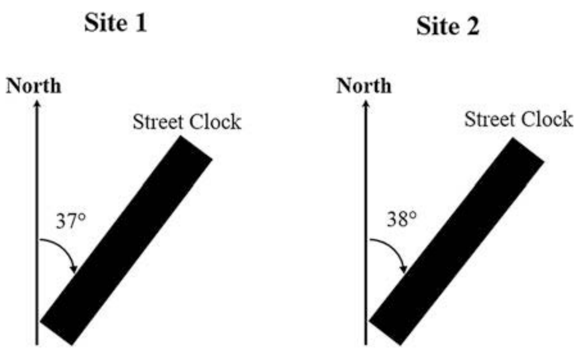



**Fig. 1** **a** Map of USP campus showing site 1 at P1 and site 2 at IPEN (Google earth image), and street thermometer at **b** site 1 and **c** at site 2, respectively

**Fig. 2** Zenith angle positioning of the street clock/ thermometers' board in sites 1 and 2



## 3 Results and Discussion

We calculated the mean hourly deviation of board temperature minus reference temperature, and discussed how markedly different the patterns were at daytime and nighttime respectively.

The board temperature generally overestimated the reference temperature at daytime (warmer board), and underestimated it at nighttime (cooler board). At site 1 and with low cloud cover, the mean deviation was higher in the morning, of about 1 °C, although it was nearly zero during the remaining hours at daytime (red line in Fig. 3). At the site 2 the mean deviation, with low cloud cover, was comparatively much higher than the site 1 at daytime, of about 3 °C, and that was kept high during most of daytime (red line in Fig. 4).

For high cloud cover at daytime, the mean temperature deviation for both sites was generally less compared to the estimates with low cloud cover. That is, at site 1 it was negative in the early hours of the morning and only slightly positive in the afternoon (blue line in Fig. 5), whereas at site 2 it was positive between 9 and 12 h local hours and nearly zero in other daytime hours (blue line in Fig. 4).

During the night the board temperature underestimated the reference temperature. At site 1 the mean deviation was nearly constant and of about −1.5 °C (Fig. 3). At the site 2 it was comparatively much less than site 1 and varied between about −2 to −3 °C, that also remained nearly steady during nighttime (Fig. 4). Interestingly, the conditions of cloud cover did not alter the mean deviation at nighttime for both sites.

We also estimated the absolute hourly deviation of board temperature minus reference temperature. We showed the maximum positive deviations at daytime (range between 7 and 16 h) and the minimum negative deviations at nighttime (range between 17 and 6 h). The patterns showed how the board temperature

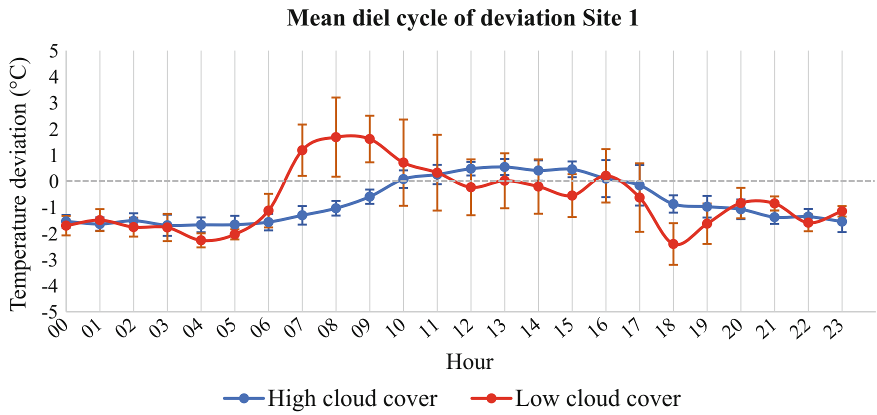



**Fig. 3** Hourly average deviation (and standard deviation) of board temperature minus reference temperature (in °C) in conditions of high cloud cover (blue) and low cloud cover (red), for site 1

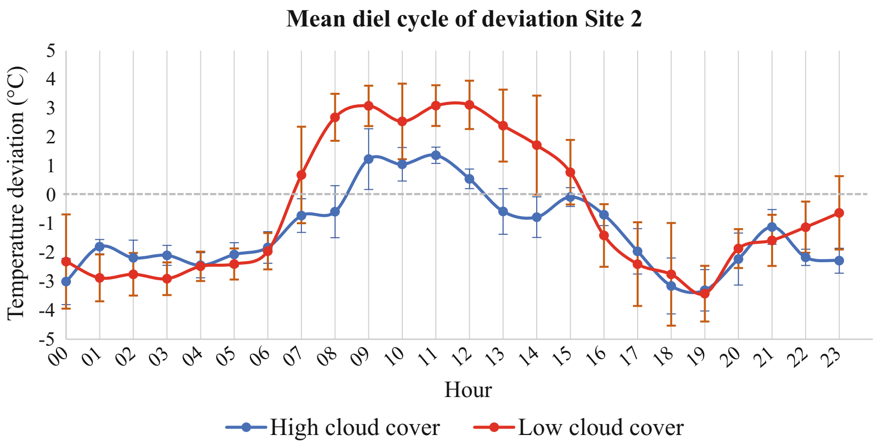



**Fig. 4** Hourly average deviation (and standard deviation) of board temperature minus reference temperature (in °C) in conditions of high cloud cover (blue) and low cloud cover (red), for site 2

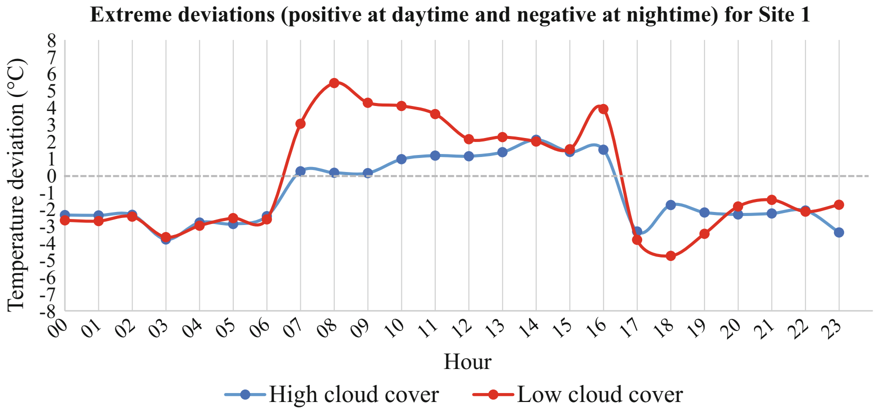



**Fig. 5** Absolute hourly deviation of board temperature minus reference temperature (in °C) in conditions of high cloud cover (blue) and low cloud cover (red), for site 1 (maximum positive deviations from 7 to 16 h, and minimum negative deviations from 17 to 6 h)

overestimated the reference temperature at daytime at much larger proportions, that appeared to be warmer up to about 5 °C in site 1 (red line in Fig. 5), and to about 7 °C in site 2 (red line in Fig. 6). Such large positive deviations were noticed with low cloud cover conditions, whereas with high cloud cover the maximum deviation was less, of about 2 °C in both sites (blue line in Figs. 5 and 6).

Likewise, at nighttime the minimum absolute deviations were strongly negative and much less compared to the mean deviation. The extreme cases were of about −4 °C in site 1 and −8 °C.

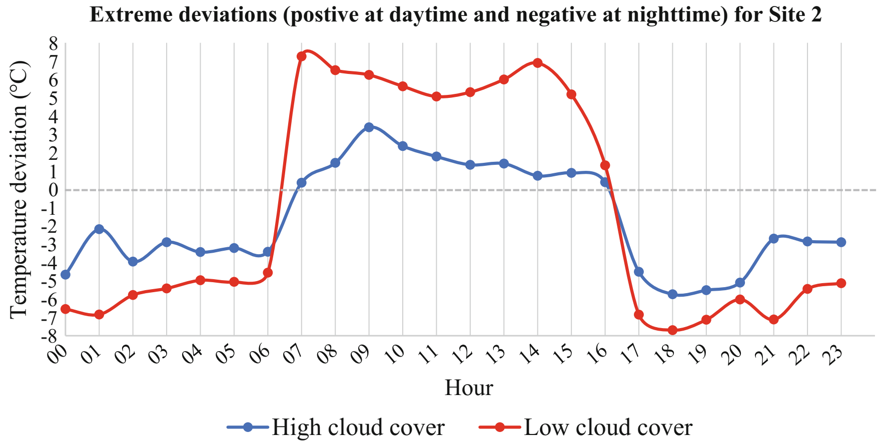



**Fig. 6** Id. Fig. 5, for site 2

## 4 Conclusions

We made a simple experimental comparison of temperature displayed in a street thermometer compared to an accurated measurement of air temperature, and noticed that the differences were substantially high and consistent with the radiation balance, absorptive characteristics of the materials, and the influence of the surrounding ambient near the device.

Our reference temperature is not to be concerned as a reference air temperature in full compliance with standard recommendations (WMO 2008), especially about the conditions of the adjacencies and ground cover. On the other hand, the purpose of our reference measurement was to capture the air temperature with an accurate thermometer and in an appropriate air environment where passers-by use to experience.

Board temperatures were generally warmer at daytime, with emphasys in clear sky conditions, that we suggest to be a result of the higher absorption of solar radiation on the board's materials. The conditions of direct radiation augmented the effect, although the conditions of diffuse solar radiation were sufficient to lead to substantial differences. One experiment (site 1) showed less differences, that was partly explained by the presence of buildings that shadowed the device, usually from late morning through the afternoon. The boards at both sites were positioned in the similar zenith angles, that favored the incidence of direct solar radiation, but were not helpful to explain the differences between the sites.

Likewise, at night the board temperatures appeared to be colder, which appears to be explained by the higher losses of infrared radiation, usually observed in materials with high emissivity, compared to the radiative losses of the surrounding air.

Positive absolute differences of temperature in daytime (warmer board) reached values as high as +7 °C, and at nighttime the negative differences were as low as −8 °C (cooler board).

It seems reasonable to attribute partly the cardinal orientation of the boards to the increasing differential warming during daytime. A board placed with 90° east-west orientation could minimize the heating. However we acknowledge the best positioning depends on a easy visualization of passers-by. Consequently the deployment design should concern how to combine these different constraints.

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# Sustainability on University of São Paulo's Campi: The Case of the Environmental Law Clinic and Its Contributions

**Alexandre Blois Crispino, Camila Vitória Bonifácio Rocha, Gabriel Antonio Silveira Mantelli, Luísa Martins de Arruda Câmara, Luiza Surita Pires de Almeida, Maria Vitória Prado Monteiro, Sinuhe Nascimento e Cruz and Thomas Terdiman Schaalmann**

**Abstract** This paper shows the importance of university extension projects for the effectiveness of sustainable campi to generate benefits for institutions and students from the social and environmental perspective. Having that in mind, the case study used is the role played by Clínica de Direito Ambiental Paulo Nogueira Neto (CPaNN), an environmental law clinic placed at University of São Paulo Law School. Initially, it is presented a historical and organizational overview of CPaNN, followed by the demonstration of CPaNN's most concrete achievements, such as the installation of a bicycle rack in FDUSP's building and the realization of educational campaigns concerning healthy habits and respect to work environment. Besides that, it concludes by demonstrating the relation between CPaNN's activities as an example of the importance of activities of Education and Public Outreach and

A. B. Crispino
University of São Paulo Law School, Rua Rumaica 242,
Vila Ipojuca, São Paulo, Brazil
e-mail: ale.bc@hotmail.com

C. V. B. Rocha
University of São Paulo Law School, Rua Caramuru 1191,
ap. 42, Saúde, São Paulo, Brazil
e-mail: c.vbr08@gmail.com

G. A. S. Mantelli
Law and Development at Getulio Vargas Foundation,
University of São Paulo, Rua Macachera, 21, Jardim Santo Amaro,
São Paulo, Brazil
e-mail: gabrielmantelli@gmail.com

L. M. de Arruda Câmara
University of São Paulo Law School,
Alameda Jaú 1325, ap. 131, Jardim Paulista, São Paulo, Brazil
e-mail: lumcamara@gmail.com



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the concretization of more sustainable university spaces. It is perceived that the positivity of these actions accumulate experiences both for their receptors (university itself and individual campaigns targets) and for their actors as well (the students involved). This is an important paper because it illustrates successful cases of sustainability projects within the university; it hopes to offer a model for other institutions, whilst being open to discussion and yearning for improvement. The method used is descriptive-inductive with exploratory goals, using the authors' own experience as the source of most of the information presented.

**Keywords** University of São Paulo · Sustainability · Environmental law
Clinical method · Education and public outreach

## 1 Introduction: Lessons from Law Students with Environmental Goals

University of São Paulo (USP) is one of the most important universities in Brazil and, besides its importance on research level, it has developed significant mechanisms to promote public awareness of science and knowledge. Nowadays, USP offers cultural options for its students and to local community as well. USP's Pro-Rectory of Culture and Extension is the administrative instance applicable to articulate these policies and, besides that, it is the body that coordinates the extension projects taken by students groups.

We believe that the clinical method is one of the most innovative ways of integrating the academic community with society, and it has gained a lot of importance in Brazilian universities in the last years (Arruda 2010). Having that in mind, this paper intends to demonstrate the various ways in which it is possible to obtain benefits from the existence of clinics as activities of university extension

L. S. P. de Almeida
University of São Paulo Law School, Rua Iperoig 690, ap. 182, São Paulo, Brazil
e-mail: luiza_surita@hotmail.com

M. V. P. Monteiro
University of São Paulo Law School, Alameda Santos 1398, São Paulo, Brazil
e-mail: mvpm8@yahoo.com.br

S. Nascimento e Cruz (✉)
University of São Paulo Law School, Avenida São João 2044,
Santa Cecília, São Paulo, Brazil
e-mail: sinuhe.cruzz@hotmail.com

T. T. Schaalmann
University of São Paulo Law School, Rua Patapio Silva 155, ap. 81,
Jardim das Bandeiras, São Paulo, Brazil
e-mail: tommy@scha.com.br

projects (a form of Education and Public Outreach), by the analysis of the case of Clínica de Direito Ambiental Paulo Nogueira Neto (CPaNN).

In methodological terms, this paper is important because it shows the actions that actually take place in the university and the effects it has amongst the inside community. By doing so it might stimulate external agents do to the same, resulting in positive effects amongst the outside community as well. Furthermore, this would be compatible with the idea that the university should, rather than close its doors to the outside community, contribute to it, which is relevant in a public university, such as University of São Paulo.

First, this paper presents CPaNN in terms of historical and organizational overview. Second, it demonstrates CPaNN's most significant work and achievements, divided in external projects, internal projects and academic projects. Finally, it concludes by analyzing the importance of CPaNN's achievements regarding the purposes set by the time of its creation and regarding the sustainability on university spaces.

Most importantly, in this work we choose to present CPaNN's projects from the perspective of its members, undergraduate students that have environmental consciousness. Despite several impediments and difficulties, they have concrete goals to improve the sustainability in their spaces and the desire to change local realities. Briefly, the method used is descriptive-inductive with exploratory goals, using the authors' own experience as the source of most of the information presented.

## 2 Historical and Organizational Overview

In Brazil, University of São Paulo Law School (FDUSP) is historically the center for legal studies and has tradition on the formation of important judges, policy makers and lawyers. In the last decade, FDUSP has seen the growing of university extension projects (education and public outreach) in its institution. Usually, these projects are coordinated by law professors and self-organized by undergraduate students that want to put in practice what they learn in books.

CPaNN is one of those projects. The entity was initially established in 2012 by a study group's experience, which dedicated its work to study topics that were related to the United Nations Conference on Sustainable Development, the Rio+20, held in Brazil on July, 2012. The goal was to qualify its students to participate in the conference as representatives of the FDUSP's students, in the name of XI de Agosto Student's Union, which was qualified as a Major Group in the event. This group brought together people who were interested in discussing environmental and sustainability matters, which stimulated the participants to develop a project that would guarantee the group's continuity.

The Clinic was named after Professor Paulo Nogueira Neto to honor such an important figure to the birth and development of the field of environmental law in Brazil. Professor Paulo Nogueira graduated in this same University, and gave us his support and recognition in a visit in 2013, on the opportunity of the Clinic's official release. Since its beginning, CPaNN is coordinated by Professor Patricia Faga Iglecias Lemos, a civil law professor specialized in environmental matters.

As a student organization, CPaNN is willing to unite theoretical study and practical activities in areas related to environmental law and sustainability, promoting critical analysis and the proposition of real solutions for matters concerning the social and environmental reality. Unlike study groups, which are developed considering specific themes in environmental law, the Clinic develops projects both within and outside the university, concerning, for instance, environmental justice and sustainable practices in the urban environment.

CPaNN's mission is to contribute actively for the promotion of sustainability both in the academic community and in society as a whole through the clinic method, uniting the theoretical study to the practical actuation in environmental Law. It is CPaNN's vision to consolidate itself as a referential academic entity in the environmental area, well known, both in and outside the University of São Paulo, because of its involvement in diverse projects. CPaNN's values are proactivity, passion, commitment, involvement, horizontality, and transparency. In terms of project organization, we separate our goals in external projects, the ones CPaNN acts beyond FDUSP's walls; internal projects, regarding sustainable measures to FDUSP community; and academic projects. Here below, we present some of the projects we have been dealing with in recent years.

## 3 External Projects: The Partnership with São Paulo's Local Environmental Agency

An important goal of university extension projects is exactly to bring out the ideas produced in those circles to the benefit of society. Over the years, CPaNN implemented projects with, to cite some, local parliament and social movements.

In the beginning of 2017, a member that works at the local environmental agency, the Green and Environment Secretary of São Paulo (SVMA)[1], became a CPaNN member and, with his help, we end up establishing a partnership with SVMA. SVMA is divided in departments, notwithstanding, here we just need to talk about the Environmental Planning Department (DEPLAN). DEPLAN has a diverse range of goals and functions, among them: the implementation of proper actions for the city, the promotion of studies about the environmental situation of the country, and the cooperation with other local secretaries. This department was the one which entered in contact with CPaNN.

[1]SVMA was created in 1993 by Law No. 11,426/1993 with the goal of defending São Paulo's environment (containment of damages) and of working in cooperation with units from various national instances and from international entities in order to optimize the secretary's actions in favor of the environment.

In this context, we were invited to go to a meeting at SVMA to have an informal conversation about the secretary, its operation and possible projects. Then, we had some inside discussions and we agreed that this was a great opportunity to produce something to the society and something capable to set our mark in the academia in relation to environmental law.[2] The project we chose to work with SVMA end up being a project that was already in progress, so that the goal was to contribute to its conclusion. The project has a multidisciplinary front with the involvement of professionals from a wide range of areas, such as geographers, engineers, and biologists. We, students of environmental law, would contribute in the legal sense of the project: a legislative lifting about seven themes of environmental ruling of the city (solid waste; atmospheric pollution; water resources; parks, green areas and conservation units; urban afforestation; climate change and sustainable development; and energy). The goal is to perform an accessible and didactical document for the population's use, so, besides the technical information (data), it will contain general information about the relationship existent between the environmental and the urban environment, creating thus a passage from a general perspective to a specific theme.

As the project was being molded, we had some time to make our thoughts straight until putting it in progress. We believe that this fluidity is an excellent thing both to the project and to the members, since it allows CPaNN to be in full harmonization with the project. It is worth saying, too, that our limited knowledge about research methodology and environmental law enables us to deliver a more thorough and didactic product, because we have to learn everything before we are able to transmit the information in a simple way. On account of everything said, it is possible to realize the great intellectual and social opportunity we have in this partnership.

## 4 Internal Projects: Sustainable Actions from Racks to Mugs

Internal projects usually have more in common with sustainable practices than the other projects carried out by CPaNN because they are concrete actions made by the students and focused on the improvement of the campus life. In this section, we present five experiences that are worth to share.

[2]Before we enter into the scope about the project itself, it is essential to point out that, in the moment we were invited to the meeting, there was already a partnership established between the USP and SVMA. This partnership was registered by a document signed by the SVMA's secretary, the head mistress of UMAPAZ (University of Environmental and Culture for Peace), USP's dean, USP's superintendent of environmental management and the head of IPT (Institute of Technological Research). However, there was a lack of established mechanism to execute the partnership, which opened room for our work.

*Bicycle racks*. We believe that bringing the debates regarding mobility is a matter of concretizing sustainability in our campi. In 2014, with the implementation of cycle paths around the FDUSP campus, it became clear the need to install a bike rack to meet the demand of students that uses this means of transportation and also to encourage the others to start using bicycles. Aside from being an environmental friendly alternative, it encourages students to lead a healthier life.

In that context, CPaNN noted that students who used bicycles did not have a safe place to leave it during classes, which made this type transportation infeasible. With partnership of students' sports association "A. Atlética A. XI de Agosto", we proposed the idea of racks for FDUSP's Dean. As agreed, it was assigned a space in the Annex Building for the implementation of the project and the Department of Purchases of the Law School carried out its construction. The bicycle rack was ready in early December, 2014, and inaugurated on March 9, 2015 with a capacity of 23 bicycles.

Thus, CPaNN began a series of actions to encourage the use of the bicycle rack. First, we made a banner used to make the location of the bike rack more attractive. Second, the Clinic began a campaign entitled "11 facts about cycling to Sanfran" in which some doubts were clarified about both the bike rack and its operation, as well as about bicycle paths available in São Paulo city. Third, we continue to develop ways to encourage the use of bicycles and draw students' attention to the new bicycle rack. The use of posters (such as the "Vade Bike") was once again a feature chosen by us, so as to draw attention from the university members and workers to the bike rack. On Car Free Day (September 22nd) we also launched an online campaign to use bicycles and public transportation to go to college, offering gifts for students who sended photos using such means of transport. The campaign had high adherence, and was considered a success by the Clinic.

With the execution of this project and the consequent greater usage of bicycle as transportation, we achieved and expect to continue to attain the following benefits: reduction of the emission of atmospheric pollutants and greenhouse gases, reduction of noise pollution; reduction of waste generated by motorized transport and reduction of water contamination; and, also, the improvement of the health of students and staff of FDUSP.

*Porão—Place for Social Interaction*. In 2014, we started and concentrated a lot of focus in our actions related to a place for social interaction in our campus, which is called Porão (literally, "Basement"). It is a place where the students and the community usually go to talk with each other, have lunch and sometimes party. We were concerned with the quality of the space, because lots of people ignore all the rules against smoking in enclosed places and smoke inside Porão. The Clinic has been working with educational politics for the students, such as making posters, banners and countless advices in social networks about the decrease in the place's quality and, most importantly, the life quality and health of the people who work inside Porão's cafeterias.

Between the members of the project, there is an accordance that the preventive measures have had real effects through the adhesion of the student community and, besides that, it is the most known campaign promoted by the Clinic. The amount of smokers decreased inside Porão as most of the smokers now go to an external area to smoke. The improvement was also noticed by the people who work inside Porão, as reported by them to CPaNN members.

Even with the improvement, we keep searching for measures that make the place less insalubrious and more sustainable. It is all about consolidating habits among the community, although, as we all know, it takes a long time to be completely successful.

*Undergraduate thesis (term paper)*. CPaNN, concerned about the amount of paper spent unnecessarily with the delivery of the course conclusion paper ("tese de láurea", in the traditional Portuguese usage), collected data on the impacts of this annual activity and calculated its ecological footprint. According to our calculations, each year, in our campus, 460 students graduate and produce a term paper that has an average of 70 pages (since the rules required only one page per sheet) and deliver it in 2 printed copies. In total, 64,400 sheets are printed each year, or 302 kg of paper. In terms of ecological footprint, we concluded, based on the Paper Calculator 3.2.1 tool (Environmental Paper Network 2014; UNESCO) that, when delivering their theses, students used the equivalent of 5 trees (1 ton of wood), used 2051 kW of energy, 767 kg of $CO_2$ was emitted, producing 263 kg of solid waste and consuming 26,127 or 105,700 l of water.

The idea of this project is to develop a modern way to deliver the term paper of the undergraduate students in a view of a sustainable university environment. Therefore, in 2015 we proposed to the FDUSP's competent body measures regarding the production of monographs in our campus, suggesting the following actions: obligatory printing on both sides of the paper sheets; allowing the use of recycle paper; change the compulsory delivery of two printed copies to one; and consent to the replacement of printed versions to digital formats.

In October 2015, an internal deliberation made by FDUSP enabled, by professors' approval, the students deliver their term papers in digital format or with double-sided printing. In May 2017, it was delivered a list with a great quantity of professors that allowed the use of digital formats. In this way, CPaNN, with the help and support from professors, was able to reduce paper usage and make a more sustainable university environment.

*Mugs*. When we started to think about turning FDUSP more sustainable, we immediately encountered a problem, a problem which is highly discussed in other colleges, but forgotten in our school: the use of disposable cups. After we talked with the staff of the dining hall of FDUSP about this matter, they informed us that almost 700 disposable cups are discarded per day during the meals (around 14,000 per month). A cup, for being made of plastic, takes thereabout 200 years to decompose. The plastic is made from petrol, a non-renewable fuel highly responsible for global warming. Furthermore, a great amount of resources is used in its production: one single plastic cup uses approximately 3 l of water on the production process and a substantial quantity of electrical energy. Thereby, in times of water shortage, drought and resources scarcity, it is paramount to make people aware of the impact produced by the use of disposable cups. That's why we concluded to encourage people to switch from plastic cups to renewable mugs.

However, we have a well-entrenched culture of using disposable cups in FDUSP. CPaNN, on the other hand, believing in the importance of the environmental education as the driving force of a more sustainable society, seeks to change the students' attitude. With the aim to recycle the 700 plastic cups used per day, we tried to put a cup collector in our dining hall in 2016. Unfortunately, we faced some logistical issues regarding the proper use of the collector, which ended up causing some nuisance to the cleaning employees of the refectory, so we had to remove the collector from the hall. Our only accomplishment in the dining hall, after all, was a direction approval to fixate posters in the refectory, aiming to encourage a more sustainable conduct from the users.

Throughout that semester we promoted, with great success, by social networks the use of plastic mugs and the reuse of disposable cups in the university parties. A person uses, according to the students that promotes several parties in FDUSP, an average of 7 cups in a party, which means that the ecological footprint of that party is something around 1400 disposable cups thrown in the trash, totalizing 4200 l of water used in the production of all those cups. Also, we have weakly parties in the Porão. Although they have a smaller public, the use of plastic cups still is substantial. So we got in touch with the parties organizers to discuss about the use of disposable cups. These conversations resulted in organizers willing to do promotions and to take other measures, in view of benefiting the mug users. After these events, we realized that a change in posture is really happening, since the organizers themselves began to invite CPaNN to sell our mugs at parties or to help them to think about measures to reduce the use of disposable cups.

At last, we elaborated a project to apply for the Participatory Budget (a way in which the extension projects try to get their projects funded by our students union) in 2016s final semester. Our proposal was to make mugs to distribute for free to all the 2017 newcomers and to the residents of the Student's House (a building where the FDUSP students can live if they are not able to afford to live somewhere else). Our proposal followed the model from USP Recycle, a project performed by USP, in which the mugs are made of a tougher and more durable plastic. We got the budget we needed and we made 500 green mugs with the saying "Sustainable FDUSP" and with the draw of a tree. It was certainly a success. Besides, we use them to drawn on promotions before the big parties at FDUSP, so that our "mugs campaign" gets more visibility.

*Living Roof at FDUSP's Annex Building*. Since 2013, we have been carrying out a project that intends to implement a living roof in one of our campus' buildings. The Living Roof Project is being carried out in the Annex Building of FDUSP, having been contemplated by financial resources from USP (USP Sustainability Edict of 2013). Currently, the project is in the execution phase, and the conclusion is expected for 2017s last semester.

Searching for simple and accessible technologies as a way to mitigate environmental degradation in our city, we found as a possible solution the implementation of living covers. Basically it consists of covering terraces of buildings (often unused area) with vegetation. The green roof has, among its many benefits, a concrete possibility of cooling the temperature down to 5.3 °C and increases the humidity up to 15.7%, becoming a place of interest for urban fauna, minimizing the occurrence of heat islands and reducing the flow of rainwater, common problems in the downtown São Paulo. By reducing the reflection and absorption of heat, the green roofs act as thermal insulation in buildings. They absorb carbon dioxide and trap rainwater, contributing to reduce the problem of rainfall in cities, preventing flooding. The possibility of using live roofs in the cities can also promote gains in the humidification and filtration of particles from the air and in the smoothing of a strongly heated thermal medium, especially where large agglomerations are found, which is what occurs in São Paulo, where is located the building where the cover is being implanted. The intention is to make the coverage of the Annex Building a Living Roof Project, the implementation of an ideology of sustainable architecture and socio-environmental integration of all (students, employees, teachers) in a place that was completely unused by our campus and could not have any other academic-institutional purpose.

The implementation of this project in the academic environment has proved to be a challenge in some ways. The first one was financial, since a project like this requires a considerable amount of money and is still not very affordable in our country. Much of the financial aid we received was through sponsorship from a Brazilian private bank. As for the rest, the USP's competent body for infrastructure (Superintendence of Physical Spaces) provided the necessary budget for our project. The other challenge was in the bureaucratic view, since the installation of a project within the reach of a building listed as historical patrimony (which is the case of the place where the installation of the cover is being made) requires a series of authorizations from different public bodies. Fortunately, our Dean helped us and became available to provide the necessary documents for the approval of the project.

These obstacles that we have to manage were a consequence of the physical space that the project occupies and of our condition as undergraduate students. In the private sphere the possibilities of a project like this to succeed without major obstacles are quite concrete, especially because private initiative has greater resources and there is even an incentive for this to occur, given that a presence of a space such as green roofs in a building adds up points to obtain the green seal by the Green Building Council (GBC), and it is well known that many companies aim for such certificates to have their public image related to environmental friendly causes, often as positive marketing strategy.

In a brief research, we could attest that a local decree added new points in some legal instruments on the environmental arena (in this case, the Environmental Commitment Term—TCA), which in turn establishes the responsibility of companies and individuals when constructing or carrying out works that, in any way, cause environmental damage to the urban space. With the contents of the decree in mind, these ventures could do environmental compensation if using green roofs and vertical gardens. So it can be said that there is an incentive in the same direction. In addition, in our local parliament, the discussion on green roofs has occurred mainly in the Parliamentary Front for Sustainability. There are, for example, bills foreseeing a discount of 15% (bill No. 622/2008) or up to 25% (bill No. 388/2013) in the taxes of the properties that own this type of roof. What we see, therefore, is an interest in promoting the creation of these green spaces in the city. In the public initiative, as an example, we have the building of the town hall of São Paulo, which has its own "suspended forest" in its cover, with large trees such as several sycamores and even 'pau-brasil' standing out among other crowns on the 14th floor.

Thus, we believe that the experience we had in establishing our project in the academic field shows that, even in an environment with so many obstacles, it was possible to install a green cover. The understanding, therefore, is that the installation of this type of space in the city tends to be even more conducive, as there will be fewer obstacles and many external incentives to do so.

## 5 Academic Projects: Environmental Information

*Academic studies*. One of the bases of the clinical method is the study of a subject, and in CPaNN our studies are focused on environmental law. We perform studies in a collective way (that we call "formations") and they occur weekly based on a specific theme chosen by the members. A team, formed in the same day of the voting, is responsible for researching the texts that will be read. Every semester we seek to improve our discussions establishing different forms of interaction. Currently, two debaters are chosen previously to present the week's texts and another member is chosen to report the main topics of the discussion. All members have the liberty to ask questions or to talk about the points they find relevant. They also can send questions or comments to the debaters if they wish.

As said before, the chosen themes must have a relation with environmental law. Among the last formations the subjects found were environmental license and specially protected territorial spaces. In 2017, the topic was agrarian law focused on the socio-environmental aspect, entering in the area of agrarian conflicts and peasant movement.

It is worth to point out that the last three formations have several points of confluence in a manner which all of them end up talking about the same subjects, but in a distinct view and perspective and them turn out to be complementary. This aspect of intersection within the themes was relevant to the choice of the semester's subject, since we try to choose pertinent topics to the law operator and, more than that, themes that can fill the existent theoretical gaps when connected to each other, enabling a broader discussion. That's why the formations are one of the foremost tools of learning inside CPaNN. Besides that, these learning experiences had lead our groups to present papers and posters in scientific events in the past years, mainly in the Brazilian Congress of Environmental Law.

*Informative Project Principle 10*. Environmental information needs to be disseminated and debated. Besides, popular participation and information are two elements that need to work together towards the implementation of public environmental policies. Principle 10 is one of the 27 principles contained in the final document of the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992—the so-called ECO-92. It establishes the commitment of governments to guarantee citizens' social participation, access to information and access to justice in environmental matters.

In this sense, CPaNN launched in 2013 the project of the Informative Magazine Principle 10, which is a weekly informative text prepared by the members of the group and made available in our institutional website. A number of relevant issues are dealt with in this newsletter, which is prepared each week by a member responsible for drafting and disseminating the text—thus seeking to provide visibility, provide information and increase the participation and discussion on the themes dear to our extension group.

We understand that the positive repercussion of this project within the academic field only confirms the importance of the publicity of the information and that, in fact, the population has an interest in participating, especially with regard to decision processes that involve governmental actions and policies that affect the environment. Thus, publicity of information and stakeholder participation would enable all citizens to demand more sustainable socio-economic development, environmental conservation and awareness of the impacts of works in dozens of regions, and to ensure a more effective participation of society in the discussion of environmental issues.

## 6 Conclusion

The construction of a mentality and of practices aligned to the sustainability precepts in FDUSP campus involves, inevitably, coping with bureaucratic resistance - found in the stages of action's implementation and institutional initiatives - and with resistance from the faculty itself and the students in the proposal's adherence.

The resistance was a present aspect in all actions of awareness and intervention guided by CPaNN at our campus. The experiences we had in the project against smoking in the Porão and in the term papers were very remarkable in this sense. For multiple times, our posters, which integrate the campaign against smoking, were ripped off by some of the students who attended the space, evidencing the existence of a strong refusal among the students to embrace our plea to better conditions of healthy place and adequate work conditions inside Porão; Thesis, in its turn, however exulting, was not widely accepted, since a broad range of the professors still demands two printed papers for the undergraduate's term paper.

Another observed point over our work concerns to the fact that the actions aiming the construction of a more sustainable environment must be promoted in a continuous way, to reinforce the cycle of habits and good practices built. Each year, newcomers enter in FDUSP and, again, we need to disseminate sustainable awareness. Gladly, we realized that the sustainable practices and attitudes fomented by us tend to be incorporated by the students, because every action we make support our ideas in a way that they end up more disseminated and assimilated by the college's community.

Our difficulties go beyond the resistance we suffer from the students and from the teachers. We feel that the bureaucracy we face inside the faculty is utterly complicated and it restrains us from doing projects that surpass the awareness we try to create inside the universities' campi. The Living Roof is a clearly example of how the bureaucracy is deterrent to the accomplishment of bigger projects. We have a hard time trying to get all the authorizations we need, which end up delaying the project for years. Yet, for being a public university, the money we have is extremely limited, which obligate us to search for external support and sponsorship so we can complete our projects. That's why it is important to us have a recognition that transcend the walls of our university. On the other hand, these difficulties are beneficial in the sense that obligate us to search an action in the society itself. Our scope of action end up being dislocated to external partnerships as happened with our partnership with São Paulo's local environmental agency.

Moreover, we believe that the positive effects of the adoption of sustainable practices and attitudes inside universities' campi tend to reach a space that goes beyond the circumscribed environment of the college walls, impacting the society. This is due to the fact that the FDUSP is an institution responsible to form the main political and governmental scene, and its students will assume relevant political offices and will influence in the formulation of law and public policy in different fields. In particular, we truly believe that the experiences accumulated throughout the student experience in a campus aligned with sustainable practices carries within the potential to create an impact in the future actions of this agent as an answer to environmental questions.

As future prospects, we have an increasing awareness of the academic community of the environmental impacts produced in such a small sample space, so that people are led to question themselves and change their daily habits in order to achieve an environmentally conscious academic space.

Although these aspects are built in an institutional level, we understand that, in some degree, it does not stop being an output of human construction, reflexing its formation and its values constructed. It is in this sense that we recognize the promotion of sustainable practices at the university's environment. It is an opportunity to impact and to contribute to the formation of professionals that, in the future, will be able to replicate these same practices in the formulation of solutions, laws and public policies in environmental questions.

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# Sustainable Campus in Brazilian Scenario: Case Study of the Federal University of Lavras

**Cristiane Criscibene Pantaleão and Tatiana Tucunduva Philippi Cortese**

**Abstract** The initiatives related to the application of sustainability in the university campus stand out internationally and focus on Europe and the USA. In Brazil there are few campuses that can be considered sustainable. The purpose of this chapter is to present actions that classified the Federal University of Lavras (UFLA) as the High Education Institution (HEI) with the most sustainable campus of the Brazilian scenario according to the UI GreenMetric World University Ranking (UI GreenMetric). This ranking was created with the purpose of classifying the HEIs globally and evaluates the campuses through 6 categories. The methodology used was qualitative analysis with a research strategy through the case study. The case analyzed in this study can be characterized as a Living Lab for Sustainability, due to the participation of the academic community in the operation of practices and interaction with the external community. This work seeks to contribute in a global way, providing an academic debate on the insertion of sustainability in the university campus, besides presenting data that can serve as reference to other HEIs who wish to follow the same path in the design or adaptation of their campuses and can contribute to the transformation of individuals, societies and cities through education.

**Keywords** Sustainable campus · Living lab · Brazilian scenario
Ranking *UI GreenMetric*

C. C. Pantaleão · T. T. P. Cortese (✉)
Graduate Program in Sustainable and Smart Cities, University Nove de Julho,
Av. Dr. Adolpho Pinto 109, Barra Funda, São Paulo, SP 01156-050, Brazil
e-mail: taticortese@gmail.com

C. C. Pantaleão
e-mail: crisarqui@hotmail.com

*Present Address:*
T. T. P. Cortese
Graduate Program in Sustainable and Smart Cities, Rua Deputado Salvador Julianelli,
s/n,1° andar, Barra Funda, São Paulo, SP CEP 01156-080, Brazil



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# 1 Introduction

Since the 1970s, associations have started to be interested in involving universities with a view to sustainable development. Historically, the first signs appeared in 1972, with the holding of the Conference on Human Development held in Stockholm, organized by the United Nations (UN). Subsequently, in 1990, with the Declaration of Taillores in France and in 1994, which preceded the signing of a sequence of other important declarations (Machado et al. 2013).

The dissemination of the sustainability culture, through cooperation between individuals, companies and governmental institutions, happens when there is an adequate environment through learning. Environmental education, as the basis of sustainable development, generates a balance between economic growth, human well-being and preservation of nature (Almeida 2015).

Shaping sustainability to influence the behavior of students, staff, and local communities indicates the HEI movement toward a greater alignment between campus-operated practices and classroom-based knowledge (Tilbury 2011).

According to Termignoni (2012), the examples practiced on university campuses through the application of SGA and shared between HEIs can become references of Small Urban Centers, also educating cities and transforming them into intelligent and sustainable spaces that provide quality of life to its inhabitants. Higher Education Institutions (HEIs) are an important part of the process of training leaders and citizens who will contribute to the development of cities with sustainability and intelligence. These, in order to develop, need multidimensional and interconnected efforts, starting from the preexisting model, but considering their problems and challenges (Ferreira et al. 2015).

Different terms are used to conceptualize the practice of sustainability in HEI, but when it comes specifically to actions in operation and experienced by internal and external actors, a concept appears that seems more appropriate to this context: Living Lab for Sustainability.

Focusing on the transformation of relationships, the methodology of social innovation that is Living Lab provides a dialogue between university and external community. The city receives a valuable collaboration in its urban and social development by absorbing educational resources derived from the academic practices that are manifested in the thematic of the campus (Catalão et al. 2011).

According to Tauchen and Brandli (2006), the vast majority of HEIs with an Environmental Management System (EMS) incorporated in their governance are in Europe and the United States; some relevant experiences also appear in Canada and New Zealand.

In Brazil, the number of initiatives is smaller and some stand out because of their importance, such as the Sustainable Campus Program of the University of São Paulo (USP), started in 2014 and planned until 2034, with the aim of making the institution a national benchmark in sustainability, in addition to being recognized internationally. To achieve the goals, some criteria have been defined, which can also characterize the campus as a Living Lab: to plan and develop sustainable projects; to consolidate campus sustainability agenda; to articulate research, teaching, culture and extension for sustainability; to integrate sustainability projects and actions; to expand and reinforce links between the campus and the city (USP 2014).

The Brazilian scenario provides numerous discussions about how sustainable development happens in HEI. This study stands out as the basis for HEIs that seek to improve the performance of their university campus infrastructure and who wish to become a Living Lab for Sustainability, as well as serve as an example for society, communities and even for the management and urban planning of cities.

In order to answer the research question that guides the investigation of this work: “How did the Federal University of Lavras become a HEI with the most sustainable campus of the Brazilian scenario featuring Living Lab?”, a qualitative approach was developed with a case study outlined by well-defined specific objectives. Its main objective is to present, in a narrative way, the actions that classified UFLA as the HEI with the most sustainable campus of the Brazilian scenario.

The present work aims to contribute in a global way, providing an academic debate about the insertion of sustainability in the university campus, justifying its importance when presenting data that can serve as reference to other HEIs who wish to follow the same path in the design or adaptation os their Campuses as a Living Laboratory for Sustainability.

## 2 Sustainable Development in HEIs

Environmental management aims to reduce the impact of economic activities on the resources of nature and can collaborate so that HEIs become a reference in their environment, in the training of citizens with “environmental awareness”, active in various sectors of society and sustainable development of cities (Termignoni 2012).

As a marketing strategy, sustainability development initiatives, adjusting resource consumption limits, enhance the company’s corporate reputation and the legacy that will be left to future generations, once sustainable development is important both for the environment and for mankind (Groenewald and Powell 2016).

Shaping sustainability in ways that influence the behavior of students, staff, and local communities indicates an HEI movement toward a greater alignment between campus-operated practices and classroom-based knowledge (Tilbury 2011).

In order for sustainable development to occur, it is not enough for HEIs to develop plans and strategies; concrete and combined actions must be taken in several areas. It is not an easy task, thinking needs to be systemic and not symptomatic and must be linked to changes in curriculum and administrative structure, creation of research programs and extension and strengthening of campus infrastructure (Leal Filho 2011).

According to Souza and Guimarães (2008), in order for HEIs to contribute to sustainable development globally, their EMS must be networked based on the principles that the term constitutes: horizontality, connectivity, multi-leadership, diversity and solidarity share, thus forming a collective movement for common goals to be achieved.

When the HEI contemplates sustainability education in its educational system, students achieve much more than academic degrees. They develop skills, concerns, values and attitudes so that they are able to become future sustainable managers (Reza 2016).

## 3 Relating Sustainable Campus and Living Lab for Sustainability

The main factors that characterize a sustainable campus are: infrastructure management, use of environmental concepts for sustainable development and campaigns or programs to adopt good practices, the combination between them should be allied to the communication that provides a better articulation between the academic community and the environmental management strategies (König 2013).

For Too and Bajracharya (2015), the main focus of a SC implementation is generally to involve and promote the minimization of the environmental impacts generated by its activities, in order to balance the use of natural resources with economic, social and cultural issues and linked to health.

Studies by Parrado and Trujillo Quintero (2015) conclude that when an HEI involves and promotes, in a local and global way, the minimization of the environmental, social and economic impacts generated by human action on its infrastructure, its campus can be considered sustainable.

In addition to enabling the engagement of the academic and external community, sustainable IES needs to network not only within its reach and with its stakeholders, but also in order to share its sustainability approaches with the community and with other universities (Too and Bajracharya 2015). The geographic space of the campus that functions as a Living Lab for Sustainability can be considered an arena, playing a fundamental role in the partnership between sectors: public, private, societies and individuals (Voytenko et al. 2016).

Living Lab can be considered as an open form of experimental and collaborative innovation, involving interested parties (companies, institutions, public or private bodies, communities, individuals) in forming partnerships so that they can share practices, knowledge, research, and even resources. This is a concept that began to emerge in the 1990s but was only disseminated from the year 2006 and can be discussed through a variety of perspectives and approaches (Veeckman et al. 2013).

AASHE (2014) delimited the concept applied to the central theme of this work, CS, as a Living Lab. By enhancing sustainability on campus, HEIs that use their infrastructure and operating practices as a learning and living environment, enable their students and staff to apply this knowledge acquired in their daily lives and replicate to the outside community.

For König (2013), a Living Lab for Sustainability characterizes a way of living on campus that provides active and creative experiences, generating learning communities. There are many perspectives involved, since sustainable development is embedded in the curriculum of HEIs, such as changing social practice, the built environment, operating systems and solving problems on campus.

Brazil is not yet familiar with the concept of Living Lab, and many national HEIs do not visualize their campuses in this way. Overall, the vast majority of HEIs that have Living Lab for Sustainability initiatives are located in the US and some examples found in web surveys are: University of Cambridge; Cornell University; Yale University; The University of British Columbia; The California State University; University of California, Santa Barbara; Duke University; Harvard University; Portland State University; The University of Manchester; University of California, Irvine; e University of Washington.

Schliwa (2013) establishes an important link in stating that Living Labs for Sustainability are an urban management tool, an integrated research infrastructure that drives innovation. Through this tool, both cities and university campuses act as a platform for real-life experiences, providing sustainable urban transitions.

## 4 *Ranking UI Green Metric and the* Brazilian Scenario

This ranking, an initiative of *Universitas* Indonesia, was launched in 2010 with the aim of promoting sustainability in HEIs and drawing the attention of university leaders and stakeholders. Today, approximately 500 IES from all over the world participate in the ranking, which provides results online on the current situation and the policies adopted by each evaluated campus, encouraging the exchange of experiences between academic communities (UI GreenMetric World University Ranking on Sustainability [UI GreenMetric] 2016).

The GreenMetric UI ranking ranks the institution through six criteria, which will be listed below, in addition to the location of its campuses that can be: rural, suburban, urban, in the center of the city or a skyscraper building. The criteria are listed and explained below. The data are made available on the organization's website, encouraging cooperation, sharing of experiences and sustainability practices among participating HEIs (UI GreenMetric 2016).

1. Configuration and Infrastructure: analysis of the relationship between university policy and the green environment in order to verify if the campus can be considered sustainable;
2. Energy and Climate Change: analysis of the use of efficient appliances, use of renewable energy, total use of electricity, energy conservation, ecological construction, adaptation and mitigation of climate change, reduction of

greenhouse gas emissions. The goal is for universities to increase energy efficiency efforts in their buildings and implement more actions to conserve natural and energy resources;

3. Waste: analysis of programs such as recycling in general, recycling of toxic waste, treatment of organic waste, treatment of inorganic waste, sewage disposal, reduction in the use of paper and plastic on campus;
4. Water: the goal is for universities to reduce water consumption, increase conservation and protect *habitat*;
5. Transportation: analysis of the existence of a transportation policy to limit the number of motor vehicles on campus, use of buses and bicycles encouraging a healthier environment, and students and staff walking on campus avoiding the use of private vehicles; and
6. Education: it is based on the thought that the university plays an important role in guiding the new generation with sustainability issues.

Analyzing the Brazilian scenario, based on the data available on the GreenMetric UI website (2016), there were fourteen participating HEIs by 2016. The Table 1 shows the Brazilian institutions with the best placements and their rankings in the general ranking and by country.

The performance of UFLA places Brazil in a leading position in the international scenario and arouses the interest of other Brazilian HEIs in knowing what is being done on its campus. As illustrated in Fig. 1, since UFLA began its participation in 2012, it has maintained a balance in the overall classification of the ranking. Between the years of 2013 and 2016 the numbers were very close, maintaining practically the same classification in 2015 and 2016. The graph also shows the evolution in the number of participating HEIs, with a significant increase from 2012 to 2016, around 100%, generating a fiercest dispute for the best places.

The University of São Paulo (USP) has participated in the ranking since it was conceived in 2010, and until 2014 its classification was attributed to some isolated

**Table 1** Brazilian IES in the GreenMetric UI Ranking 2016

| Brazilian HEIs | Brazilian Rating 2016 | General rating 2016 |
|---|---|---|
| Federal University of Lavras | 1° | 38° |
| Federal University of Viçosa | 2° | 139° |
| Pontifical Catholic University of Rio de Janeiro | 3° | 157° |
| Federal University of São Carlos | 4° | 209° |
| Federal Institute of Education, Science and Technology of Southern Minas Gerais | 5° | 217° |
| Pontifical Catholic University of Rio Grande do Sul | 6° | 245° |
| University of São Paulo | 7° | 278° |

*Source* Prepared by the authors and adapted from UI GreenMetric (2016)

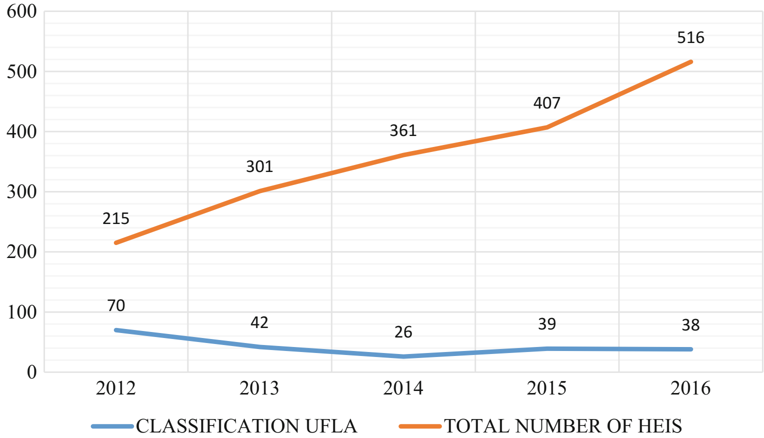


**Fig. 1** Overall rating of UFLA in UI Ranking GreenMetric. *Source* Prepared by the authors based on UI GreenMetric (2016)

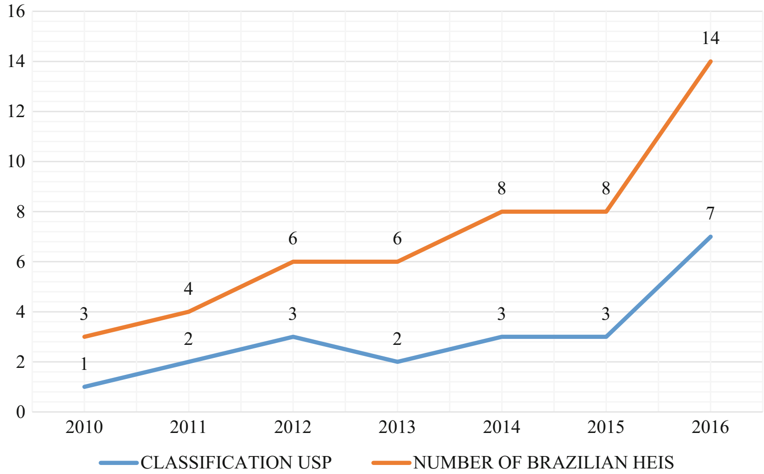


**Fig. 2** Rating of USP among Brazilian HEIs in Ranking UI GreenMetric. *Source* Prepared by the authors based on UI GreenMetric (2016)

actions practiced in its campuses. The classification, over the years, remained balanced and could change significantly after the implementation of the environmental program developed in 2014. Figure 2 presents the data cited and illustrates the increase in the enrollment of Brazilian HEIs to participate in this ranking.

## 5 Context

For this research was chosen a qualitative approach, which happens in two phases according to Martins and Theóphilo (2009): the first as a research process, information gathering, data and evidence, and the second confronting and relating the material found with the question Search, reviewing and adjusting if necessary.

The chosen research modality is the case study, which was developed in UFLA, classified in the last five years as the most sustainable HEI in Brazil and Latin America, by the UI GreenMetric. The case study requires the use of multiple data collection procedures, it is a research design that can be characterized by dealing with "how and why" questions with the intention of thoroughly investigating contemporary facts and understanding a given phenomenon comprehensively. Always maintaining impartiality in the analysis of the sources of evidence (Yin 2015).

The choice of this IES as the object of the case study is justified due to its importance as one of the Brazilian institutions most engaged in the pursuit of sustainable development and for having many sustainability actions in operation. These actions also show signs that the HEI may be considered a Living Lab for Sustainability.

By means of triangulation of the evidence, which according to Gil (2009), consists of the convergence of the results obtained from different sources, the final result of this work was generated. The information points that were crossed in this line of investigation resulted from the following procedures:

(A) Bibliographical research through a systematic literature review;
(B) Research and documentary analysis of the GreenMetric UI; and
(C) UFLA empirical research (field data collection and interviews).

In the item "b", indirect observation was used, through surveys on the organization's website and item "c" direct and indirect observation and collection of primary and secondary data, through field surveys, interviews, Sustainability reports, images, videos, and web searches. Subsequently, as a procedure to analyze the collected material, content analysis and discourse analysis were developed.

## 6 Results and Discussions

One of the managers of the Environment Department (ED) affirms that the implementation of sustainability projects is a challenge because "[…] so that the actions of the plan can work, it is necessary goodwill and engagement of the entire academic community, From the central administration of the institution to the students, which is in fact happening at UFLA". This enthusiastic speech demonstrates the acceptance of the new management model by the entire academic community and emphasizes the presence of the Living Lab for Sustainability concept in the IES philosophy.

The main actions that classified UFLA as HEI with the most sustainable campus in the Brazilian scenario were identified in the field survey, through the analysis of sustainability reports, documents and transcription of speeches and interviews. Based on the criteria and indicators established by the UI Green Metric ranking, they will be presented in a narrative form, providing discussions about the theme.

1. Configuration and Infrastructure

UFLA is a federal public university, well respected by the Ministry of Education (MEC), in relation to teaching quality, compared to other Brazilian public and private institutions. And in its mission, it presents a commitment to environmental responsibility: "Preserving the integrity of the academic community; Preserve the fauna, flora and springs" (Universidade Federal de Lavras [UFLA], 2017b).

Founded in 1908 as an institute, in 1963 it was federalized and became a university in 1994. It currently has a population of 17,000 people on its campus. It is located in the city of Lavras in the State of Minas Gerais, 230 km from Belo Horizonte and between two important metropolises: São Paulo and Rio de Janeiro.

It has a university campus with an area of 600 hectares, being approximately 250,000 square meters of built area. In addition to the campus area, it has two experimental farms, one for animal and plant breeding, used by the Agronomy and Agricultural and Agricultural Sciences course and the Technology Transfer Farm, both nearby but outside the city (Universidade Federal de Lavras [UFLA], 2017a).

The institution has an Environmental and Structuring Plan, called Eco University Project, with management of the Environmental Department (ED). It was started in 2008 as a socio-environmental commitment of the HEI and aimed to involve the entire academic community in the sustainability practices operated on campus. The plan has been receiving modifications and adjustments since its inception, but always with the objective of contributing to the institution's sustainability practices (Universidade Federal de Lavras [UFLA], 2016).

A senior management member describes in his speech the reality of HEI before the implementation of the Environmental and Structural Plan "[…] we taught students all the correct practices of sustainable development, management and conservation of the environment, but we did not practice here. It was like that saying: 'blacksmith's house, wooden skewer'" (Speech report).

It has an area of 29 ha where 90,000 tree saplings were planted and technical recommendations for restoring ecosystems with re-vegetation models. In an area of 65 ha, with native vegetation in the perimeter of the 15 springs that exist in the campus, actions of recovery and conservation of Permanent Preservation Areas (PPAs), legal reserves and areas of environmental interest were implemented. Planting of native species, 51,000 seedlings from 2009 to 2011, in several areas of the institution, including where the springs are located.

It has a fire brigade, consisting of approximately 30 trained men, security guards, students, administrative technicians and teachers with the objective of preventing and fighting fires on campus, acting in the reconstruction of firebreaks and cleaning of combustible materials, besides serving the external community, when necessary.

2. Energy and Climate Change

The plan that conducts the management of electric power operates without prejudice to the activities of the campus and also brings other types of benefits that go beyond the environmental dimension as described by one of the members of the top management "[…] generated a direct savings of R $ 7 million in the cost of the institution, a figure that is reversed in the university's end of teaching, research and extension activities, in management improvements and integration activities with the local and regional community" (Speech report). These data are from the year 2015 and also privilege, in addition to the environmental, social and economic dimension of the tripod of sustainability.

Actions directed at energy management have a direct impact on climate change and are being heavily implemented and operated by the institution: Exchange and restructuring of all campus electric power systems foreseeing growth in the next 30 years; Installation of energy meters in sectors and departments, aiming to detect environments with higher consumption; Exchange of lamps in sectors, departments and public areas, by technologies of lower consumption; Implementation of demand controllers in air conditioning apparatus; Installation of capacitors to reduce the reactive power in the distribution network of the campus; Installation of new energy panels with suitable circuit breakers, surge protection devices (atmospheric discharges) and standardization in accordance with standards.

Renewable energy sources have already been implemented in new and existing buildings, such as: solar energy capture in Student Housing (AE) and in the University Restaurant (UK), used for heating the water; Installation of plates for capturing photovoltaic energy in the ceiling of the stations of bicycle, used for nocturnal illumination of the same ones; Project of a photovoltaic plant and studies to search and integrate other forms of renewable energy, such as wind.

In new buildings, the adoption of constructive techniques that consider aspects such as greater lighting and natural ventilation in classrooms, resulting in low energy consumption, reduction in environmental impact and costs for the university.

The Biogas generated in the process of the Sewage Treatment Station (STS) will be used as an alternative energy source to operate the system itself, producing electricity or heating the effluent. This action also contemplates the concern with climate change, reusing and avoiding the emission of greenhouse gases. The facilities are already underway and, soon, the STS will also be self sufficient in energy.

3. Waste

As an example of UFLA's initiative in the management of waste, emissions and effluents, one of the most important was the construction of the STS, considered a reference in technology and innovation. The solid waste from the STS is used in agricultural production research and the structure ensures that the water is properly treated before returning to the environment. Involves students, staff, teachers in the implementation and operation of the station. The STS has eliminated 145 cesspits on campus, receives 300,000 l of sewage daily, but the total capacity is 700 thousand.

There are a total of 50 sets of waste bins on the campus for selective collection, plus five for collection of batteries. All this process is monitored and evaluated by the *Educampus* environmental education project with effective participation of employees from all sectors of the University, including the collection of recycled paper; and the collection and recycling of construction materials. The selective collection is carried out in partnership with a local cooperative, which makes the withdrawal and destination of the recyclable material, besides the participation and integration of the students.

A member of the outside community who participates indirectly in the campus sustainability actions exalts the importance of UFLA practices "[…] the pick-up truck passes the campus twice a week and takes the recycled material to the cooperative, where it is separated and sold for recycling. We give lectures to the freshmen, teaching them how to do the separation in the republic…" (Speech report). In this speech the external community, besides presenting an interaction with the academic community, recognizes the work of the institution in favor of sustainable development.

The institution launched a campaign called *UFLA Recicla*, based on the principle of 3 Rs: reduce, reuse and recycle, with the aim of reducing waste generation to the maximum, and awakening awareness in all academic communities to adopt sustainable attitudes. The freshmen receive a kit with the institutional mug and an ecological bag when they are received by HEI. A student's survey of the administration department showed that before the launch of this campaign, 80% of the space in the bins was taken by the disposable cups.

4. Water

The institution, which is 100% self sufficient in this resource, has a Water Treatment Station (WTS) with 25 years of existence, functioning twenty-four hours a day. One of the DMA members who know the system in detail says "[…] it does standard conventional treatment, it's enough because of the good quality of water available on campus, which is easy to treat. It is in the process of expansion, a project to meet future demand of 20 years ahead. With the magnification, there will be a labor saving eliminating the night shift. […]" (Interview report).

The rainwater collected and treated by the WTS is stored in a collection area with a capacity of 1,600,000 l, built after the implementation of the Environmental and Structural Plan. After treatment, the water comes out bright and ready to be reused in the cleanliness of off-campus areas, irrigation of gardens and planting areas, which is interesting because it contains nutrients such as nitrogen and phosphorus. The wastewater is directed to artificial lagoons (containment basins), avoiding the superficial runoff and making possible the supply of the groundwater table and other areas of recharge.

In the new constructions, implantation of automatic taps and toilets with coupled boxes, which contributes to a decrease in water consumption. In the old structures of the institution, the bathrooms are being renovated with the same resources of consumption control. A new campaign titled “Water: Do not Let It End” began in October 2014 and has been mobilizing the academic community to raise awareness and saving of water resources in an intensive environmental education work with the outside community.

5. Transport

The UFLA institution carried out the construction of the 6 km bike path; spread volunteer hitchhikers across the campus, with signs indicating where to go; built five bike stands and stations for up to thirty bicycles, located on the main avenue and close to the class pavilions; and also implemented internal public transportation by bus, which travels across the campus, without charging user fees.

The *Ciclovia Legal* campaign was launched, to alert on issues involving the safety of the academic community and visitors, the need for pedestrians not to invade the space for bicycles and cyclists to respect the sidewalks.

6. Education

On the website of the institution, a link directs the ED and its coordinators, from where the platform that describes the Eco University Project can be accessed. Accountability to the Federal Court of Accounts (TCU—Brazil) is made through reports prepared by the ED, but the data is not yet publicly available on the website. The plan is for this to be done soon.

There is a very diversified exchange between UFLA and other institutions, as narrated by one of the ED members, who has already lectured in public schools in the city about safety in chemical laboratories “[…] some HEIs come to visit UFLA to learn about these waste management programs. UFLA also serves as an example and reference to other institutions in Brazil, in relation to the sustainability actions it practices […]” (Interview report). Chemistry students, for example, collaborate in laboratory routines and also conduct research, functioning as an internship.

In addition to several course options, disciplines, incentive to academic projects related to sustainability and made available by the institution, the same narrator describes the participation of students in the campus sustainability practices “[…] students with or without scholarship, through selection process or on a voluntary basis. The institution has a program in which the low-income student has a scholarship, linked to work on research projects and this encourages participation in the actions” (Interview report).

As education through campus experience, experiments with plants are done in the STS by students of Biology, to verify their reaction when fertilized with waste generated by the station, which have phosphorus, nitrogen and urea in its composition. Students and teachers of the Agronomy course use the organic waste for studies in gardening, for studies on biodiesel and composting techniques that can be implemented in the campus infrastructure in the future.

The institution promotes events such as the international workshop held at UFLA: “Impacts of Global Changes in the Fire Regime, Operation and Structure of Tropical Landscapes”, as well as courses such as agro ecological architecture, which taught techniques of bamboo and thatch construction.

In the administrative vision of the HEI, the campus is considered a reference for cities and other institutions that wish to follow the same path, “[…] UFLA is once again setting an example for public institutions, for small towns and even for the great institutions of the country, which have not yet achieved the progress we have made in the environmental area. Basically, now we are aware of what we teach for our students in the classroom, we practice within our institution” (Speech report).

## 7 Conclusions

UFLA has in its campus the perfect stage to develop the project Living Lab for Sustainability with success. The campus of the Brazilian university is rich in natural resources such as water, has large areas of permanent preservation, many springs, rich biodiversity, and has always developed and maintained the Environmental and Structural Plan. The climatic conditions of the country and the city also favor the capture of solar energy, the use of natural ventilation and lighting, among other facilitating factors.

The institution capitalizes on the infrastructure of its campus to educate for sustainability. The involvement of the administrative management is essential, since even though there is already a SC infrastructure in operation, the Living Lab only happens when the institution is organized and the top management approves and commits itself to its implementation. The institution can be characterized as a Living Lab for Sustainability, depending on the practices it has, and can evolve through gradual achievements, since there is no single way to implement this concept.

The study showed that it is not viable that there is a dichotomy between SC concepts and Living Lab for Sustainability, they need to develop and walk together, complementing each other. The collaborative learning community that is the Living Lab, if applied to sustainability, must contemplate its dimensions: economic, social, environmental and add the cultural dimension that is a relevant part in this balance. Many paradigm shifts become major challenges because of the cultural barrier presented by many individuals, organizations and communities.

In Brazil, until these days, there are no HEIs with projects of Living Laboratory for Sustainability implemented in their campuses, which constitutes a restriction of research, making it impossible to carry out comparative studies in the country. Another limitation was the low number of scientific articles found in the world, dealing with the Campus theme as a Living Laboratory for Sustainability.

There are many studies on Sustainable Campus, but still few related to the central theme of the work that is Living Laboratory for Sustainability in this context, revealing the need for more research in the area. The theme is extremely relevant to the reality of Brazilian HEIs and can contribute to the transformation of individuals, societies and cities through education.

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## Author Biographies

**Cristiane Criscibene Pantaleão** Master in Sustainable and Smart Cities from the University Nove de Julho. Specialist in Teaching for Vocational Education from the University Nove de Julho. Specialist in Business Management from the University Cidade de São Paulo. Graduated in Architecture and Urbanism from the University São Judas Tadeu.

**Tatiana Tucunduva Philippi Cortese** Postdoc in Architecture and Urbanism from the Faculty of Architecture and Urbanism of the University of São Paulo (2017). Ph.D. in Sciences from the University of São Paulo. Master in Public Health from the University of São Paulo. Specialist in Environmental Law from the Faculty of Law and Faculty of Public Health of USP. Graduated in Law. Professor of the Graduate Program in Sustainable and Smart Cities and the Master's Program in Administration—Environmental Management and Sustainability of University Nove de Julho—UNINOVE. Professor of GVLaw. Invited lecturer at SENAC University Center. Author of the books "Smart and Sustainable Cities" and "Climate Change: from global to local". She works in the areas of Environmental Law; Smart and Sustainable Cities; Sustainability Management; and Climate Change, interacting with interdisciplinary and multidisciplinary groups.

# Analysis of Energy Consumption and Efficiency at University of Passo Fundo—Brazil

**Amanda L. Salvia, Giovana Reginatto, Luciana L. Brandli, Vanessa T. da Rocha, Rangel C. Daneli and Marcos A. L. Frandoloso**

**Abstract** University of Passo Fundo is located in the South of Brazil and currently has around 20 thousand students, distributed in all of its campuses. In its Social Responsibility Policy, it addresses the environmental issue in several items, committed to establishing guiding principles to sustainable development. This paper aims to present a survey of electricity consumption at the university main campus, between 2004 and 2016, in addition to presenting the actions that have been developed in order to contribute to greater sustainability—and reduction of this consumption. The methodology consists of collecting energy data in the responsible sector of the university, followed by the description of the actions that have been developed, in order to make the campus greener. Finally, based on research about practices applied in universities around the world which have excellence regarding energy efficiency actions, a discussion about their possible application at University of Passo Fundo is presented. The results show that electricity consumption per campus unit area has been constant in recent years, whereas the costs have increased considerably. It is also observed that there is still much to learn from external experiences in order to contribute to the University's environmental and energy eco-efficiency programs.

**Keywords** Energy efficiency · Sustainable campus · Efficiency actions

## 1 Introduction

Sustainable campuses contribute significantly to local and regional sustainable development. Higher education institutions (HEI) play a key role in training students who are aware, responsible and concerned with environmental issues

A. L. Salvia (✉) · G. Reginatto · L. L. Brandli · V. T. da Rocha · R. C. Daneli
M. A. L. Frandoloso
College of Engineering and Architecture, University of Passo Fundo,
Campus I, BR 285/Km 292, São José, Passo Fundo, RS 99052-900, Brazil
e-mail: amandasalvia@gmail.com



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(Tauchen and Brandli 2006). In this context, to insert practices such as reuse of rainwater and minimum water consumption, to develop efficient energy consumption, using alternatives which favor it are very important actions (Amr et al. 2016; Faghihi et al. 2015).

According to Alshuwaikhat and Abubakar (2008), universities can be considered small cities. This is because it is necessary to design an infrastructure that supports the needs of academics, regarding mobility, service delivery and use of energy as the main source. Due to the high energy consumption on campus and the environmental impact caused, institutions are seeking organizational and technological measures of energy efficiency to reduce damages (Kolokotsa et al. 2016).

According to Thomashow (2014), university campuses are exemplary places to practice, explore and build sustainability. Sustainable projects can be introduced gradually to the level of complexity. For example, by the use of vegetation—through green wall artifacts-, under analysis of the possibility of implementing in the facade of the campus buildings, improving thermal and acoustic performance (Poddar et al. 2017); the design of photovoltaic panels to capture sunlight (Hasapis et al. 2017); or even the implementation of a web-based campus energy management system that, according to Kolokotsa et al. (2016), can efficiently generate energy, monitor and analyze the energy levels of all buildings individually and collectively. This system, in addition to contributing to the efficient use of energy, encourages users to be aware of how much is being consumed.

These measures contribute in a relevant way to the development of sustainability, causing HEIs to seek ways to shape their campuses, turning them into green, modern and intelligent. Thus, knowledge and solutions founded on universities can be used to combat the global environmental crisis (Thomashow 2014).

Among the first steps towards applying energy efficiency practices is the monitoring of the energy consumption diagnosis. Authors focusing on energy management indicate the evaluation of financial costs, electricity consumption, electricity consumption per area and per period, among other energy indicators to be evaluated in order to contribute to monitoring and suggesting practices (Saidel et al. 2005; Santos et al. 2014). The results of the diagnosis can encourage the identification of energy practices that could be applied in HEIs, and the monitoring of indicators help the analysis of the relation between the institution needs and the efficiency of each practice.

In the context of sustainable campus, this paper focuses on energy efficiency practices in the University of Passo Fundo, analyzing a local situation from national and international experiences. As a prominent university in the state of Rio Grande do Sul, it is gradually developing practices that contribute to its energy efficiency. Thus, this paper aims to present its case study, through survey of electricity consumption at the university main campus, between 2004 and 2016, in addition to presenting the actions that have been developed to contribute to greater sustainability—and reduction of this consumption.

## 2 Energy Efficiency Practices at Universities

In order to have technological development, it is imperative that universities acquire and approach sustainable practices in their campuses; this way, a sustainable and conscious society is developed (Tauchen and Brandli 2006). Some examples of practices at universities around the world were addressed, illustrating the development of sustainability in campuses. Table 1 summarizes the findings.

Brazilian universities have been developing their role in the sustainability pathway. The University of São Paulo (USP) has developed the Permanent Program for the Efficient Use of Energy (PURE), which has the purpose of generating energy

**Table 1** Examples of sustainable practices in universities

| University | Practice | Country |
|---|---|---|
| PUCRS—Pontifical Catholic University of Rio Grande do Sul | Sustainable Use of Energy (USE) | Brazil |
| UNISINOS—Unisinos University | Environmental Management System (EMS) | Brazil |
| USP—University of São Paulo | Permanent Program for the Efficient Use of Energy (PURE) | Brazil |
| UFLA—Federal University of Lavras | Eco University Project | Brazil |
| UFRJ—Federal University of Rio de Janeiro | Energy Program | Brazil |
| UFPEL—Federal University of Pelotas | Good Energy Use Program (PROBEN) | Brazil |
| UNISUL—Unisul University | Energy Efficiency Program (PEE) | Brazil |
| UBC—University of British Columbia | Energy Management Plan | Canada |
| Technical University of Crete | Camp IT—web based energy management system | Greece |
| Osaka University | Information System—measure and summarize university electric power consumption | Japan |
| UCC—University College Cork | University Energy Awareness Programme | Ireland |
| University of Brescia | The Brescia Smart Campus | Italy |
| University of Oxford | Lower Carbon Futures Programme | UK |
| University of Nottingham | Carbon Management Plan 2010–2020 | UK |
| Harvard | Resource Efficiency Program (REP) | USA |
| UC—University of California, Berkeley | Real-time Energy Use Software and Photovoltaic Painels | USA |
| Eastern Connecticut State University | The Institute for Sustainable Energy | USA |
| Stanford University | Energy and Climate Action—Stanford Energy System Innovations (SESI) | USA |
| Jaén University | Univer Project | Spain |

saving actions, promoting reforms of the lighting system through efficient and economic lamps, encouraging the shutdown of devices, among others (USP 2017).

Likewise, the Unisinos University was the first institution in Latin America to receive the ISO 14001 certificate because of its commitment to reducing environmental impacts. Its Environmental Management System (EMS) program had the function of integrating academics with projects related to environmental issues (Unisinos 2017). The Pontifical Catholic University of Rio Grande do Sul (PUCRS), in turn, created the program called USE—Sustainable Use of Energy, which emphasizes the essential incentive to the academic community in the awareness of the use of energy (PUCRS 2010).

With the Eco University Project, the University of Lavras (UFLA) addresses sustainability in a concrete way. The project is divided into nine items that discuss the university's commitment to the socio-environmental issue. From chemical waste management to energy management, the project encourages students to participate in the actions, committing themselves to the cause (UFLA 2013).

The Federal University of Rio de Janeiro (UFRJ) is a great investor when it comes to sustainability. The Green Fund project covers other more specific programs, such as the Water Program and the Energy Program. The latter has the function of creating energy saving systems, such as: installation of smart meters, photovoltaic panels, solar parking, installation of LED lamps in common areas, among others. The exchange of lamps, for example, estimates a reduction of 15.8 MWh/month, resulting in monthly savings of approximately USD 2000.00, besides the non-emission of 200.08 tons of carbon monoxide (CO) in the atmosphere (UFRJ 2017).

The Federal University of Pelotas (UFPel) considers a citizenship exercise to use energy correctly. With the Good Energy Use Program (Proben), the academic population is encouraged to save energy—through efficient equipment and correct habits-, avoiding waste and dealing with energy responsibly, resulting in cheaper invoices and collaboration for the preservation of the environment. From September 2006 to April 2016, energy savings reflected a reduction of more than USD 1000000.00 in energy use expenses, approximately USD 9200.00 per month (UFPel 2017).

The Unisul University, Pedra Branca Unit, through Celesc's Energy Efficiency Program (EEP), replaced 1100 old lamps installed in the campus buildings with LED lamps. It also installed photovoltaic panels, predicting a generation of 55.02 MWh per year. The project began its functionality in April of that year (Unisul Hoje 2017).

The University of British Columbia (UBC) is one of the largest energy consumers in Canada. Therefore, it has developed programs that encourage its efficient consumption. The Energy Management Plan addresses five energy consumption items: consumption monitoring, use of benchmarking, identification of excessive consumption and setting of targets, dissemination of results and search for other conservation and energy efficiency opportunities. Since 1998, when the program was started, good results are being achieved in relation to the economy, as it saved around 36,000,000 kWh per year, resulting in a cost reduction of more than 7 billion dollars annually (UBC 2017).

Technical University of Crete developed an efficient web based energy management system, that manages the energy consumption in the campus buildings and spaces of public use, besides monitoring the energy load and performing energy analysis per building and for the campus as a whole. Another positive point is that it interacts with each user through questionnaires, e-mails and forms, and generates overall strategy based on historical data (Kolokotsa et al. 2016).

Osaka University in Japan, through the Department of Environment and Energy Management (DEEM), has installed an information system accessible through intranet, which is able to measure and summarize, with a frequency of 30 min, the total energy consumption of each institution building. This system contributes to the sort by quantity consumed in each establishment, so they can be classified in three levels of consumption. As a result, the system also assists in the installation and promotion of renewable energies, such as photovoltaic panels, since all the consumption data are measured through the system, which generates 22% energy savings (Yoshida et al. 2017).

The University College Cork has the University Energy Awareness Program. This program describes the main items responsible for energy efficiency, such as energy savings at night and during weekends, for user-authorized equipment shutdown, as well as the use of Positive Impact Green IT Management which turn computers off at night, and the Energy Champion Profile, which helps people become more familiar with energy issues (UCC 2017).

The University of Brescia has created a program called The Brescia Smart Campus to present energy efficiency through smart grid management, data collection, control and automation. In addition, the system also assesses user awareness. Therefore, the next step of the research is to generate renewable energy through sunlight, as well as heating and cooling control (De Angelis et al. 2015).

The University of Oxford develops research related to the Lower Carbon Futures Program, focusing on sustainability and climate change, since future energy systems need to be highly efficient and based on sustainable resources. The program studies changes needed to deliver transitions to these systems, highlighting changes in technology, behavior and practices, markets, policy and governance (Oxford 2017).

The University of Nottingham, with the Carbon Management Plan, discusses several relevant factors related to sustainability. As for energy, it includes projects for the use of wind energy, photovoltaic panels, biomass and solar water heating, with good analysis of investment, payback period and carbon savings (University of Nottingham 2016).

With the REP (Resource Efficiency Program) program, Harvard addresses sustainability issues such as waste of water and food, energy consumption, and the importance of recycling. As for energy efficiency, it addresses a few key items, such as using LED bulbs, encouraging academics to take short baths, washing clothes in cold water, being careful with ventilation problems, broken air conditioners, as well as turning off electronic equipment and room lighting when not in use, among others (Harvard 2015).

The University of California, Berkeley, has developed a software to show the use of energy on campus in real time (Berkeley U.C. 2017). In addition, the university produces 1 MW of renewable energy, with the capture of sunlight through photovoltaic panels. This program is responsible for an 80% reduction in carbon dioxide emissions, equivalent to 118 cubic meters, directly collaborating towards sustainability on campus (Berkeley U.C. 2016).

The Eastern Connecticut State University created The Institute for Sustainable Energy. This institute addresses energy efficiency issues through research, education, and technical support to the students (Eastern Connecticut State University 2017). Other activities include Energy Benchmarking (by gathering, interpreting, and analyzing energy data to determine the efficiency of a building and track energy use), Greenhouse Gas Inventory (through quantification of a campus's carbon emissions and track progress in reducing them) and Climate Action Plan (describes actions the university will implement to reach their carbon neutrality goal).

Energy and Climate Action is a plan that has been under development since 2009 by Stanford University. The plan deals with items related to the efficiency of buildings on campus, continually improving it and creating a high-efficiency standard for new ones. The SESI Project (Stanford System Energy Innovations), in its third edition, has the task of transforming fossil fuel energy into energy with more efficient heat recovery, reducing campus emissions by 68% at peak hours (Stanford 2017).

The photovoltaic system is one of the renewable energy systems most used by universities. Jaén University, for example, with the Univer Project, aimed to integrate a medium-scale photovoltaic plant in the campus, locating it in parking lots, facades and pergolas. The system was designed to research and produce approximately 280 MWh per year, representing about 8% of demand (Drif et al. 2007).

## 3 Method

This paper was developed with a specific approach, focusing in a case study of University of Passo Fundo (UPF). This university has been working in professional training since 1968. It has a multi campi structure, located in seven cities, with a total of 18,945 students enrolled in undergraduate, master's, doctorate, high school and language courses. It offers 60 undergraduate courses, in addition to postgraduate courses (UPF 2017a). It is characterized as a community university, as it contains several research and extension projects, assisting the local and regional community.

The focus of this study is Campus I of the institution, the main campus, located in the city of Passo Fundo, state of Rio Grande do Sul, south of Brazil. According to Bortoluzzi et al. (2004), the campus has an area of approximately 35.5 ha. Its structure is composed of 12 Academic Units, in addition to UPF Parque, where investment in research and innovation takes place, and other extension and development sectors (UPF 2017a).

The methodological steps followed by this paper are presented below:

(a) Initially an analysis of the energy consumption in the Campus I of the university is made, collecting data from 2004 to 2016, due to information availability. This analysis is done by presenting the indicators of electricity consumption (kWh), campus built-up area ($m^2$), cost of electricity consumption (USD), electricity consumption per unit area ($kWh/m^2$), and variations observed from any given year to the next one (%). This information was collected from the Campus Administration Division.
(b) Sustainability practices existing in the university are then presented, which, in one way or another, contribute to energy efficiency in its aspects, such as energy saving, energy waste reduction and cost reduction. These practices were also collected with the team from the Campi Administration Division, through the Electric System Sector.
(c) Finally, practices to improve the energy efficiency are suggest for University of Passo Fundo, based on the literature review about success cases in other universities, national and international, related to energy, including implementation of renewable energies on campus, use of systems to control consumption, waste reduction programs, among others.

## 4 Energy Consumption at Campus I of University of Passo Fundo

The Campus I corresponds to approximately 85% of the energy consumption of the entire University of Passo Fundo, a fact that alone justifies the analysis of this consumption and possible measures to contribute to its energy efficiency. Table 2 shows the evolution of the indicators selected for analysis.

Overall, between 2004 and 2016 the campus had its built-up area expanded 35.45%. Great part of that happened between 2005 and 2006 (8.41% of expansion), but, on the other hand, the consumption showed a decrease of 7.76%, with cost savings of more than 45%. This happened due to the installation of a 1.45 MW system of own generation, using diesel, not only supplying the lack of energy by the local energy company, but also allowing the university to fit into the group of high voltage commercial consumers, having reduced rates.

In the following years, the built-up area expansion remained within the percentage of up to 4.45%; however, energy consumption varied widely. In the period 2008/2007, there was a reduction of costs and stabilization of electricity consumption. On the other hand, in 2009, UPF observed an increase in the number of students, besides increasing the informatization of its academic and administrative

**Table 2** Energy consumption, built-up area and energy costs at UPF—Campus I (2004–2016)

| Year | Built-up area ($m^2$) | Consumption (kWh) | Cost (thousand USD) | Consumption per area ($kWh/m^2$) |
|---|---|---|---|---|
| **2004** | 88987.99 | 3,914,408 | 477.78 | 43.99 |
| **2005** | 90735.15 | 3,981,060 | 586.77 | 43.88 |
| Δ 2005/2004 | 1.93% | 1.67% | 18.57% | −0.26% |
| **2006** | 99071.34 | 3,694,457 | 403.30 | 37.29 |
| Δ 2006/2005 | 8.41% | −7.76% | −45.49% | −17.66% |
| **2007** | 99147.84 | 4,421,650 | 441.63 | 44.60 |
| Δ 2007/2006 | 0.08% | 16.45% | 8.68% | 16.38% |
| **2008** | 103293.84 | 4,422,510 | 424.56 | 42.81 |
| Δ 2008/2007 | 4.01% | 0.02% | −4.02% | −4.16% |
| **2009** | 108104.47 | 5,490,587 | 679.23 | 50.79 |
| Δ 2009/2008 | 4.45% | 24.15% | 59.98% | 18.63% |
| **2010** | 108183.65 | 5,639,818 | 653.80 | 52.13 |
| Δ 2010/2009 | 0.07% | 2.65% | −3.89% | 2.57% |
| **2011** | 109457.87 | 5,911,441 | 670.74 | 54,01 |
| Δ 2011/2010 | 1.16% | 4.59% | 11.73% | 3.47% |
| **2012** | 109909.61 | 4,275,696 | 459.08 | 38.90 |
| Δ 2012/2011 | 0.41% | −38.26% | −61.34% | −38.83% |
| **2013** | 111794.95 | 4,946,512 | 469.89 | 44.25 |
| Δ 2013/2012 | 1.69% | 13.56% | 2.30% | 12.08% |
| **2014** | 114928.36 | 5,758,720 | 627.17 | 50.11 |
| Δ 2014/2013 | 2.73% | 14.10% | 25.08% | 11.70% |
| **2015** | 118599.28 | 5,767,925 | 1,031.30 | 48.63 |
| Δ 2015/2014 | 3.19% | 0.16% | 64.44% | −2.94% |
| **2016** | 120535.92 | 5,860,274 | 989.16 | 48.62 |
| Δ 2016/2015 | 1.63% | 1.60% | −4.09% | −0.02% |

*Source* Prepared by the authors based on University Activity Reports from 2004 to 2016—UPF (2005, 2017b)

activities, and also the use of air conditioners in laboratories. As a result, energy consumption increased 24.15%, while the costs increased almost 60%.

The 2010–2011 period did not show a great expansion of infrastructure (0.07 and 1.16%, respectively), however, energy costs showed a significant increase of 11.73%. In 2011, it was observed the highest value for the indicator of energy consumption per unit of area within the studied period. On the other hand, 2012 shows one of the smallest results of this indicator, reflecting a decrease in consumption and energy costs, possibly as a consequence of the high value observed in the previous year and the application of saving measures. Another explanation relies on the fact that, in Passo Fundo, during the winter of 2012 the temperatures were slightly higher than in 2011 (Embrapa Trigo 2017), demanding less energy consumption for heating classes and laboratories.

In 2015, there was a large increase in the electricity cost, which did not correspond to growth in area or consumption. This happened because, in this period, Brazil suffered from water crisis, so the energy tariff had an additional proportional to consumption, according to the National Tariff Policy. Costs increased by 64.44% over the previous year, representing an increase of 115.85% over the entire period 2004–2015. In 2016 this cost was reduced, but the concern with consumption remains.

Comparing the indicators of relative consumption per unit of area, in 2004 the value was 43.99 kWh/m$^2$, and in 2011 it had the highest value, of 54.01 kWh/m$^2$, meaning an increase of 22.78%, especially related to the increased requirements for informatization of academic activities and air conditioning. In recent years, this indicator has been reduced, remaining stable around 48 kWh/m$^2$.

Throughout the period analyzed, the university had a considerable expansion by construction of new buildings, such as Law Building, in 2006, the Science and Technology Park, in 2013, and the new facilities of the Engineering and Architecture Building, in 2015. This expansion has generated discussions about the centralized model of energy supply, and it is increasingly important to assess the current conditions of the distribution system, always trying to invest more in renewable energy.

## 5 Energy Efficiency Actions at University of Passo Fundo

The UPF Administration Division, through the Electric System Sector, defined some actions aiming to reduce the electricity consumption and its costs for all campuses. Table 3 summarizes its actions and aims.

Regarding Action 1, it is being possible to verify the cultural change in the correct use of electrical equipment through the implementation of internal regulations aiming energy efficiency, as well as in acquiring more efficient equipment. Concerning Action 2, through the management of cost and consumption indicators, reduction targets are being implemented.

The development of Action 3 is justified by the need of measuring and managing energy consumption per building, so that it would be possible to implement specific actions aiming at energy efficiency for each academic unit and its consumption peculiarities.

On the other hand, Action 4 is slightly more practical, through the adoption of internal policy for the acquisition of air conditioners with inverter technology. Considering the large amount of air conditioning equipment in the university, as well as the long periods of use per day, it can represent an investment that is worth it. According to Zografakis et al. (2011), this kind of equipment is more expensive than regular ones, but it achieves electricity savings that can provide a good payback period, depending on local conditions and operational mode.

The program to replace electrical equipment with low energy efficiency, described in Action 5, allows the reduction of energy consumption to perform the

**Table 3** UPF Energy Efficiency actions

| | Action | Aim |
|---|---|---|
| 1 | Implementation of internal regulations | To establish rules, aiming energy efficiency in the acquisition and use of electrical equipment |
| 2 | Management indicators of electricity consumption and cost in the campuses | To measure and control energy consumption, as well as set targets for its reduction |
| 3 | Measurement and management of electricity consumption in each building within the university structure | To manage the consumption of electricity by building, determining specific actions aiming its reduction |
| 4 | Acquisition of air conditioning systems with inverter technology | To reduce energy consumption by up to 60% in the use of these systems |
| 5 | Program to replace electrical equipment with low energy efficiency | To reduce the electricity consumption by increasing the efficiency of the equipment connected to the electric grid |
| 6 | Program to replace sodium vapor lamps by LED ones in the external lighting area of the campuses | To reduce energy consumption as well as maintenance costs through LED technology with longer lifespan; also, to increase brightness and visual comfort. |
| 7 | Program to replace fluorescent lamps by LED lamps in the internal installations of the campuses buildings | To reduce energy consumption as well as maintenance costs through LED technology with longer lifespan; also, to increase brightness and visual comfort |
| 8 | Improvements in distribution networks in medium and low voltage of campuses | To eliminate electricity losses by replacing undersized networks and distribution system connections |
| 9 | Electricity quality management | To increase efficiency in the energy consumption through control of power factor index and harmonic distortions |
| 10 | Automation of lighting systems in the streets and other external areas of the campuses structure | To reduce the energy consumption and increase lamp lifespan through the control of lighting when it is not being used |

*Source* Prepared by the authors based on data from UPF Administration Division—Electric System Sector—UPF (2017c)

same service. The return on investment period for air conditioners is on average six months to one year.

The replacement of sodium vapor lamps by LED technology in the campus streets and other outdoor lighting areas of the campuses (Action 6) is contributing to reduce energy consumption by up to 40%, with payback period between 12 and 18 months. In addition, the university gained in lamps lifespan, better luminance and visual comfort, and reduced maintenance costs. According to Daneli (2017), 24 sodium vapor lamps of 250 W were replaced by 150 W LED lamps at UPF, reducing energy consumption from 49,680 kWh/year to 19,874 kWh/year, which represents a 40% save. Considering that the cost of kWh is USD 0.186, USD 5544.29 are expected to be saved in consumption, added to USD 409.83 expected savings in maintenance, resulting in USD 5954.12 total savings per year. The investment payback was obtained through the relation between the cost of acquisition of the LED lamps (USD 7847.88) and the estimated savings that this technology can provide.

Action 7, similarly to the last one, indicates the replacement of fluorescent lamps by LED ones in internal installations of the buildings. According to Fauth (2014), the current standard of fluorescent lamps is 32 W (TLD32W840NG Philips), that represent 44 W per unit (including the reactor), with luminous flux of 3200 lm and a luminous efficiency of 72.73 lm/W. The proposal of replacement suggests LED lamps with 22 W (ZL-2810), 2080 lm and 82.48 lm/W. The in-loco measurement obtained a real luminous flux of 3627.60 lm. In his analysis, Fauth concludes that with the use of LED lamps at the university, there would be a 47% reduction in energy consumption, in addition to improved level of illuminance.

Actions 8 and 9 are very technical, aiming to improve medium and low voltage distribution networks of the campuses and electricity quality management. They allow to eliminate energy losses through replacement of undersized systems and connections and to increase the power factor of the installations, occupying the system in its majority by useful energy to consumption, without energy wastes and fines from the energy company.

With the automation of the lighting system in the streets and other external areas of the campuses, according to Action 10, it is possible to use the lighting structure only during commercial hours of the University. This reduces the electricity consumption as well as increases the lifespan of the system.

It can be seen from the actions mentioned above that the adoption of sustainable and efficiency practices, besides contributing significantly to the environmental aspects of energy consumption, also generates a reduction of costs, contributing for the possibility of investments in other improvements.

## 6 Practices Suggested to University of Passo Fundo

As presented before, University of Passo Fundo already has many actions under development when it comes to sustainability and energy efficiency. But some more can be suggested, based on the research made in the literature review, regarding other universities.

The main similarity between UPF and the examples of practices in other universities is the investment in LED lamps. However, other experiences can also contribute to its implementation success. For example, it can be learnt that besides existence of some practices, turning them into programs would strengthen its application and receive more attention. UPF could invest in options like the ones developed at PUCRS and USP, engaging students and professors in the activities. It would be an option to improve energy efficiency but also environmental education.

The experience of Unisinos, by investing in the Environmental Management System is quite important either, since this kind of approach is not very used by universities. The EMS is largely applied in industries, but in academic centers it is more common to study it just in class. It would be a great opportunity to take advantage of the system and its energy savings potential, in addition to contribute to practical knowledge of students, that could verify the methodology and results in their own campus.

Other practice that could work for UPF would be the investment in solar energy, mainly because of the good potential for that generation in south of Brazil. The experiences of Unisul University, Jaén University and University of California show this practice can generate large amount of energy, and it would contribute for UPF's energy security and use of renewable energy. Discussing renewable energy, University of Nottingham also invests in wind and biomass energy, and that could be an option for UPF, at least considering long-term periods.

Climate change and action are not subjects well approached in UPF actions. The reason may be related to the fact that the concern lays more in energy savings and change of academic behavior. Next step has to include the climate discussion, as was made by Eastern Connecticut State University and Stanford University.

UPF actions have much in common with the ones developed in University of British Columbia, University of Crete and University College Cork, especially when it comes to consumption monitoring, identification of excessive consumption, management of energy consumption per building and energy savings at night and during weekends. On the other hand, University of Passo Fundo can learn from these external experiences, by using the set of targets, research for energy efficiency opportunities, benchmarking, and interaction with users through questionnaires, e-mails and forms.

## 7 Conclusions

The analysis of the energy consumption of Campus I shows that it has been following the Built-up area growth of the university, but whilst the area increased about 35%, consumption increased almost 50% between 2004 and 2016. This happens because the consumption depends not only on the area growth, but also depends on the number of students of the institution and its systematization and increase in the number of laboratories and air conditioners. The electricity consumption per campus unit area has been approximately constant in the period of analysis, whereas the costs have increased considerably, which indicates the need to seek greater incentive for actions of efficiency and mainly use of renewable energies. The investment in these actions tend to be positive considering the financial economy, the energy savings and also the role of the university in educating people and professionals. Therefore, it is important to set an example and take advantage of these opportunities as contributors of education.

In a whole perspective, the analysis of energy consumption in university buildings can be an example to exchange experiences among institutions, in order to improve concrete actions related to natural resources and, in a wider level, the sustainability. Energy is a feasible way to show its relevance, in economical and learning terms, but needs the commitment of the actors/agents: teachers, students, staff and, of course, the directors and leaders.

At this point, the case study at UPF and this research could contribute to other universities with similar characteristics, in terms of procedures and future actions to add eco-efficiency in their policies to assist them on implementing a sustainable campus and to show how important it is to measure their performance over time.

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## Author Biographies

**Amanda Lange Salvia** has a degree in Environmental Engineering (2014) and she is currently a doctoral student in Civil and Environmental Engineering at Passo Fundo University, in South of Brazil. She has experience in research since 2011, and current interests include energy efficiency, sustainable cities, environment management and sustainable development goals.

**Giovana Reginatto** is a student of the graduation course in Civil Engineering at Passo Fundo University, in South of Brazil. She is also a scholarship student Pibic/CNPq. Her interests are related to sustainable management projects and energy efficiency.

**Professor Luciana Londero Brandli** is graduated in Civil Engineering (1995), Master's degree in Civil Engineering (1998) and Ph.D. in Production Engineering (2004). Pos Doctorial Research at Hamburg University of Applied Sciences (2014). She is currently Associate Professor in the University of Passo Fundo, south of Brazil, working in the Master Program in Engineering and Environment. Her current research interests include sustainability in high education and green campus, environment management, management of urban infrastructure, sustainable cities and green buildings.

**Vanessa Tibola da Rocha** is graduated in Architecture and Urbanism from the University of Passo Fundo (UPF-2013), Master's degree in Engineering by the Post-Graduate Program in Civil and Environmental Engineering (concentration area of infrastructure and environment) of the University of Passo Fundo (UPF-2016), where she is a doctoral student (CAPES). It presents scientific experience in the areas of infrastructure, environment, sustainability, urbanism, architecture, urban planning and management.

**Rangel Casanova Daneli** has a degree in Electrical Engineering (2015) and is a Master's student in projects and manufacturing processes at Passo Fundo University in southern Brazil. He has experience in power generation and distribution, automation, electrical projects and energy efficiency.

**Professor Marcos Antonio Leite Frandoloso** has a degree in Architecture and Urbanism at Federal University of Pelotas (1986), Master in Architecture at Federal University of Rio Grande do Sul (2001). Currently he is Ph.D. candidate at Polytechnic University of Catalonia, Barcelona, Spain, focusing on eco-efficiency and environmental management at universities. He has experience in Architecture and Urbanism with emphasis on building and environmental planning, acting on the following topics: energy efficiency, energy and environment, sustainable construction, bioclimatic architecture, architectural heritage, ecodesign and urban ecology. He teaches at University of Passo Fundo since 1995, in Architecture and Urbanism, Environmental Engineering and Product Design; besides teaching in post graduation courses in another institutions.

# Sustainable Project for Rainwater Catchment in Low-Income Houses

Célia Fudaba Curcio and Jane da Cunha Calado

**Abstract** This article is the result of a scientific and didactic-pedagogical research, which presents an efficient way of managing scientific initiation scholarship projects with groups of undergraduate students in Civil Engineering. The method was based on the fundamental of Meaningful Learning and the construction of Research Reports, As a complement to these instruments, Research Reports worked as documents of individual activities and groups. Several Brazilian cities suffer constantly with water resources due to the scarcity of rainfall in certain regions. Irregular water distribution led to the development of a rainwater catchment system for non-potable use, with analysis of applicability. To ensure that the characteristics of rainwater are harmless to human health, the analysis of its physical-chemical properties was carried out. The scope of the scientific initiation project included the dimensioning of the reservoir volume, observation of the hydrological cycle and average monthly rainfall index of the city of São Paulo. The system was designed according to the Brazilian Standard of Regulation, in compliance with NBR-15527/2007, NBR-5626/1998 and NBR-12217/1994. The project is important because presents a sustainable option, whose results will contribute to the minimization of the social problem, Brazilian and worldwide, which is the inappropriate use of water.

**Keywords** Catchment rainwater · Meaningful learning · Preservation of water resources

C. F. Curcio · J. da Cunha Calado (✉)
Universidade Nove de Julho, Av. Dr. Adolpho Pinto 109,
São Paulo, SP 01156-050, Brazil
e-mail: jadehera@hotmail.com

C. F. Curcio
e-mail: celia.curcio@gmail.com



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## 1 Introduction

The severe drought that affected some regions of Brazil, starting in 2014, resulted in the largest water crisis among our history, especially in the Metropolitan Region of the city of São Paulo. Data from the National Water Agency (ANA 2015) have shown that considering each one of eight water reserves that supply the Metropolitan Region (Alto Cotia, Baixo Cotia, Alto Tietê, Cantareira, Guarapiranga, Ribeirão da Estiva, Rio Claro and Rio Large), responsible for the delivery of 65 thousand liters of water per second, five of them reached critical levels of water. This fact was responsible for a very important water crisis that threatened water supply.

The Environmental Reports of the World Wide Fund for Nature (WWF Brazil 2015) provided data on the world percentage of water and mentioned that less than 1% of the amount of fresh water is available for consumption. Silveira (2008) points out that this amount of fresh water has uneven distribution on the planet, with regions of scarcity or even no water available for human consumption.

Cunha and Augustin (2014) recall that in Brazil "until 1960, nature was seen as an inexhaustible source of resources", when the idea of progress overlapped, without limits, to environmental issues. Although water is a renewable resource, water consumption has increased significantly as world population grows. Man himself compromises the supply of water in the world for inconsequential activities, such as deforestation, pollution of water bodies, contamination by chemical substances such as heavy metals and agrochemicals.

In several regions of the planet, the rainfall index has undergone variations that hinder the availability of water and compromise the supply to the urban centers. An example of this was the water crisis suffered by the city of São Paulo in 2014, when the scarcity of rain reduced production in the springs and the amount of water from the reservoirs that supply the Metropolitan Region of the city.

Citizens who suffered from lack of water during the critical crisis of the supply crisis intensified their search for sustainable alternatives to solve the problems caused by rationing in the supply of drinking water. Several systems for collection, storage and use of rainwater were developed, as measure to enable the reduction of consumption and final cost of services.

Due to this scenario, the academic interest in developing a project to collect and store rainwater was aroused. This study was proposed to the students of Scientific Initiation of the courses of Bachelor in Civil Engineering, as a resource of social development and instrument of investigation and learning in Physics, its phenomena, relations and properties.

According to Severino (2008), "Scientific Initiation represents an academic instrument that allows students to enter the reality of science research, has an epistemological and pedagogical character, as well as social, if it is developed as an extension activity".

This research proposed to design a system with individual reservoirs to store rainwater, destined to non-potable use, according to the procedures of Law nº 15.967, of January 24, 2014—Municipal Code of the Environment (2014).

The collection of water is made exclusively from the roofs. The differentials of the product are the increase of the quality of life and the possibility of the reduction in the consumption of drinking water.

The multidisciplinary study was divided in two stages, lasting six months each, and in the first semester the bibliographic survey, theoretical basis and study of the scientific contributions on the subject were carried out. The second stage consisted in the analysis of the viability of the water use and technical elaboration of the project.

The main purpose of the study was to develop a system for collecting rainwater, according to the requirements of the current Legislation, ABNT-NBR and Inmetro Regulations, and to meet the specificities of the project. The suggested method of study incorporates concepts of Significant Learning, development of Conceptual Maps and Research journals as management tools for data collection, recording of ideas and observations, which generated further discussions, inspections and data analysis.

Bastos (2011), considers the use of diarism in education for the study of time and practices of self-writing, subjectification of the subject and construction of individual and social memory. This capacity develops through the daily memorial, to all parts of outer and social life, as well as in the personal, physical, moral and intellectual aspects.

Hess (2009), uses the Journal of Research for graduation studies as mediation of transductive thoughts to hypothetical-deductive thoughts. Moreira (2011) points out that meaningful learning occurs when the research makes sense and the student relates the new knowledge to previous knowledge.

Novak and Gowin (1984) argues that the educational event combines meanings and feelings between teacher and student, thus adding the humanist aspect of meaningful learning presented by Ausubel et al. (1968), which re-signifies the concepts of learning, associates knowledge and experience, assigning it a meaning. The proposed method associated with information records in the Research Journal facilitated the organization of research, gathering data that contributed to the scientific conclusions, and collaborated to intensify the teacher-student relationship.

## 2 Theoretical Basis

Several factors can be related to global climate change and variation in the rainfall cycle, a fact that can be perceived by the scarcity of rainfall in several regions of Brazil. Data from the National Institute of Meteorology (INMET 2016) show that the Southeast Region has suffered the effects of the worst drought in the last 80 years.

The consequences of these changes can be seen in the metropolitan region of the city of São Paulo, which had below average rainfall and reduced water volume in the region of springs that contain important rivers and dams, responsible for water supply, such as the Paraíba do Sul river, the source of the São Francisco river and the Sistema Cantareira.

A recent report, supported by WWF Brazil (2015), pointed out that deforestation in Amazon could have an important impact on the climate, reducing forest perspiration and changing the dynamics of clouds and rainfall on the continent. Another report presented by the Food and Agriculture Organization of the United Nations (FAO 2015) estimates that “more than two-thirds of the world’s population will suffer from lack of water by the year 2050 due to excessive consumption in food production and agriculture, Degradation of natural resources and climatic impacts”. The data presented by the WWF Brazil report (2015) are alarming, when we observe that 97% of the planet’s water is in the regions of seas and oceans, leaving only 3% of fresh water in the world. However, of this freshwater percentage, more than two-thirds are located on the glaciers and are not available for consumption. Thus, less than 1% of the world’s total water is consumed.

Given this scenario, it is possible to say that the water supply crisis has a global effect. Another factor contributing to this scenario is the fact that freshwater sources are found in underground aquifers, rivers and lakes, which are often polluted, contaminated or unfit for consumption. According to Jacobi et al. (2015a), “the issue of water supply has interfaces with food security, health protection, agricultural and industrial production, and a variety of other human needs.”

Jacob et al. (2015b) reinforces the idea that the water crisis in São Paulo became worrisome and was aggravated by the water depletion of the region’s main resources. Data from Companhia de Saneamento Básico do Estado de São Paulo (SABESP 2016) point out that, before the drought period, the Sistema Cantareira, responsible for supplying the Metropolitan Region of the city of São Paulo, has garnered 9 million residences. During the period of greatest decline in the system and reduction in the water level of the springs, this number was reduced and, due to the imminence of lack of water, it was necessary to use the technical reserves, also called “dead volume” (SABESP 2016). Portion of the supply was absorbed by the Sistema Guarapiranga and Sistema Alto Tietê, equivalent to 1.8 million residences, remaining to the Cantareira reservoir the amount of 7.4 million residences.

These data reinforce the importance of preservation in the water source region, as discussed by Gribbin (2009), as it shows the relationship between the water crisis and the lack of rainfall in the water supply system, since the areas of protection and recovery of water sources Are areas effectively or potentially used for public supply. Jacobi et al. (2015a) associated climate change with deforestation in the northern region of the country, especially the Amazon Region. Faced with so much evidence, the greatest certainty, singular and collective, is about the urgency of preserving the environment and adopting alternative measures for the conscious use of resources.

All these factors have contributed to actions aimed at the preservation of existing water resources and the interest in contributing to the protection of the hydrological cycle of nature. Researches on the preservation of the environment, the improvement of living conditions and the rationalization of the use of natural resources have been implemented. However, according to Louly (2008), those efforts demand a new environmental, ecological and sustainable behaviour, above all in encouraging simple projects, not necessary involved with technological high complexities, easy to build and touchable for the main population. Among these projects is the storage and use of rainwater for non-potable purposes.

Resolution No. 54 of the Conselho Nacional de Recursos Hídricos (CNRH 2005) recommends that “no good quality water should be used in activities that tolerate water of inferior quality” and defines criteria for the use, considering that “it reduces the discharge of certain Pollutants in receiving bodies, conserving water resources”. The guidelines for the use of rainwater are set out in Norma Brasileira NBR 15.527 (ABNT 2007)—Rainwater: Use of roofs in urban areas for non-potable purposes. The design of the rainwater collection system must comply with technical standards, NBR 5,626 (ABNT 1998)—Cold water installation and NBR 10,844 (ABNT 1989)—Rainwater installations.

The water coming from the rains, in general, has no use, are directed to the sewers and pour into the streams and rivers. Capturing these waters and encouraging the construction of rainwater storage and use systems provides additional benefits, such as reducing consumption and the adequate use of drinking water, flood control, and reducing the flow of water to the basins In urban areas that have a high coefficient of soil sealing and difficulty in drainage. (Law 12,526 of January 2, 2007). Brazil does not have specific legislation for the use of rainwater. The legal basis of Brazil is the Federal Constitution (1988), Decree 24.643 of July 10, 1934, Water Code, which in Chapter V, article 103, states that: “Storm Waters belong to the owner of the building where Directly, and may dispose of them at will, unless there is a right to the contrary”, Law Nº. 7,663, of December 30, 1991, establishes rules for the State Policy for Water Resources, Law 9,433 of January 8, 1997, Which instituted the National Water Resources Policy and Law nº 15.967, of January 24, 2014, Municipal Code of the Environment.

Reused rainwater represents savings in water consumption in areas that do not use potable water. Vasconcelos and Ferreira (2007) emphasize their use in washing the sidewalks, the playground, cars, irrigation of beds and gardens, the reserve for fire cases and even bathrooms in common areas.

The lack of scientific studies on rainwater harvesting and residential use made it difficult to review the literature and compromised the comparison of results with other similar facilities. Due to this limitation, it is proposed the continuity of the presented study and analysis of other systems, with the purpose of eliminating difficulties, by means of the comparison of the results.

## 3 Methodology

The scientific initiation project proposed by the supervisor of this research consisted in the proposal of installation, in popular residence of up to 70 square meters, of rainwater collection and utilization system, with a water roof. The study analyzed the mean annual rainfall volume and the capacity required for the rainwater reservoir. We used the mathematical calculations suggested by Tomaz (1998) to discuss the installed viability of the resources.

Rainwater harvesting was idealized by means of gutters installed on the roof and allocated to 1/3 of the right foot. The water directed to a first reservoir is discarded to eliminate the impurities deposited in the roof. Water taken to the rainwater tank is considered clean for non-potable use. Rainfall data were obtained from the Instituto Nacional de Metereologia (INMET 2016).

The method suggests the application of the principles of meaningful learning as a tool to support the studies. Students were instructed to compile the results of searches in journals, called Search Diaries, with free formatting, to record information, ideas, data collection and observation. The established criteria are the chronological clarity of the activities carried out, the organization of the reflections and self-evaluations, the presentation and writing, which would generate further discussions, inspections and analysis.

## 4 Rainwater Capture and Storage System

Rainwater that falls on the roof is collected by means of rails allocated 1/3 of the right foot, in a strategic position to allow the water to be drawn to the self-cleaning tank. NBR 15.527: 2007 guides the disposal of the first rain that falls on the roof, because these waters carry microorganisms and atmospheric pollutants washing the surface. The use of stored water should be exclusively for non-potable use, in sanitary basins, garden watering, car wash and backyards. According to Vasconcelos and Ferreira (2007), a roof with an area of 200 $m^2$ can capture approximately 250,000 l of water per year.

The system has four reservoirs installed, three on the roof and one on the ground floor. The water of the first minutes of rain is directed to the self-cleaning tank, to be discarded, according to NBR 15.527:2007. The rainwater reservoir directs this water reserved for the discharge, located on the ground floor. The system does not provide for the installation of pumps, because the water is driven by mechanical means, gravitational. The third reservoir receives potable water from the distribution network and the reservoir 4, located on the ground floor, receives rainwater for use in garden irrigation and backyard or vehicle washing (Figs. 1 and 2).

Table 1 presents the behavior of the hydrological cycle and rainfall index throughout the year. The averages are calculated from data observed in 30 years, to identify the rainier/dry and hot/cold seasons of the region.

In order to verify the maximum volume of rainwater, which can be captured, the following mathematical calculation is used, according to Tomaz (1998).

$$\mathbf{Q} = \mathbf{P.A.C} \tag{1}$$

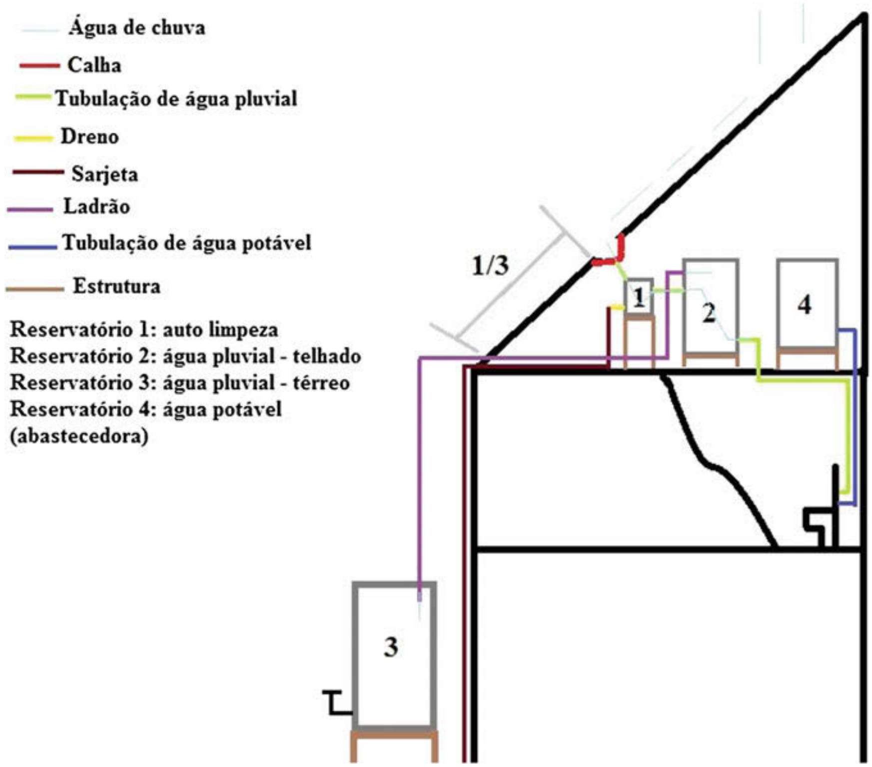


**Fig. 1** Outline of installed rainwater harvesting system (*Source* Students of Scientific Initiation 2017)

As follows:

Q = Annual volume of rainwater, cubic meters
P = Mean annual rainfall, meters
A = Projected coverage area, square meters
C = Runoff coefficient, adopted = 0.8.

Data:

Precipitation = 1443 mm → 1443 m (City of São Paulo)
Projected area = 50 $m^2$
Runoff coefficient = 0.8.

$$Q = P.A.C \rightarrow Q = 1443.50.0.8 \rightarrow q = 58 \text{ m}^3/\text{ano} \tag{2}$$

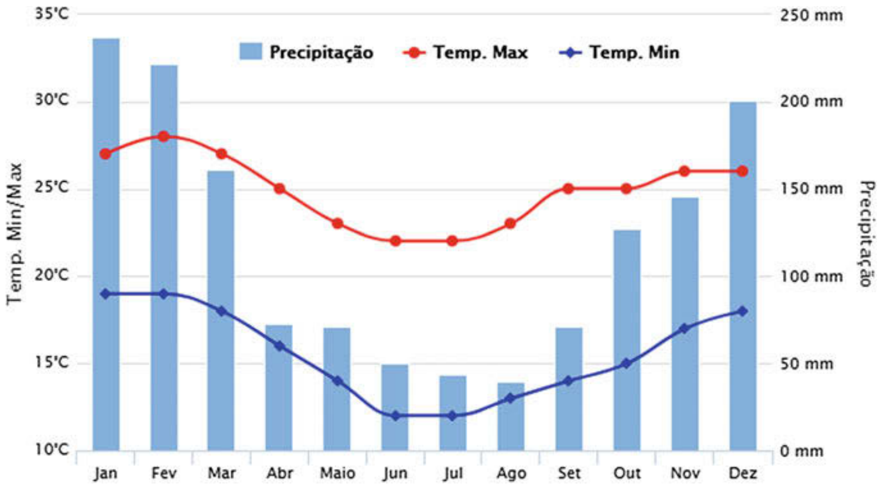


**Fig. 2** Precipitation and temperature throughout the year (*Source* Climatempo 2017)

**Table 1** Average precipitation in the city of São Paulo in the last 30 years

| Month | Precipitation (mm) |
|---|---|
| January | 237 |
| February | 222 |
| March | 161 |
| April | 73 |
| May | 71 |
| June | 50 |
| July | 44 |
| August | 40 |
| September | 71 |
| October | 127 |
| November | 146 |
| December | 201 |

*Source* Climatempo (2017)

Taking into account the table with the data of the hydrological cycle and average annual rainfall of the last 30 years, on roofs with an area of 50 m$^2$, the maximum annual catch is 58 m$^3$/year.

Being the capacity of the 1000-l rainwater reservoir and the approximate monthly average of 4833.3 l, surplus water is eliminated by the thief of the rainwater reservoir and will fill the 1000-l reservoir installed on the ground floor to supply the demand for irrigation of gardens, Floor and car washes. The excess water is discarded into the sewer.

## 5 Conclusion

At the end of the twelve months scheduled for the elaboration of the rainwater harvesting project for non-potable domestic use, the students of Scientific Initiation presented studies that involve the current Legislation and the Brazilian Standards for the use of rainwater.

The elaborated research project was able to meet the residential demand during the dry season and reduce the consumption of drinking water for purposes, in which there is no need for potability, such as: sanitary basins, garden and garden watering, Floors and cars, among others.

It was decided to install the rainwater collection system chute 1/3 of the right foot, to enable rainwater to be collected and to supply the reservoir, without the need to use pumps, taking advantage of the Gravitational Force for water conduction Through the pipe until discharge. The use of rainwater in discharges dispenses the chemical treatment for potability and makes it more practical and accessible.

In addition to the preservation of water resources, the capture and utilization of rainwater provides benefits to residents, such as reducing consumption and saving in the monthly supply services account, and to cities, it brings benefits when it contributes to flood control, with the Reduction of water flow velocity for watersheds in urban areas that have a high coefficient of soil sealing and difficulty in drainage.

The collected data during the bibliographic survey and recorded in the diary were worked by the students and transferred to the scientific report. It was also possible to relate the development of the research and teacher's guidelines recorded in the journal with the scientific report.

Students used the Research Diaries to record the collected data and the perception about the proposed project. The research carried out demonstrated that the Scientific Initiation contributed to provide meaningful learning and use it in the elaboration of the project of a rainwater capture and utilization system for installation in a popular house.

The presented proposal presents some limitations, especially for the restricted bibliographical revision and lack of works focused on the abstraction and distribution of water in the system. Another factor is related to the design stage and there is no comparative parameter, which would enrich the discussions of the presented results. As a proposal for the continuity of the study, it is suggested the analysis of other facilities, in order to compare the results and to resolve any impasse regarding the variants used.

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# Assessing Sustainability Culture at the University of São Paulo—São Carlos

**Rodrigo Martins Moreira, Tadeu Fabrício Malheiros, Robert W. Marans, Noah J. Webster and Andrew L. Hupp**

**Abstract** Universities have the responsibility of promoting an awareness of sustainability among its students, faculty, and staff. They are also responsible for producing groundbreaking scientific knowledge, and sharing relevant experiences with the public. The University of São Paulo's Environmental Policies are in its final steps of development. Accordingly, the release of these Policies is an opportune moment to begin the process of assessing the culture of sustainability on the University's São Carlos Campus (USP-SC). During the spring 2016 academic term, researchers at the University conducted a survey of its students, faculty, and staff to measure sustainability behaviors and levels of engagement and awareness of sustainability on campus. The survey was developed in collaboration with researchers at the University of Michigan (U-M) and was patterned after surveys conducted as part of U-M's Sustainability Cultural Indicators Program. The survey was deployed inside Sustainability Culture Indicators Program (SCIP) been applied at UofM since 2012, and replicated at USP-SC in 2016. USP-SC's Waste Policy is current in its final steps for enactment, therefore, creating a baseline data ex-ante the publication, will allow comparison in future years and how the policy impacted USP's reality. This paper uses data from 2016 application. Survey respondents were asked questions via an online platform about their sustainability-related behaviors and awareness including transportation, sustainable food purchases, conservation behaviors, waste prevention, and environmental management of green (natural) areas on campus. This paper presents and compares descriptive findings for students, faculty, and staff at USP-SC, and presents findings from an examination of the links between sustainability behaviors, awareness, and engagement. The researchers will keep applying

R. M. Moreira (✉) · T. F. Malheiros
Sciences of Environmental Engineering Graduate Program,
São Carlos School of Engineering – University of São Paulo,
Av. Trabalhador Sãocarlense, n 400, P.O. box 359, São Carlos,
SP 13566-590, Brazil
e-mail: moreirarmt@gmail.com

R. W. Marans · N. J. Webster · A. L. Hupp
Institute for Social Research, University of Michigan,
P.O. Box 1248 426 Thompson St., Ann Arbor, MI 48106-1248, USA

 
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the survey in further years, so a comparative study can be deployed with the baseline data acquire ex-ante the USP's Waste Policy enactment. In this context, this work finds that in general that staff presented a more adequate behavior towards waste prevention, followed by faculty and undergraduate students. Further papers will discuss a comparative study between USPSC's and UofM's application results, discussing different university's cultural, financial, and social realities.

**Keywords** Environmental management · Behavior · Higher education institutions Indicators

## 1 Introduction

Universities have the responsibility of promoting sustainability awareness among students, faculty, and staff (Kristanto et al. 2014; Krizek et al. 2012; Little and Green 2009; Moldan et al. 2012; Zain et al. 2012). They are also responsible for producing groundbreaking scientific knowledge, and sharing relevant experiences with the public (Levy and Marans 2012). These spaces are key to implement practices and deploy strategies to engage communities in actions to raise culture of sustainability (Lukman and Glavič 2006).

Universities throughout the world have combined efforts to lead its community's behaviors to a more sustainable path (Gupta and Kumar 2013; Juárez-Nájera et al. 2006; Levy and Marans 2012), this reflects on creation of sustainability offices and committees that engage campus members to build policies, plans and programs that set goals (Lozano et al. 2013).

The University of Michigan (UofM), in 2012, started the Sustainability Culture Indicators Program (SCIP), and deployed a framework to assess the university's community culture and behaviors aspects. By applying surveys, researchers from the Institute for Social Research managed to gather behavioral aspects information concerning transportation, food, waste prevention, energy and water, being applied yearly since 2012 until 2015. The SCIP results are presented in indexes form and show, for example, how much the community is committed to recycling programs. Hence, the SCIP behavioral results are being crossed with operational data, for example, how much energy consumption was reduced. The University of São Paulo—São Carlos Campus, in 2014 started efforts to replicate this UofM's SCIP framework, by adapting the survey to its reality.

The University of São Paulo's (USP) Environmental Policies are in its final steps of development. One of these policies is directed specifically waste management, and it has its background support in Brazil's National Solid Waste Policy, setting prevention goals and predicting creation of plans and programs.

Thus, this moment before the release of these Policies is an opportune moment to assess the culture of sustainability of the University of São Paulo—Campus of São Carlos Campus (USP-SC), by creating a baseline data ex-ante the publication, allowing comparison in future years and how the policy impacted USP's reality.

Several technologies and management strategies tackling waste prevention are being deployed, although not much effort addresses whether these initiatives influence the individual and community culture regard waste issues.

In this context, this work finds that in general that staff presented a more adequate behavior towards waste prevention, followed by faculty and undergraduate students. Future comparative studies will be deployed using University of São Paulo, São Carlos Campus and University of Michigan data. Hence, this research opens a path to future researches.

### 1.1 Universities as a Living Research Laboratory

Academia must always be at the frontier of knowledge production and is responsible for forming opinion and disseminating scientific knowledge and innovative technologies for society (Krizek et al. 2012; Müller-Christ et al. 2014; Velazquez et al. 2005).

University campuses, therefore, translate into places to foster sustainability practices, providing practical and theoretical support for transition actions aiming at a management model focused on sustainability, as well as human resources trained and ready to respond to the challenges of the future (Ceulemans et al. 2015; Figueiró and Raufflet 2015).

This discussion is further reinforced by the final document proposed by the UN meeting, Culture: A driver and an enabler of sustainable development, published in 2010, a decade after the Millennium Declaration, emphasizing the importance of culture, discussed from the perspectives and its relation to development, as well as its contribution to achieve the Millennium Development Goals. This premise is justified by the results obtained through studies of statistics, data and indicators that present that culture can translate into a strong driver of development, with social, economic and ecological impacts. Cultural aspects have a high relevance in the economy and poverty reduction. Cultural heritage, cultural and creative industries, sustainable cultural tourism, and cultural infrastructure can serve as strategic tools for revenue generation, particularly in developing countries, given their rich cultural heritage and substantial workforce.

Higher Education Institutions management should be presented as good practices laboratory for innovation in diagnostic and monitoring systems for pressure on natural resources and socioeconomic aspects (Genus and Theobald 2014; Lozano et al. 2013; Velazquez et al. 2008). This discussion relies on the university's role in being a model of best practices of sustainability for waste prevention (Baldwin and Dripps 2012; Barua and Mohiuddin Ekram 2014; Botelho 2012; Felder et al. 2001; Suttibak and Nitivattananon 2008), which should be inserted, for example, in its purchasing processes, focusing on products certified in social responsibility and choosing organic products and locally produced, reduce consumption of paper and disposable products; reduce consumption and prevent water and electricity losses; Buildings and facilities with thermal comfort, with green roofs and larger windows for lighting optimization; outreach programs focused on dialogue and training of students regard sustainability, so they also become agents of change and leadership committed to the theme; increase the number of courses and disciplines with teaching processes focused on sustainability; and to foster, through events, academic media and other vehicles, a culture sustainability based with actions throughout the campus and external community, among several other initiatives (Kelly et al. 2006).

In this sense, it is important to insert at university end activities the Sustainability Culture concept, understood as a reflection of values, behaviors and levels of understanding and commitment, degrees of integration and dispositions within a community, aligned with the concept of sustainable development. Universities are key spaces to raise sustainability awareness for current and future leaders, with innovative solutions to the greatest global challenges through research, teaching and outreach activities. In this sense, universities emerge as facilitators of best practices in strategic sustainable development (Shriberg 2002).

Hence, universities have the responsibility of encourage its community to develop a culture of sustainability within and outside university's facilities, by these means, actors, will consolidate as promoters of sustainability leaders (Marans and Shriberg 2012).

In Brazil, universities have been mobilized to expand their research and human resources training in sustainability fields (Palma et al. 2011), as well to implement sustainable policies within their campuses transversally through teaching, research and outreach. This presents great opportunities to use campuses as laboratories to deploy and implement innovation in sustainability (Müller-Christ et al. 2014). Thus, aware current and future decision makers regarding sustainability, is key to consolidate sustainable development and social justice.

To measure sustainability culture, two components need to be integrated. The first deals with the behavioral aspects, which refers to monitoring how people are changing their attitudes (in the gym, in the company, in their homes, and daily activities) related to themes such as mobility, shopping, food, etc., for a better alignment with the sustainability concept. The second component is eco-efficiency, which refers to the practice of producing more efficient and effective goods and services, while continuously reducing the consumption of natural resources and emitted pollution. That is, measuring eco-efficiency on the university campus is to calculate the academic impacts and services produced at the University in relation to the level of pressure it exerts on natural resources crossing this data with the communities behavioral and cultural aspects.

## *1.2 Waste Management at Universities*

Recycling initiatives play an important role in a High Education Institution community behavioral changes regard waste management (Baldwin and Dripps 2012; Elfithri et al. 2012; Iojă et al. 2012; Mamat et al. 2015; Suttibak and Nitivattananon

2008; Zain et al. 2012; Zorpas and Lasaridi 2013). These kinds of initiatives must consider both operational/logistic and cultural aspects (Levy and Marans 2012). In the USA, an increasing number of the universities are developing and implementing in their daily activities actions to reduce waste generation, reuse and recycling (Mason et al. 2003).

The Brown University, for example, has a continuous a successful waste management program working for the past 45 years. These initiatives usually begin with waste characterization, the Autonomous University of Baja California, the percentages of non-recyclables, potentially recyclables, and recyclables wastes were, respectively of 34, 34 and 32% (Ramírez Barreto 2008). In 2006 the Michigan State University launched the Be Spartan Green Environmental Stewardship Initiative, which part of it was the recycling program. All of this examples show that this is not a recent discussion, and yet, HEIs have a lot to improve in their waste management practices.

Inside a university it can be seen that recycling rates vary throughout the campus buildings depending on its size and category (Fox 2011). This is due the diverse amount of efforts that are put inside each building.

## 2 Methods

### *2.1 University of São Paulo Description*

The State of São Paulo has the greatest universities in Brazil, researches of its universities are at frontier of scientific knowledge. Moreover, São Paulo universities act as cultural mosaics, attracting students from all over the world, adding different experiences, addressing different problems of society from different perspectives (Baldwin and Dripps 2012; Iojă et al. 2012; Mason et al. 2003; Suttibak and Nitivattananon 2008; Zorpas and Lasaridi 2013).

University of São Paulo has 11 campuses distributed throughout the state, four in São Paulo, one in Bauru, one in Piracicaba, one in Pirassununga, one in Lorena, one in Ribeirão Preto and two in São Carlos, summing a total of 92,792 students (Undergraduate and graduate), 6008 teachers, and 17,450 employees.

At USP—São Carlos, case study of this work, actions to raise awareness regarding culture of sustainability in its community would potentially reach 10,394 people (undergraduate 5388, postgraduate 3407, faculty 532, employees 1067) (USP 2017). These data illustrate the potential number of people affected by actions that lead to sustainability.

Thus, University of São Paulo's Environmental Policies are in its final steps of development. There are 11 policies, discussing Energy, Water, Green Areas and one specifically addressing Waste Management. Accordingly, the release of these Policies is an opportune moment to begin the process of assessing the culture of sustainability on the University of São Carlos School of Engineering (USP-SC).

Hence, one of main policy goals is waste prevention, which is the focus of this paper results description.

# 3 Data Sources

## 3.1 Sample Description

The survey was deployed inside Sustainability Culture Indicators Program (SCIP) been applied at UofM since 2012, and replicated at USP-SC in 2016. This paper uses data from 2016 application, Table 1 presents total population sample of students, teachers, and staff.

As described by Marans et al. (2015), sample designs purpose is to obtain relatively significant amounts of responses from the entire university's community of students, staff and faculty.

The sample selection purposed to reach the largest number of respondents as possible, to do this, e-mails of all undergrad students, staff and faculty from São Carlos School of Engineering department were gathered.

E-mails contained a brief description of the survey objective, the estimated time of response, the link to the survey and the research group identification. The e-mails were scheduled to be sent weekly, in different days of the week, at different times of the day, this methodology aimed to reach respondents at different times, trying to adequate their different schedules.

# 4 Measures

Sustainability Issues covered by the survey were waste prevention, travel behavior, conservation behavior, and sustainability engagement. The survey was applied to students, staff and faculty through an online platform. Thus, the analysis reported in this paper focuses on waste prevention.

**Table 1** Overview of the sustainability culture indicators program population of students, faculty, and staff respondents samples at University of São Paulo—Campus of São Carlos

| Specifications | Total university of São Paulo—Campus of São Carlos sample | Total of University of São Paulo—Campus of São Carlos response rates in 2016 application | Total of University of São Paulo—Campus of São Carlos response rates in 2016 application (%) |
|---|---|---|---|
| Undergraduate students | 2477 | 235 | 9 |
| Faculty | 206 | 61 | 30 |
| Staff | 353 | 100 | 27 |

Examples of questions asked by the survey regarding waste prevention are: *Over the past 12 months, how often did you segregate recyclable garbage, you use reusable bags, compost in your current home? How often do you encourage your friends and family to save water, conserve electricity, reuse plastic bags, buy fewer things, buy environmental friendly products.; In general, how committed you are to the sustainability issue?; etc.* Table 2 presents descriptive information regarding the number of responses for each studied item at the survey.

**Table 2** Descriptive information regard the number of responses for survey items

| Waste prevention descriptive table | | | | | | |
|---|---|---|---|---|---|---|
| 2016 | University of São Paulo | | | | | |
| | Undergrad students (%) | Undergrad students | Staff (%) | Staff | Teachers (%) | Teachers |
| Over the past 12 months, how often did you do the following things in your current home? | | | | | | |
| *Segregate recyclable garbage* | | | | | | |
| Never | 20 | *48* | 3 | 3 | 2 | 1 |
| Rarely | 11 | *27* | 9 | 9 | 0 | 0 |
| Sometimes | 13 | *31* | 16 | 15 | 8 | 5 |
| Always/most of the time | 55 | *129* | 72 | 69 | 90 | 53 |
| Not applicable | | | | | | |
| Total | 100 | | 100 | | 100 | |
| Number of respondents | | *235* | | *96* | | *59* |
| *Use reusable bags* | | | | | | |
| Never | 24 | *57* | 4 | 4 | 2 | 1 |
| Rarely | 22 | *52* | 18 | 18 | 14 | 8 |
| Sometimes | 24 | 57 | 31 | 31 | 26 | 15 |
| Always/most of the time | 29 | *69* | 47 | 47 | 59 | 34 |
| Not applicable | | | | | | |
| Total | 100 | | 100 | | 100 | |
| Number of respondents | | *235* | | *100* | | *58* |
| *Compost* | | | | | | |
| Never | 82 | *191* | 61 | 59 | 69 | 40 |
| Rarely | 9 | *21* | 17 | 16 | 12 | 7 |
| Sometimes | 4 | ***9*** | 14 | 13 | 7 | 4 |
| Always/most of the time | 6 | *13* | 8 | 8 | 12 | 7 |
| Not applicable | | | | | | |
| Total | 100 | | 100 | | 100 | |
| Number of respondents | | *234* | | *96* | | *58* |
| How often do you encourage your friends and family to do the following things? | | | | | | |
| *Reusing plastic bags* | | | | | | |
| Never | 13 | *29* | 4 | 4 | 5 | 3 |
| Rarely | 22 | *47* | 6 | 6 | 16 | 9 |

(continued)

**Table 2** (continued)

| Waste prevention descriptive table | | | | | | |
|---|---|---|---|---|---|---|
| 2016 | University of São Paulo | | | | | |
| | Undergrad students (%) | Undergrad students | Staff (%) | Staff | Teachers (%) | Teachers |
| Sometimes | 26 | *57* | 25 | 24 | 26 | 15 |
| Always/most of the time | 39 | *84* | 65 | 62 | 53 | 30 |
| Don't know | | | | | | |
| Total | 100 | | 100 | | 100 | |
| Number of respondents | | *217* | | *96* | | *57* |
| *Buy fewer things* | | | | | | |
| Never | 12 | *27* | 11 | 10 | 5 | 3 |
| Rarely | 19 | *41* | 8 | 7 | 16 | 9 |
| Sometimes | 31 | *68* | 46 | 42 | 32 | 18 |
| Always/most of the time | 37 | *81* | 36 | 33 | 47 | 27 |
| Don't know | | | | | | |
| Total | 100 | | 100 | | 100 | |
| Number of respondents | | *217* | | *92* | | *57* |
| *Buy environmental friendly products* | | | | | | |
| Never | 28 | *59* | 16 | 15 | 21 | 12 |
| Rarely | 32 | *68* | 20 | 19 | 19 | 11 |
| Sometimes | 29 | *61* | 40 | 38 | 40 | 23 |
| Always/most of the time | 12 | *26* | 23 | 22 | 19 | 11 |
| *Don't know* | | | | | | |
| Total | 100 | | 100 | | 100 | |
| Number of respondents | | *214* | | *94* | | *57* |
| Do you support or not the following government policies, even if you had to pay for? | | | | | | |
| *Prohibit the distribution of plastic bags in supermarkets* | | | | | | |
| Strongly support | 32 | *69* | 33 | 30 | 41 | 25 |
| Moderately support | 30 | *64* | 32 | 29 | 26 | 16 |
| Neither support nor oppose | 16 | *35* | 12 | 11 | 13 | 8 |
| Moderately oppose | 13 | *27* | 11 | 10 | 7 | 4 |
| Strongly oppose | 9 | *19* | 12 | 11 | 13 | 8 |
| Total | 100 | | 100 | | 100 | |
| Number of respondents | | *214* | | *91* | | *61* |
| In general, how committed you are to the sustainability issue? | | | | | | |
| Very committed | 21 | *45* | 11 | 10 | 21 | 11 |
| Somewhat committed | 49 | *106* | 45 | 41 | 49 | 26 |
| Not very committed | 28 | *62* | 0 | 0 | 28 | 19 |
| Not at all committed | 2 | *5* | 45 | 41 | 2 | |
| Total | 100 | | 100 | | 100 | |
| Number of respondents | | *218* | | *92* | | *56* |

### 4.1 Creating the Indices

Items responses were grouped to create the University of São Paulo—Campus of São Carlos Waste Prevention Indexes. The indexes have the purpose of presenting the survey's findings in a more succinct way.

### 4.2 Applying the Survey

During the 2016 first semester of the academic year, researchers at the University of São Paulo—Campus of São Carlos applied a survey to students, faculty, and staff at São Carlos School of Engineering, to measure sustainability behaviors and levels of engagement and awareness of sustainability.

The survey was developed in collaboration with researchers at the University of Michigan (U-M) and was patterned after surveys conducted as part of U-M's Sustainability Cultural Indicators Program.

Survey respondents were asked questions via an online platform about their sustainability-related behaviors and awareness including transportation, sustainable food purchases, conservation behaviors, waste prevention, and environmental management of green (natural) areas on campus.

### 4.3 Data Analysis

Researchers used the Statistical Package for Social Sciences (SPSS) software and Bonferroni statistical test for statistical analysis.

## 5 Findings

### 5.1 Overview Description

Table 3 summarizes the response data information regarding mean scores and statistical significance for Waste Prevention Awareness, Waste Prevention Engagement and Waste Prevention and Sustainability Commitment Indexes for University of São Paulo—Campus of São Carlos staff, faculty and undergrad respondents.

All the indexes presented statistical significance when compared between staff, faculty and undergrad groups.

**Table 3** Mean scores and statistical significance for waste prevention awareness, waste prevention engagement and waste prevention and sustainability commitment indexes for University of São Paulo—Campus of São Carlos staff, faculty and undergrad respondents

| Index | Mean scores | | | Significance |
|---|---|---|---|---|
| | Staff | Faculty | Undergrad | |
| Waste prevention awareness | 322 | 307 | 293 | *** |
| Waste prevention engagement | 334 | 298 | 255 | *** |
| Waste prevention and sustainability commitment | 299 | 293 | 199 | *** |

## 5.2 Specific Indexes Statistical Significance Description

The questions regard waste prevention were grouped in three indexes to describe staff, faculty and undergraduate students engagement, awareness and sustainability commitment regard waste prevention.

The indexes are the following: Waste Prevention Awareness Index, containing the questions: Over the past 12 months, how often did you do the following things in your current home? 1. Segregated recyclable garbage; 2. Use reusable bags; 3. Compost.

For this index, statistical significance was noticed when compared the means between undergraduate students and staff, and undergraduate students and faculty. There is no significance between staff and faculty.

Staff respondents group presented more Waste Prevention Awareness then undergrads; the faculty respondents group presented more Waste Prevention Awareness then undergrads; And staff respondents group presented more Waste Prevention Awareness then faculty respondents group.

When asked over the past 12 months, how often did you do the following things in your current home? *Segregate recyclable garbage, 129 (*55%) undergraduates, staff 69 (72%), and faculty 53 (90%) answered *Always/Most of the time.* Regard the item *Use reusable bags* the main answers were for *Always/Most of the time,* which, 69 *(*29%) undergraduates, 47 (47%) staff, and 34 (59%) faculty, when asked if they Compost waste, the main answers were *Never,* with 191 (82%) undergraduates, 59 (61%) staff, and 40 (69%) faculty.

The Waste Prevention Engagement Index contains the following questions: How often do you encourage your friends and family to do the following things? 1. Reusing recyclable bags; 2. Buy fewer things; 3. Buy environmental friendly products.

For this index, statistical significance was noticed when compared the means between undergraduate students and staff, and undergraduate students and faculty, and between staff and faculty.

Staff respondents group presented Waste Prevention Engagement than undergrads; the faculty respondents group presented more Waste Prevention Engagement than undergrads; And staff respondents group presented more Waste Prevention Engagement than faculty respondents group.

When undergraduate, staff and faculty were asked if how often do you encourage friends and family to reuse plastic bags? The main answers were

*Always/Most of the time* with, 84 (39%) for undergraduates, 62 (65%) for staff, and 30 (53%) for faculty. When asked about how often do you encourage friends and family buy fewer things, the main answers for undergraduate and faculty respondents group were *Always/Most of the time* 81 (37%), and 27 (47%), respectively. And for staff respondent group the main answer was *Sometimes* with 42 (46%). For the item *Buy environmental friendly products* the main answer for the undergrad group was *Rarely*, with 68 (32%) of responses, for staff and faculty, respectively, the mains answer was *Sometime,* with 38 (40%), and 23 (40%), of responses.

The Waste Prevention and Sustainability Commitment contain the following questions: Do you support or not the following government policies, even if you had to pay for? 1. Prohibit the distribution of plastic bags in supermarkets; 2. In general, how committed you are to the sustainability issue?

For this index, statistical significance was noticed when compared the means between undergraduate students and staff, and undergraduate students and faculty. There is no significance between staff and faculty.

Staff respondents group presented more Waste Prevention and Sustainability Commitment then undergrads; the faculty respondents group presented more Waste Prevention and Sustainability Commitment then undergrads; and staff respondents group presented more Waste Prevention and Sustainability Commitment then faculty respondents group.

For the item 2. In general, how committed you are to the sustainability issue? Most of respondents answered that they are *somewhat committed* to the sustainability issue, with 106 (49%) undergraduate, 41 (45%) staff, and 26 (49%) faculty.

## 6 Conclusions

This paper was deployed at São Carlos School of Engineering at the University of São Paulo.

The researchers concludes that by applying surveys it was possible to identify individual and collective behaviors, the opportunity of asking specific themed questions and then presenting results as composite indexes are an interesting tool to assess and present culture of sustainability.

In sum, concludes that staff presented a more adequate behavior towards waste prevention, followed by faculty and undergraduate students.

### *6.1 What USPSC Learned and Perspective for Future Applications*

a. *Challenges faced by USPSC researchers*

The main challenge faced by USPSC researchers was making people to answer the questionnaire.

A way found to overlap this situation was to schedule e-mails, once a week, sent in always in different times of the day. Also, the responsible teacher used to fill the questionnaire as a task for the courses he was teaching. Other publicity strategies used were:

- Creating a video with the research purpose and description, with the link to the survey, the link for the video was embedded at the invitation e-mail sent to the respondents. This strategy presented good results.
- Asking the schools' official journal to release two articles about the research, the first containing a brief description of the project and the second containing an interview with the responsible teacher and the Environmental Management Superintendent, also with the link to the survey.

b. *Future: Comparative study with next years' application results*

The SCIP-USP is a multi-year research project that aims to measure the culture of sustainability at University of São Paulo, in this sense the researchers will keep applying the survey in further years, so a comparative study can be deployed with the baseline data acquire ex-ante the USP's Waste Policy enactment, also, a comparative study will be deployed with data *ex-post* its enactment.

Thus, the SCIP applied at USPSC was just a pilot scale effort, researchers now have the university's Environmental Management Superintendent support, and now the survey will be applied to the whole University of São Paulo, at all campuses.

By systematically and periodically presenting key signals to assist in the processes of management of the university campuses daily activities will provide subsidy for decision making.

SCIP Survey is a key tool to support high management and is relevant to several sectors of the university. The current indicator systems used at the university do not yet have a structure that integrates these two key components—Eco efficiency and behavior. This is one of the main innovations proposed by this research project. Future works will present and compare descriptive findings for students, faculty, and staff, also, data regard natural resources consumption at USP, and present findings from an examination of the links between sustainability behaviors, awareness, and engagement.

c. *The Eco-efficiency versus behavior project at University of São Paulo—Campus of São Carlos*

The structure of indicators under construction will put in the same basket two important components, technology and the internalization of sustainable actions and culture (in the part of management, maintenance and in the individual activities of the day to day). By developing different strategies from one building to other, it will favor analyzing the best strategies through a synergistic process. That is, the questionnaire will work to show how physical changes are strengthening the culture of the university community and how technological innovations influences behavior changes.

This study will provide researchers with an insight into the sustainability behavior of the USP community, thus informing management process where sustainability awareness interventions are needed, in a building scale.

The results from the Sustainability Culture Surveys and Eco Efficiency indicators will be cross-checked. This, due to the behavior and values of individuals have a direct influence on resource consumption, and waste generation. The consumption of these resources, in addition to being influenced by technology and equipment conservation, is influenced by the way individuals use them. That is, understanding these relationships—innovation, capacity building, awareness—are key to improving management for sustainability. If innovation is not internalized by potential users, there is a decrease in performance and waste of resources.

The cross-referencing of performance and behavior indicators allows to accurately capture these relationships and to feed back the management, research and teaching processes. Extrapolating this scenario to other institutions, such as Banks or industries, which have thousands of branches spread across the country, one can observe the potential impact that this analysis can provide to managers.

If these agencies, for example, implement innovations in energy saving systems, what will be the social-environmental impact? How significant will be the engagement of employees and users?

d. *Future: Comparative study between USPSC's and UofM's results*

Further papers will discuss a comparative study between USPSC's and UofM's application results, discussing different university's cultural, financial, and social realities and how they may influence undergraduate, staff and faculty culture of sustainability.

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# Public University Houses Community Garden to Promote Sustainability in São Paulo

**Devani Salomão and Victor A. M. Reis**

**Abstract** The objective of this article is to analyse the extensions of sustainability in the public education sector, considering the perception change of teachers, students and the community regarding the use of public spaces to implement a community garden in the University of São Paulo Medical School (FMUSP). Launched in 2013, it aimed to address issues related to environmental education and shared waste management. Nowadays, in addition to permanent education and awareness activities, environmental techniques are also applied, pursuing sustainability through natural resources conservation, conscious consumption and reduction of waste, promotion of three R's concept (Reduce, Reuse and Recycle) and reduction of the ecological footprint of both individuals and institutions. The employed method used interviews with the creators of this project and with some of its participants as well. It was possible to verify that public education and environmental management operating together could promote and intensify the reduction of the waste of raw materials and increasingly scarce resources, such as water and energy. Finally, it is recommendable to apply some practical measures such as outlining tactics that generate recognition of this partnership, the value of its activities and the reputation of the agencies involved.

**Keywords** Sustainability · Community garden · Environmental management
Medical school

D. Salomão (✉)
Escola de Comunicações e Artes da, University of São Paulo – ECA-USP,
São Paulo, Brazil
e-mail: devani@usp.br

V. A. M. Reis
Instituto de Matemática e Estatística da, University of São Paulo – IME-USP,
São Paulo, Brazil
e-mail: victor.alexandre.reis@usp.br



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## 1 Introduction: History of the Emergence of Community Gardens in the World

Germany is considered the pioneer country of urban agriculture in Europe, whilst the origin of urban gardens is associated with Daniel Gottlieb Moritz Schreber (1808–1861), head of an alternative orthopaedic clinic located in Leipzig. Although his profession was not linked to agricultural activity, Schreber became part of the history of the country's urban gardens when he proposed outdoor treatment for sick children in his care (Gröning 1996). Because of the progressive reduction of available space for this kind of therapy, several citizens joined in an initiative to form an association—on 10 May 1864—, whose main objective was to build a playground, far from the city, to provide better conditions for weakened children. Four years later, in 1868, Carl Gesell (1800–1879), who was supervising his kids' activities, thought of incorporating into this playground an area of flowerbeds with an educational aspect. However, given the detachment of children from this type of activity, the parents ended up enjoying it the most, even extending these beds in lots of larger physical dimensions. Those new lots were then known as "Familienbeete", or family beds (Gröning 1996). As the success of these production allotments increased, they became known as "Schreber Gardens". By 1870, about one hundred units had been created. Berlin was also one of the cities that adopted such initiatives, although the reasons were not the same as in Leipzig. In the German capital, urban gardens had a less educational approach, focusing more on economical social aspects, due to its industrialization and the rural exodus that drove the growth of the city. These gardens were then an expression of the poverty and misery lived at that time (Turowski 2002).

## 2 Social and Health Importance of Urban Gardens

Urban gardens constitute an integral activity of what is called urban agriculture. Over time, the latter has been used to identify and define different realities. In the first decades of the last century, urban agriculture was used to define an activity then understood as archaic and, in a sense, inappropriate and temporary—with a role of alleviating the damages due to wars or economic crises—or identified for recreational purposes, aesthetic use and beautifying the city (Smit et al. 2001). However, more recently, other functions appeared as well, namely environmental, safe and healthy food and social cohesion functions. Smit et al. (2001) define urban agriculture as

> An industry that produces, processes and sells food, fuel, and other outputs in response to the daily basic demands of consumers residing in intra-urban or peri-urban locations. Urban agriculture typically involves varied products, as well as (re)utilization of natural resources and urban waste, contributing to food security, population health, animal life, the environment, and the formation of a cohesive community.

**Table 1** Differences between intra-urban and peri-urban agriculture

| Intra-urban agriculture | Peri-urban agriculture |
|---|---|
| Located in small-scale spaces and in urbanized locations | Located in larger spaces that are in danger of becoming urbanized |
| Done in areas of high population density | Done in less densely populated areas |
| Technology tailored to the small size of the locations and gardeners' subsistence | Technology tailored to large parcels and marketing of products |
| High cost of land | Lower land cost |
| Closer to markets | Far from markets |
| Natural resources are scarce | Increased availability of natural resources |
| Worse air quality | Better air quality |
| Part time work | Full time work |
| Expansion is possible, but it can never transform into peri-urban agriculture | Due to increasing urbanization, it can be possible to transform into intra-urban agriculture |

*Source* Adapted from "Implementation Guide for Intra-urban and Peri-urban Agriculture" (FAO 2001: 14)

For the United Nations Food and Agriculture Organization (FAO 2001), urban agriculture can be located within the geographical limits of a city, or in the territories that surround them, assigning the denominations of intra-urban and peri-urban agriculture, respectively. In addition to the location, FAO also identifies other variables in order to distinguish these two types of agriculture, as shown in Table 1.

## 3 Urban and Peri-urban Agriculture (AUP) in Brazil

There is not a definitive single definition of AUP. Thus, several authors (Smit et al. 2001; Mougeot 2001; Machado and Machado 2002) discuss this issue. In Brazil, the main reference to this definition comes from the resulting document from a survey carried out in eleven Brazilian metropolitan regions in 2007, coordinated by the organization Network for the Promotion of Sustainable Development (REDE), based in Lima, Peru:

> AUP is a multi-dimensional concept that includes production, processing and provision of services in a safe way to generate agricultural products (vegetables, fruits, medicinal and ornamental plants, either cultivated or derived from agro-extractivism etc.) and livestock (of small, medium and large size animals) aimed at self-consumption, trades, donations or commercialization, (re)using efficiently and sustainably local resources and inputs (soil, water, waste, labour, knowledge etc.). (Santandreu and Lovo 2007: 13)

This concept is closely related to activities that can be practiced in intra-urban or peri-urban spaces, being linked to the urban or metropolitan regions' dynamics and articulated with the territorial and environmental management guidelines of the cities.

In Brazil, AUP should be oriented to promote agro-ecology, healthy habits, building knowledge respecting its dialogue, respect for ethnic, racial and cultural diversity, gender equality, social and environmental justice and solidarity, food sovereignty and nutritional food security, a just, solidary and family economy, responsible consumption and the participation, empowerment and autonomy of urban and peri-urban farmers (Santandreu and Lovo 2007).

Five categories characterize AUP initiatives:

1. Agricultural and livestock production: aromatic, medicinal and ornamental plants, fruits, small, medium and large animals, fishes, agro-extractivism etc., inputs such as seeds, seedlings, compost, humus etc., water and solid waste reuse;
2. Transformation of at least one AUP product, in an artisanal way, into a small familiar or community agroindustry, promoted by civil society or public authority;
3. Marketing in the form of a fair trade, of in natura or processed products, in the urban production chain and in institutional (traditional to organic) markets, both formally and informally;
4. Self-consumption, trades and donations to institutional spaces or the community;
5. Services such as research, training, generation of technologies, advisory services, local credits and others.

Of the AUP experiences in Brazil, 75% are located in either capitals or metropolitan regions, which is important since it concentrates relevant population contingents, as well as the lack of cultivable soil and high percentages of urbanization.

Thus, through AUP it is possible to contribute to improve life of the urban population and the sustainability of cities. From this multi functionality concept, AUP has the potential to motivate productive and ecological cities that respect the socio-cultural diversity and promote food and nutritional security (Kiss 2015).

## 4 Agro-Ecology and Principles Coming from Ecology

Agriculture in urbanized cities is not new, but organic and agro-ecological techniques have been more frequently promoted by international, governmental and non-governmental organizations only in recent years in response to the multiple social, economic and environmental problems of cities.

Agro-ecology refers to the application of concepts and principles derived from ecology in the construction and management of production systems (Gliessman 2000). For Altieri (1987), agro-ecology is a science that studies ecosystems integrating knowledge of agronomy, ecology, economics and sociology. Over the years, this term has also been associated with social, political, environmental and economic movements, since agro-ecology proposes a model of agricultural development that represents an alternative to the usual agribusiness model.

Agro-ecology as a cultivation practice refers to techniques that allow food farming in harmony with environmental preservation and promotion of social responsibility. Therefore, agro-ecology concerns management techniques that do not contaminate the soil, water and food itself that are produced by small and medium-sized farmers. Thus, the agro-ecological cultivation counts on techniques of intercropping and rotation throughout the year. These techniques allow greater resistance of plants to pests and are based on a physical and biological balance to avoid the use of pesticides. In addition, agro-ecology depends minimally on external inputs and it aims to minimize losses and use of resources, space and nutrients (Assis and Romeiro 2002).

There are several terms such as organic agriculture, agro-ecology and clean agriculture, which are often used as synonyms by managers, farmers and others involved in agriculture, but it is important to note the difference between them. Organic farming refers to a production system that promotes healthy soils, ecosystems and people. It is based on ecological processes, biodiversity and cycles adapted to local conditions as an alternative to the use of inputs that might cause adverse effects. Agro-ecology, as mentioned, is a more complex production science that includes social, environmental and economic ethics, embedded in principles of solidary economy and fair trade (Brasil 2012).

Clean agriculture refers to agricultural cultivation free of pesticides, but does not necessarily follow other types of organic method prescriptions. Local government bodies created these terms to recognize agricultural practices without the use of pesticides. Especially in cases of agriculture in urban areas, there are a number of restrictions to obtain organic certification.

## 5 Urban and Peri-urban Agriculture in São Paulo

São Paulo is Brazil's largest metropolis with more than twelve million inhabitants (IBGE 2016). The city has undergone over the last three decades a clear change in its economic profile. From a strong industrial character, it has increasingly assumed a role as a tertiary city, providing services and serving as the country's main business hub. The city is spread in an area of 1523 km$^2$, of which 222 km$^2$ are cultivable areas, comprising less than 15% of the municipal territory. The location and context that develops agriculture in São Paulo is quite diverse: it takes place from squares or roofs in both noble and needy areas of the city, from downtown to the western region, such as Vila Madalena and Pinheiros. In the poor regions, as in the east zone, agricultural activities take place below electric lines that are characterized as empty spaces, organized by the producers themselves, relatives or residents of numerous neighbourhoods.

In the rural area of the city, located in the southern part, there are areas of wellsprings and a set of conservation units such as natural parks and the municipal

Environmental Protection Areas (APAs) Capivari-Monos and Bororé-Colônia. The roles of agriculture in the city vary between leisure, income generation, exchange of experiences, environmental mitigation, forested areas conservation, water resources and areas of springs protection, waste management and food production. Most of the agricultural activity is in the south area of the city in the districts of Parelheiros and Marsilac. There are 353 km$^2$ rich in natural resources, limpid water (the region produces 24% of São Paulo's drinking water) and forests.

In the southern portion of the city, there are about 400 rural producers and it is where most of producers with AUP activities work. They produce vegetables, some fruits and ornamental plants. In the city of São Paulo, there is a specific legislation regarding AUP—law number 13,727, from 12 January 2004—that creates the Program of Urban and Peri-urban Agriculture (PROAURP) and defines its guidelines (State of São Paulo 2004, 2010).

In general, there are a plethora and multiplicity of activities, combining production, commercialization and consumption of produced foods. There are also experiences, albeit less representative, of transformation of the product in a traditional way, i.e., the possibility of adding value to the production.

In the east zone of the city, there are about 40 community gardens, in which mostly families work, whose main activity is vegetable production. It aims mainly for self-consumption and commercialization of food. The producers adopt different marketing systems, among which stand out the direct sale in the garden and organic and agro-ecological fairs.

São Paulo also provides technical assistance services, rural continuing education and promotion to community gardens in two houses of agriculture, one in the east and the other in the south zone. This work with families of farmers has as its main goal the agro-ecological production transition to ensure environmental preservation and healthy food for the population.

With the enhancement of AUP, it is intended to promote economic and local development. For this, there is the challenge of expanding the orientation and training activities for farmers, combining production with commercialization and income generation, seeking better credit to pursue AUP opportunities and mapping the multiplicity of activities, as well as the socioeconomic characteristics of producers.

The *Casa da Agricultura Ecológica* José Umberto Macedo Siqueira, which was formalized through decree number 47,280 of 16 May 2006, aims to meet local specificities in the implementation of the municipal policy for AUP, prioritizing the aptitude and the regional agricultural vocation. Better known as Parelheiros Ecological Agriculture House (CAE), it provides services through the Department of Development, Labour and Entrepreneurship (SDTE) from the Food and Nutrition Security Coordination (COSAN), which is responsible for the Department of Agriculture. This agency coordinates actions related to AUP in the city of São Paulo. The main purpose of CAE is to strengthen and support the urban and peri-urban farmer through the creation and implementation of public policies focused on the theme. Farmer families in the districts of Parelheiros, Marsilac and Grajaú have priority in their services.

By 2014, 35 farmers made the transition and were made official as agro-ecological—this is a process of about three years of paperwork—and another 14 are certified organic farmers.

In 2016, the program *Agriculturas Paulistanas* was launched, with the objective of articulating different government agencies and its respective actions to expand the services focused on food production in the city of São Paulo. Farmers can use machines delivered by the "Agricultural Patrol", allowing easiness in dealing with the land and boosting production.

In addition, the city has 32 greenhouse schools that are part of the Community Gardens and Nurseries Program. As its first step, articulations with Work Operation Program (POT) were established, combining agro-ecological and organic training through theoretical and practical activities of soil management and cultivation, work and income for unemployed and socially vulnerable people. The next step is to restructure the greenhouse schools (through renovation of space, reconstruction of greenhouses etc.), mobilization of entities, agencies and people of the surroundings to participate in formative actions in agro-ecological and organic production in order to popularize the techniques and promote the production in small edible gardens etc., thus corroborating the premise of environmental preservation.

Considering the potential of AUP and its challenges presented in the city of São Paulo, there is a growing political interest for future actions and interventions to contribute to the work that boosts the implementation of the Income, Education and Food Security Policy.

## 6 School Food

In the first quarter of 2016, the plan for the progressive introduction of organic or agro-ecological food in schools was concluded, with a massive process of social inclusion and public consultation. This plan foresees that, by 2026, 100% of the food served in schools should be either organic or agro-ecologically based. This is an important step towards guaranteeing a healthy diet for children, directly influencing their health conditions, as well as for rural development and the promotion of agro-ecological transition and organic production.

## 7 Regional Inequalities in Availability and Access to Food in the City of São Paulo

According to Duran (2013), there are regional inequalities in access to healthy foods, such as fruits and vegetables, in the city of São Paulo, favouring the richest regions. For example, consumption of fruits and vegetables was 40 and 26% higher, respectively, in neighbourhoods where there were more places selling these products.

The researcher studied locations selling food for consumption at home, such as supermarkets and small markets and the commercialization of food for immediate consumption, like restaurants, snack bars, bakeries etc. The access to healthy food was measured from indexes that summarized the data collected and validated in all places found in the sample based on the availability, variety, price and promotion of food. Below each of these findings are listed in detail.

a. Location of public facilities (farmer's, street and municipal markets) and private establishments (supermarkets) for food marketing.
   - Higher concentration of street markets, markets and municipal markets in the richest regions of the city, especially in the centre and the western zone. Both north and east regions have also a greater number of these places, when compared to the south region, which presents the lowest concentration of these public facilities in São Paulo.
   - Greater concentration of markets, supermarkets and hypermarkets in the middle and high-income regions of São Paulo: downtown and west zone.
   - Small neighbourhood markets most often found in neighbourhoods of lower socioeconomic status.
b. Differences between the various types of food-selling places.
   - Street, municipal and small farmers' markets had the greatest access to healthy food (including availability, variety, promotion and advertisement), followed by supermarkets. Small neighbourhood markets had the worst rates of access to healthy food.
   - Facilities located in neighbourhoods with higher socioeconomic levels—whether they were small neighbourhood markets, supermarkets or street markets—had better access to healthy options when compared to similar places, but located in areas with lower socioeconomic level.
c. Impacts of food availability on consumption.
   - Using secondary data about the location of street markets, markets and municipal markets in the city, there is an ecological association with the consumption of fruits and vegetables: regions with greater concentration of these places had a higher prevalence of vegetables consumption (greater than five times a week).
   - Using the individual data, the consumption of fruits, vegetables and sugary drinks (processed juices and soft drinks) was associated to the measures of the local food environment—all places that sell food that are up to 1.6 km to where each person lives.
   - Consumption of fruits and vegetables among low-income individuals living in neighbourhoods with low density of supermarkets, markets, street and municipal markets was significantly lower than among low-income individuals, but living in areas of high density of these kind of food-selling facilities.

- The participants who lived in areas with a greater offer in both quantity and variety of sugary drinks had a 15% higher prevalence of regular consumption of these beverages (greater than 5 times a week). Lower sugar prices in poorer regions of the city were also associated with its higher consumption.

The research concluded that there are differences in access to healthy foods in São Paulo, favouring the city's regions of medium and high socioeconomic levels.

Public policies and interventions aimed at reducing inequalities in the population's access to healthy food should consider the impact of aspects of the food environment, such as location of public food-selling facilities, as well as availability, price, variety and quality of the food, either healthy and unhealthy, being marketed.

## 8 Sustainable Development

Sustainable development is understood as a form of social change that is added to traditional development objectives: the goal of achieving ecological sustainability (Lélé 1991). In general, it seeks a better quality of life for everyone, both now and in the future, being a progressive vision that associates three key aspects for its materialization (Buckingham-Hatfield and Percy 1999): social justice, economic development and environmental protection. The sustainable city seeks to adopt a way of life based on the capital of nature and achieve social justice and economic and environmental sustainability. Social justice will necessarily have to be based on economic sustainability and equity. In turn, these require environmental sustainability, which ensures the preservation of biodiversity, human health and air, water and soil quality, at sufficient levels to maintain human life and the well-being of societies, as well as animal and plant life forever (Charter of European Cities and Towns Towards Sustainability 1994).

A garden is a small piece of fenced land where vegetables, ornamental plants and fruit trees are grown, subject to an intensive production technique. Urban gardens have enormous biological richness, as their moisture and soil depth characteristics, combined with frequent mobilizations and incorporations of organic matter, increase the level of microbial life in the soil and contribute in a significant way to maintain food chains (Magalhães 2001). These are green spaces of high biological wealth with many beneficial functions for the city. However, in general, their size is conditioned by the availability of land, which is usually little. According to Pinto (2007), urban gardens contemplate multiple uses:

- Green spaces, which deflate the city environment and provide, among other benefits, the improvement of nature, upgrading water infiltration, air renewal, recycling of organic waste (composting), representing alternative spaces but complementary to the traditional green space, and may also constitute as agricultural gardens;

- Food spaces, where the city inhabitants can obtain in a simple and fast way the products they usually eat, allowing the self-sufficiency of fresh products and, if they comes from organic farming, of healthy products;
- Economy spaces, where those can economically obtain food and thus increase their income;
- Leisure and recreation spaces, for relaxing moments, coexistence, facilitating social integration.

Urban gardens represent a fundamental element in urban spaces because they bring together the three key aspects of sustainable development previously mentioned: social justice, economic development and environmental protection, and can therefore contribute significantly to the sustainable development of any city (Pinto 2007).

## 9 Agriculture as a Solution to Environmental, Economic and Social Problems

AUP has been promoted as a solution to a set of social, environmental and economic problems faced in cities by various international bodies, national and local governments, as well as various civil society organizations. Bringing people closer to consumers of organic and natural products advocates AUP as a solution to multiple problems, as it promotes savings regarding what is spend on food purchases, psychological health, community living and healthy food. It can also be an income-generating activity that could boost financial autonomy and provide better life quality for low-income people.

In Latin America, the United Nations Development Program (UNDP) and UN-Habitat, through the Urban Management Program for Latin America and the Caribbean (PGUALC) for Urban and Peri-urban Agriculture in 2004, and the National Plan of Agro-ecology and Organic Production in 2013, predicted to promote agro-ecology by the AUP. The State of São Paulo also launched the São Paulo Organic Program in 2013, and several municipalities have programs to promote AUP, such as the Community Gardens Program in Campinas, instituted in 1997 (Brasil 1997), and the Program of Urban and Peri-urban Agriculture in São Paulo, launched in 2004.

## 10 The Experience of the Community Garden in FMUSP

Paulo Sérgio Zembruski is an agricultural technician who also holds a bachelor degree in journalism and currently works at FMUSP's Scientific Documentation Service. He first noticed in 2011 an area inside FMUSP's vivarium that could serve as a garden. On his own, he got appropriate tools, prepared the soil and started planting some vegetables. As soon as the crops were harvested, there was a lot more food than the vivarium workers were able to eat in their daily meals. According to Paulo, each time more people were coming to collect fresh vegetables, mostly due to word of mouth. One day, Thais Mauad, an associate professor of the Department of Pathology of FMUSP, got to know the initiative and was "delighted". She then questioned Paulo if there were areas in FMUSP available to house a community garden and he pointed out more than a handful of possibilities.

FMUSP's community garden was created on 5 June 2013 during FMUSP's environment week. As it was built in an area of 520 $m^2$ on a roof, Paulo implemented the same method used at McGill University, from Montreal, Canada, to fill big containers cut in half with soil and use them as receptacles for seeds and seedlings. There were six of these containers when the garden was settled in 2013 and it rose to 54 of them four years later. These plastic containers were not the best option for the temperatures of the Brazilian summer though, so Paulo suggested to use Styrofoam boxes for the more sensitive plants. According to Paulo, using Styrofoam's insulating properties was a very positive experience that "amazed our fellows from Melbourne University that visited to know more about this work". Zembruski also emphasized that foreign researchers from over 20 international universities came to visit and learn about this facility that cultivates more than 400 different species of medicinal and edible plants.

Márcia Saldanha Kubrusly, pharmacist and volunteer at FMUSP's community garden since 2013, stated that she had no previous experience in farming and it was a very gratifying experience, not only because of everything she learned about sustainability, but also all the other volunteers she befriended with. Márcia was amazed with how differently the food grown there tasted compared to what she was used to get in the supermarket. She also edited a guide of medicinal plants and its phytotherapic applications with Kátia Cristina Dantas, a biochemical pharmacist and a volunteer as well. Kátia said that working there changed her relationship with the food she consumes, as she started to eat healthier and inserted a broader variety of vegetables in her diet.

## 11 Conclusion: Urban Gardens as an Agent of Change

Urban gardens are elements of educational, health, economic and social contexts since their emergence in Germany. More recently, they are also related to sustainable actions, given the entire conjuncture that involves this kind of farming of not harming the environment and using natural resources intelligently. They have also brought back the concept of neighbourhood, encouraging a greater closeness between man and the environment and between individuals of the same community.

It is interesting to notice that Brazil, despite its size of over 8 million $km^2$ and with about 85% of the population concentrated in urban areas, only recently some of its inhabitants have put their hands on the dirt to produce part of what they eat, harmoniously with nature.

Currently there are more than 70 community gardens around São Paulo. Several groups and networks that have been interested in the subject have emerged, such as the “Urban Farmers”, which was created in 2011 by journalists to taught urban agriculture classes. There are already more than 40,000 members spread all over Brazil in this group.

*Horta das Corujas*, based on Vila Madalena, was São Paulo’s first urban garden. However, as it is still a very recent initiative there is no appropriate legislation, these gardens arise spontaneously in several places and are run by different groups that have their own guidelines.

Two community gardens hosted by USP were visited. There is a very small cultivated area at the Faculty of Public Health. Meanwhile, at FMUSP there is barely any spots available, with many kinds of spices, herbs, vegetables and flowers planted. The project creators, prof. Thais and Paulo informed that many people from the neighbourhood visit the area, not only to volunteer, but also to learn how to make small gardens at their homes.

The location of *Horta das Corujas* and *Horta da FMUSP* are presented in Image 1.

São Paulo, in general, has not yet awakened to healthy eating, as Zembruski says: “We are still far behind other cities that have well-publicized campaigns for years now. There are projects that use every wasteland available with cropping. There you have food, people work in the surroundings and the neighbours occupy these spaces.”

Because FMUSP’ community garden is located within a highly respected institution, there is a fine alignment of education, social and economic interests, regarding both healthy eating and management of environmental resources optimization. Professors, students and the community have seen that roof transform into

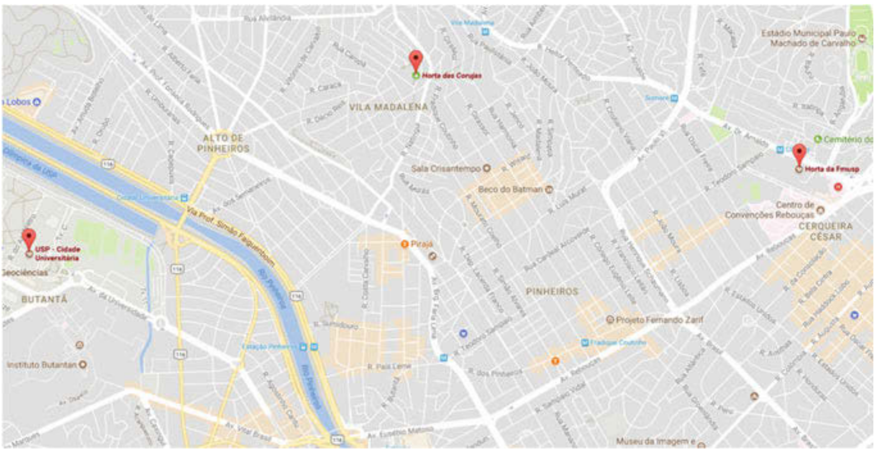


**Image 1** Location of *Horta das Corujas* and *Horta da FMUSP* relatively to USP’s main campus

a verdant public asset that anyone can visit and take care of, which certainly helps to emerge the citizenship feeling.

It is notorious that planting food for self-consumption lowers the pressure on natural resources, helps containing the temperature increase and reduces waste production. In addition, the garden provides free leisure and stimulate a healthy diet, since the products grown there are 100% organic.

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## Author Biographies

**Professor Devani Salomão** is a postdoctoral researcher at ECA-USP with the Project "Public Communication and its Implications in the Principles of the Food Guide for the Brazilian Population", on public policies that aim obesity control. Postdoctoral degree at USP (2014), funded by the National Council for Scientific and Technological Development (CNPq), whose subject was the investigation of the existence of sustainable management in pharmaceutical industries, analysing management discourses and practices in some multinationals of this sector. Postdoctoral degree at Universidade Metodista de São Paulo (2011), UNESCO Chair of Communication for Regional Development, when the functionality of Elderly Person's Fall Prevention Manual was examined, a mean of communication of the Institute of Medical Assistance to the Public Servant of the State of São Paulo. Received her doctorate (2005) and master's degree (1999) in Public Relations at ECA-USP. Coordination for the Improvement of Higher Education Personnel (CAPES) funded both projects. Specialist in Teaching in Higher Education at the Federal University of Rio de Janeiro (2002). Bachelor in Social Communication, with emphasis in Journalism, from Instituto Unificado Paulista (1977). Volunteered in the International People's Project (IPP) of the non-profit organization CISV, an international organization that educates and inspires actions towards a more just and peaceful world. In this program, CISVers act together with local organizations to involve actively the participants in existing projects or in a new and punctual one specially developed for this partnership. Two of those were named Global Food Security and Urban Cultivation; and Farm Adventure: Social Learning in Nature Education and took place in Helsinki, Finland and in Darmstadt, Germany, respectively. Currently teaches, as a visiting professor, at Universidade Federal de São Paulo (UNIFESP) at the Development Centre of Higher Education in Health. Acts as the media consultant and advisor for the Medical Association of the Institute of Medical Assistance to State Civil Servants of São Paulo, whose professionals work in the State Civil Servants Hospital, which focuses on teaching and research. Has experience in studies of causes, functioning and consequences of the relationship between society and the mass media. Her main research topics are the interface with public communication, public health, public policies, public administration and public policies evaluation, management practices, sustainable management, organizational discourse, public communication, communication for the elderly, communication for health workers and its audience, producing communication material, interpersonal communication and content analysis.

**Victor A. M. Reis** is a fully qualified member of the *Instituto Brasileiro de Atuária* and a student member of the Institute and Faculty of Actuaries (IFoA). He is currently a master's student in Statistics at IME-USP. He obtained his bachelor degree in Actuarial Science at Faculdade de Economia e Administração da USP (FEA-USP) while also having an educational background in Environmental Engineering at *Escola Politécnica da USP*. IFoA's International Student Consultative Forum member for the Americas. Volunteered for more than 20 years for the non-profit organization CISV, an international organization that educates and inspires actions towards a more just and peaceful world, in many of its programs and in different roles as well, as a participant, leader or staff. International People's Project (IPP) programme co-coordinator in CISV São Paulo chapter. Has work experience in solvency and economic capital modelling for insurance companies, actuarial design of insurance products, statistical analysis with several applications, diagnostic studies and advisory for new businesses and environmental solutions, economic-financial modelling, due-diligence and valuation, system dynamics and scenario-based modelling. His main research interests include general and life insurance, pensions, actuarial mathematics, simulations, risk management, Bayesian analysis, survival analysis, decision theory, education, finance and investment, resources and environment, water treatment, waste management, energy and environmental health.

# Environmental Governance of Solid Waste in USP *Campuses*: The University as a Laboratory for Environmental Public Policies

**Patrícia Faga Iglecias Lemos, Ana Carolina Corberi Famá Ayoub e Silva and Carolina Corrêa Moro**

**Abstract** The environmental governance of solid waste appears as an essential guideline to ensure the sustainability. The challenges imposed on cities such as non-generation, reduction, reuse, recycling, treatment and environmentally adequate allocation of growing volumes of waste are also matters that concern universities. The focus will be on the University of São Paulo (USP), which is developing practical initiatives and researches regarding the formulation of environmental public policies in general, as well as an example for other universities. This article will present how USP is developing the governance of solid waste in accordance to Brazilian Legislation.

**Keywords** Sustainable campus · Solid waste management · Environmental governance · Green universities

## 1 Regulatory Overview on Environmental Governance of Solid Waste

Lemos, in work devoted to study solid waste and post-consumption responsibility, developed an overview of Brazilian legislation regarding the environmental management of solid waste under post consumption responsibility. According to the

P. F. I. Lemos
Department of Civil Law, Faculty of Law, University of São Paulo, São Paulo, Brazil

P. F. I. Lemos
University of São Paulo, São Paulo, Brazil

A. C. C. F. A. e Silva (✉)
Environmental Science at PROCAM/USP, University of São Paulo, São Paulo, Brazil
e-mail: anacarolinafama@gmail.com

C. C. Moro
Faculty of Law, University of São Paulo, São Paulo, Brazil



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author, the first national standard on the subject was published in 1975, through Decree 1.413/75, that established that entrepreneurs should be responsible for the waste generated in the industrial process (Lemos 2012).

This concern over industrial waste was reinforced by the NEC Resolution nº 006/88, through which environmental licensing itself demanded that the entrepreneur managed the waste generated in his productive process (Mukai 2007).

Afterwards, pulverized standards were drawn up to regulate the environmental management of certain categories of waste, especially those of a hazardous nature, such as pesticides. During the decades of 1990 and 2000, due to the lack of a general norm on solid waste, the National Environmental Council (NEC) took on a leading role. Its Resolutions established quality standards as to waste and post-consumption reverse logistics for some sectors, such as pesticide packaging, ports and airports (CONAMA Resolution nº 5/93), lubricant oils (Law nº 9.965/00, Decree nº 4.136/02 and CONAMA Resolution nº 450/12), construction (CONAMA Resolution nº 307/02), batteries (CONAMA Resolution nº 257/99) and unusable tires (CONAMA Resolution nº 416/09).

However, it was only in 2010, with the publishing of the National Policy for Solid Waste (NPSW), instituted by Law nº 12.305/2010, that solid waste was recognized as social and environmental good, that is, assets containing environmental, economic and social value.

After the NPSW, a model of governance of these social and environmental good was adopted, surpassing the simple one-off management previously adopted. This governance model seeks an integrated management, decentralized and including participation of all actors of the product's life cycle, creating effective co-responsibility (Moro 2017).

## 2 Solid Waste and Sustainable Cities

The main world leaders established in the United Nations (UN) 17 guidelines for the construction of a new agenda on sustainable development: the Sustainable Development Goals (SDG).[1] The tutelage of solid waste is directly touched by at least five SDG, which are: "*Goal 6: Ensure access to water and sanitation for all*"; *"Goal 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation"*; *"Goal 11: Make cities inclusive, safe, resilient and sustainable"*; *"Goal 12: Ensure sustainable consumption and production patterns"*; e *"Goal 14: Conserve and sustainably use the oceans, seas and marine resources"*.

Whether on sanitation, eco-design of new products to lessen waste generation or to improve reuse, whether on territorial planning to manage landfills and diminish socioenvironmental injustice in waste management, or even about pollution of the

[1]ONU. Disponível em: https://nacoesunidas.org/conheca-os-novos-17-objetivos-de-desenvolvimento-sustentavel-da-onu/ Acesso em: 17 de maio de 2017.

oceans and water courses, one must consider the appropriate management of solid waste as a way to prevent environmental damage such as the contamination of soil and water resources, as well as to tutor the rational access to environmental resources while encouraging reuse, recycling and other forms of usage.

Solid waste must therefore be understood as socioenvironmental goods whose adequate environmental governance is both necessary and urgent. The redefinition of "garbage" as solid waste and, therefore, socioenvironmental goods is the result of a long historical process which, in Brazil, was influenced by a strong action from reusable and recyclable waste collectors.[2] The Brazilian experience regarding waste governance adds to the environmental values, through the environmental services rendered by the adequate waste management, and to economic values, through the creation of a new market chain of reuse and recycling and environmentally appropriate disposal, the social values, since the waste has income and jobs generation potential.[3] It thus arises a Right to the Waste, in the words of Maria Alexandra de Sousa Aragão, strongly connected to the environmental justice principle.[4]

This definition of solid waste as socioenvironmental goods, to Lemos, directly reflects in the legal nature analysis, which has thereon a Public Law connotation, and entails the update of the interpretation of property under the light of the social function principle.[5] A direct consequence of this interpretation was the Statement nº 565 of the VI Civil Law Journey, establishing that "There is no loss of property through abandonment of solid waste, which are socioenvironmental goods according to Law nº *12.305/2012*".

## 2.1 The National Policy for Solid Waste

The Brazilian legislation is relevant and tries to minimize the environmental impacts.

As mentioned above, in 2010, the National Policy for Solid Waste (NPSW) was enacted under the Law 12.305/2010. The Law 12.305/2010 introduced Brazilian law to post-consumption responsibility and reverse logistics, establishing a number

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[2]MORO, Carolina Corrêa. *Governança ambiental dos resíduos sólidos: um olhar crítico sob o prisma do direito privado.* Dissertação de Mestrado (Programa de Pós Graduação em Direito da Faculdade de Direito da Universidade de São Paulo). 216 pgs. São Paulo, 2017. p. 80.

[3]MORO, Carolina Corrêa; MARAMBAIA, Gabriel Carvalho; MANTELLI, Gabriel S.; SILVA, Ana Carolina Corberi Famá Ayoub e. Justiça Ambiental e Resíduos Sólidos: Ressignificação e Empoderamento do Catadores de Materiais Reutilizáveis e Reciclácveis. In: Ambiente, sociedade e consumo sustentável [recurso eletrônico]/20. Congresso Brasileiro de Direito Ambiental, 10. Congresso de Direito Ambiental dos Países de Língua Portuguesa e Espanhola, 10. Congresso de Estudantes de Direito Ambiental. São Paulo: Instituto o Direito por um Planeta Verde, 2015, pp. 392–407.

[4]Aragão, Maria Alexandra de Sousa. Cadernos CEDOUA: O Direito dos Resíduos. Coimbra: Almedina, 2003.

[5]LEMOS, Patrícia Iglecias Faga. *Resíduos Sólidos e Responsabilidade Civil Pós Consumo*. 2ª ed. rev. e atual. São Paulo: Revista dos Tribunais, 2012. p. 87.

of obligations for the supply chain (manufacturers, importers, distributors and dealers) (Lemos 2012).

The NPSW established guidelines for National, State, Regional and Municipal Solid Waste Plans. The specific goals of the Law include: providing incentives for recycling industries to help in the use of recycled raw materials; encouraging the use of clean technology in order to minimize environmental impacts; promoting a management hierarchy of reduce, reuse, recycle and ensuring that solid waste disposal is completed in an ecologically and environmentally responsible way; prioritizing green government procurement; and integrating reusable and recyclable materials in actions that involve responsibility life cycles.

The NPSW provides a solid regulation about solid waste management and it is aligned with international tendencies and practices. However, facing the Brazilian context, there are many challenges of implementation. In another work we already analyzed the elements that these kinds of governance have to deal.

> There are several operations involved in waste management: selective collection, transportation, storage, treatment or recycling, recovery, disposal and monitoring. The choice between any of them, together or separately, is not enough by itself. Other aspects should also be considered depending on the product and its manufacturing, from cradle to grave, involving all stages since development, sourcing of raw materials and inputs, productive process, consumption, destination and final environmentally appropriate disposal. In all of them, waste prevention and eco efficiency of products should be sought, as well as the use of the best available technology. (Lemos et al. 2013)

To overcome these problems, the NPSW created a new institution: the shared responsibility for the product life cycle. In short terms, it implies that all actors involved in the life cycle of the products will have some type of responsibility in the end of these cycle, or, in other words, these actors will have individual but linked obligations in waste management (cf. Lemos 2012).

Another important instrument designed by the NPSW is the obligation of implementation of reverse logistic system for some kind of solid waste that are considered more relevant and when is demonstrated the economic and technical viability of these kind of measures. One example is the general packaging sector that was called to present proposals for the system implementation by the Ministry of Environment after a study of viability was completed.

## *2.2 Regulation for Solid Waste in São Paulo State*

Once a general overview on solid waste regulation in Brazil is established, we'll move on to the regulation scenario on São Paulo State, where University of São Paulo has its *campi*.

São Paulo State edited its State Policy for Solid Waste (SPSW) before even the NPSW was edited. Law nº 12.300/06 laid the guidelines for waste governance for the State, anticipating a number of instruments and concepts adopted in the NPSW itself (Lemos 2012).

The SPSW was regulated by Decree nº 54.645/09 in São Paulo State, which, apart from establishing concepts and definitions, also details the instruments of the SPSW. The planning and inventories systems laid out in the Decree stand out from the guidelines presented by state legislation, as does the treatment to the contaminated and degraded areas (Góes and Silva 2012).

Aside from these norms, the São Paulo State Office for the Environment (SOE) has established a series of resolutions to regulate the environmental governance of waste in the São Paulo State. The SOW Resolution nº 15/2017 must be underlined, as it rules over the environmental licensing of business ventures or activities related to solid waste.

## 3 The University as a Laboratory for Public Policies

After setting the general scenario and establishing the need for reflection on solid waste as social and environmental good liable to governance, one must reflect on the roles of the universities in this challenge.

According to the university census conducted by the Anísio Teixeira National Institute for Studies and Educational Research (NISER), in partnership with the Education Ministry (EM), in 2013 Brazil had 2391 higher education institutions. The same research also indicated that, on the same year, 991,010 students graduated with a bachelor or technological degree (INEP). The numbers demonstrate the weight of the higher education in Brazil. But what is the role of this academic community on the solid waste governance?

The University of São Paulo (USP) is the largest university in South America, counting with an academic population of nearly 150,000 people (127,000 students, 17,000 staff members and 6000 teachers). The USP has several *campuses* around the state of São Paulo.

By its size and representativeness, USP works as a veritable laboratory for the development of public policies. In cases such as solid waste management, the University allows projects to be tested in a minor scale and perfected before being applied to the entire population.

To Klaus Frey, the study of environmental public policies presents particularities, involves an institutional arrangement and ways to deal with a number of new social actors (Frey 2000). The development of policies seems to be a smaller challenge compared to their effective implementation.

Brazilian environmental standards are mostly well written. The biggest challenge is the effectivity of these standards, or the practical application through public policies. In these terms, the experimental utilization of USP can be highly valuable.

To Boaventura de Sousa Santos it is possible to rethink the public universities as a space to create solutions to social issues. The writer defends "promoting research alternatives to formation, extension and organization that lead to the democratization of the university public property, that is, to the university's specific contribution to the definition and collective solution of social issues, both national and global" (Santos 2008, p. 57).

## 4 University of São Paulo's Solid Waste Governance and Research Experience

University of São Paulo is composed by *campuses* located in many cities in São Paulo State. Various sorts of waste are produced, such as gardening and pruning residue. The management of each kind of waste is done individually, as will be further detailed.

On the University City Campus, the average waste generation is 187 ton a month. Recyclables amounts to 66 tons a month. A company was hired to segregate a good deal of the recyclable material, which is sold and returned to the production cycle. That shows the University is working hard to observe the NPSW, prioritizing the reuse and recycling of materials.

There are multiple examples of initiatives for environmental governance of solid waste in the University of São Paulo. The University, in its many *campuses,* has programs that are pilots for future public policies.

One of these initiatives is the "Computer Waste Disposal and Reuse Center" (CWDRC) program. The program proposes the reuse and sustainable disposal of electronic waste, including obsolete computers. It is a pioneer action in the University.

CWDRC was founded in December 2009 and allows the computer waste of USP to be sustainably disposed and maybe reused in the production chain. The electronic waste is received from Capital and Country units, both from inside and outside the USP community.

Equipment received is loaned for reuse in USP laboratories, technical schools and philanthropic institutions, after having its conditions checked and being analyzed by a technical team. At the delivery, a voluntary delivery term is signed, allowing verifying the self-declared quantity of equipment, which is weighted and accounted for.

CWDRC also works as an electronic components bank for USP units. Waste unsuited to recycling is sold as scrap, in a thoroughly well managed and registered process.

Entities undertake to return equipment that no longer has useful life to CWDRC, and are contemplated with a sustainable disposal (USP 2017), which guarantees a full life cycle responsibility over the product.

Another positive action was the creation of the Superintendence of Environmental Management (SEM) in 2012, which propels the development of significant experience in sustainability, including waste management.

Although environmental and sustainable actions at USP started in the 90s, it was only with the creation of SEM that many actions related to sustainability became part of an official program for the entire University.

The main purpose of SEM is to promote environmental sustainability in all campuses incorporating the board in all policies, plans and activities, in the areas of teaching, research, extension and management. The initiatives are based on three goals: (1) Towards Zero Carbon Emissions: (2) Our campuses as a lab for our cities and (3) Sustainable actions.

The SEM coordinated groups of more than 150 professors, students and staff to create "the USP Environmental Policies" based on the structure proposed for the national policy for solid waste (NPSW), defined in four phases:

Phase 01—Definition of Sustainable Policies
Phase 02—Definition of Sustainability Issues Plans
Phase 03—Sustainability Masterplans with 11 Thematic Chapters
Phase 04—Sustainability Program of each school or department

Thus, the USP Environmental Policies was divided in 11 + 01 sections, 11 thematic policies and 01 management policy of thematic policies that are still being perfected and are thus divided: (a) Administration; (b) Greenhouse Gas Emissions; (c) Energy; (d) Water; (e) Solid Waste; (f) Mobility; (g) Fauna; (h) Green Areas; (i) Sustainable Buildings; (j) Environmental Education; (k) Land use; (l) Sustainability Policy; (m) Solid Waste Policy.

The motivations to create a thematic policy about Solid Waste in USP was to meet the requirement of National Policy on Solid Waste (NPSW), in order to reduce the environmental impacts of the assets disposed of through human activities. This concern also includes hazardous waste. In addition, the university created a working group (WG) to monitor the implementation of the policy. The mean purpose of the WG is to determine the work's guidelines in accordance with the NPSW, that is: non-generation, reduction, reuse, recycling and disposal of environmentally solid waste.

In order to deal with the complexity of waste management, the policy adopt a multidisciplinary approach and a systemic vision. In addition, it is guided by a series of principles, of which we highlight the access to information, cooperation, shared responsibility, transparency, prevention and precaution.

It is important to demonstrate that there are already measures being put in practice by the USP's SEM, like waste inventories, selective collect, promotion of scientific research, continuity of educational processes and disposal that is environmentally appropriate. Moreover, the University believes that by adopting sustainable patterns of consumption, including products whose production chain is sustainable, and environmental education, it is possible to secure health and the environment.

The "USP Recycles—from Pedagogy to Technology" is a permanent program in University of São Paulo, currently ran by SEM, whose function is to articulate and facilitate the program's promotion and implementation.

Through teaching, informing and integrated waste management initiatives, USP Recycles seeks to transform University of São Paulo in a model of responsible consumption and adequate waste disposal. The target of the program is the USP Community (students, teachers, researchers, staff and visitors) in various units.

Where possible, USP Recycles also seeks to assist the general public, by means of on-site, telephone and e-mail consults.

Furthermore, the program envisages collaboration in open events and support to projects conducted in schools.

## 5 Conclusion

The governance of solid waste is a challenge for all countries in order to secure the sustainability for the present and future generations. In Brazil, since 2010, with the edition of the NPSW, there is a solid regulation about waste management and important instruments of environmental protection. What is now in the country's agenda is, actually, the implementation of this policy, in order to ensure that the solid waste governance meets its economic, social and environmental goals. In these matter, the universities are a strategic place to experiment alternatives and to create various models of public policies. This paper is more relevant when we talk about public universities, which have to commit with social problems. The University of São Paulo is already assuming this position of public policy laboratory with a series of measures, programs and researches.

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# How Entrepreneurship in Higher Education Helps to Sustainable Development at the Local Level: The Case of Tecnocampus

**Marian Buil Fabregà**

**Abstract** It would seem that the combination of the location of university campuses and entrepreneurship studies is not a big issue on sustainable initiatives taken by universities. But choosing the right place as well as powerful entrepreneurship topics in higher education are key elements to success in sustainable development on the local level. This paper presents the case of Tecnocampus, University College affiliated to Pompeu Fabra University, which is located in a Scientific and Innovation Park near Barcelona. Tecnocampus is one of the 25 first good practice case studies throughout Europe chosen in 2016 by the University-Business Cooperation in Europe, an initiative from the European Commission. Inspired by the triple helix model, university, innovative companies and public authorities work together to manage and develop the university studies focus on the sustainability of the campus and local development. Finally, concrete examples of sustainable ideas taken on the campus are explained. Some of them are the Health studies Campus, the Entrepreneurial studies Campus, the use of Living Labs such as incubators, innovation labs or Fablabs and the university culture life. The results show how universities can develop sustainable strategies focusing on entrepreneurship and choosing the right location. This paper will be useful to anyone interested on developing sustainable initiatives on campuses using entrepreneurship and establishing relations with local businesses and the public authorities in order to develop sustainability at the local level.

**Keywords** Education · Entrepreneurship · Entrepreneurial university
Environmental commitment · Social commitment · Sustainable development
Sustainability

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M. B. Fabregà (✉)
Department of Innovation and Entrepreneurship Business Studies,
Escola Superior en Ciències Socials i de l'Empresa Tecnocampus,
Pompeu Fabra University, Avinguda Ernest Lluch, 32, 08302 Mataró,
Barcelona, Spain
e-mail: mbuil@tecnocampus.cat



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## 1 Introduction

Today's economic, financial and social unpredictable changes have shown that increasing volatility and growing challenges, such as climate change and terrorism, require that people who run organizations develop new skills to address current and future challenges (Augier and Teece 2009; Teece 2012; Alonso-Almeida et al. 2015a). Therefore, the complexity of the current environment demands that new organizations have a leadership with new capabilities (Wilden et al. 2013; Lanza and Passarelli 2014; Alonso-Almeida et al. 2017), with positive impact on sustainability development in organizations determined by social, environmental and stakeholders commitment (Alonso-Almeida et al. 2017; Buil-Fabregà et al. 2017).

Furthermore, stakeholders are becoming increasingly important (Carroll and Buchholtz 2014; Alonso-Almeida et al. 2015b) in market orientation and in the strategic policies of institutions. From the point of view of sustainability, stakeholders feel more identified with institutions that engage in social and environmental issues than with those that adopt a passive or reactive attitude towards these issues (Chen et al. 2015). Crittenden et al. (2011) mention as illustrative examples of social and environmental commitment the reduction of the consumption of scarce resources; degradation of the environment; responsible management of the supply chain; reducing the impact on climate change; detection of increased consumer awareness of sustainable development; Increasing global economic stability through sustainability and proactive management of institutions' processes to protect the natural environment.

But, how these new capabilities concerning sustainable development could be learnt and acquired? The entrepreneurial university introduced by Etzkowitz and Leydesdorff (1996) plays and important role in teaching such sustainability concerns.

Concerning the social change, a driver of the current social system is the global nature of the new knowledge economy, where productivity and innovation are key factors for the competitiveness of companies, institutions and territories. This geographical concentration of innovation leads to the appearance of external economies resulting from geographical proximity (Cooke et al. 2004), but it can also generate network economies due to the interaction between agents through regional cooperation networks (Asheim and Coenen 2005; Asheim and Gertler 2005).

This dynamic proximity and interaction can lead to the emergence of an innovative environment, understood as a socio-economic system, where agents establish relations of cooperation and competition.

Many economic studies show that innovative entrepreneurship is essential for economic growth to be able to reach and generate relational skills which are the basis of the processes of emergence and development of local innovation systems (Acs et al. 2006). The entrepreneurial universities are rethinking their roles and positions towards the three missions of the university: teaching, research and knowledge transfer. They combine the three missions into a common framework, thus become institutions of public service responsibilities in the development of social environment, in collaboration with other public and private institutions. According to the OECD (Organization for Economic Cooperation and Development) the third mission of the University of the XXI century covers all activities related to the generation, use, application and exploitation of knowledge and skills outside academia.

It is a fundamental role of universities to generate entrepreneurial processes of innovation and responsible entrepreneurship, helping to build a knowledge society framed within a new model of sustainable development more resistant to cyclical crisis. It is necessary to take advantage of the significant reserves that still exist in the range of interaction between the university and the society, with a strong and broad involvement in areas such as: technology transfer to the business world and to society in general, training of entrepreneurial professionals, promotion of innovative technology companies, encouraging community initiatives of interest to the public and offering specialized services that respond to real social needs.

This paper describes the case of Tecnocampus (Pompeu Fabra University) as an example of this new model of entrepreneurial university and concrete actions and examples taken to contribute to the sustainability development.

## 2 Entrepreneurial University

The original concept of entrepreneurial university was first introduced by Clark (1998), and then by Etzkowitz (2004), with the triple helix model, which defines the transformation processes that leads up to this type of university.

Clark focuses on and internal perspective, setting the characteristics and nature of the entrepreneurial university as an institution capable of adapting to new social and economic needs. Etzkowitz (2004) presents the entrepreneurial university under an external perspective, as a new academic model; in which academic teaching and research combined with the capitalization of knowledge transform innovation needs of enterprises in new scientific knowledge with technological application. I always emphasize the strong dependency link between the university and the social and economic environment, the flexibility and innovation of organizational structure and culture, and the importance of knowledge capitalization.

The entrepreneurial university is to facilitate the creation of value for society and its individuals benefit for new and innovative practices. The concept derives from the maturation of the basic concept of entrepreneurship to include the socio-economic value and creating jobs and entrepreneurship. This socioeconomic mission in nature can be understood as an extension of the traditional university missions of teaching and producing research. On the basis of the entrepreneurial university there is also innovation as Peter Drucker mentions (the effort to generate a focus change, directed to the economic and social potential of a company). The purpose of the entrepreneurial university academic knowledge is transformed into a social and economic value. Clark (1998) identifies five areas for the transformation of the organization into an entrepreneurial university:

- a core government set the vision and the strategy to follow.
- a support structures (e.g. technology transfer office) and mechanisms of interaction with the environment (territory, industry).
- a diversified funding base.
- a powerful academic activity, based on interdisciplinary research which seeks excellence.
- an integrated and entrepreneurial culture of the organization.

Etzkowitz (2004), meanwhile, identifies the entrepreneurial university the following elements:

- the organization of the research group.
- the creation of a database of research with commercial potential.
- the development of mechanisms to move research out of university.
- the ability to organize companies within the university.
- the integration of academic and business elements into new formats (e.g., research centers between universities and business).

Leydersdorff (2012) introduced the evolution of the triple helix model (-*where university, industry and government cooperates to the bring innovation to the market and contribute to sustainable development*—Etzkowitz 2008), to the quadruple helix model and the N-triple helix model.

The quadruple helix model embeds the triple helix model with the factors of:

- Business: young entrepreneurs or students with business ideas
- Research: Universities
- Public administration: Governments
- And it also adds a fourth factor which is the civil society who are the citizens who have initiatives related to societal challenges which can be helped with innovative solutions. In this fourth factor could be included ONGs, consumer associations, users, etc. who tend to demand social and environmental commitment from institutions.

Furthermore, in the same work Leydersdorff (2012) states that a quintuple helix has to be defined as a result of socio-ecological transition and the context of natural environments for society. The European Commission (2009) identified the 'socioecological transition' as one of the major challenges for current and future societies and economies. Carayannis et al. (2012) describe how more sustainable development can be considered feasible, in reference to the socioecological change of the global warming, for the national level and for positive effects that may arise for society due to targeted investment into the education system of the *Quintuple Helix* model.

The inclusion of students with business ideas in the factor of business of the quadruple helix model states the importance of teaching entrepreneurship in higher education in order to transform them in young entrepreneurs committed to the socio-ecological demands from the environment to help the sustainable development.

To summarize this part, it is necessary to state that the construction of this new model requires to introduce and promote the entrepreneurial spirit in college, and to incorporate entrepreneurship naturally and transversally to all university curriculum. Entrepreneurship should be a daily action of connection with reality, and not enough infrastructure to support business creation: it is necessary to understand students and teachers the importance of the entrepreneurial attitude and must prepare them to develop it in their area of expertise. The entrepreneurial university becomes a determinant of innovative cluster, with the addition of external agents to their governing bodies, the approach to the business of the surroundings and participation in global networks of knowledge.

## 3 The Case of Tecnocampus: A Hub of Knowledge, Entrepreneurship and Business to Contribute to Sustainable Development

Tecnocampus is one of the 25 first good practice case studies throughout Europe chosen in 2016 by the University-Business Cooperation in Europe an initiative from the European Commission. Dr. Richard Woolley developed the case of Tecnocampus using an interview with Tecnocampus' stakeholders. The 25 first good practices, including the Tecnocampus case study used in this research, are available on the case study resources of the University-Business Cooperation in Europe.

Tecnocampus is an ecosystem where students, entrepreneurs, businesses, researchers, academics and local government interact to share knowledge, contribute to sustainable regional economic development and build successful futures. The co-located university faculties, start-up incubator, business park and technological centers, are connected through the common focus on entrepreneurship that is integral to all Tecnocampus education in business, health and technology. A wide range of education, incubation and commercial activities intersect and underpin a modern entrepreneurship scene, led by successful young entrepreneurs, that fuses the Catalan tradition of medium-sized family businesses with the flourishing international spirit of entrepreneurship and innovation.

TecnoCampus Mataró-Maresme Foundation is a nonprofit organization initiated by the Mataró City Council and the Maresme County Council in order to manage and develop the university studies and business and enterprise park of the TecnoCampus as well as extending the its sustainable benefits to local level companies and society. It is a private-law foundation with a public service vocation in the field of education and business development.

The governance of Foundation, which is overseen by the Boards of Governors, the highest governance body, is based on a system of public and private collaboration. The Boards of Governors made up of representatives from public authorities, the university and the company. In this respect, the Foundation's structure takes its inspiration from a triple helix model.

The mission of TecnoCampus Mataró-Maresme Foundation follows the standards of most scientific and Business Parks state in the literature (Löfsten and Lindelöf 2002; Zhang 2005; Lööf and Broström 2008; Yang et al. 2009). These standards are to contribute towards the economic and sustainable development of the region, acting as a driving force behind the generation of knowledge, training, business and innovation. In this sense, entrepreneurial skills are taught to university students in order to have more job opportunities (Kucel et al. 2016) or to be more sensitive to sustainability issues (Alonso-Almeida et al. 2015a; Buil et al. 2016).

In order to fulfil our mission, Tecnocampus embrace the following central objectives:

1. Developing a range of higher education opportunities that focus on high-level professionalism and which are committed to ensuring employment positions for our graduates.
2. Managing a Business and Enterprise Park that helps to enhance the competiveness of companies, innovation and internationalization, while strengthening links between the University and local companies.

## 4 Background

The City of Mataró lies on the Mediterranean coast north of Barcelona in Catalonia. It was formerly a stronghold of textile production. The city council's commitment to fostering professional education had historical roots in the creation of the Miquel Biada Institute in the 1950s, which led to the formation of the Industrial Technical Engineering School of Mataró in 1983. In 1999, the Tecnocampus Foundation was created, through an agreement that incorporated the already established polytechnic and business schools in Mataró. When economic reliance on textiles declined, the local municipal administration led investment in the Tecnocampus infrastructure as a way of meeting future social and economic challenges in the region to foster sustainable development at the local level. A health school was added to the polytechnic and business schools and the university centers then formed the integrated education-business-entrepreneurship design of the campus space. Tecnocampus is an affiliated center of the prestigious Universitat Pompeu Fabra (UPF) Barcelona, which awards 16 undergraduate and Masters level degrees. Tecnocampus covers more than 50,000 m$^2$, with the three teaching schools located alongside the two towers hosting the preincubator, the start-up incubator (and conference facilities) and the Business Park. The Business Park includes 18,000 m$^2$ of space, hosting both established local companies and new firms emerging from the start-up incubator, which takes up one floor of the twin towers of the park. The infrastructure design is intended to facilitate informal interactions and ease of movement for students, staff and businesses across all these elements of the campus.

## 5 Objectives and Motivations

The mission of Tecnocampus is to create a holistic knowledge and business ecosystem that contributes to economic and sustainable growth and social progress, by hosting three university schools, a business park and incubator center and by generating new opportunities among them. The goals that support this mission are to:

- provide high quality education and innovative learning opportunities for students entering the workforce and/or becoming successful entrepreneurs;
- promote, develop and support emerging start-up companies;
- generate spaces and moments for interactions between companies;
- make visible the supply and demand of products and services;
- stimulate informal relationships among people who work every day at Tecnocampus;
- stimulate the sense of belonging at Tecnocampus

The key driver of the Tecnocampus model is the creation of an entrepreneurial ecosystem that is based on both formal and informal interpersonal interactions facilitated by the collocated and purpose built infrastructure, institutional coordination and cooperation. A homology between social and spatial relationships underpins this ecosystem.

## 6 Stakeholders

There are 3000 students at Tecnocampus following courses in engineering, computer games, media studies, business administration, marketing, tourism, logistics, nursing, physiotherapy and sports sciences. Mandatory entrepreneurship courses are embedded in all degrees. Masters courses are available in entrepreneurship and innovation and in health and tourism management, whilst a range of extra-curricular offerings are available through the Business Services Department. Tecnocampus is home to 159 academics and 62 administrative and service staff. Academic research groups in key linked areas include entrepreneurship, socio-economic welfare, signal processing, public health technical standards, health and ageing. Tecnocampus governance is a hybrid private non-profit foundation and public ownership model. The Tecnocampus Board is composed of representatives of the quadruple helix:

public administration, business, UPF and civil society. The president of the board is a representative of the city council of Mataró. The board includes the General Director of Tecnocampus, who is directly responsible for the management of the three schools, the Business Park and the incubator. The hybrid Tecnocampus governance model confers strategic and management flexibility beyond that accorded wholly public HEIs in Spain. Around 120 companies are resident in the Tecnocampus Business Park. The companies present in the Business Park include more than 1000 staff employed onsite. These companies provide mentorship and share their entrepreneurship experiences within the Tecnocampus ecosystem. They can also benefit from the access to and the recruitment of emerging talent and young creators from the student body. The Business Services Department is responsible for the companies in the Business Park, the incubator and the transition of successful start-ups to the park.

## 7 Inputs

Total student numbers at Tecnocampus have grown rapidly to reach 3000, from a base of 1207 in 2010–11. In 2015–16, 91.6% of new enrolments chose Tecnocampus as their first choice study destination. All students study entrepreneurship-related courses within their degree programme, regardless of their field of study. The most entrepreneurship intensive undergraduate degree is Business Administration, which devotes 25% of its credits to the topic. Students who pursue higher-level entrepreneurship competences can take the Master in Entrepreneurship and Innovation. A 2500 $m^2$ space is dedicated to a Convention Centre, which hosted more than 300 events in 2014, including conferences, and visits of international business groups. Academic staff members at Tecnocampus are committed to the use of innovative teaching methods. The Department of Quality, Learning and Innovation (SQAI) trains academics in the use of innovative teaching methods and technologies. There is an increasing focus on teaching entrepreneurship using active learning models that promote interactivity, such as 'the flipped classroom' and other innovative methodologies. Raising staff enjoyment and confidence is also considered a benefit of this process, which helps drive quality performance. The study program Masters in Entrepreneurship and Innovation requires the students to enter the course already with a project in mind. The approach combines teaching with incubation activities to promote an outcome that satisfies requirements of the educational program, while provides the opportunity to also develop a start-up company simultaneously. Tutors assigned to the students, often from the private sector, play an important role in these activities. Research on entrepreneurship at Tecnocampus was started in 2012, and the activities are mainly concentrated around the Research Group on Competences, Entrepreneurship and Occupations (CEO). CEO has a particular research focus on the creation and use of entrepreneurial competences. There are other 5 researching groups in different areas in Tecnocampus. All 6 groups had a number of 82 publications in 2015–16. Tecnocampus represents more than 50 m euros of investment from stakeholders including the Mataró municipal government. Principal funding sources include student fees, revenues from business services and the commercial rents generated by the Business Park, further to donations and public subsidies. The annual budget is around €20 m.

## 8 Entrepreneurial Activities to Enhance Sustainability

The core orientation of Tecnocampus toward entrepreneurship is driven by a suite of activities across education, incubation and business that together create an entrepreneurship ecosystem. All degree courses introduce entrepreneurship to spark interest and motivation. The core education areas of technology, health and business are mirrored by research activities and the presence of start-ups and companies working in these areas on campus, allowing the integration of activities involving businesses and local entrepreneurs. Students with emerging ideas can qualify for residency in the preincubator located next to the incubator. The **pre-incubator** was developed as tool for students to see role models of successful start-up companies in action, to provide this visualization of what is possible. Students from the pre-incubator are invited to spend time with CEOs of start-ups, some of whom become their tutor. 6 Extra-curricular activities such as the Innoempren.

**Extra-curricular activities** such as the Innoempren program, the Weekend Challenge, the Hackathon Challenge, Instal Party are both designed to promote and develop the entrepreneurial ethos among students from the outset of their university education, and to provide an initial point of orientation for students who have business ideas. Students of Business Administration can also receive credits for these activities as part of the **Business Projects** course of their degree. The Innoempren university program features intensive entrepreneurship program as it involves weekly meetings for six months. The focus is on prototyping, lean methodologies, minimum viable products, developing customer validation approaches and other demand side elements of the project. The Innoempren program for students will soon also be affiliated to the Youth program of Santander bank to allow students to compete for the top prize of a trip to Silicon Valley. Weekend Challenge is a two-day hackathon focusing on entrepreneurship, where students work on their own ideas or develop new projects. The winners of this challenge gain free access to the preincubator and represent Tecnocampus at the **IntEntSem international program**. IntEntSem takes place for one week per year, each time at a different participating European university. The most recent winning team was interdisciplinary in its approach, composed of students from the three different schools. This activity is designed to broaden the understanding students have of the different roles and paths that entrepreneurial activities can provide if they team up with partners with different competences. This is also an effective interdisciplinary program as participants come from different degrees. The entrepreneurial issues confronted in the program also develop students' understanding of the international dimension, including the legal and cultural challenges of working across countries. Growing involvement in incoming and outgoing **Erasmus mobility** for students and staff also increases internationalization. The **incubator** has the capacity to host up to 25 start-ups originating from both inside and outside the university. The time spent in the incubator is maximized in three years. The incubator facility is highly popular, and it is fully subscribed. Incubation activities incorporate a range of activities, and start with the assignment of a tutor, creating a company dashboard, specialized consultancy services from local companies and mentoring. A **funding road map** is developed with industry advice and pitching opportunities arranged to facilitate meeting private investors. Marketing and social media planning is developed and a weekly open networking event is held to help connect with the local business community. Established industry professionals in marketing, funding, branding and sales provide advice through monthly meetings. Start-ups are required to transit to the Business Park after successful completion of the three years in the incubator. Tecnocampus is also one of seven business accelerators that make up the Start-Up Catalonia network. Another benefit of having the Business Park co-located, is that students from the Business School can undertake **internships with companies** in the Business Park as part of their courses. Most companies in the Business Park participate in the internship program, in which students work on tasks or projects currently underway in the business. Students who work on internships might be paid for their work. Furthermore, CEOs from Business Park companies as well as external business leaders provide guest lectures and case studies for the student groups. This **bi-directional exchange of learning and experience** sharing is central to the Tecnocampus ecosystem model. Oher regular activities include the 'Nit del emprenedors' (**Entrepreneurs Night**) event presenting awards for best ideas, successful start-ups and a student prize. A new initiative since July 2015 is the **Junior Enterprise program**, in which a student enterprise is situated for a time in the Business Park. This activity is designed as a further bridging step between 7 entrepreneurship training and practice. Junior Enterprises also often involve students from all three schools, promoting an interdisciplinary approach to entrepreneurial activities. The **Business Community program** is designed to generate more opportunities for collaboration and networking by providing a platform for participants in the Business Park to get to know each other. This program includes a market place, designed to stimulate trade agreements and a Business Corner to present one's enterprise to another. Company Seeks a Partner provides a channel to facilitate the launch collaborative work, product development among companies in the park. Informal measures include the after-work weekly meeting to share coffee or a drink. Whilst these activities are primarily designed to develop connections and opportunities among companies located in Tecnocampus, students and firms from outside can also participate as appropriate. The main objective is to build the entrepreneurial sustainable business ecosystem for the benefit of all those involved in Tecnocampus. Other avenues for entrepreneurship training at Tecnocampus include a three-week **summer school** and the Innoempren High Performance Program for entrepreneurs, which is targeted at start-ups or business that are closer to the market space. It focuses on project validation and development activities, and are addressed to pre-seed, short experience start-ups and established company phases. Participants in this program come from both outside Tecnocampus and from the incubator and business. The focus of the high-performance program is transformation of the idea or startup into a consolidated business. Additionally, two or three times per year Tecnocampus conducts an **investors' forum** to connect startups and investors. The Tecnocampus Incubator has also provided some pre-seed funding for startups lacking finance for aspects of their initial development, as investors are more available closer to the market stage.

## 9 Research Groups on Entrepreneurship and Innovation

There are 12 research groups in Tecnocampus. Two of them are related to entrepreneurship field of study: CEO (Competences, Entrepreneurship and Occupability) Research Group and GRIC (Group of Research in Innovation and Competivity). CEO is an interdisciplinary research group dedicated to unraveling which are the competencies that foster entrepreneurship and how can they be used most productively in the labor market. GRIC researches in innovation and entrepreneurship focus on the generation of knowledge from the innovative process and its impact on the productivity and competitiveness of companies and territories.

## 10 Outputs

As of 2015–16, Tecnocampus had 751 university-business cooperation agreements in place. A total of start-up companies created reached 61. Daily users of the Business Park had grown from 3204 in 2013–14 to 3556. To date 542 entrepreneurs have used Tecnocampus business services. A total of 814 companies have passed through the business accelerator program. Most students who complete coursework internships with companies in the Business Park have been hired by the firms where they did their internship on completion of their degree training.

## 11 Impacts

Tecnocampus' start-ups have generated revenue and employment, much of which remains linked to the local region. The local labor market is smoothing as students' internship and linked education opportunities reduce company employee search and recruitment costs. The presence of former students in companies in the Business Park, helps create a feedback loop where alumni contribute to Tecnocampus education and extra-curricular activities. The employment of students with tailored competencies reduces induction and training costs of new employees. The increasing reputation of the Tecnocampus model has a flow-on effect to the desirability of the courses on offer and is raising the entry standards required for incoming students.

## 12 Supporting Mechanisms

Tecnocampus can be considered a strategic instrument of local government, industry and education stakeholders to construct a dynamic interface that trains young people with an orientation toward business and entrepreneurship under the banner of jointly constructing the future. Operational instruments include a suite of cooperation activities including student internships, curriculum development, guest lectures and events featuring local entrepreneurs and businesses, student pre-incubator facility with business mentors and numerous mechanisms for formal and informal interactions between university and business stakeholders in Tecnocampus.

## 13 Barriers and Drivers

However, funding for early stage start-ups remains a barrier to acceleration of some new businesses. Although some limited pre-seed funding can be accessed through Business Services, a medium-term strategy of Tecnocampus is to try to address this problem through agreements with private investment sources. Additionally, Tecnocampus is rapidly approaching full capacity in both its educational and business park operations. Strategic planning and decision-making in relation to the utilization of the current space and the desirability and potential for expansion is an emerging challenge.

## 14 Future Challenges

It is a challenge for the management with regards further expanding the operations that both the size of the student body and the number of resident companies in the Business Park have reached the current maximum capacity. An educational challenge is to bring students from the different schools into the same classroom for entrepreneurial classes. This is difficult to achieve technically in relation to the competences and learning outcomes associated with different degrees. However, the benefits for interdisciplinary of developing this approach make it also a desirable next step in curriculum development. Tecnocampus also seeks to foster a more extensive research culture linked to entrepreneurship, with increased support funding and promotion of research activities. Extending the international engagement of Tecnocampus at all levels is another identified challenge. From the university perspective this includes promoting Erasmus students and other programs abroad for both incoming and outgoing students. Currently a Degree in Business Administration and Innovation Management is fully taught in English, with the goal of having half of all classes taught in English. Internationalization of the Business Centre is also being promoted, particularly through networking with other incubators in Spain and Europe. Sustainability is also a motivation of the recent internationalization program developed by the Business Park. This focuses on three lines: internationalization of the Business Park itself, the internationalization of the located companies, and the promotion of an internationalized culture across the Park. The Business Park plans to join an international network of Business Parks under the Go Global 10 Program. With regards to the internationalization of companies, initiatives under the 'Go International' program include providing guidance and defining agendas to international companies that visit Tecnocampus, including a gateway to the Spanish market program available for incoming businesses. Foreign market training is also available for Park companies that want to open new international markets. To promote the culture of internationalization, the International Business Club holds periodic meetings and networking events, among other initiatives.

## 15 Context

Tecnocampus is defined by its three education schools and the research that shapes the knowledge base driving entrepreneurship and start-ups. The focus on progressively increasing the extent of interdisciplinary in the process of formation and the creation of start-ups seeks to leverage the complementarities of the technology, business and health fields.

## 16 Key Success Factors

A critical success factor is the working relationship between the three educational schools and the Business Services Department to foster opportunities to contribute to economic growth. Collaboration on the design of new course offerings within the degrees ensures maximum opportunities for student immersion in an entrepreneurial business culture that underpins the Tecnocampus ecosystem model. Students who finish their education at Tecnocampus will be intimately familiar with the day-to-day life and requirements of businesses. Also, students can see successful examples of start-ups and businesses located in Tecnocampus and trace their trajectory through the development process. Success stories generate motivation and help clarify the pathway. Grades and course outcomes are directly related to the performance of entrepreneurship activities.

## 17 Monitoring and Evaluation

The Annual Report produced by Tecnocampus charts growth in all key indicators since 2010–11 to the present. These indicators form the information basis for strategic and operation planning and an input for evaluation against key success factors.

## 18 Sustainability Measures

Institutional sustainability is advanced through the Tecnocampus Foundation Board, which includes a mix of industry, government and education stakeholders. Their interests are in the continuation of the education-business interface created and furthering of its observable impacts. Innovation is an important part of the sustainability approach, with a new business center for health specific start-ups in development. The RIS3 program (http://s3platform.jrc.ec.europa.eu/home) is an agenda under the Europe 2020 framework that aims to promote clustered areas of smart specialization (European Union 2012; Foray and Goenaga 2013; Foray and Rainoldi 2013). Tecnocampus, together with other stakeholders of the region, has presented two proposals to create regional specializations in smart textiles and health. Tecnocampus already has considerable expertise in these areas, which can be further developed through knowledge intensive activities, entrepreneurship and innovation to provide a sustainable future focus for the region. The internationalization challenges that are a current strategic focus are also considered to be contributing sustainability measures. Finally, the integration of entrepreneurship into all courses and the emphasis put on professional development are critical to the experience of Tecnocampus as an immersion in entrepreneurial attitudes, thinking and activities.

One greening program is about Healthy Campus.

***Healthy Campus*** is an initiative of Tecnocampus that aims to promote university's community health. In the year 2010 it was created the Network of Healthy Universities in Catalonia. Its goal was to enhance the universities as environments promoting the health of students, professors, administrative and services staff, and the society in general. TecnoCampus shares this philosophy and that's why it has adhered to the Red along with the rest of Catalan universities.

The World Health Organization (1986) define the promotions as an individual health process fear of qualification in order to increase its control over the determinants of health and, so therefore improve your health.

The determinants of health are all the (positive and negative) factors that influence and condition people's health. Thus, we speak about determinants of health to refer to social and economic environment, the physical environment, the individual characteristics of each person and their behavior.

Healthy Campus proposes a perfect framework to design, develop and evaluate strategies to promote health, based in intersectoriality, the empowerment and the participation, the holistic vision of health, as well as the feasibility and sustainability strategies of the Proposals.

## 19 Transferability

The Tecnocampus model is transferable and can be tailored to local/regional needs in terms of technical and educational specialization. The model requires a large financial investment, a high level of triple-helix coordination combined with effective institutional flexibility, and a strategic vision to develop the project over the medium to long term.

## 20 Awards and Recognition

Students from Tecnocampus have won the prestigious UPF Emprèn prize of 10.000 € from Pompeu Fabra University for student entrepreneurship in five of the past seven years. A student of the tourism and business administration degree, won the 2014 Yuzz prize awarded by the Banesto Foundation for her project Prometteo, a tourist smartphone application for hearing impaired people. In 2015, a group of four students from the computer games degree won Best Computer Game 'Commemorations 2015' awarded by the Catalonian Regional Government. Many other projects had won different prizes or recognized as innovate solutions for detected problems. In 2015–16, the total amount of final degree projects on entrepreneurship in business marketing and tourism degrees are 48%. The 22% of business ideas generated in all Tecnocampus entrepreneurial programs and activities had become start-ups. The satisfaction perceived by students from the overall programs is 8 out of 10.

## 21 Conclusion and Recommendations

It is possible to enhance sustainable development under entrepreneurial curricula of students. Developing new capabilities which help them to generate new and sustainable business ideas which could be transformed into new businesses, to foster dynamic and unpredictable changes and to contribute to long term sustainability of organizations.

The analysis of the Tecnocampus case provides a number of relevant recommendations for companies, public policies and academia.

First, the rapidly changing and competitive environment that companies face calls for the development of business management models that result in competitive advantages that are sustainable in the long term. Companies should consider to work hand by hand with the local government and university in order to deliver value to society. There are different possible actions to take into account. One of them is the location of the company in a Scientific Park where this cooperation is close or establish a collaborative local network. Another possibility is that companies propose some real entrepreneurial projects to be developed by university students.

Second, this approach is key to manage the current economic and social environment and should be considered by those responsible for proposing and managing policies for the industrial development and support of small and medium-sized enterprises. Furthermore, governments should also take into account the possibility to use entrepreneurship as a way of giving response to demands from society.

Finally, future research lines are proposed for the academia. First, it is necessary to continue studying the role of society in the helix model in order to develop innovation and bring value demanded for them. Second, other cases in higher education using entrepreneurship as a way of sustainability should be studied and compared with the existing ones. Third, more proposals consistent with sustainability to create regional specializations following the recommendations from the European Union should be develop.

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# Challenges for Promoting the Urban Afforestation at the Federal University of Recôncavo da Bahia in Cruz das Almas, Bahia (Brazil)

**F. B. Piasentin, L. C. Mendes, K. Watanabe and J. M. Delgado-Mendez**

**Abstract** The extension project *Arborizar* UFRB implemented at the Federal University of Recôncavo da Bahia (UFRB) in Cruz das Almas, Bahia (Brazil) originated from students' demand for higher shade levels on campus. The low shade levels reduce the well-being of the academic community, especially of those who have to walk long distances between buildings exposed to intense radiation and high temperatures. The project aimed to promote the planting of shade trees in the campus. First, the project's structure and research methodology are described. Then, the experience of its first year of implementation is discussed by examining the main obstacles encountered and the strategies adopted to overcome these and by identifying the main outcomes obtained. This article is relevant for educators implementing sustainability initiatives involving urban afforestation on campus.

**Keywords** Tree planting · Extension · Urban afforestation · Participation

## 1 Introduction

The Federal University of Recôncavo da Bahia (*Universidade Federal do Recôncavo da Bahia*—UFRB) was created in 2005 in the Recôncavo Region of the State of Bahia (Brazil). Its creation is the result of a national policy intended to expand and create new universities in the interior of the country (Nascimento and Helal 2015). Even though it has been recently created, UFRB has been preceded by institutions dating back from imperial times. In 1859, the Imperial Bahian Institute

F. B. Piasentin (✉) · K. Watanabe · J. M. Delgado-Mendez
Centro de Ciências Agrárias Ambientais e Biológicas, Federal University of Recôncavo da Bahia, Av. Rui Barbosa 710 Centro, Cruz das Almas 44380-000, Brazil
e-mail: fpiasentin@ufrb.edu.br; florapro2002@yahoo.com.br

L. C. Mendes
Centro de Ciências Exatas e Tecnológicas, Federal University of Recôncavo da Bahia, Av. Rui Barbosa 710 Centro, Cruz das Almas 44380-000, Brazil



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of Agriculture (*Imperial Instituto Baiano de Agricultura*—IIBA) was created (Universidade Federal da Bahia 2003) in what is now the municipality of São Francisco do Conde in the Recôncavo Region. The institute functioned as the first school of agronomy in South America (Rodrigues 1987). The region at the time concentrated declining sugarcane plantations and the objective of the IIBA was to search for agricultural solutions to recover these plantations (Rodrigues 1987; Universidade Federal da Bahia 2003).

The headquarters of UFRB is located in Cruz das Almas, but other campi are located in five other municipalities in the Recôncavo Region.

The campus in Cruz das Almas harbors two Centers; Center for Agrarian, Environmental and Biological Sciences (*Centro de Ciências Agrárias, Ambientais e Biológicas*—CCAAB) and Center for Exact and Technological Sciences (*Centro de Ciências Exatas e Tecnológicas*—CETEC). These two center offers 17 undergraduate courses, from which agronomy, forest engineering, biology, agroecology, veterinarian medicine, environmental and sanitary engineering, civil engineering, among others.

Cruz das Almas is located in the Atlantic Forest biome. The conservation of this biome is very important, given that it possess one of the most diverse and threatened biodiversity in the world. Even tough it is currently reduced to less than 10% of its original extension, it still harbors a very high plant diversity, with more than 20 thousand vascular species, from which 8 thousand endemic (Brasil 2010). It should be noted that in the municipality of Cruz das Almas only 2.62% of the Atlantic Forest is conserved whereas the Brazilian environmental legislation states that 20% of the area should be conserved (Santana, 2017).

The area of the Cruz das Almas campus has approximately 1389 hectares (Alexandrino 2012). In the main area of the campus, where the buildings are located, the native vegetation was removed and converted into pasture and eucalyptus plantation. Since its inception in 2005, there were several attempts to promote the urban afforestation of the campus initiated by at least five different persons, among which technicians and professors. In 2010, a document entitled "Planning of the urban afforestation of the access roads of UFRB" (*Planejamento da arborização das vias de acesso dos campi da UFRB*) was elaborated by three professors with the objective of giving instructions for a landscape firm, which would be hired to carry out the afforestation in the campus. However, the firm was never hired.

The urban afforestation at UFRB is under the responsibility of the Environment and Gardening Nucleus (*Núcleo de Meio Ambiente e Jardinagem*—NUMAM) of the Superintendence for Infrastructure and Physical Space Planning (*Superintendência de Infraestrutura e Planejamento do Espaço Físico*—SIPEF). It is also responsible for the maintenance of gardens (external and internal) in all the campi (UFRB 2017). Its staff is composed by three office employees and 13 field workers.

Despite the efforts, in 2016 many areas in the campus, especially those where students used most, were still lacking shade trees, exposing pedestrians to direct sun radiation and extreme temperatures, affecting negatively the quality of life of the academic community. The area of the campus is also widely used by local people as a place for practicing physical activities such as walking, jogging and cycling. It should be noted that the mean temperature in the city is 24.2 °C and the annual precipitation level is 1200 mm, which is not regularly distributed throughout the year. The rainy season usually starts on March and ends on July. From November to March maximum temperatures registered are above 30 °C (Silva 2016).

The planting of trees in the urban environment can bring several benefits such as; the reduction of high temperatures, energy conservation in buildings, decline in air and water pollution, and an overall increase in the well-being of the population. Furthermore, the planting of native trees can promote the conservation of native fauna, by creating an appropriate habitat where wildlife can feed and live.

The need for more shaded areas within the campus motivated some students from the environmental and sanitary course to elaborate and propose an extension project to some professors. Three professors agreed to participate in the project. The project, which is coordinated by a student and a professor, started to be implemented in June 2016. The project received the title *Arborizar UFRB* (Afforest UFRB).

The project's main objective was to improve shade levels in the campus by promoting the planting of shade trees. The main expected outcomes were the promotion of a better quality of life to the local community by providing temperature control, social, aesthetic, ecological, psychological and spiritual benefits. The project also aimed at educating environmentally the new generations by developing indoor and outdoor activities with children from a nearby public school.

In this article we aim at presenting the project's methodology and describe the activities and strategies adopted during its first year of implementation. After that, we will assess the strategies, identify the main outcomes obtained and reflect over the main obstacles, deficiencies, challenges and opportunities encountered. This article may be relevant for individuals interested in implementing urban afforestation initiatives at the university level.

## 2 The Structure of the Project

Initiatives promoting the urban afforestation have been carried out in several Brazilian Universities motivated by the quest for sustainable development and the goal of achieving a better environmental quality in the universities' campuses. In the campus of the State University of Feira de Santana (*Universidade Estadual de Feira de Santana*—UEFS) (Santana and Santos 1999) in Feira de Santana, a city that is approximately 65 km away from Cruz das Almas, an urban afforestation project was implemented in 1999. For its implementation, the recommendations given were the use of plant species from *caatinga*, the local biome, and the avoidance of exotic plants (Santana and Santos 1999). Therefore, preference was given to native tree species in order to promote the conservation of the local threatened biodiversity and ensure a good adaptation to local conditions. Another usual recommendation for afforestation projects in urban areas is to ensure a diversity of tree species to avoid phytosanitary problems. According to Franco (2006), projects of urban afforestation should not be limited to the implementation phase (planting of seedlings in the field), but should also include the maintenance and development phases of seedlings, which are perhaps the most crucial ones for the survival of seedlings.

The Project *Arborizar UFRB* was structured in different phases. The first phase consisted in the study and selection of the tree species most appropriate for urban afforestation, considering characteristics such as growth rate, height, type of leaves, types of fruits, among others. In any afforestation plan it is recommended that tree species should be chosen with care in order to meet appropriate criteria such as having small flowers and fruits, large and medium leaves, resistant branches (Matos and Queiroz 2009), absence of spines, among others. It was defined that priority should be given to local native tree species. Also at the initial phase an on-line survey was carried out with individuals from the academic community in order to identify their perceptions towards the campus shade levels and their preferences regarding the selection criteria for trees to be used for urban afforestation in the campus.

The following phase was the collection of seeds of the selected species. After that, the seeds were sowed and seedlings were maintained in the plant nursery until achieving the appropriate stage to be planted in the field. Several activities were required to maintain seedlings, such as: filling bags with compost, watering, removal of spontaneous plants, protecting from diseases and pests, transplanting seedlings to bigger planting bags when required. Before planting the seedlings in the field, the actual trees in the selected area to be afforested were mapped using GPS technologies in order to elaborate the afforestation plan. The dates of the planting were informed to the academic community in order to mobilize them and stimulate their participation.

The planting of seedlings in the field and its maintenance formed the last phases of the project. The maintenance of seedlings required the monitoring and protection against ants and livestock as well as watering. The project coordinators were committed to agroecological principles. Thus, agroecological techniques and practices were preferred in relation to conventional ones. Assistance from professors with specializations in agroecology and forestry was sought when needed.

## 3 Methodology

This study adopted a descriptive and exploratory research approach. It is an applied research, since it aimed to generate knowledge for practical application directed to the solution of a specific local problem. The methods of research, a mix of qualitative and quantitative, were:

(1) An online anonymous survey with seven questions, from which seven closed questions and one open question, was developed and distributed through e-mail to teachers and through the social network media in order to reach the academic community at large (Annex 1). The first three questions were related to the respondent's identification and the other five questions aimed at identifying their perception about the current afforestation and shade levels on the campus and their preferences about the benefits of urban afforestation and regarding shade trees' selection criteria. A quantitative and qualitative analysis of the data obtained was carried out.
(2) Participant observation of the project's activities and of interactions among participants was done by the author and co-authors of this study.
(3) Primary data was generated through the registration of the activities of the project.

These sources of information allowed the triangulation and validation of the data. The data obtained was analysed and used for identifying the main outcomes achieved and assessing the main barriers, challenges and opportunities encountered during the implementation of the project. The main strategies adopted to overcome the barriers encountered were also identified and analysed.

The online survey could have been enriched by a larger number of open-ended questions that would perhaps provide a deeper understanding on the respondents' perceptions and preferences. Also the organization of focus groups or individual interviews with participants of the project to discuss the main barriers encountered could have provided another important source of data.

## 4 Results and Discussion

To obtain an insight into the academic community's perception of shade levels and overall urban afforestation on the UFRB campus in Cruz das Almas, an online survey was conducted from August 2016 until March 2017. The online survey was answered by 93 individuals, from which approximately 56% were undergraduate students, 34% were professors, 7% were classified as others (post-graduate students and other categories not classified in the survey) and 3% were technicians. Approximately 31% percent of the respondents were linked to the environmental and sanitary engineering course whereas 27% of the respondents were connected to the agronomy course. In relation to the means of transport adopted, almost 24% of the respondents reach the university on foot (15.1%) or by bicycle (8.6%). Most of the respondents (76%) use motorized vehicles. It would be interesting to assess whether higher shade levels on-campus would influence the number of individuals using sustainable means of transport (walking and cycling).

The survey data revealed that about 90% of the respondents were not satisfied with the shade levels on-campus, perceiving it to be very poor (52.7%) and poor

(37.6%). Only 9.7% considered it to be regular. There were no responses assessing on-campus shading as good or excellent.

The benefits of afforestation for the *UFRB* campus most valued by respondents were the promotion of shading (4.74) followed by the reduction of high temperatures (4.73). These results corroborates with the negative perception towards on-campus shade levels mentioned above. Other benefits evaluated in decrescent order of importance by respondents were: biodiversity conservation (4.53), air purification (4.51), carbon sequestration (4.42), attraction of native fauna (4.35), landscape aesthetics (4.17) and reduction in sound pollution (3.79).

The most valued criteria for selecting native tree species to be used in the afforestation of the campus according to respondents, in decrescent order of importance, were: high aesthetic value (6.05), high height (5.83) and rapid growth (5.82). Other selection criteria assessed as having lower importance were: absence of spines in branches (5.71), broad leaves (5.63), dense canopy (5.28), fall-resistant branches (5.27), high degree of threat of extinction (4.77), production of fruits for native fauna (4.43), and high longevity (4.21). Therefore, tree species exhibiting high aesthetic value, tall stature or fast growth were preferred over threatened, longeve or species producing fruits for native fauna. This result corroborates in part with the previous result, in which respondents prioritized shading and temperature reduction as the most important benefits promoted by trees for the UFRB campus in relation to other benefits less related to thermal confort. Even though landscape aesthetics was not judged as highly compared to the other benefits of afforesting the campus, aesthetics was judged the most important criteria for the selection of tree species. Therefore, the results indicate that it would be desirable to select species with high aesthetics value that are capable to provide a "tall and fast shade".

The project team was authorized to use NUMAM's plant nursery and available tools to produce the tree species seedlings. It also received the support of NUMAM's field work employee, who daily assisted the plant nursery. In one of the first meetings with the NUMAM responsible, it was explained that each year around 200 tree seedlings were planted in the field. The main reasons attributed to the loss of trees on campus were water shortage during the dry period of the year combined with the lack of a functioning water tank trunk for watering the seedlings, insects' attacks (especially ants), the damage caused by livestock external to the university that would enter the campus area and eat the seedlings or step onto them, and vandalism. Another point stressed by the responsible was that NUMAM had no financial resources available for purchasing seeds, seedlings, planting bags or any other material required in the production of seedlings. NUMAM devised a mechanism to circumvent this shortcoming by promoting a barter system where seedlings were exchanged with the materials needed for its activities with private individuals. In addition, NUMAM usually resorted to seeds that could be found locally and to seedlings donated from individuals or private companies. The lack of materials required for seedlings' production was, thus, the first challenge encountered during the implementation of the project.

To overcome the lack of financial resources, fund-raising activities (a raffle, the sale of used clothes and objects, and events) were organized by the project team. With the funds raised it was possible to purchase materials like: planting bags, hats, gloves, stools, watering cans, snacks for social events, and even one water bomb for irrigating seedlings. As an alternative to the purchase of the planting bags, a campaign was organized to collect UHT (Ultra High Temperature) cartons in classrooms' pavilions for reutilization as bags for sowing seeds. In this way, the project, wherever possible, promoted the reuse of resources, reducing costs and the environmental impact of resources that would otherwise end up in the city's dumps. In addition, the project also received donations in money and materials from individuals and institutions. Through the intervention of a professor that collaborated with the project, a private company donated a new plastic shading net screen for NUMAM's plant nursery, which was in a bad condition.

At the start of the project, ten students linked to the university's Prorector for Affirmative Policies and Student Issues (*Pró-Reitoria de Políticas Afirmativas e Assuntos Estudantis*—PROPAE) were selected. These students received a monthly scholarship and had to participate in an institutional project, dedicating 12 h per week to it. The students were selected after an interview with the project team, where their motivation to participate in the project was assessed. This proved to be a good strategy, specially considering that the activities involved in the production of seedlings were very demanding in labor.

Besides involving students from PROPAE, the project also recruited volunteer students who did not receive any financial reward. These students would obtain a certificate of participation delivered by the university's Prorector for Extension (*Pró-reitoria de Extensão*—PRO-EXT) at the conclusion of the project. On the course of the year there were a total of 32 students (including PROPAE students) from several undergraduate courses participating in different activities of the project. The creation of a public group in a social network media in the internet, which currently sums more than 400 members, contributed to disseminate the project's objectives and activities among the academic community. This was important for gaining public support to the project.

Opening the project to volunteers proved to be an important strategy in order to organize joint efforts to carry out the activities in a more effective way. On the other hand, dealing with a large group demanded more time to coordinate and organize teams and their respective activities.

A challenge encountered in dealing with a large group was how to motivate students (both volunteers and those linked to PROPAE) to participate in the project's activities and avoid free-riding. One way to deal with this challenge was to promote team work by creating and organizing small working groups, in which one student would assume the leadership and coordinate the actions with the other members. Students linked to PROPAE were designated as leaders in working groups responsible for the organization and execution of different tasks such as: collection of seeds, maintenance of seedlings, fund-raising activities (raffle and sale of second-hand objects), among others. Another mechanism employed to stimulate students' participation was to monitor students' presence in the plant nursery's weekly activities by having each student registering in a notebook the hours dedicated to the project.

Given the lack of financial resources, native tree species for afforestation would have to be selected on the basis of the availability of their seeds within the campus and in the city. This condition could somehow limit the variety of species employed in the afforestation. To increase the variety of species, seeds from exotic species were also collected and sowed. One hundred and thirty seedlings from ten native tree species were donated to the project by the State University of Santa Cruz in Ilhéus, a city in Southern Bahia, also located in the Atlantic Forest biome.

An important strategy employed was the obtainment of support and commitment from the university's rectorate (top management of the university) to the project's plan, goals and activities. As a result, the rector authorized the purchase of materials needed for the plant nursery, which were very expensive to be acquired with the project's funds. However, due to the slowness of the bureaucratic process involved in public purchases, the acquisition of the materials needed had not been accomplished at the time this paper was completed.

The collaboration with professors from CCAAB and junior enterprises was crucial for the capacity building of volunteers in topics such as the agroecological management of ants, production of native tree seedlings, compost elaboration and GPS techniques. The collaboration with the junior enterprise ConstruRec resulted in a digital map of the existing trees in the campus area that was used in the afforestation plan.

Some of the major outcomes promoted during the first year of the implementation of the project were: raising the awareness of the local community about the urgency of planting more shade trees in the campus; obtaining financial funds for executing the project's activities; stimulating volunteer and team work among participants; promoting the integration among students from different courses and between students, technicians, professors and field workers; building the capacity of volunteers. Furthermore, the project team produced almost 2000 seedlings from 17 different species (Table 1; Fig. 1); promoted environmental education activities in public schools; elaborated a digital map containing the actual trees on-campus to be used in the afforestation plan (Fig. 2); mobilized the academic community to participate in the planting of seedlings; and contributed to the organization of the planting of around 600 seedlings in areas where shade trees were most needed. In the first planting event, around 350 seedlings were planted by first-year students as a form of integration with other students as an alternative to hazing practices, commonly adopted in Brazilian universities (Fig. 3).

It should be highlighted that the presence of the field worker employee who managed the plant nursery was crucial to the success of seedlings' production, since he regularly watered seedlings during vacations, holidays, and recess of classes, when most students would be away from the city. In addition, the employee provided instructions to volunteers on a daily basis, sharing his empirical knowledge with students.

**Table 1** Seedlings' species produced by *Arborizar UFRB* Project

| Common name | Exotic (E) or native (N) species | Scientific name |
|---|---|---|
| Acácia roxa | N | Cassia grandis |
| Barriguda | *N* | *Chorisia glaziovii* (Kuntze) E. Santos |
| Carolina | *E* | *Anadenanthera pavonina* L. |
| Chuva-de-ouro | *E* | *Cassia fistula* L. |
| Flamboyant | *E* | *Delonix regia* (Hook.) Raf. |
| Ingazeira | *N* | *Inga edulis* Mart. |
| Ipê amarelo | *N* | *Handroanthus chrysotrichus* (Mart. Ex DC) Mattos |
| Ipê rosa | *N* | *Handroanthus heptaphyllus* (Vell.) Mattos |
| Jatobá | *N* | *Hymenaea* sp. |
| Jacarandá-da-Bahia | *N* | *Dalbergia nigra* (Vell.) Benth. |
| Moringa | *E* | *Moringa oleifera* Lam. |
| Mogno | *E* | *Swietenia macrophylla* King |
| Nim | *E* | *Azadirachta indica* A. Juss. |
| Pau-ferro | *N* | *Caesalpinia ferrea* C. Mart. |
| Pata-de-vaca | *E* | *Bauhinia forficata* Link. |
| Sibipiruna | *N* | *Caesalpinea pluviosa* DC |
| Sumaúma | *N* | *Ceiba pentandra* (L.) Gaertn. |

With the planting of the seedlings in the field, new obstacles were encountered. These were represented by ants' attacks and the risk of seedlings being damaged by livestock external to the university.

Even tough the campus area is owned and managed by UFRB, the monitoring to prevent the access of external livestock to the campus is deficient and there are no sanctions to prevent the access and use of grazing resources by the local community. Therefore, the lack of common agreed rules between university management and local community can result in the potential destruction of tree seedlings with negative impacts to the future afforestation of the campus. The situation has already produced several problems, besides the damage to tree seedlings, such as the degradation of water springs and loss of plants that were part of field experiments carried out by researchers.

Even tough it doesn't solve the causes of the problem, the palliative solution proposed by the project team to reduce the potential damage to seedlings was the construction of bamboo fences around these. Bamboo is locally available, requiring only labour of employees to cut it with the appropriate tools. However, a more effective and long-lasting solution to this problem would have been the building of a communication and interaction platform between UFRB management, town hall authorities and local herdsmen's representatives in order to establish some common rules for accessing and using the grazing area inside the campus as well as sanctions

**Fig. 1** Seedlings cultivated on the plant nursery by the project staff (April, 2017)

to those not complying to the rules. For instance, it could be established areas where locals could take their livestock without the risk of causing damage to seedlings. In the past, this problem was solved by UFRB by collecting foreign horses and cows in a specific place and returning the animal to the owner only after the payment of a fine. However, this mechanism was discontinued for legal reasons.

Several technical difficulties were encountered during the implementation of the project related to the production of seedlings. For instance, questions related to what native tree species should be selected, how to store seeds in an appropriate manner, how to control insects attacks on seedlings, and how to build a fence around seedlings, emerged. These difficulties were overcome in part by interacting with professors and technicians, who had greater technical knowledge and experience in the area and collaborated with the project. With the decrease in the

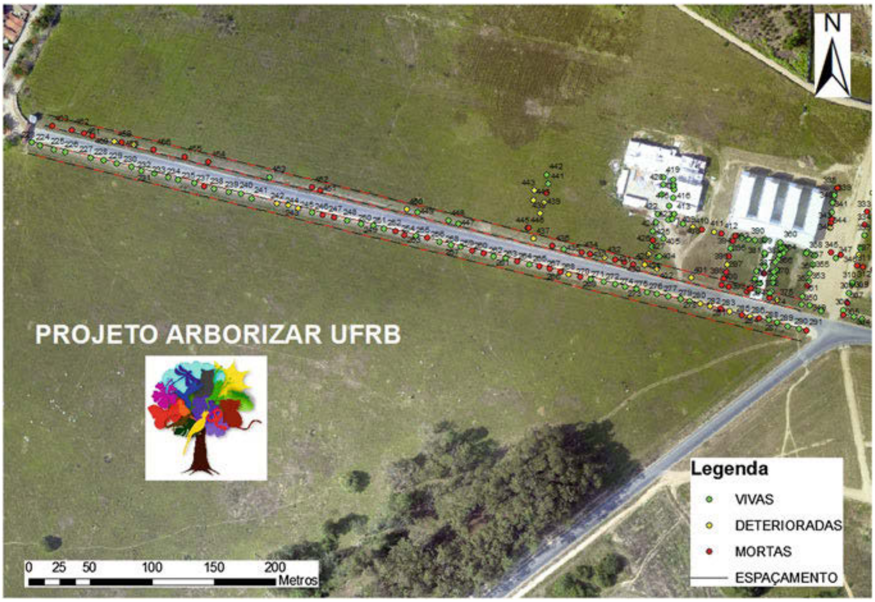


**Fig. 2** Mapping of the trees along the main access roads to the campus and their status; alive (in green color), damaged (in yellow color) or dead (in red color)

precipitation levels and increase in the dry periods, solutions to promote the watering of seedlings would have to be devised.

Besides the already-mentioned lack of resources for seedlings' production, other obstacles faced during the implementation of the project were the poor infrastructure of the plant nursery and of the "house" used for the storage of seeds and the absence of an urban afforestation plan for the entire campus. The latter obstacle could be overcome by building a collaboration network between NUMAM/SIPEF and existing professors at CCAAB who possess expertise in landscaping, agronomy and forestry engineering to design an integrated urban afforestation plan for the campus.

## 5 Final Considerations

The poor shade levels in the UFRB campus at Cruz das Almas gave an opportunity for professors, technicians and students to develop an extension project aimed at increasing on-campus shade levels in the long-term. The implementation of the project achieved important outcomes, which went beyond the planting of trees' seedlings in the campus. The obtainment of these outcomes was made possible by the involvement and participation of students, professors, technicians and field workers.

**Fig. 3** Preparation for the planting of 350 seedlings in the “Ecological Hazing” event (May, 2017)

The *Arborizar UFRB* Project has also motivated the development of new projects, which will be implemented in 2018. One of these projects seeks to recover the hydrological conditions of a degraded watershed area within the campus and should require the productive capacity of the project’s plant nursery. Another project, this one having an educational character, aims to convert the plant nursery into an experimental didactic learning place for public schools. Finally, an environmental educational project in formal education is going to be implemented at local public schools with the aim of stimulating the familiarization of students with the “world” of trees, plant nurseries, and the planting of trees in the schools’ yard.

Even though the project has achieved important outcomes, there are still major institutional challenges that need to be tackled in order to allow the advancement of afforestation practices at UFRB and in its wider context. Therefore, it is necessary that the project team continues devising mechanisms and strategies that stimulate collaboration among the different sectors at UFRB and between UFRB, the town hall government and public schools. In this sense, we hope that the project's activities and its new future branches continues stimulating students, professors, technicians, and the community at large to understand the importance of trees for achieving a local sustainable development and of promoting their active engagement.

## Annex 1. Questionnaire

This questionnaire is part of the extension project *Arborizar* UFRB approved by the *Centro de Ciências Agrárias, Ambientais e Biológicas* (CCAAB) at Federal University of Recôncavo da Bahia (UFRB). It is anonymous and does not involve risks to the participants. Its objective is to identify the perception of the academic community and residents towards the current afforestation in Cruz das Almas campus. You are free to choose to participate or not in this research. You will have to answer a questionnaire with eight questions, which should take in average five minutes.

1. **What is your function at UFRB?**

   1 ( ) Student
   2 ( ) Professor
   3 ( ) Technician
   4 ( ) Outsourced employee
   5 ( ) Visitant
   6 ( ) Other (specify)

2. **If student or professor, at which course are you linked to?**

   1 ( ) Agronomy
   2 ( ) Agroecology
   3 ( ) BSc. In Exact and Technological Sciences
   4 ( ) Biology
   5 ( ) Civil Engineering
   6 ( ) Computer Engineering
   7 ( ) Fishing Engineering
   8 ( ) Electrical Engineering
   9 ( ) Forest Engineering
   10 ( ) Mechanical Engineering
   11 ( ) Environmental and Sanitary Engineering
   12 ( ) Cooperative Management
   13 ( ) Veterinary
   14 ( ) Animal Science

3. **What is the main mean of transport do you use to reach UFRB?**

   1 ( ) Bus
   2 ( ) Car
   3 ( ) Motorcycle
   4 ( ) Free-ride
   5 ( ) Bicycle
   6 ( ) Walking

4. **In your opinion, the level of shade in the campus of UFRB at Cruz das Almas is:**

   1 ( ) Very poor 2 ( ) Poor 3 ( ) Regular 4 ( ) Good 5 ( ) Excellent 6 ( ) Other (specify): ____________

5. **What would you suggest in relation to the afforestation in Cruz das Almas campus?**
6. **Afforest means planting trees. Evaluate the different benefits of afforestation for the UFRB campus in Cruz das Almas.**

   **Shading**
   **Aesthetics**
   **Temperature control**
   **Sound pollution reduction**
   **Air purification**
   **Native fauna attraction**
   **Biodiversity conservation**
   **Carbon storage**

8. **Classify, in order of importance, the following criteria for the selection of Atlantic Forest native tree species for the afforestation of the campus.**

   **High height**
   **Dense canopy**
   **Fruit production for native fauna**
   **Absence of spines on branches**
   **Broad leaves**
   **High aesthetic value**
   **Fall-resistant branches**
   **High level of threat of extinction**
   **Rapid growth**
   **Higher longevity**

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# The USP-SP Community's Understanding About Sustainability

**Margarida Maria Krohling Kunsch, Iara Maria da Silva Moya and Vivian Paes Barretto Smith**

**Abstract** The Superintendence of Environmental Management (SGA) of the University of São Paulo has implemented a number of activities to identify and strengthen sustainable practices at the campuses. In this context, this study aims to identify the university constituencies' understanding about sustainability and the possible ways of social participation. The quantitative research took place at São Paulo Capital campuses in 2016, with the participation of more than 1500 respondents. This empirical study encompassed four dimensions of investigation: (1) the assessment of individual adoption of key definitions on sustainability; (2) the global dimension of sustainability, with the application of the UN MyWorld Survey; (3) the local dimension of sustainability, with the analysis of individual habits and behaviors, and; (4) the stakeholders willingness to participate and the options of engagement. The conclusion contributes to both managerial and theoretical developments, as the study can support the educational and communication actions of SGA for promoting a more sustainable campus; and further the theoretical discussion about the social participation of students, employees, and scholars to embed sustainability in higher education institutions.

**Keywords** Communication · Sustainability · Education for sustainable development · Behavior · UN MyWorld survey

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M. M. K. Kunsch (✉) · I. Maria daS. Moya · V. P. B. Smith
Escola de Comunicações e Artes, University of São Paulo, Av. Prof. Lúcio Martins Rodrigues, 443 - Butantã, São Paulo, SP 05508-020, Brazil
e-mail: mkkunsch@usp.br

I. Maria daS. Moya
e-mail: iaiamoya@usp.br

V. P. B. Smith
e-mail: vivi.barretto.smith@gmail.com

 
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## 1 Introduction

In a globalized world, communication is critical to promote sustainability. Building sustainability requires changes in values and habits of entire populations. The way human beings communicate about nature changes their behavior and perceptions towards the natural environment (Corbett 2006; Littlejohn and Foss 2009; Cox 2010). As a result, Communication presents itself as the path to construct a new social consciousness and worldview of the need to have a sustainable planet.

UNESCO, since 1972, has been calling universities to participate in the sustainable development agenda (UNESCO 1972). However, research and practice began to develop in the 1990s and only recently the number of universities engaged in the sustainability agenda, beyond teaching and research, has increased. This includes universities implementing environmental management systems (Alshuwaikhat and Abubakar 2008; Kaplowitz et al. 2009). There are three main dimensions of activities a university should focus on, in order to achieve its sustainability: (1) university's environment management system; (2) public participation and social responsibility; and, (3) sustainability teaching and research (Alshuwaikhat and Abubakar 2008).

With this in mind, the Center for Studies on Organizational Communication and Public Relations (CECORP), at the School of Communications and Arts (ECA) of University of São Paulo (USP), has defined sustainability as one of the main research topics.

In the early 2010s, the Superintendence of Environmental Management—SGA of the USP, established a group of activities to identify and strengthen environmental practices throughout the campuses. One of the goals was to engage the university's constituencies to adopt sustainable practices addressing one of the sustainability demands of a university. The project "Communication for Sustainability: USP community's understanding of sustainability" was developed to identify the community's—faculty, employees, and students—thoughts regarding sustainability, and to propose actions to improve sustainable habits and behaviors. The project identified a baseline of the university's constituencies understanding of sustainability. This was a pioneer study of great social relevance for the USP community.

The purpose of this article is to present the quantitative results of this project carried out with 1500 participants at USP campuses in the city of São Paulo in 2016. The study contributes both to (1) managerial development as it addresses the demands and future potential actions of SGA; and to (2) theoretical development into the topic of environmental education and communication efforts of universities, that remain relatively less explored in the theory (Kaplowitz et al. 2009). The study also reveals forms of participation of teachers, employees, and students in the construction of sustainability, and communication strategies for the university stakeholders.

Given a large number of USP campuses across the state, the data collection was restricted to USP constituencies located in the city of São Paulo and did not include campuses in other cities. As a result, a limitation of this study, the research findings do not reflect all campuses' opinion about sustainability. Methodological constraints included the unavailability of mobile online platforms, which could impact the participation of the younger generation.

The text is structured in six parts. The first part presents a synthesis of the research project. The second part carries some of the theoretical assumptions that guided the study followed by the third part, which presents USP data from the city of São Paulo and the profile of the survey participants. The fourth and fifth parts record the results of the quantitative survey and address USP community's understanding of global sustainability, the issue of local sustainability, and the suggestions on approaches to stakeholder participation. Finally, in the sixth part, the main conclusions are presented.

## 2 The Research Project

The research project was implemented in two phases. The first phase consisted of a broad bibliographical research of the literature on the general and specific themes of the study, serving as the basis for the theoretical-methodological reference adopted in the second phase, the empirical research.

The empirical research consisted of two stages, the first, qualitative and the second, quantitative. The two stages play the role of complementation and contribute to better understand the analyzed subject (Minayo and Sanches 1993). The universe of the study consisted of teachers, employees, and students of USP campuses in the city of São Paulo.

The qualitative, exploratory stage, held in November 2014, through focus groups, sought to verify the various understandings regarding sustainability, as well as to identify action recommendations for the campus. In addition, it served as an indicative and pre-test of the quantitative questionnaire, aiming to evaluate its formatting and the understanding of the content.

The quantitative survey was carried out from August to December 2016. The sample covered 1504 respondents and it was considered statistically representative, given the safety margin of 95% and an error margin of 3%. The questionnaire was developed, specifically for the quantitative research, to be self-administered online in a website designed with visual resources to facilitate and encourage its completion. It consisted of 41 questions, which took few minutes to be completed (average of eight minutes per participant).

## 3 Theoretical Assumptions

The theme of sustainability has mobilized the attention of the world, especially in the last three decades. It should be noted that 21 global conferences have already been held—the Conferences of the Parties (COPs)—by the UN, dealing with issues such as sustainable development, environment, climate, greenhouse gas emissions, etc., which have had the participation of about 195 countries. Among all the conferences already held, the following stand out: Rio-92—Rio de Janeiro, Brazil, 1992; Kyoto Protocol—Japan, 1997; Johannesburg—South Africa, 2002; Rio+10—Rio de Janeiro, Brazil, 2002; COP 15—Copenhagen, Denmark, 2009; Rio+20, Rio de Janeiro, Brazil, 2012; COP 19—Warsaw, Poland, 2013; and COP 21—Paris, France, 2015.

Despite the UN's efforts to attract attention and action of member countries of the COPs, the environmental balance of the planet remains at risk. Many of the agreements have not advanced beyond signing, and some of the richest and most developed nations in the world have not committed themselves to them.

The term sustainable development comes from the Brundtland Report, issued at the UN Conference in Stockholm in 1987, which defined sustainable development as the one that "meets the needs of the present without compromising the ability of future generations to meet their own needs (WCDE 1987, 8)".

The theme sustainability has received attention from various entities, non-governmental organizations (NGOs) and institutions, as well as scholars and experts from various fields. We highlight here some authors that we took as the basis for this study. Capra (1997), for example, considers that sustainability requires a pattern of organization that takes into account interdependence, recycling, partnership, flexibility, and diversity. For Viola (1996), what is at stake in sustainability is the quality of life and not pure material consumption. Naess (1997), founder of Deep Ecology, defends the value of nonhuman life as well, that is to say, all living beings are members of the "Oikos-home", the planet Earth.

According to Boff (2012), sustainability implies a new cosmological vision, encompassing the universe, the Earth and all manifestations of life. It requires not only the maintenance of natural capital but also its regeneration, reproduction, and coevolution.

Elkington (1997) presents the concept of sustainability through three pillars: economic prosperity, environmental quality, and social justice. The economic pillar is the financial results centered on economic capital only. The environmental pillar is associated with eco-efficiency, with the supply of goods and services that respond to human needs with adequate prices, promoting quality of life and reduction of ecological impacts. The social pillar covers issues related to the well being of people, including the real meaning of social development, involving ethical, cultural and quality of life aspects.

In the UN Secretary-General's High-Level Panel report on Global Sustainability (UNGSP 2012), sustainability, beyond the balance of sustainable development pillars, must "eradicate poverty, reduce inequality and make growth inclusive, and production and consumption more sustainable, while combating climate change and respecting a range of other planetary boundaries" (UNGSP 2012, 11).

The complexity of globalization becomes a phenomenon and a new paradigm for understanding today's world. National societies see their power reduced to the advance of the global society, which, according to Ianni (1994), appears as a new object and as a new paradigm of the social sciences. It happens due to societal pressures linked to the fragile condition of the life preservation on planet Earth, added to social inequalities that devastate entire populations. Organizations in globalized society assume an importance never existed before, as they were transmuted into new species on Earth (Senge et al. 2007). On the other hand, a sustainable society can only exist if there is a social agreement within and inter generations and nations, who are willing to care for Humanity well-being in the long term, in an ethical and solidarity manner (Cordani 1995).

In this way, dialogue and tolerance will be key factors for mutual understanding and bridging between nations and countries (UNESCO 2011). In the global society, the incorporation and assimilation of sustainability still have a long way to go. To effectively promote sustainability, society needs communication through all media platforms.

Communication allows us to generate meaning, articulate our differences and weave our present and future (Pérez 2012). Communication organizes us. Society has in the communication its possibility of existence, maintenance, and change (Baldissera 2009).

Furthermore, once communication sciences are combined with environmental sciences, the value of communication for human-nature relations is amplified (Smith 2015). Cox (2010) synthesizes environmental communication as both the pragmatic and symbolic mediums in which human relationships to the natural world take place, and therefore, the human understandings of the environment are revealed. The manner in which societies construct the environmental problems and negotiate its solutions is shaped by communicative experiences (Cox 2010).

According to the understanding set forth in USP's SGA Publication, sustainability goes beyond environmental aspects because it encompasses multiple dimensions and has been under a continuous process of construction (SGA 2013). It is also important to think of sustainability as a normative and comprehensive goal. For the UNEP (2011), sustainability is a long-term, vital goal. In the words of Veiga (2010), sustainability is the fourth ideal, to be added to the already known values of modernity: freedom, equality, and fraternity.

In the viewpoint of UNESCO (2011), the social and human dimensions must also be considered in the vision of sustainable development, with a picture of the creation of sustainable societies. The Sustainable Development Goals (SDGs) provide a guide that seeks to respond to the challenges of the world of today, an agenda with five areas of action, defined as the five "P's": (1) People: "eradicate poverty and hunger in every way and guarantee dignity and equality"; (2) Planet: "protect the natural resources and climate of our planet for future generations"; (3) Prosperity: "guarantee prosperous and full lives, in harmony with nature"; (4) Peace: "promote peaceful, fair and inclusive societies"; (5) Partnerships: "implement the agenda through a strong global partnership" (PNUD 2015).

For Kunsch (2009), in this entire context, organizations have a decisive role in the incorporation and assimilation of sustainability, in partnership with public authorities and organized civil society. Communication is a strategic factor to promote practices among those various players. Governments are called upon to take the lead in preparing policies and strategies that promote sustainability.

Companies and various civil society organizations have a responsibility to promote debate and dialogue through new forms of communication, to contribute to the large-scale transformation of human values and behaviors in the pursuit of a more sustainable life and the preservation of the planet.

Universities must also do their part. In the report "An agenda of actions for sustainable development" (UNSDSN 2013), when discussing the topic of education, the authors consider that schools are expected to teach the SDGs to face our society challenges of sustainable development. It is from this perspective that it becomes necessary to verify with the stakeholders of the USP community what their understandings of sustainability are.

## 4 USP in the City of São Paulo and the Profile of the Participants of the Research

USP, in its campuses located in the city of São Paulo, had, in 2014, a population of 79,308 people, consisting therein, besides the University City in Butantã (CUASO), the Health/Law Quadrilateral and The School of Communications, Arts, and Humanities (EACH—USP Leste). The population is grouped into administrative employees, faculty, and students. The USP adopts, for the classification of its courses, three large areas of knowledge: Exact Sciences, Biological Sciences, and Humanities (USP Statistical Yearbook 2015).

Table 1 describes the distribution of USP population and the survey participants, demonstrating the proportional correspondence between the study universe and the quantitative sample.

The USP population was comprised of 80% of students, 51% of undergraduate students and 29% of graduate students. Faculty made up 5% and non-teaching staff, 15%. In the survey, the proportion of students was much lower (62%), 37% of undergraduate students and 25% of graduate students, while the share of teachers (11%) and non-teaching staff (26%) was 37%, well above their presence in the population. This result evidences the greater interest and mobilization of those participants in the discussion of the sustainability issue in the university, perhaps

**Table 1** Population and participants of USP, of the capital city, according to USP areas of knowledge

| USP areas of knowledge | Population | | Participants | |
|---|---|---|---|---|
| | *f* | (%) | *f* | (%) |
| Exact sciences | 17,112 | 22 | 332 | 22 |
| Biological sciences | 18,847 | 24 | 443 | 29 |
| Humanities | 40,411 | 51 | 659 | 44 |
| USP management[a] | 2,938 | 3 | 70 | 5 |
| USP | 79,308 | 100 | 1,504 | 100 |

[a]Considers employees of high-level administrative bodies

due to their institutional long-term relationship, unlike the students who have a temporary presence at the university.

In the demographic axis, considering the gender of the participants, the survey showed that women made up 59%, while men represented 41%. The female presence was higher than the male in the Humanities area (60%) and especially in the Biological Sciences area (72%), but in Exact Sciences men were 60% and women 40%.

Regarding the age, 59% of the participants of the research were between 21 and 40 years old, 31% were over 40 years old and 10% were 20 years old or less. The variations between the areas of knowledge were not very significant, with the largest variations occurring in the Management area, with a greater participation of the age group over 40 years (55%).

## 5 USP Community and the Understanding of Global Sustainability

In order to grasp the opinion of the USP community on global sustainability, two different studies were used as references to empirical research. From the study of Kunsch a question pattern was used to know the opinion of the respondents on sustainability from the presentation of sustainability phrases of well-known authors, evaluated through a scale of agreement (Kunsch et al. 2014; Kunsch 2015).

In the USP community surveyed, the data showed that three statements stand out, with more than 80% of total or partial agreement. One was the assertion that associates sustainability with the quality of life and rejects high consumerism (Viola 1996). The second statement was referred to the so-called intergenerational sustainability, with the issue of preserving the conditions for future generations (Brown 1992). The third sentence addressed the three pillars of sustainability: economic, social and environmental (Elkington 1997).

The results pointed to an understanding of sustainability based on the proposition of intergenerational sustainability, reproducing the formal concept of sustainable development from Brundtland Report (1991) and, also on the idea of harmony of the platform of sustainability, with the economic, social and environmental pillars, called the triple bottom line; both concepts having been formalized at the Rio-92 Conference. That was added by the choice of Viola's (1996) statement, which expands this concept and includes quality of life, in addition to material consumption, covering aspects such as health, long life, education, healthy relationships and clean environment, anticipating issues that are discussed below.

The other reference study adopted was the UN MyWorld Survey (2015). That survey aims to answer the question "What should be the priorities of the post-2015 development agenda?", by the selection of the six most relevant topics from a list of 16 themes, namely: (1) access to drinking water and sanitation; (2) access to quality food; (3) access to energy at home; (4) telephone and internet access; (5) support for

**Table 2** UN MyWorld Survey—The 6 priorities of USP community

| Priorities | (%) |
|---|---|
| 1—Access to drinking water and sanitation | 88 |
| 2—Quality education | 82 |
| 3—Access to quality food | 66 |
| 4—Honest and active government | 50 |
| 5—Access to energy at home | 47 |
| 6—Improving health services | 44 |

people who cannot work; (6) combating climate change; (7) quality education; (8) eliminate prejudice and discrimination; (9) honest and active government; (10) equality between men and women; (11) political freedoms; (12) improve job opportunities; (13) improve health services; (14) improve transport and roads; (15) protection against crime and violence, and; (16) protect forests, rivers and oceans. The UN MyWorld Survey is considered one of the defining instruments of the SDGs.

In the USP community, access to drinking water and sanitation was the most significant issue as chosen by 88% of the participants. Noteworthy, the water reservoirs serving the city of São Paulo suffered a severe drought in the last few years. Quality education was highlighted by 82%; a subject that is at the top of the choices of Brazil and the world, considered the principal value for people from anywhere, in very rich, rich and poor places (Moya 2016). The third priority, chosen by 66% of the participants, refers to access to quality food, which implies nutritious food and the refusal of hunger. In the fourth position, with a choice of 50%, there was an honest and active government, a desire of all Brazilians, surprised daily by the revelations of investigations about corrupt companies and politicians. The fifth priority was access to energy at home, according to a choice of 47%, ahead of improved health services, the sixth priority, according to 44% of USP community.

Table 2 shows the results of those priorities for a better world, a better life. According to the USP community, they were based on social issues, similar to Brazil's priority choices (education, health, government, and water) and of the World priorities (education, health, government, and food) (Moya 2016).

## 6 USP Community and Local Sustainability

With regards to local sustainability, two approaches were developed: the first was the analysis of domestic habits and behaviors of the USP community in relation to sustainability; and second, the evaluation of suggestions for improving sustainability at USP and proposing forms of participation in favor of that improvement, both topics were also explored in the qualitative research.

The analysis of habits and behaviors in relation to sustainability was based on a survey conducted by the Ministério do Meio Ambiente [Ministry of the Environment] (2010) held periodically with the Brazilian population.

The issues indicated aspects of USP community's behavior in relation to everyday practices (which certainly also occur within the university campuses) and which could be campaign themes for raising awareness and behavior change, in relation to the areas of energy, water, and conscious consumption. These were the following results presented at Table 3. In the topic of energy, six habits and behaviors were evaluated: 95% of the survey participants usually, or most of the time, turn off the lights when not in use; 86% usually replace incandescent lamp bulbs with fluorescents; 79% usually reduce the consumption of electricity at home; 75% usually turn off the computer when not in use; 60% usually reduce gas consumption at home; but only 37% usually unplug the electronic devices. Those results showed an effective concern with energy consumption.

Concerning the use of water, five habits and behaviors were evaluated, and 94% of participants usually close the tap while brushing their teeth or washing dishes; 90% usually avoid wasting water; 71% do not wash the yard and car using a hose; 65% usually reduce the time in the bath; but only 34% usually reuse the water from the washing machine.

In regards to conscious consumption, six habits and behaviors were addressed, with 78% of participants usually buying household appliances that consume less energy. On the other hand, all other habits and behaviors evaluated receive less than 50% adherence. Those were: buy products that come in recyclable packaging (47%), buy products made from recyclable materials (30%); pay more for products grown without chemicals (25%); pay more for products and services that promote local development (20%); contribute money to organizations that take care of the environment (6%).

Two topics were also included there: the use of plastic bags, and trash and disposals. While 57% of the participants usually use recyclable shopping bags, only 24% do not use plastic bags; which showed the presence of the habit of using plastic bags. In the topic trash and disposal, all percentages were above 60%, with 77% of participants usually discarding batteries in appropriate places; 71% usually discard electronic devices, cell phones, and TVs in appropriate places; 69% usually separate household waste; and 61% usually separate cooking oil; the results indicated the commitment of the USP community also to the issue of waste.

The second approach evaluated suggestions for improving sustainability at USP and proposing methods of participation in favor of this improvement, presented at Table 4. The most important aspect of improving sustainability at USP, according to 71% of participants, was the use of selective waste disposal in all campus environments. For 55%, USP people should be sensitized for sustainability and 43% were willing to participate in social projects with the surrounding community. The other five aspects suggested improving sustainability at USP were seen as important by a third or less of the participants. Those were: reducing energy consumption in campus environments (36%), use more public transportation (33%),

**Table 3** USP community main household habits and behaviors in relation to sustainability

| Areas | Habits and behaviors | (%) |
|---|---|---|
| Energy | Turn off the lights when not in use | 95 |
| | Replace incandescent lamp bulbs with fluorescent ones | 86 |
| | Reduce energy consumption at home | 79 |
| | Turn off the computer when not in use | 75 |
| | Reduce gas consumption at home | 60 |
| Water | Close the tap when brushing the teeth or washing the dishes | 94 |
| | Avoid waste of water | 91 |
| | Not wash the yard and card using hose | 71 |
| | Reduce bath time | 65 |
| Conscious consumption | Buy household appliances that consume less energy | 78 |
| | Discard batters in appropriate places | 77 |
| | Dispose of electronic devices, cell phones and television in appropriate places | 71 |
| | Separate household waste | 69 |
| | Separate cooking oil | 61 |

**Table 4** Most important aspects of improving campus sustainability

| Aspects | (%) |
|---|---|
| Use selective waste disposal in all campus environments | 71 |
| Sensitize USP people for sustainability | 55 |
| Participate in social projects with the surrounding community | 43 |
| Reduce energy consumption in campus environments | 36 |

denounce prejudice and discrimination (31%), reduce personal water use (20%), and report abandoned animals on campus (12%).

Regarding to the methods of participation for the improvement of sustainability at USP, as presented at Table 5, half of the participants were willing to participate in awareness-raising and/or training campaigns (56%); to participate, when invited, in a periodic joint-effort with the USP community (49%); and to participate in planting of seeds, green areas on campus (48%).

Yet, little more than a third of the participants were willing to participate in the technical-administrative structure of environmental management linked to the administration of their unit (37%) and to be part of a regular working group with USP community (35%).

From the participants, 17% did not know/did not intend to help, which could be interpreted, in its inverse, as more than 80%, or four out of five people, as a high mobilization indicative for participation in improving campus sustainability.

**Table 5** Ways to improve USP campus sustainability

| | (%) |
|---|---|
| Participate in awareness-raising campaigns and/or training | 56 |
| Participate in periodic joint-effort with USP community | 49 |
| Participate in planting of seedlings/green areas on campus | 48 |
| Participate in the technical-administrative structure of environmental management | 37 |
| Sign requests with sign-in | 35 |
| Be part of a regular working group with the USP community | 35 |
| Does not know/ does not intend to help | 17 |

## 7 Conclusions

The study concludes that USP community's understanding of sustainability is based on two dimensions. On the one hand, there is the human dimension of sustainability, upon assuming the key concepts that make up, historically—since the Rio-92 Conference, the sustainability speech promoted by the UN and adopted by organizations in general. Therein understood both the intergenerational issue, with concern for future generations and the balance of the sustainability—economic, environmental and social pillars. On the other hand, there is the understanding that global sustainability passes through the recognition of the planetary dimension, a recent approach evidenced in the Rio+20 Conference, which deals with life in general on Earth and the threat of global warming and climate change.

Moreover, in making the choice of priorities for a better world, all items chosen, except water (access to drinking water and sanitation), and yet in a condition of personal use, refer to aspects directly related to the daily life of people: quality education, access to quality food, honest and active government, access to energy at home and improving health services.

In the matter of local sustainability, there are several domestic habits and behaviors linked to sustainability, adopted by more than two-thirds of the USP community; and most of them, by more than 90%. That is the case, for example, of switching off the lights when not in use, closing the tap when brushing the teeth or washing dishes, avoiding wasting water.

To improve sustainability at USP, the foremost concerns are the use of selective waste disposal in all campus environments, followed by the need to sensitize USP people for sustainability. On the other hand, actions such as the reduction of energy consumption on campus and even the reduction of personal water consumption are scarcely valued. Regarding the methods of participation towards improving sustainability at USP, the participation in awareness-raising campaigns and/or training, participation in periodic joint-efforts with USP community and participation in planting seedlings, green areas on campus have the sympathy of half the USP community.

The main lessons learned from the study are related to the fact that the daily individual practices remain strongly linked to the idea of sustainability in a global dimension. More than collective actions, the sustainability agenda is seemed as demands on social improvements- regarding pressure on governmental institutions —and behavior change on the citizens' level.

From this perspective, communication is fundamental. It is necessary to disseminate a notion of sustainability conceptualized in terms of daily activities linked to impacts on the planet and global/local environmental governance. These approaches, presenting the negative and positive outcomes of individuals and institutional actions, could contribute to clarify assumptions and change behavior towards a better world.

The study demonstrated to be an important resource not only to comprehend the understanding of the sustainability of the USP community but also as a channel for raising awareness on the theme, besides the mobilization on answering the survey itself. The study contributes both to the managerial aspect of sustainability at campuses, as SGA demands the implementation of practices with educational and communication efforts. And to the ongoing theoretical discussion related to communication and sustainability at universities, campaigns, and social participation.

As future research, CECORP intends to carry out an annual sustainability survey, which will be extended to other campuses in the countryside of the State of São Paulo. An important issue to be addressed in the near future is the new sustainability agenda, the SDGs. Who knows what? What targets and goals can be adopted as citizens and members of the university community? What orientation is expected of the university?

There is also the opportunity to go one step further in the sustainability dialogue and communication practices, through public presentation of the results, with open sessions of reflection on the data obtained, involving faculty, employees, and students of USP community in search of a more sustainable personal and university life.

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## Author Biographies

**Professor Margarida Maria Krohling Kunsch (B.Sc., M.Sc., Ph.D.)** Full Professor at School of Communications and Arts of University of São Paulo (ECA-USP). Former Dean at ECA-USP. Professor in Theories and Processes of Institutional Communication at ECA-USP. M.Sc. and Ph.D. in Communication Sciences at ECA-USP. Research scholar registered at the National Counsel of Technological and Scientific Development (CNPq) at level 1B. Head at research group Center for Studies on Organizational Communication and Public Relations (CECORP) at ECA-USP.

**Dr. Iara Maria da Silva Moya (B.Sc., M.Sc., Ph.D.)** in Communication Sciences at School of Communications and Arts of University of São Paulo (ECA-USP). B.Sc. in Sociology. M.Sc. in Hospitality at University Anhembi Morumbi (UAM). Specialist in Sociodrama/Pedagogical Dramatherapy—Role Playing. Specialist in Social Management (INDES/BID/ONU). A researcher at Center for Studies on Organizational Communication and Public Relations (CECORP) at ECA-USP. Researching sustainability and social responsibility since 2003.

**Dr. Vivian Paes Barretto Smith (BA, M.Sc., Ph.D.)** in Communication Sciences at School of Communications and Arts of University of São Paulo (ECA-USP). M.Sc. in Environmental Science at Graduate Program on Environmental Science of University of São Paulo (PROCAM-USP). A researcher at Center for Studies on Organizational Communication and Public Relations (CECORP) at ECA-USP. A researcher at the Stakeholder and Network study group at School of Economics, Business and Accounting of the University of Sao Paulo (FEA/USP). Post Graduate Professor at SENAC.

# UFSC Micro Basin—A Preliminary Study: A Stream to Call It Ours

**Ariane Laurenti, Victor Ybarzo Fechine, Aline Gonçalves C. de Vasconcelos, Franciele dos Santos, Marjana Cavalleri, Mateus Reis and German Gregório Monterrosa Ayala Filho**

**Abstract** The object of this study was the micro basin of *Campus* UFSC, component of the surface slope and drainage network of Itacorubi Hydrographic Basin (HB) in Florianópolis city (Brazil). The HB is the unit of planning and environmental management preferred, but the establishment of a sub unit as the *Campus* UFSC micro basin can be exemplary. The objective of this exploratory research conducted between April and July 2011, was to characterize and locate the water

A. Laurenti (✉)
Centro de Ciências da Saúde - Departamento PTL,
Federal University of Santa Catarina – UFSC,
Trindade, Florianópolis, SC 88040-960, Brazil
e-mail: ariane.laurenti@ufsc.br

V. Y. Fechine
Departamento de Engenharia Sanitária e Ambiental,
Federal University of Santa Catarina – UFSC,
Sala 062 – CTC, Trindade, Florianópolis, SC 88040-900, Brazil
e-mail: victorybarzo@gmail.com

A. G. C. de Vasconcelos
Servidão Arlindo Manoel Vieira, 234, Itacorubi,
Florianópolis, SC 88034-685, Brazil
e-mail: alinegcvasconcelos@gmail.com

F. dos Santos
Rua Germano Klann 270, Águas Claras, Brusque, SC 88357-140, Brazil
e-mail: fran_dsantos@hotmail.com

M. Cavalleri
Rua Senador Alberto Pasqualini 156, Botafogo, Bento Gonçalves
RS 95700-598, Brazil
e-mail: marjana_cavalleri@hotmail.com

M. Reis
R. Joe Collaço 478, Santa Mônica, Florianópolis, SC 88035-200, Brazil
e-mail: mateussreis@gmail.com

G. G. M. A. Filho
R. Engenheiro Max Gerken 66, Glória, Joinville, SC 89216-045, Brazil
e-mail: gg.ayala@gmail.com



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drainage network contributors of micro basin of the *Campus*, select the main and associate them with environmental indicators. 72 source points of water contributions to the formation of the *Campus* UFSC micro basin were identified, photographed, georeferenced, mapped and organoleptically characterized. Surrounding critical areas in the public health sphere—as well as socio-cultural and landscape patrimony, quality of specific ecosystems and local economy—were identified. This study proposed environmental indicators in order to guide a plan for conducting water quality diagnosis and identification of factors that negatively impact the aquatic ecosystem of UFSC C*ampus*. The construction of environmental and sustainability indicators for the study of environmental conditions in this area is necessary and urgent, because it is a tool of great importance for driving programs working towards the recovery and revitalization of the Itacorubi HB and in the monitoring of its development.

**Keywords** Micro basin UFSC · Higher education and sustainability
Environmental indicators · Water pollution · Hydrographic basin

## 1 Introduction: Hydrographic Basin as a Space for Environmental Studies

In Brazil, income inequality and social exclusion are factors that drive flows of migratory population movements from rural areas or small urban centers towards large cities and, more recently, from large cities to small and the medium-sized ones, which offer better employment opportunities (Braga 2006). In addition, the lack (or inexistence) of an environmental public policy as a support for urban territorial management and planning has led to the expansion of new urban centers in an environmentally and socially inefficient way (Nascimento and Vianna 2009; Mireya et al. 2014).

Merely technical solutions have not been enough to promote sustainable development of urban areas in Brazil. Based on this fact, the concept of sustainable development would not be enough to overcome the ecologically unsustainable rational economic model, although being born of an environmental crisis generated by an economically inefficient, environmentally damaging, and socially perverse productive process. In order to add theoretical consistency to the understanding of socio-environmental sustainability, it is necessary to deepen the understanding relevant connections between natural, social and exact sciences with politics and economy.

Universities are important references for society, whereas they are preserved as important centers of knowledge. These institutions produce solution to the problems experienced by society, as an opportunity to improve life quality, as well as a place of people education. In that sense, universities realizations and how they are performed will act as a parameter for many sectors of society (Sorentino et al. 2011).

However, as discussed by several authors (Leff 2001; Tauchen and Brandli 2006; Albareda et al. 2017; Braßler and Block 2017), within the framework of the university system, there is a set of difficulties to the formation and work of interdisciplinary teams. This issue ranges from the holistic approach—necessary for social and environmental sustainability—to the lack of a knowledge capable of expressing the complexity of interactions between natural and social systems.

Limited and partial nature of disciplinary knowledge, by not grasping the connections between social and natural aspects, has restricted itself to internalizing ecological and technological norms, sometimes disregarding a social conflict analysis, as well as the political dimension that permeates environmental field (Leff 2001). In these difficult circumstances, acting in an interdisciplinary way does not mean a secured path to the formation of a group with a different disciplinary knowledge, but only the construction of a process that focuses on the object of study in an interdisciplinary way. In this sense, connections are established between the direct object of an action and problem generation/overcoming forces.

It is always a great challenge to find the best way to express environmental degradations caused by human intervention. This issue is due to the different levels of degradation, which range from a milder disturbance to situations when ecosystem is completely destroyed.

The establishment of a Hydrographic Basin (HB) as a territorial unit of environmental planning and management was a technical attempt to overcome the understanding that anthropic actions would be restricted to the point of intervention, as well as its positive or negative impacts. In the words of Yassuda (1993), the hydrographic basin is the unitary stage of interaction between water and physical, biotic, social, economic and cultural environments. This fact allows an assumption that it is not possible to treat the environment dissociated from anthropogenic actions and from the interdependence between natural ecosystems and civilizational development.

Itacorubi HB has registered one of the highest urban expansion rates in Florianópolis. UFSC, as well as other public and private institutions, have been the main motivators of this expansion in the region (Florianópolis 1994; Santos 2003; Collares et al. 2004). This basin is included in part of the sewerage network of Florianópolis since 2003, but it has not been enough to assure water quality. Despite the high number of important and large-scale institutions located within Itacorubi's HB, the protection of its waters from contamination caused by sewage generated from economic activities and residences is not avoided (Laurenti 1993; Bueno 2000; Cristo 2002; Florianópolis 2009).

Although the delimitation of an ecoregion is facilitated by a territorial definition of a BH, ecological features observed at smaller scales—such as in micro or sub-basins—may also provide management subunits to solve localized environmental problems (Calijuri and Bubel 2006). Therefore, this project delimited UFSC *Campus* micro basin as the territorial base for the environmental unit to be studied. Moreover, this restriction is also justified by limitations of the project itself, that is, to be carried out in only 4 months, without any financial aid and exclusively by voluntary students and the research professor.

Environmental indicators and descriptors are widely used to estimate the conditions of natural and social ecosystems. In this way, these tools can assess impacts, formulating, planning and implementing environmental (preventive or curative) policies and strategies. Later, it is possible to evaluate the performance of proposed policies and actions (IBGE 2002; OECD 2003).

Descriptors are generic and qualitative characteristics of the system that represent and guarantee their stability. The indicators collaborate in the investigation of the characteristics that will give significance to the chosen descriptors, providing simple and synthetic information on the environmental condition of the studied environment. Since there is no set of global indicators adaptable to any reality, it is necessary to evaluate and analyze the context (social, economic, cultural) where environmental systems are inserted. It happens because they describe specific processes, for which they are applied in a particular way.

Depending on the theoretical model adopted, environmental indicators are constructed within restrictive or broad concepts. Conceptual models have evolved from the most simplistic ones, like PSR (Pressures, State, Response) (OECD 1993), to more complex ones, like DPSIR (Driving forces, Pressures, State, Impact, Response) (PNUMA-CIAT 1996; Smeets and Weterings 1999).

DPSIR model allows usage of several categories of indicators: (a) direct or indirect causes associated with environmental state (pressures linked to human activities); (b) environmental quality (natural environment condition or state); (c) impacts of anthropic activities on the environment (negative or positive effects); (d) actions (responses and remedial, prospective and alternative policies). In this way, the DPSIR model can perform an integrated environmental assessment, considering both the human activity sectors that generate driving forces and pressure elements that generate impacts on the state of the environment (living conditions of human populations, ecosystems, and natural reserves), which require responses of different types and levels.

Although this study has carried out activities in the field for the environmental and social data collection in the region, they are not discussed in this article. This article will address only the opportunity of proposition of environmental indicators obtained from socio-environmental observations, like developers and advisors for a planning stage of the diagnostic study of socio-environmental ecosystems.

A debate about the genesis of inefficiency of public policies on urban spatial planning and its influence on social and environmental quality goes far beyond the intention and capacity of the study.

The motivation to carry out the project approached by this paper was born out of the desire to contribute to life quality and citizenship of marginalized and impoverished populations around UFSC micro basin. Additionally, it is also intentional to contribute to the construction of an institutional environmental policy for UFSC.

In fact, two important initiatives, between 2012 and 2014 and still in progress, promoted by the UFSC Central Administration were strongly inspired by this research, in the environmental area, covering the UFSC *Campus* micro basin and neighborhoods surrounding the Institution.

One of them was the signing of a Protocol of Intent between UFSC and the Municipality of Florianópolis, where the University conditioned the transfer of part of its territory to the region's road expansion, only if the Municipality and Catarinense Water and Sanitation Company (CASAN) would expand the current sanitation network to all districts adjacent to the *Campus*, due to problems of streams contamination by sewage coming from surrounding urban agglomerations. The other initiative was the financing of an institutional development project entitled "Recovery Project of Water Quality on Streams of Reitor João Davi Ferreira Lima Campus".

## 2 UFSC Micro Basin

UFSC university community is represented by 40,000 people, including students, technical and administrative staff, teachers, and outsourced service staff. The surrounding region concentrates various economic activities of the tertiary sector (commercial and services) and houses federal, state and municipal government agencies. UFSC *Campus* micro basin (Fig. 1) is a component part of Itacorubi drainage basin, which has a total area of 26.582 $km^2$.

The drainage micro basin receives contribution of streams originated in a few hills surrounding the C*ampus*, which also cross several residential neighborhoods (Pantanal, Trindade, Córrego Grande, Carvoeira and Serrinha) with a great heterogeneous social formation. The main stream, called Rio do Meio, runs about 4.0 km and crosses the *Campus* in a south-north direction, being recharged by the tributaries Serrinha, Pantanal, Cesar Seara, Eletrosul, and Carvoeira, which mouth is Itacorubi Mangrove.

The micro basin is located between the geographic coordinates 27°35′–27°36′ S latitude and 48°30′48°31′ W longitude, with an area of 6.023 $km^2$, and hydrographic network of 17.413 km (LABDREN 1997a, b). Other of the basin characteristics are in Table 1.

## 3 Research Methods—Field Activities

This study was based on exploratory and descriptive research, involving bibliographic consultation and field observations. The field research, with predominantly qualitative characteristics, occurred between 04/2011 and 07/2011. Field activities involved:

(a) **identification, description, photographic registry and georeferencing of water contributions components of the UFSC *Campus* micro basin**: 72

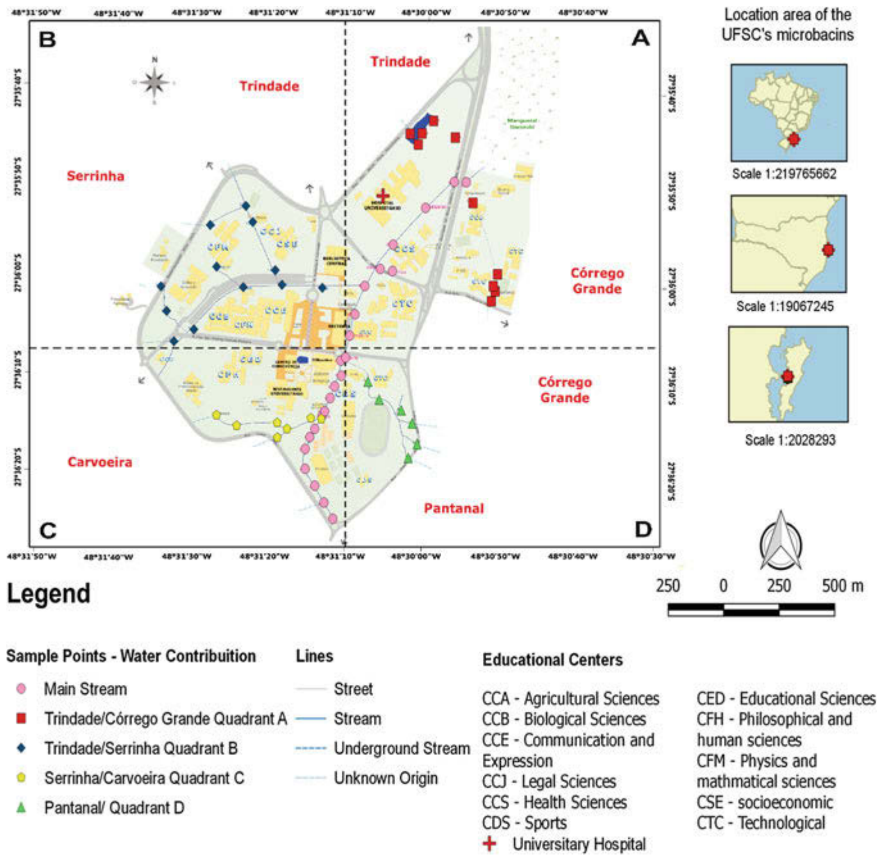


**Fig. 1** 72 hydrographical contribution points within UFSC micro basin, divided by quadrants A, B, C, D, and "Rio do Meio". *Source* Adapted from LABTATE base map: http://labtate.ufsc.br/. Georeferenced points overlapped in satellite image

points of water contribution were identified. Water contributions: every water flows from pipelines, ditches, channels, tributary streams or any other means merging into the main course, Rio do Meio. Every analysis was carried out on non-rainy days, and the volume of precipitation and atmospheric temperatures considered were those of two days before the field trips.

(b) **organoleptic (color, odor, turbidity) and thermal characterization of the samples:** Odor, color, and turbidity characterization were sensorially obtained and were associated with a scale of values from 1 to 3 according to Table 2. Odor classification: the sample was inhaled immediately into the collection container itself by at least three of the team participants. Color and turbidity: an aliquot of the collected sample was versed inside a 250 ml Erlenmeyer flask up to the 150 ml mark and compared side by side, on white paper and under natural light, compared to another one containing distilled water. Water

**Table 1** UFSC micro basin main characteristics (Adapted from LABDREN 1997a, b)

| Parameter | UFSC micro basin | Unit |
|---|---|---|
| Drainage area | 6.023 | $km^2$ |
| Hydrographic network length | 17.413 | km |
| Perimeter | 13.015 | km |
| Compactness coefficient | 1.48 | |
| Form factor | 0.294 | |
| Drainage density | 26.22 | $km/km^2$ |
| Average length of runoff | 26.22 | km |
| Average mean slope | 0.18 | m/m |
| Max elevation | 446 | m |
| Min elevation | 1.3 | m |
| Drainage basin source elevation | 88.5 | m |
| Drainage basin mouth elevation | 4.7 | m |
| Distance from basin source to mouth | 3.531 | km |
| Total slope | 18.51 | m/m |
| Main river sinuosity | 79.7 | % |
| Highest Strahler's stream order | 4 | |

**Table 2** Scale of values attributed to the odor, color, and turbidity of water samples collected in the micro basin of *Campus* UFSC

| Parameter | Sensory attribute | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Odor | Odorless | Moderate to unpleasant | Very unpleasant |
| Color | Colorless | Gray or brownish | Dark brown to black |
| Turbidity | Translucent | Translucent to turbid | Very turbid |

*Note* Samples associated with numbers 2 and 3 were considered possibly contaminated by wastewater

temperature: obtained by immersion of Hg thermometer into the samples collected at the water contribution points.

## 4 Research Methods—Data Treatment

For data treatment, a few definitions were made, including:

(a) **definition of environmental descriptors or indicators**: Conceptual model DPSIR was selected, interrelating the essential or primordial properties of the ecosystem to the urban expansion (environmental quality × living conditions). The choice of the environmental pressure indicators guided the others (state,

**Table 3** Quadrants symbology representation for data displayed in Fig. 1

| Quadrant | Symbols | Neighborhood | Points |
|---|---|---|---|
| A | ■ | Trindade/Córrego Grande | 1–11 |
| B | ◆ | Trindade/Serrinha/Carvoeira | 1–14 |
| C | ⬟ | Carvoeira/Pantanal | 1–8 |
| D | ▲ | Pantanal | 1–7 |
| Rio do Meio | ● | | 1–32 |

impact/effect, response) after analyzing the significant characteristics of local elements, which attributes could describe both dimensions of stress on the environment and aspects related to environmental sustainability, and living conditions of surrounding population (impacts, responses). All of the indicators (pressure, status, impact, response) are followed by the IN, EX or IN/EX labels, which respectively mean: UFSC indicator, indicator external to the UFSC Campus, and indicator for both.

(b) **graphic expression of results**: the 72 sampled points, previously photographed and georeferenced were recorded cartographically, overlapping the quadrants of the generated map, from the modification of a map produced by LABTATE/UFSC. The spots were previously positioned on the area's satellite image using Google Earth software. The micro basin was divided into four quadrants, each one containing a main streamflow. The quadrants relate water contributions of external sources (neighborhoods around the *Campus*) or internal to UFSC, to the tributaries of and to Rio do Meio (Fig. 1). The sampling points respect an individual numeration, in ascending order, into the direction "Neighborhood-Rio do Meio". Rio do Meio, through crossing the *Campus* and being present in several quadrants, received a number and color of its own, regardless its position. Table 3 represents how each quadrant was displayed in Fig. 1 data.

## 5 Discussion of Research Findings

The circumstances of non-existence of an interdisciplinary team and basically formed by undergraduate students, therefore technically limited, imposed an alternative formulation: to design a project which focus on the object of study was transdisciplinary.

The unified motivation of the team revolved around two aspects: the inexistence of a socio-environmental policy guided by the institution, reflected in the inefficiency of sectoral policies for internal environmental demands in relation to the *Campus* environment; The aspiration of students majoring in Sanitary and Environmental Engineering for a model of "Sustainable UFSC".

From the pedagogical point of view, we sought to adopt a holistic approach to address the complex interrelationship between society and nature and, technically, delimited the microbasin of UFSC *Campus* as a unit space fundamental to the study.

Itacorubi HB has been undergoing an uncontrolled urbanization mainly since the 1980s. This uncontrolled advance exerts pressure on forest ecosystems and mangroves, demanding investments in inspection and basic infrastructure by public authorities. The deficiency of the adopted public policies is reflected into the increase of the environmental and social degradation: deforestation on slope instability; increase in population density; occupancy of environmental preservation areas; formation of areas of poverty generating neighborhoods or areas with poor housing standards and basic infrastructure; increased crime rate; insufficient basic sanitation services (drinking water, sewage, urban drainage, and waste management); contamination of waters in rivers and streams which are form the Itacorubi Hydrographic Basin and UFSC *Campus* microbasin.

The environmental dimension of the disorganized expansion over the microbasin, resulting from socioeconomic factors (unequal distribution of income in Brazil, rural exodus, lack of municipal territorial and environmental planning), generates pressures and impacts, even to different degrees, on the ecosystem. The runoff drained to the microbasin, originated mainly in the surrounding hills, flow to the lower parts forming new streamflows delineated by occupation and deforestation, and follow towards the formation of a central river that crosses the *Campus*, "Rio do Meio". Rio do Meio, in its flow, receives contributions from tributaries until it meets the mouth at Itacorubi Mangrove. Soil sealing, deforestation, and lack of sanitation have increased the volume of runoff and flooding of lowland areas, the contamination of surface waters by sewage effluents, erosion and silting of canals, contamination of Itacorubi Mangrove, besides other calamities (Cristo 2002).

The social dimension of this type of urban expansion assumes even greater proportions, given that "the environmental conditions affect human health and well-being, both directly, for instance through pollution, and indirectly, through adverse effects on ecosystems, biodiversity or even natural Disasters and industrial accidents (Eurostat 2015). From the point of view of human relations, degradation is expressed in the increase of robberies and drug traffic, indicating high crime and lack of public safety.

Although the monitoring of physico-chemical and biological parameters has not been carried out, which certainly limits construction of indicators and may make it impossible to analyze the sensitivity of state indicators in relation to changes in the pressures that will guide management actions, this project considered that the DPSIR (Driving Forces, Pressures, State, Impact, Response) conceptual model allows preliminary proposition of environmental descriptors, from observations of environmental phenomena and some measurements in the field, as well as analysis of physical, chemical and biological data. 72 water contribution points were identified, some of which not previously recorded, possibly due to the lack of relevance. However, from the environmental point of view these small contributions can not be neglected and therefore were considered by this study.

It was evidenced by the analysis of bibliographical data that the set of pressures and impacts occurring in the microbasin is a result of social inequality. In this case, this inequality is locally aggravated by the lack of urban planning and investment in basic infrastructure. However, the indicators suggested in this study intend to focus on the pressures to propose a monitoring program and actions that can mitigate the environmental and social impacts in the area.

It was also verified that it is possible to treat the indicators in three areas: (a) internal (IN)—where the pressure and impacts are derived exclusively from the UFSC and therefore the responses are the initiative of the institution; (b) external (EX)—where the pressure and impacts come from the neighborhoods and whose response requires the intervention of governmental powers and the supervision of environmental agencies external to the UFSC; (c) Mixed (IN/EX)—where pressures and impacts may be (or not) generated internally, but the response depends on actions that may or may not include UFSC and an external institution.

During the field study, the division of the quadrangle microbasin showed that there were similarities between them so that it was possible to propose a set of general descriptors rather than specific ones per quadrant. In all quarters, critical points of significant impact on public health, socio-cultural and landscape heritage, the quality of specific ecosystems, and the local economy were identified.

The descriptive pressure chosen to express environmental and social degradation of the area was the urban expansion, with pressures on: land use and occupation, water resources, and basic infrastructure and public safety. The most expressive and visible impacts of the pressure on land use are: irregular buildings, deforestation, erosion, frequent flooding, landscape disintegration and landfill of the Itacorubi Mangrove.

Morphometric characterization of the hydrographic basin is an important study in hydrological or environmental analyses, and aims to elucidate the issues related to the local and regional environmental dynamics, especially in relation to erosion and floods. However, the hydrological behavior of a HB is not only a function of its geomorphological characteristics and its type of vegetation, but it is also affected by anthropic actions, since interventions in the natural environment interfere in the processes of the hydrological cycle. In this sense, UFSC is not only one of the most important institutions within the Itacorubi Basin, but it is a major responsible for the pressure on the real estate expansion of the region.

The loss and degradation of the mangrove habitat, by occupying its area for urban expansion in general and that of UFSC buildings in particular, is a critical problem for the University. Some examples of how UFSC interfered in this environment in the past, even legally supported,[1] were: the construction of aquaculture

[1]Since 1969 UFSC has been legally in possession of the Itacorubi Mangrove, granted by the Federal Government by Federal Decree No. 64340 for "housing the Teaching and Research Centers and other planned bodies, due to the new concepts of the University Reform…". Since

tanks of the Department of Aquaculture (CCA), now deactivated; the building Institute of Biomedical Engineering; the construction of an animal house and a Central Warehouse; and the channeling and rectification of several watercourses. More rectilinear courses tend to carry more sediment and export suspended material to the mangrove.

Impacts related to land use and occupation, such as erosion and flood events were verified in the *Campus* microbasin. Floods are quite frequent, especially during the summer (Vieira 2007). Erosion processes in the basin were located mainly in the C quadrant, and in less crowded areas, on the banks of the unpaved canals, where the tree roots then emerged.

The intensity of soil water erosion depends mainly on rainfall, soil type, topography, and vegetation cover. Therefore the relationship between rainfall erosivity and soil erodibility, when combined with deforestation, is substantially increased and the erosion process accelerated. In addition, the microbasin has low drainage capacity, a low slope relief, shallow channels and rocky or waterproof soil, which makes it difficult to infiltrate and then favors runoff. As a result, there is greater susceptibility to flooding and erosion, especially when receiving high volumes of water during rainfall. It is possible to discipline the streamflow by containing the banks on one hand and, on the other hand, to facilitate the infiltration of the water in the soil, besides providing growth and the increase of the soil cover with proper vegetation for eroded soils.

UFSC Master Plan, presented in 2013, showed the territorial occupation rates for buildings and preserved areas, and the potential of using the territory still available in the *Campus* microbasin. So there is a call to take it back immediately. The evidence, however, is that the entire microbasin is in permanent modification and urbanization, and that its expansion totally lacks planning.

The environmental pressure descriptor "water resources and infrastructure" is also applicable in all of the four quadrants. Although the greatest contribution to changing water quality comes from the surrounding districts, there is also the contribution of UFSC itself.

Until 2003, prior to the connection to the insular sewerage network of Florianópolis, part of the effluents served by UFSC (laboratories, kitchens, toilets, etc.) were collected in septic tanks. However, some of these effluents, mainly small kitchens and some laboratories, were dumped into pipes flowing into the channels of the microbasin that flows into the Mangrove. During the field research, it was verified the existence of points of wastewater into the streams, which seem to originate from nearby UFSC buildings: the cooling system of the CERTI Foundation's power plant, the University Restaurant, the Publisher of UFSC and the Centers of Education CSE, CFM, CCS and CDS.

Water from the streams and pipes from surrounding neighborhoods, which enter the *Campus*, were characterized as containing wastewater. This was justified by the

2002, with the creation of the Itacorubi Mangrove Municipal Park, mangrove management is being shared with the Florianópolis Municipal Government.

foul odor, milky and grayish coloration, and presence of foams. Inside UFSC *Campus*, contaminated water runs through the channels in shallow water mirrors and waterproofed grounds, covered with mud.

The color and odor of water inflows outside *Campus* showed clear indications of contamination by sanitary sewers. The waters of natural courses—when there's prevalence of organic colloids (humic and fulvic acids) and inorganic compounds such as iron and manganese oxides—appear brownish, but translucent and odorless. When water is contaminated with domestic effluents, it predominates colloidal matter and other materials that cause turbidity and a characteristic coloration, generally grayish and milky, as well as foam.

Temperature variations are part of the normal climate regime, and natural water bodies exhibit seasonal and diurnal variations, also varying according to flow and depth. In this way, its temperature is close to atmospheric or lower. When contaminated by industrial or domestic effluents, temperature is generally higher than that of running water. In this sense, it was considered that waters which had a temperature higher than atmospheric one had a great possibility of receiving waste water.

For the pressure indicator related to "water quality" and "basic infrastructure", it is possible to act on state indicators. According to the type of pollution expected, it is possible to propose the variables to be monitored. By associating the legal compliance indicator (CONAMA 2005), which is an obvious criterion because one of the aspects always present in a management process is compliance with legal regulations, a good degree of balance was achieved in the relationship between the state Ecology, aquatic quality and public health. Moreover, the association between the indicator of pollutant loads and that of compliance with the legislation is particularly interesting, since it not only identifies possible non-compliance with legislation, but also points out situations that require special attention.

In addition, the state indicators: "pollutant loads" (for domestic sewage, gas station effluents and mechanical workshops, and pesticides used in combating vectors or in family farming), "dilution capacity" and "compliance with Legislation" take into account the possibility of pollutants generated in local economy and the fight against vectors for public health, the sensitivity of the water body to pollutant loads (residence time and concentration) and legal control over generators.

Finally, the descriptor of "public security", originated externally to the Institution, exerts its influence on life quality of the university community in two ways: directly within the Institution's territory; and outside, because a significant part of it inhabits the surrounding neighborhoods. The urban occupation of the Itacorubi HB area is characterized by a high population density of diverse social composition, which also conditions the analysis of urban pollution. In lower areas of the basin, we have denser neighborhoods, due to verticalization of residences and a strong composition of middle and upper middle class, sectors (Trindade; Carvoeira; Pantanal; Parque São Jorge; Itacorubi; Morro do Mangueirão in Pantanal; Morro do Quilombo in the Itacorubi; Morro da Cruz near the Penitentiary; and Morro da Serrinha near Carvoeira and Trindade) of smaller population density due to the horizontal residential units, but not less clustered, since properties are small. By reproducing what is happening in large cities, workers, students and criminals, especially drug traffickers, co-inhabit; the last ones identifying potential young clients in these neighborhoods. UFSC has programs that help drug users of the university community and outside it an unofficial program of car washers. However, for acts of vandalism, robbery and drug trafficking, which are becoming more frequent, only palliative proposals such as, for example, the isolation of the Institution by fences or ostensive policing are suggested. A Global Institutional Socio-Environmental Political Project (GISEPP), which performs the interface of the university community-local community environment, could be an alternative capable of coping with the social pressures that contribute to the degradation of the general quality of the environment and, finally, affect the Biodiversity.

**Table 4** Environmental indicators proposed for the micro basin system at UFSC *Campus*

| Descriptors | | Indicators | | |
|---|---|---|---|---|
| Forcing | Pressure | Impact | State | Answer |
| Disordered urban sprawl | Occupation and land use | Suppression of mangrove area (IN; EX) | Habitat loss and fragmentation (Biodiversity) (IN; EX; IN/EX) | Institutional social and environmental policy from UFSC (IN) |
| | | Irregular constructions (EX) | % Deforested area (IN; EX; IN/EX) | Master Plan of the UFSC *Campus* (IN) |
| | | Occupancy of risk areas (EX) | N. of floods (IN; EX; IN/EX) | City Master Plan (EX; IN/EX) |
| | | Ditches with black and gray sewage runoff (IN; EX; IN/EX) | Geomorphological changes (IN; EX; IN/EX) | Reallocation of the composting system (IN) |
| | | Habitat loss and fragmentation (Biodiversity) (IN/EX) | Composition and soil type (IN; EX; IN/EX) | Monitoring and management of the mangrove (IN/EX) |
| | | Erosion points (IN; EX; IN/EX) | % Area eroded in the CFH forest (IN) | Development of projects and curricular subjects in the area of knowledge (IN) |
| | | Floods (EX) | Population density (IN; EX; IN/EX) | Development of inter and transdisciplinary research and extension projects for the micro basin environment (IN; IN/EX) |
| | | Deforestation (IN; EX; IN/EX) | Migratory flow (IN; EX; IN/EX) | Depletion of the micro basin and the Mangrove (IN; IN/EX) |

(continued)

**Table 4** (continued)

| Descriptors | | Indicators | | |
|---|---|---|---|---|
| Forcing | Pressure | Impact | State | Answer |
| Disordered urban sprawl | Occupation and land use | Expansion of CAMPUS (IN) | N. of households served with water supply, sewage and garbage collection (EX; IN/EX) | Social registration (EX) |
| | | Composting system (IN) | Quality of housing | Public policies of urban settlement (EX) |
| | | Stagnant pond HU (IN) | | |
| | | Landscape disintegration | | |
| | Water resources and infrastructure | Water contamination (IN; EX; IN/EX) | Water quality parameters (CONAMA, 357/ 2005) (IN; EX; IN/ EX) | All of the above and MORE: |
| | | Waterproofing of soil (IN; EX; IN/ EX) | % Deforested area (IN; EX; IN/EX) | |
| | | Basic infrastructure (sewage, potable water and waste collection) (EX; IN/EX) | N. of households served with basic sanitation (water, sewage and waste collection) (EX) | Restructuring of the use and quality of HU pond (IN) |
| | | Insect proliferation (EX; IN/EX) | Capacity of water course dilution (IN; EX; IN/EX) | Restructuring of the drainage system (IN/ EX) |
| | | Decrease in the use of the forest area of the CFH for leisure (IN; IN/EX) | Organic and metallic pollutants (IN; EX; IN/EX) | Monitoring of waters in the watershed (IN) |
| | | Pollutants of external economic activity (EX; IN/ EX) | Drainage system (EX; IN/EX) | Inspection of polluting economic activities (EX) |
| Disordered urban sprawl | Water resources and infrastructure | Legal disagreement (IN; EX) | Water flow on canals (IN; EX; IN/EX) | Permanent collection of solid waste from the canals (IN) |
| | | | Canal height variation (IN; EX; IN/EX) | Restructuring of use and quality to the UFSC Forest (IN) |

(continued)

**Table 4** (continued)

| Descriptors | | Indicators | | |
|---|---|---|---|---|
| Forcing | Pressure | Impact | State | Answer |
| | Public safety | Increased theft and robbery (IN; IN/EX) | N. of students and/or care of users of legal and illegal drugs (IN) | Construction of the UFSC bicycle rack (ARQ/UFSC project) (IN) |
| | | Decrease of external leisure areas (IN) | N. of workers and/or service of users of legal and illegal drugs (IN) | Internal policy for coping with drug use (IN) |
| | | Trafficking and drug use (IN; IN/EX) | Level of forest use for leisure (IN) | Policy to combat drug trafficking (IN; IN/EX) |
| | | Precarious housing for low-income students (IN) | N. of indoor and outdoor leisure areas at UFSC (IN) | Master Plan for UFSC (IN) |
| | | Accessibility of disabled people (IN) | Quality of student housing (IN) | |
| | | | N. of students attended with scholarships (IN) | |
| | | | N. of health care of the population due to infection or infection (EX; IN/EX) | |

*Note* (IN) refers to UFSC indicators. (EX) refers to external indicators. (IN/EX) refers to indicators for both UFSC and external

The socio-environmental indicators suggested and presented in Table 4 can assist in the evaluation of natural and anthropic impacts of occurrence in the area, and collaborate in a Management Plan for the Itacorubi Basin/UFSC *Campus* Microbasin.

## 6 Conclusion and Recommendations

The Itacorubi HB, from the hills to the Itacorubi Mangrove, shows signs of compromise, particularly accelerated by uncontrolled urban sprawl. This unbridled advance translates into indicators of environmental and social degradation in the basin such as: deforestation of slopes; increase of population density in areas of environmental preservation by migratory flows; lack of sanitary infrastructure; water pollution; formation of concentrated areas of poverty; increased crime, among others.

For the basin scale the use of indicators is desirable as a tool for Itacorubi Basin Management Programs, as well as for UFSC *Campus* Microbasin. Systematic monitoring of water quality is a procedure that will allow monitoring the performance of the suggested response and pressure indicators.

One of the important results of this research, was to have been an inspiration for Central Administration of UFSC, that between 2012 and 2014, promoted two projects, still in progress, very important for the environmental quality of the *Campus* microbasin and nearby neighborhoods.

Despite this, much still needs to be done by the institution. The construction of an environmental policy by UFSC may generate programs outside the university, it is recommended a set of corrective and proactive educational and technical actions in the environmental, public health and basic sanitation fields: an integrated monitoring program, involving UFSC, and municipal and state environmental agencies from Itacorubi HB and *Campus* UFSC micro basin; redefinition and rehabilitation of the UFSC micro basin; a geographical approach regarding land use planning; an ecological approach to ensure a new ecological balance; and, finally, social and ethical approaches to ensure social well-being through physical spaces.

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## Author Biography

**Professor Ariane Laurenti** lecturers on Toxicology (Department of Pathology) at the Federal University of Santa Catarina (UFSC) since 1997. She has a major in Chemistry (Bachelor and Licentiate) from UFSC and a Ph.D. in Environmental Sciences from Università Degli di Venezia—Italy (1993). Ariane also holds the position of Socio-Environmental Management Advisor at UFSC since 2013, representing this institution in environmental matters involving government agencies and the Federal Public Ministry. Currently, her activities are focused on the didactic-pedagogical field, with the development of research projects and actions in the environmental area.

# Experiences in Sustainability of Two Public Universities in Different Contexts: The University of Copenhagen and the University of São Paulo

**Silvia Sayuri Mandai and Fernanda da Rocha Brando**

**Abstract** Universities, especially the public ones, play an important role in the formulation and implementation of public policies of Sustainability, and in teaching people who can act in the construction of sustainable societies. The purpose of this study was to establish relationships between the realities of two public universities in different contexts, the University of Copenhagen (UCPH) and the University of São Paulo (USP). Then, internships were taken at both universities, UCPH and USP, from 2015 to 2016. We made observations and dialogues, and analyzed reports, books, as well university environmental policies, strategies and practices on sustainability. Based on these two experiences, it was possible to identify convergences and divergences between policies, strategies, and practices related to sustainability. Here, some categories were discussed: the context of each University influencing its actions, sustainability offices, as well their goals, plans, and strategies for biodiversity protection, environmental education, waste management and cooperation related to sustainability. It has been noticed challenges for universities to integrate sustainability into education, research, outreach activities, direct campus operations, and community involvement. However, UCPH and USP are trying to overcome and improve them.

**Keywords** Planning · Public policies · Sustainable development
UCPH · USP

S. S. Mandai (✉) · F. da Rocha Brando
Department of Biology, Faculty of Philosophy, Sciences and Letters
at Ribeirão Preto (FFCLRP), University of São Paulo,
3900 Bandeirantes Avenue, Ribeirão Preto, São Paulo, Brazil
e-mail: silvia.mandai@usp.br

F. da Rocha Brando
e-mail: ferbrando@ffclrp.usp.br

 
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# 1 Introduction

## *1.1 Universities and Sustainability*

Urban growth has faced many problems, especially the lack of planning in urban centers. So, many obstacles need to be overcome. Issues such as water crisis, waste management, energetic use and biodiversity conservation have been debated. In this perspective, the term "sustainability" has been widely used and, in general, is associated with the fact of attending present needs without compromising future generations (World Commission on Environment and Development 1987). In other words, attitudes that can support human needs and activities throughout the generations, taking into three main factors: economic development, social improvement and environment protection (World Commission on Environment and Development 1987).

Although large-scale measures are controlled by the major decision-makers, as politicians and businessmen, a change at individual level is significantly important. This is related to critical thinking and small changes that can achieve relevant movements towards the improvement of the country, in a process of shared management and planetary citizenship.

In this context, the universities, especially the public ones, play an important role in the formulation and implementation of public policies on sustainability. Furthermore, it is important training people who want to work in the construction of sustainable societies (IARU 2014). In special, young people are considered the main drivers for a more sustainable future, particularly students who will occupy high offices (Green 2013; Zsóka et al. 2013). The University is a public institution intimately linked to the country's project (Santos 2005). Thus, "a sustainable campus should be environmentally healthy, with a prosperous economy through energy and resource conservation, waste reduction and with efficient environmental management" (Alshuwaikhat and Abubakar 2008). Then, it should promote equity and social justice, exporting these values to the community" (Alshuwaikhat and Abubakar 2008). Otherwise, as an organization, the sustainability of a university is related to operational issues comprehending energy, water consumption, emissions, waste management, materials, food services, green spaces and transportation (Brinkhurst et al. 2011; Suwartha and Sari 2013).

In this aspect, the universities, including their infrastructure, in a simplified way, simulate the urban centers' buildings. They are characterized for single opportunities to trigger sustainability practices through many dimensions, individually or in nexus, such as education, research, outreach activities, direct campus operations, and community involvement, applying environmental management systems, public participation and social responsibility (Cortese 2003; Alshuwaikhat and Abubakar 2008; Fadeeva and Mochizuki 2010; Leal Filho 2011; Müller-Christ et al. 2014). Based on the relevance of them, a great number of universities around the world have committed to this responsibility to achieve sustainability in their institutional practices (Lozano et al. 2015), highlighting the last two decades (Ceulemans et al. 2011; Lozano et al. 2013; Shephard 2008). These are the cases of University of Copenhagen (UCPH) and University of São Paulo (USP).

### 1.2 The University of Copenhagen

UCPH is a public university, under the national responsibility. As well as the city of Copenhagen, it is considered a model of Sustainability, embedded in the culture of the town. The structure of the buildings, the transport of people, the technologies used, the mechanism of waste disposal, and the resource use are important points which should be analyzed in a manner of improvement in the sustainability sector. Statistics provided by the UCPH Sustainability Report indicate a significant improvement over the years in all sectors of the institution (Green Campus 2014). This is a result of initiatives promoted by the university and the city.

Moreover, the University has ambitious goals to become the most sustainable university in the world, with the project "Green Campus 2020: Strategy for Resource Efficiency and Sustainability" (Green Campus 2013). Despite this, there are remaining challenges, which include physical and laboratory facilities, as well as sustainable culture (Green Campus 2013).

### 1.3 The University of São Paulo

USP is a public university, maintained by the State of São Paulo government, and is considered the major institution of higher education and research in Brazil (USP 2016).

This University has the Superintendence of Environmental Management (SGA—"Superintendência de Gestão Ambiental" in portuguese), whose main goal is to incorporate and institutionalize the principles and sustainable practices in university's management. In this way, it becomes an example for students and society, encouraging actions and projects that aim a healthy environment, promoting environmental security within the campuses, stimulating the rational use of resources, educating towards sustainability, seeking to build a sustainable university in a shared management (SGA 2016).

## 2 Goal

The purpose of this work is to establish relationships between the realities of two public universities in different contexts, the University of Copenhagen (UCPH) and the University of São Paulo (USP) about their practices involving sustainability.

## 3 Methodology

In an attempt of exchanging experiences in the field of Sustainability, internships were taken at both universities, UCPH and USP, from 2015 to 2016. The first co-author of this study, started her internship at USP (Brazil) in August, 2015 at the Superintendence of Environmental Management with the USP Recicla's project called "Sustainability, environmental education and waste management at the students' houses in the campus of Ribeirão Preto at the University of São Paulo". In this period this person was in contact with SGA's activities and plans for developing environmental policies to USP.

In December of 2015, the first co-author got a scholarship, supported by USP Innovation Agency, for an internship at UCPH (Denmark) for three months. Analysis and careful observations of the practices, strategies, and goals of the UCPH were held, as well dialogues with universities' managers [Faculty of Health and Medical Science, Faculty of Science, Faculty of Humanities, and Faculties of Law, Social Science and Theology]. Materials produced by this University in the area of sustainability and environmental education were also analyzed.

Furthermore, from April to December 2016, this person was an intern at SGA again, now, by supervision of the second co-author of this article. These experiences allowed both authors to gather some data on policies, strategies, and practices about sustainability, from educational materials, reports, books, websites, observations, dialogues in technical visits, and contact with managers, students and staff involved in the actions. These data were treated considering the institutional documents available and the notes taken. We, therefore, tried to establish some comparisons between UCPH and USP. All of these results are presented below. Four actions have been highlighted: (I) Ecological Reserves and Wild Campus, (II) PAP and Green Ambassadors, (III) Waste management, and (IV) Cooperation networks at the end of the section.

## 4 Results and Discussion

Based on these two experiences, it was possible to identify convergences and divergences between policies, strategies, and practices related to sustainability. Each university has very different contexts, like geographic location, region's culture, economic and social aspects, type of vegetation, biodiversity, community needs, legislation, and city infrastructure. Nevertheless, some similarities could also be seen.

First, both Universities are public: UCPH is a responsibility of the national government, while USP, of the state of São Paulo's government (KU 2016; USP 2016). Although each University has its own policies and characteristics, they are under federal, state and municipal powers, following laws, norms, and measures of these instances. Thus, some of the differences noted between the Universities are related to policies external to the Universities and not only by avant-garde strategies in the area.

In general, it can be said that UCPH focuses mainly on infrastructure, with emphasis on excellence in energy utilization and management (dialogues with managers and staff; Green Campus 2013; Green Campus 2014). They believe that structural change is capable of delivering better results in the area of Sustainability, being associated with operational activities (Brinkhurst et al. 2011; Suwartha and Sari 2013). Some examples: automatic energy control; monitoring water consumption; solar panels to energy production and to heat the water, buildings with low carbon production (e.g. the Green Lighthouse); investment in equipment with low carbon production, mainly in the laboratories (observations; dialogues with managers; technical visits; Green Campus 2014)]. In addition, UCPH must follow the laws of the municipality of Copenhagen strictly, in order to avoid fines, which would mean extra expenses [e.g. waste management (dialogues with managers)]. This is supported by ambitious goals of Green Campus and relevant alliances with different universities (Green Campus 2014).

Otherwise, at USP, the leading focus was, until 2012, on environmental education issues and waste management, coordinated mainly by the program USP Recicla, forming and advising students, staff, teachers and the external community. Furthermore, the environmental theme has been treated by USP for a long time, in several disciplines, in different faculties, institutes, and in the management of its campuses. However, the University noticed the lack of strategies that would promote the incorporation of the environmental dimension within the institution. Then, in 2012, it was created the Superintendence of Environmental Management (Resolution N°6062/2012) (SGA 2016). So, other programs, projects, and strategies have been implemented since then [e.g. USP Environmental Policy in its 11 sectors (SGA 2016)]. The main purpose of SGA is to plan, deploy, maintain, and promote environmental sustainability on its campuses and research areas of USP. Also, to incorporate the environmental dimension of sustainability across the board in all policies, plans and activities, in the areas of teaching, research, extension and management (SGA 2016). Its goals are towards zero carbon emissions, campus as a lab for cities, and sustainable actions (SGA 2016).

## *4.1 City of Copenhagen and the University of Copenhagen*

Copenhagen is the capital and the most populous city of Denmark with 1,263,698 inhabitants (DK 2015). It is situated in the Zealand and Amager islands and was founded as a fishing village in the 11th century. However, it only became the capital of Denmark-Norway in the 15th century, becoming an important European regional center in the early 17th century. Since the 21st century, Copenhagen has undergone strong urban and cultural development, promoted by investments in its institutions and infrastructure (Bayliss 2007).

The city of Copenhagen is recognized for being one of the most eco-friendly cities in the world. It sets out the ambition to become the first neutral carbon city in 2025 (DK 2015). This objective goes in parallel with the Copenhagen 2025 Climate Plan, a plan adopted since 2009 by the city hall of Copenhagen (DK 2015). One of the medium-term targets was to reduce carbon emissions by 20% by 2015. Fortunately, this goal was achieved by Copenhagen in 2011. And if all the city's efforts are counted since 1995, Copenhagen has reduced its emissions by 50% (DK 2015).

About the CPH 2025 Climate Plan (2012), it consists a holistic plan with a set of specific goals and initiatives within four major areas: energy consumption, energy production, green mobility and initiatives in the field of city administration (CPH 2025 Climate Plan 2012). An example is the increased tax of public transportation and bicycles use, which significantly reduced the traffic jam of the city and improved the population's health. Since 2005, one billion Danish kroner have been invested in cycle paths and high-traffic bicycle paths infrastructure (Cathcart-Keays 2016). One of the results is that 45% of the inhabitants of Copenhagen use their bikes daily to and from work or school, also increasing the living conditions of its residents (Henley 2017).

In addition to these developments, the city also has a climate change adaptation plan (Copenhagen Climate Adaptation Plan). As the city will be affected by global changes, it must be prepared for these changes, which directly interfere with the quality of its residents' life. Regarding measures to reduce $CO_2$ emissions, Copenhagen has invested in renewable energy sources [e.g. solar and wind power (State of Green 2016)]. These sources account for 27% of the energy used by the country (2014) and wind energy accounts for about 5.6% of that energy production (2014) (State of Green 2016).

Many of these Copenhagen city goals emerged after the oil crisis in the 1970s (Rüdiger 2014). As Denmark is completely dependent on the import of this resource then the country decided to change its direction in relation to energy demand and changed its interests in spite of the environment (Rüdiger 2014). As a result, green measures, such as energy efficiency, renewable sources, waste and resource management, clean air, and sustainable cities have become embedded in Danish practices. Over time, the country realized that economic and environmental policies can go hand in hand (State of Green 2016). Therefore, since 1980, Denmark has grown to become a global leader in the development of new technologies and sustainable solutions, inspiring other nations, companies, and citizens around the world to invest in sustainable ideas (State of Green 2016).

UCPH is the oldest university in Denmark (since 1479) and its administrative structure differs markedly from USP. There is the administration linked to the rectory, with a broader management, with the support of the Campus Service. In addition, each Faculty has its own managers (Campus Service), which are people hired only for the administration of services and buildings. Teachers focus only on teaching and research, and are not as participative in the management of the University since there are other actors in the area (dialogues with managers and staff).

The University has four campuses, the central, the north, the Frederiksberg and the south of Copenhagen. The first comprises the faculties of Theology, Law and Social Sciences, and part of the faculty of Health and Medical Sciences (KU—Introduction 2016). The northern campus is the largest of all, encompassing 14,000 students from the Faculties of Science and Health and Medical Sciences (KU—Introduction 2016). The Frederiksberg campus houses part of the Faculty of Sciences with ample green areas (observation during technical visits). Finally, there is the South campus with 11 thousand students of the Faculty of Humanities (KU—Introduction 2016).

The distances between the campuses are short, being possible to move from one to another by bicycle or by public transport (observation). There are medieval buildings and new ones, such as the Faculty of Humanities, which is only two and a half years old (dialogues with managers). In this way, the needs of each Faculty can vary widely.

## *4.2 City of Ribeirão Preto and the University of São Paulo*

USP is a public institution, whose responsibility is to the State of São Paulo government (USP 2016). It is considered the Institution of Higher Education with better placement in Brazil, with high impact research (QS World University Rankings 2016). It presents seven campuses, located in seven different cities. Because the USP internship belonged to the campus of Ribeirão Preto, this work will focus on the context of the University of São Paulo based on the city of Ribeirão Preto.

The city of Ribeirão Preto is located in the state of São Paulo with 604,682 inhabitants (IBGE 2010) and its name is due to the river that crosses the city (Suarez Lopes 2011). Until the 19th century, the region was populated only by Caiapós, whose food was based on maize and cassava, still living from hunting, fishing, collecting honey and native fruits (e.g. jabuticaba, araçá and passion fruit) (Suarez Lopes 2011). Over the years, however, the region has been dominated by farms (Suarez Lopes 2011).

In 1856, the city of Ribeirão Preto was founded, at a time when the region received many miners who left their lands already exhausted and looked for pastures to cattle (Suarez Lopes 2011). In the early twentieth century, the city began to attract immigrants, who went to work in agriculture, mainly coffee, one of the main sources of income in that period. With the establishment of the Mogiana railway line in 1883, an important development took place in the municipality, which allowed the expansion of the coffee culture. Nevertheless, from 1929, coffee began to devalue, while the industrial sector began to expand (Suarez Lopes 2011).

Economic growth needed cultural and academic development. In this context, the Faculty of Medicine linked to USP was established in 1948 (RP 2012; USP-RP 2016). Today, about 20,000 people use the campus every day, and there is an offer of 25 courses in three areas: exacts, biologics and humanities (RP 2012).

The original and predominant vegetation of the municipality is the Atlantic Forest and Cerrado (Marques 2007). The city has two conservation units, Morro do São Bento Environmental Preservation Area (APA), and the Ecological Station of Ribeirão Preto. Urban, industrial and crop expansions, such as coffee and sugarcane, were responsible for the elimination of a large part of the native forests that occupied about 80% of the State, now reduced to 13.94% of the original area (Ceeflorusp 2016).

### *4.3 Brief Comparison Among Copenhagen and Ribeirão Preto as well UCPH and USP*

Copenhagen has a high level of social equity and HDI, within a small country (Denmark) with a low population (about 1 million), and indexes of biodiversity lower than in Brazil. Also, there is a culture of separating waste in many categories. Ribeirão Preto has a floating population almost equal to the number of inhabitants of Copenhagen, because it attracts many individuals to its commerce, industry, and universities. Its country is considered a mega biodiversity place, but with high social inequities. The city does not have many sustainability incentives yet, such as the absence of "coleta seletiva" ("selective collect of waste"—literal translation) as a municipal service.

Still, both cities present different histories, Copenhagen is much older than Ribeirão Preto, in a country with a shortage of energy sources (coal, oil, waterfalls). This dependence facilitated the implementation of policies for the production of energy from renewable sources. Brazil already has its major supply from hydroelectric plants. This, combined with the high costs of other renewable sources of energy (e.g. wind and solar energy), might have made it difficult to invest in other technologies.

The size of the two universities is quite different. USP has campuses in seven different cities, each one with its own particularities, while UCPH comprehends four campuses in the city of Copenhagen, under the management of two municipalities Kobenhavn and Frederiksberg. If we compare USP in Ribeirão Preto with UCPH, the number of teachers, employees, and students is not so different, but in relation to biodiversity, it is higher in Ribeirão Preto (there are even areas of permanent protection there). The structure of the administrative organization is different: at UCPH, the Campus Service is responsible for administrative matters, while at USP, teachers and some employees dedicate themselves for teaching, research, extension and administrative issues. The extension is important, especially because of social inequities in Brazil. In relation to the Administration, because they participate in many of the decisions, they may feel more engaged in certain initiatives and might try to engage their students, too. Still, at UCPH, many of the decisions, for example, about sustainable infrastructure, are coordinated only by Campus Service, and thus, teachers are often not so engaged.

### 4.4 Superintendence of Environmental Management and Green Campus

Both UCPH and USP have entities, the Green Campus and the SGA, responsible for proposing, coordinating and taking care of policies, strategies, and projects on sustainability, respectively. In the case of USP, SGA has a plan from 2014 to 2034 to stand out USP amongst the 100 best universities in the world in the area of Sustainability. These agencies have six challenges in common: (1) engaging as many people as possible, (2) approving projects, (3) obtaining financial support, (4) creating and disseminating content, (5) motivating different managers through dialogues, and (6) developing projects that help to achieve the proposed goals.

On the composition of these two entities, the SGA participants are mainly teachers, and some educators and students/trainees. On the other hand, Green Campus comprehends two employees and one trainee (dialogues with Green Campus and SGA). The people of the last one focus only on sustainability issues of the university, while in the first one, some teachers may be overloaded. However, the diversity of people in SGA can also enrich and facilitate the proposition of ideas, more related to the daily life of the University. Although recent, SGA has been able to develop projects, programs, and policies that positively impact the environment (SGA 2016).

SGA has the Environmental policy in the university, and UCPH has the "Green Campus 2020" strategy. The main goals of the last strategy are divided into six categories: (A) $CO_2$/climate: a 65% reduction of $CO_2$ emissions from energy consumption and transport per Full Time Equivalent; (B) energy: a 50% reduction in energy consumption per Full-Time Equivalent; (C) resources: a 20% reduction in overall waste volume per Full Time Equivalent, recycling of 50% of the waste produced, and a 30% reduction in water consumption per Full Time Equivalent; (D) chemicals: procurement and construction without health and environmental contaminants, and reduction of the university's total pollution and chemical environmental impact; (E) organization and behavior: sustainability and resource efficiency in all major decisions and actions, and awareness of UCPH as a sustainable university and sustainability as an everyday practice; and (F) campus as a living lab: development and demonstration of future sustainable solutions on campus (Green Campus 2014).

About the Environmental policy, some documents were elaborated to guide and legitimize social and environmental actions at USP, in order to promote a more efficient environmental management, in accordance with the University's principles (SGA 2017; SGA 2016). The topics covered management, water and effluents, green areas and ecological reserves, sustainable buildings, environmental education, greenhouse gas emissions and polluting gases, energy, wildlife management, mobility, waste and land use, and occupation (SGA 2016). In summary, they aim to promote an integrated environmental management that improves the quality of life of its users and society. Its principles are prevention and precaution, reasonableness and proportionality, transversality of education, interdisciplinarity, transparency, participation, access to information, shared responsibility, and respect for local specificities.

In the next sessions, four relevant actions for both universities will be analyzed: (I) Biodiversity protection: Ecological Reserves at USP and the Wild campus project at UCPH; (II) Environmental Education: the Socio-Environmental Training Program for technical and administrative employees—PAP at USP, and the Green Ambassadors program at UCPH; (III) Waste Management; and (IV) cooperation networks involving sustainability.

I. Ecological Reserves and Wild Campus

The creation of the USP Ecological Reserves sought to allocate significant remaining areas of native vegetation contained in USP campuses, aiming the conservation, teaching, research, extension and, when necessary, restoration. Most of the ecological reserves are composed of fragments of semideciduous and closed forests, which still maintain considerable native biodiversity, as well as their structural and functional integrity (SGA 2016). These reserves seek to contribute to the conservation of local/regional biodiversity and ecosystem services. Also, to produce knowledge, train human resources, and promote activities of culture and extension, offering services to the community, and serving as a living lab for the elaboration of public policies (SGA 2016). The majority of USP's ecological reserves were created through a decree of the Rectory in 2012 (Santos 2017).

In the case of Ribeirão Preto (SP), originally occupied by semideciduous and cerrado vegetation, currently has 3.8% of its forested area, restricted to a few scattered fragments (Ceeflorusp 2016). So, research for restoration and management of degraded areas is a strategic activity for the conservation of such resources. Thus, between 1998 and 2005, a forest of native species was planted in the campus of USP in Ribeirão Preto (75 ha), which represented a 20% increase in the vegetation cover of the urban area (Ceeflorusp 2016). Of these, 45 ha were used for the establishment of an in vivo gene bank, implanted from seeds of 3450 matrix trees cataloged in 450 forest remnants of the region, aiming to rescue 45 species of semideciduous forest (Ceeflorusp 2016). This bank is relevant for keeping high genetic variability for future restoration projects. After the establishment of the forest, CEEFLORUSP (Center for Forestry Studies and Extension of USP) was established.

Wild Campus is an initiative of UCPH to bring nature closer to people. Ten thousand seeds of Danish native plants were planted to bring life, color, and aroma to the north campus, totalizing 650 $m^2$ (Science—Vild campus 2016). The idea was to create a different experience amidst the bustling city of Copenhagen and still inspire residents and visitors from these planted areas to further explore the countryside of Denmark. In total, there are about 80 different species of plants in these areas and the selection of the species was assisted by the Center of Macroecology, Evolution, and Climate (Science—Vild campus 2016). There is also the target to conduct monitored visits to these areas, explaining about microhabitats, native plants, insects, and the importance of their conservation (dialogue with Wild Campus' responsible).

In general, the Ecological Reserves seek the conservation of USP's green areas, as well as the restoration of native forest along its ecosystem services. As Wild Campus, it has Environmental education initiatives with students. Wild Campus attempts to make the University greener by bringing native Danish seeds to a recreation space for users of the Science campus.

Thus, the projects cited try to bring together students, teachers, and employees to nature, while collaborating with research and Environmental education. Thus, both initiatives are part of the environmental management, important for a sustainable campus (Alshuwaikhat and Abubakar 2008).

II. PAP and Green Ambassadors

USP had a program called PAP (People that learn Participating—"Pessoas que Aprendem Participando" in portuguese) from 2013 to 2015 in four groups (PAP1, PAP2, PAP3 and PAP4), forming about seventeen thousand employees in periodic meetings and lectures (Meira et al. 2014; Sudan et al. 2015). Inserted in a critical and emancipatory perspective in Environmental Education, PAP aimed to educate the university community environmentally, to expand the insertion of sustainability in university management, and to promote sustainable articulated actions (Meira et al. 2014; Sudan et al. 2015). Based on the capillarity architecture, PAP was committed to mobilizing other groups of the university through theoretical courses and monitored practices (Meira et al. 2014; Sudan et al. 2015).

A relevant point of PAP was that, when employees got together they could motivate each other. Besides, they are a key point because they remain in the University for a long time, while students and researchers have a shorter cycle. This does not mean that the last ones should not be engaged, however, investing in employees' development is a strategic policy (Meira et al. 2014; Sudan et al. 2015), offering stability and continuity in the implementation of programmes on campus (IARU 2014).

On the other hand, at UCPH, there is only an initial orientation for staff, students and teachers in the beginning of the semesters, but future advice are the responsibility of the Green Ambassadors (Green Campus 2014). These are students and volunteer staff who assist the Green Campus in publicizing campaigns and implementing Green Campus recommendations at their workplaces in an attempt to change people's behaviors in their daily lives (e.g. "Green Action" campaign) (Green Campus 2014). The most significant results were achieved in laboratories, where there is high energy consumption by equipment such as freezers and exhaust fans (Green Campus 2014).

Both projects aim to form diffusers of sustainability ideas by the University, that is, people who engage others to have more sustainable practices in UCPH and USP. Both have volunteering aspects, but at UCPH it involves undergraduate and graduate students, researchers, staff, and teachers, while at USP, the priority was permanent employees (dialogues with some Green Ambassadors, Green Campus staff, and PAP's responsible). Training people for sustainable practices fostering a culture of environmental awareness is imperative (IARU 2014), and UCPH as well USP are working on it.

III. Waste Management

Ribeirão Preto does not have a selective collection of waste by municipal government, while in Copenhagen the legislation is rigorous about this, and the more people separate their waste, fewer costs they will have. Thus, UCPH follows these guidelines by presenting a great number of containers in their colleges, according to their needs, and it seeks to inform its users about the correct separation. For instance, at the Faculty of Health and Medical Science, there are about 20 kinds of separation [e.g. rocks, laboratory glass, glass, common paper, confidential paper, soft and hard plastic, electronic material, iron, organic waste, lamp, wood, soil, shelves and garden waste (data provided by the Faculty's staff)]. At USP in Ribeirão Preto, there is a division between recyclable and non-recyclable waste, the first one collected by a cooperative of Ribeirão Preto (Mãos Dadas), which has a partnership with USP (information provided by one of USP Recicla's representant).

In addition, on the subsequent destination of recyclable waste, at USP, it goes to a cooperative and then, to a recycling company. In Copenhagen, the collections are carried out by the recycling companies of different categories of materials. Thus, there is a stimulus for the city's own project to improve this system of separation more and more. Still, through dialogues with different actors, it was possible to observe high credibility about the recycling system.

Regarding solid waste, USP has projects inside USP Recicla to implement composts in order to reduce the volume of waste that goes to the landfill (observations in technical visits). However, at UCPH no compost plans were reported on the campuses, but two managers said that the city has a project to collect food waste for the production of fertilizers and biogas (dialogues and observations during technical visits).

About the reuse of materials, USP Recicla distributes mugs every year for its newly enrolled students, while at UCPH, employees have mugs in their offices. Moreover, there are plans for Green Campus Students to talk to canteens to reduce the prices to whom brings his/her mug. These are simple initiatives, but, in the future, they can bring significant results to the planet. At USP, there are also exchange shelves, which stimulate its users to exchange objects to other people, reducing the purchase of new products and the generation of waste (Sudan et al. 2007).

All the cited initiatives are linkage to sustainability in the campus, involving energy and resource conservation, waste reduction and efficient environmental management (Alshuwaikhat and Abubakar 2008).

IV. Cooperation Networks

Both universities belong to university networks, in which, at some point, are linked to sustainability theme. UCPH is part of a local network, COSI (Copenhagen Sustainability Initiative); a regional one, the NSCN (Nordic Sustainable Campus Network); and two global networks: the IARU (International Alliance of Research Universities) and the International Sustainable Campus Network (ISCN) (Green Campus 2016). On the other hand, USP participates in a regional network, ARIUSA (Alianza de Redes Iberoamericanas de Universidades por la Sustentabilidad y el Ambiente); and it is part of global alliances the UI GreenMetric, the IUSDRP (Inter-University Sustainable Development Research Program), the WC2 Network, the GUPES (Global Universities Partnership on Environment for Sustainability) and the ISCN (SGA 2016).

Such international cooperation is very important since it is a relevant way of exchanging experiences between universities, which have similar local and regional contexts. Furthermore, the universities in these networks can develop projects together and exchange students, staff and teachers to learn from each other's experiences. An essential point, then, is that universities should take advantage of their participation in these networks in order to improve themselves. Among the actions of international cooperation, stands out USP participation in the project "Definition of indicators of evaluation of the sustainability in Latin American Universities", coordinated by Autonomous University of Madrid, in 2012, in the ARIUSA network. Another instance was the Green Guide elaborated by the IARU (available in http://issuu.com/sustainia/docs/iaru_green_guide?e=4517615/9654178), which is part of the challenges and opportunities for universities in the field of sustainability, with a special focus on environmental issues. The aim was to form the actors of the future and to inspire other universities to become more sustainable.

Therefore, these networks have favored the dialogue and the exchange of experiences between the universities in the world, theoretically and practically, and the insertion of USP and UCPH in the scenario of sustainable universities. Moreover, they have contributed to inspiring other universities in this way, fostering a culture of environmental awareness. This "is why sustainability program leaders need to locate passionate individuals in a variety of campus positions, and then engage them in projects, policies, and operational initiatives (…)" (IARU 2014, p. 11).

Our study analyzed some topics about the field of action in the sustainability of UCPH and USP, but other issues could also be investigated in the future, such as events about sustainability, water management in Universities, and sustainability education in University *curriculum*. We also highlight the relevance of including people's participation in universities' sustainability actions, aiming to engage staff, students, teachers and the community around, creating spaces of reflection and learning.

## 5 Conclusion

This paper is an initial panorama of how sustainability has been incorporated in public universities in different contexts. We found divergences and convergences among USP and UCPH, which were analyzed considering the context of each University, the action of the sustainability offices, the strategies for biodiversity protection, environmental education, waste management, and the networks related to sustainability. In general, the main focus of the UCPH has been on infrastructure and management, associated with environmental education, while at USP, until 2012, the environmental education and waste management were the main targets by USP Recicla. However, other plans, programs, and strategies have been incorporated in the Institution by the SGA since its creation. We highlight the importance of a dynamic relationship with universities networks, and strategies for communication, such as continuous reporting, and the promotion of workshops. These attitudes are important for inspiring other universities to adopt plans, programs and projects aiming sustainable actions, and for individuals' education in the society, creating people concerned with sustainability aspects in an integrated view. An analysis of how the context of the University, like the culture and the legislation of a country or municipality, strongly influences its strategies was also carried out. There are still challenges for higher education institutions to integrate sustainability in education, research, outreach activities, direct campus operations, and community involvement; which all can be correlated to financial predicaments and barriers to behavior change. Nevertheless, UCPH and USP are seeking to improve their practices and plans in sustainability.

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# Electricity Consumption Assessment: Case Study of University of São Paulo Campus of São Carlos

**Sofia Moreira de Andrade Lopes, Rodrigo Martins Moreira and Tadeu Fabrício Malheiros**

**Abstract** The interest in energy efficiency and clean energy generation grows in exponential steps. Along with this, the importance to apply the principles of sustainable development in everyday activities increases. Researches and development projects that work with smart grids have increasingly become relevant, presenting answers to this global demand and allowing technology to work fulfilling sustainable development gaps. Therefore, the goal of this paper was to create an electricity consumption profile of buildings at University of São Paulo—Campus of São Carlos, and analyze the pattern of consumption developed by the university community. Posteriorly, proposals based on Gibson's principles towards sustainable development were drawn to assist the university in reducing electricity waste and awareness of the coherent use of this resource. Some of the results regarding community demonstrated concern in controlling the energy consumption and engaging in sustainability activities. An observed challenge was that university's community is not included in decisions making about sustainability and that information about these decisions are not well shared. This electricity consumption profile can be posteriorly used as a baseline to an online system that includes data from the consumption and that is available for everyone, providing information to decision making.

**Keywords** Sustainable development · Smart grids · Gibson's principles

## 1 Introduction

One of the alternatives that has been analyzed to contribute to the environmental health of the planet, is the energy sources from fossil fuels consumption replacement with renewable energy sources. These renewable energy sources need sun,

S. M. de Andrade Lopes (✉) · R. M. Moreira · T. F. Malheiros
São Carlos School of Engineering, University of São Paulo,
Rua Miguel Petroni 166, São Carlos, SP 13566-590, Brazil
e-mail: sofia.moreira.lopes@usp.br



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wind or geothermal energy to work, and that is better because these types of energy suffer natural and ongoing maintenance. Thus just minimum impacts are imposed to the planet when the potential of these forms of energy are explored (ELETROBRAS 2017). The negative impacts caused by these renewable energy sources occur basically during the production of the equipment used in its operation. Some impacts due to visual and noise pollution have also been reported, but can be easily overcome.

The union between renewable energy sources and automation technologies into electric distribution networks is the foundation to a smart grid network creation. The concept of smart grids has been applied widely by countries seeking to reduce their energy consumption. According the *US Department of Energy,* Smart Grids are defined as an intelligent network that provides communication between the dealership and the customer (ENERGY.GOV 2016). Also, there must be control over all points of the network. It is a fully integrated system that is accessible, reliable, economical and above all, sustainable (CGEE 2012).

To the *International Energy Agency* (IEA) some features that a network must meet to be considered intelligent are: supply quality electric power; use sources of low environmental impact energy; be resistant to disturbances, natural disasters or external attacks; accept informed consumer participation; have the ability to detect, analyze and recover fails in the network itself (self-healing) (IEA 2011).

A smart grid also allows the consumer participation in the network performance. With information that flows continuously in both directions and come from the network to the consumer with information regard the consumption patterns, prices, service quality and is possible for consumers to adapt their consumption behavior to save natural resources and money (Rivera et al. 2013). Besides, the use of renewable energy sources to supply consumers own demand is very encouraged, with this grows the use of photovoltaic systems in several houses.

In 2012, The Brazilian Electricity National Agency (ANEEL) approved a Normative Resolution (Nº 482/2012) that enabled consumers to install small generators in their houses to generate their own energy. Thus customers could exchange energy with the dealers reducing the electricity bill and if the consumption of the residence is less than the produced the consumer can receive credits that may be used to pay their next energy bills (ANEEL 2015).

In this paper, the aspect of the smart grids concept that will be used are: The use of alternative sources to generate energy and the importance to have control over electricity consumption.

Furthermore, the use of the smart grid technology contributes to Sustainable Development actions and Goals (SDG) adopted by United Nations Educational, Scientific and Cultural Organization (UNESCO). By encouraging the use of alternative energy sources and hybrid or electric cars, it collaborates with the reduction of the consumption and dependence on fossil fuels and greenhouse gas emissions (UNESCO 2015a).

This type of technology is studied in many research centers, mostly presented in higher education institutions (HEI). These institutions have a main role in promoting new forms of knowledge through innovation (UNESCO 2015a). They are responsible for future professionals training, and are also strong opinion makers (Nishimura 2015). Therefore, is their responsibility to stimulate in their community the development of curiosity for new technologies

Thus, investing in education is key to achieve sustainable development, help with understanding the link between society and the environment, and it encourages people to participate in the organization of their citizenship (Tauchen and Brandli 2006). Therefore, when inserting sustainability issues in their agendas to promote Education for Sustainable Development, these HEIs are showing people how to lead a life more engaged with social and environmental problems (UNESCO 2015a). Thus, projects about smart electricity grids can be used as models and show innovative opportunities for the community.

## 2 Intents

This study has as main objective to optimize the electricity consumption at USP campus of São Carlos by crossing results of the behavioral understanding of the university stakeholders in relation to sustainability issues such as the consumption of energy with an estimated electricity consumption profile of five buildings in the university.

Furthermore, proposals to improve the energetic system of the campus have been presented. These proposals were based in Gibson (2006b) criteria for sustainable development.

The project aims to promote environmental awareness and encourage initiatives in the area of clean energy generation at a Higher Education Institution. In addition, the control and planning of energy usage, presented in this study, are essential for the network to become more efficient and secure with positive return in economic, social and environmental aspects.

## 3 Literature Review

For this study, the vision that best expresses the concept of sustainable development was proposed by Professor Gibson (2006b), which established requirements that should be met for progress towards sustainability.

These requirements are (Gibson 2006b):

- Intergenerational equity—Take actions today that can be maintained and that increase the opportunity and the ability of future generations to live in a sustainable way;
- Maintenance of natural resources—Ensure ways for people to live their lives in a sustainable way and reduce the threats to environmental systems and natural resources integrity;

- Social-ecological civility and democratic governance—Society and governments awareness to apply sustainability requirements;
- Integration of current and long term situation—Apply the principles of sustainability to reach all the benefits and gains they offer;
- Ecologic system's integrity—Establish balanced relationships between society and environment, maintaining the integrity of the socio-ecological system.
- Sufficient resources for subsistence and access to opportunities—Ensure that every person has access to the necessary things to live a decent life and to seek improvements without compromising future generations;
- Intragenerational equity—End social inequality ensuring opportunity of choice for everyone in an equal manner;
- Precaution and adaptation—Unnecessary risks should be avoided to the fundamentals of sustainability. The managers must be prepared for unexpected situations.

The requirements shown above are also explained in the book Curso de Gestão Ambiental, published by Manole Ltda. "Teacher Training in Environmental Education and Its Relation with the Sustainability Culture in Two Undergraduate Degrees at USP" presents these principles, it was written by Carla Grigoletto Duarte and Tadeu Fabrício Malheiros (Duarte and Malheiros 2014).

## 4 Methods

This study consists of two different analyzes, a quantitative and a qualitative one. The first consists in obtaining physical data to estimate the electrical consumption of five buildings previously chosen in the University of São Paulo. The second form of analysis, qualitative, was developed with the application of two questionnaires. One of them was used to collect information on the inclusion of sustainability in daily work from the employees of maintenance sectors of the campus institutes. The second one, the questionnaire Sustainability Culture Assessment at USP São Carlos was applied to observe sustainability behavior in the daily habits of administrative staff, teachers and students in the campus.

After the analyzes described above, the proposals based on Gibson's principles will be created. These proposals are shown in the Results section and they were created to meet the profile obtained by comparing the results of the initial analyzes.

### *4.1 Quantitative Analysis*

With the data knowledge regard the amount of electronic equipment it was possible to have a theoretical consumption profile of the buildings. The result of this analysis could be compared with the responses from the questionnaires that were applied to the university community. Thus, the users behavioral usage patterns of the buildings contributed to understanding of how electricity consumption can be influenced by stakeholders' cultural aspects.

The study was carried out between the days 23 and 29 of October in 2015. The energy consumption data was collected in the following buildings, to collect staff and students profile, of the University of São Paulo: the administrative building of the City Hall, the Educational Technology Center for Engineering (CETEPE), the classroom buildings B and D. These buildings are shown in Fig. 1.

In addition, the administrative building E1 was also included in the study, as the number of electronic equipment of this building had already been collected in previous works.

After the data collection, the information regard electricity consumption of each device, according to its model, was searched. These information, alongside with the amount of devices were calculated with the Eq. 1. This equation also takes into consideration the number of hours that each electronic is used during a work day. For the calculation of the consumption of air conditioning equipment, it was considered that all were operating at a temperature of 20°, standard usually followed by the university community.

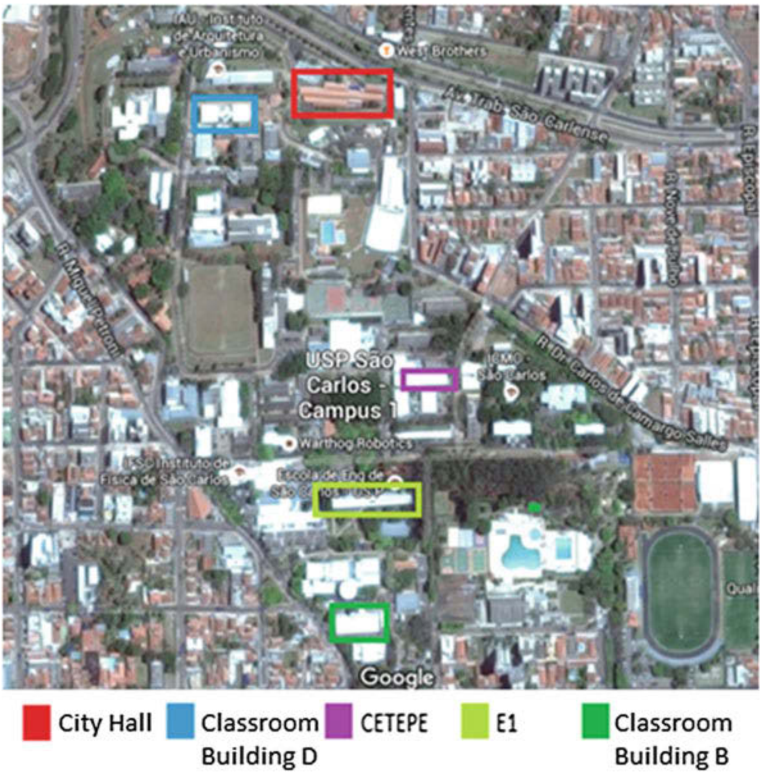


**Fig. 1** Location of the buildings

**Daily consumption of an electronic device**

$$\textit{Daily Consumption}\ (kWh) = \frac{\textit{Total Consumption}\ (kW) * \textit{Number of hours that the device is used per day}\ (hours)}{1000} \tag{1}$$

## 4.2 Qualitative Analysis

### 4.2.1 Interviews with the Maintenance Sectors

The USP Campus of São Carlos has the following units: School of Engineering of São Carlos (EESC), Institute of Physics of São Carlos (IFSC), Institute of Chemistry of São Carlos (IQSC), Institute of Mathematics and Computing of São Carlos (ICMC), Architecture and Urban Planning Institute (IAU) and City Hall. The maintenance sectors of all these units were included in the research, except the Institute of Architecture and Urbanism, because it does not have a maintenance department.

The contact with the sectors was made by e-mail, these were sent directly to the managers of all departments maintenance sections. They agreed to schedule interviews and to contribute with data for this research. The interviews took place during the months of November and December of 2015, it happened in the rooms managers and the content its content was recorded. The interviewer was instructed not to influence the answers with help or comments.

The managers and the technical workers had to respond to several questions, some of them were different for each group. In both questionnaires the first section was about identification, asking mainly about the employment status of the respondent, such as the work time in current position.

For the managers, this section also investigates the knowledge of some concepts related to sustainability and the involvement of the interviewed with sustainable. One other section of the their questionnaire talked about the engagement with sustainable activities such as participation in courses and programs that deal with this theme.

Both groups answered questions about the process of identification and repair of failures in water and energy systems in campus buildings. Also, both of them expressed their views about the university's actions towards sustainability.

The number of respondents was 10 employees. The data obtained in these interviews were posteriorly used to create a behavioral analysis of the campus maintenance sectors in relation to SDG.

#### 4.2.2 Sustainability Culture Assessment

The other questionnaire applied was proposed to reach teachers, students and administrative staff. Each group had to answer different questions, but all questions dealt with the same theme, the insertion of sustainability actions in the daily routine of the interviewed. These questionnaires were developed in parallel with the University of Michigan and cover different dimensions of people's lives, such as eating habits, transportation, engagement in sustainable activities, among others.

Links with the questions were sent to the university community through email and through social networks. In addition, a team circled the classrooms explaining the purpose of this study to students and asking for their support. Also, for some employees of the administrative staff the answers were granted during in a personal interview. The total number of valid answers was: 1110.

## 5 Results and Discussion

### *5.1 Sustainability Culture Questionnaires Versus the Energy Consumption of the Buildings*

The results on the amount of electronic equipments along with the behavioral results, compose an energy consumption profile closer to reality. This way when crossing data of energy use of the device with the information about the way this equipment is used is possible to understand more fully how the power consumption of this equipment happens, and consequently the building in which it is located.

Figure 2 shows the relationship of the amount of equipment in all analyzed buildings.

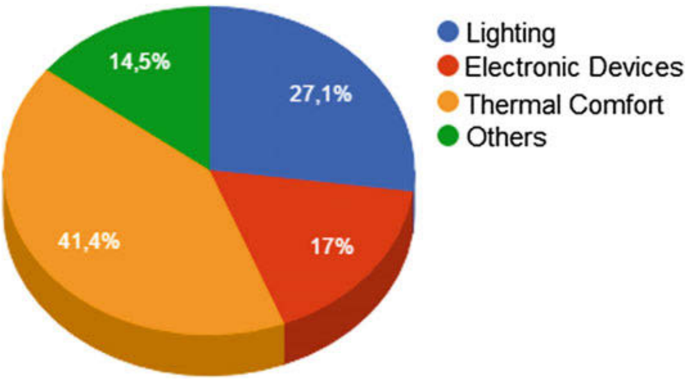


**Fig. 2** Quantity of equipments in the buildings

Note that devices with greatest potential for energy consumption are related to thermal comfort. The culture of sustainability questionnaire presented questions about how the usage of each one of these types of equipments is made.

The main questions that deal with the thermal comfort, lighting and use of electronic devices will be presented below:

*"How often do you do the following things to save energy in your activities at the university?"*

- *Use natural lighting and ventilation;*
- *Close windows and doors when the air conditioner is on;*
- *Turn off lights and electronic devices when not use.*

The answers to the topics of this question demonstrated that there is a concern by the respondents in saving energy and also indicates that people seek natural forms of lighting and thermal comfort. As well as they try to be rational in the use of these equipment, closing doors when air conditioners are being used and turning off electronic devices and lights when they are not needed.

This is very important because, according to the Fig. 2, the type of equipment that has the greatest potential for spending energy are used for thermal comfort and lighting. So, if its use is done consciously by the community the actual energy expenditure will not be as high as estimated.

*"How appropriate is the internal thermal comfort of the building (s) where you work?"* and *"Do you think there is influence of the thermal comfort in the consumption of energy?"* are complementary questions that talk about this type of equipment, thermal comfort equipments. In their responses people indicated dissatisfaction with the thermal comfort of the working places. In addition, most of the respondents linked the lack of thermal comfort with a higher consumption of electricity. However, a low number, a considerable number of people replied that did not knew about this relation or even that it does not exist. This may indicate a lack of information or interest on part of these people on matters relating to sustainable use of electricity.

In this way, it can be concluded that the lack of thermal comfort encourages the use of air conditioners which is not positive in terms of sustainability for triggering a high power consumption and often contribute to the use of this equipments in a unnecessary and unregulated way, leading to waste.

*"In the facilities of USP in São Carlos, how often do you observe the following forms of waste:"*

- *Air conditioning and fan unnecessarily on.*

Unfortunately, this question above returned a high number of people claiming to verify energy wasted at the university. Some questions were about people behavior at their houses, so the answers could be compared with the ones about their behavior in the university. One example of this questions is:

*"Over the last 12 months, how often did you do the following things in your current home:"*

- *Turn off the lights when you leave the room?*
- *Unplug electronics when they are not being used?*
- *Turn off the computer?*

Most groups showed a greater concern to reduce waste in their own homes rather than at the university. This can be inferred from answers to the topics presents in the last question.

The reason for this increased sensitivity of people with waste in their homes may be financial. That is, in their homes people have greater awareness of energy expenditure, because they are directly affected by it in their energy bills. This financial aspect is a stimulus that does not exist at the university.

Another thing that can be seen in the responses is that the energy spent on lighting is perceived by more people than the expense of other equipment. This may be due to the fact that the lamps do not have the *stand by* mode, as other electronic equipment. So its unnecessary use becomes more visible, while the energy consumption of devices that are on stand by mode goes unnoticed. To this fact can be attributed to the greater sensitivity of people turn off the lights, but not these other equipment.

In any case, even if the respondents have answered, in most cases, that they take actions that contribute to the conscious use of energy, they also pointed out that there is a high energy waste present in the daily routine at the university. This waste is observed through lamps and devices, as air conditioners and computers, that remains unnecessarily connected.

This fact, combined with the data in Fig. 2, which shows that the sum of the potential energy consumption of electronic devices, light bulbs and thermal comfort equipments reaches over 80% of total estimated consumption for buildings, indicates an alarming situation. Because if there is too much waste, it is likely that the energy potential of the buildings is fully explored, which only generates environmental, economic and social damage to the university.

## *5.2 Sustainability Culture Questionnaires Versus Questionnaires Applied to the Maintenance Sections*

In the questionnaires applied exclusively to the maintenance sectors, the two groups of respondents (technical workers and managers) had common characteristics such as gender, all the interviewed were male; age, most of them was more than 40 years old; working time, more than half of the employees of both groups are at the university for over 10 years. The feature that most diverged between technical workers and managers was the level of education, among the first group none had completed higher education, while for the second group this was the most current level of education present on the answers.

For Sustainability Culture Assessment questionnaires, the goal was to reach the largest possible number of employees, for this, the profile of the respondents varied greatly in the aspects mentioned above for employees in maintenance sectors. In this section the main questions about employee's engagement will be analyzed in both questionnaires, that means, in the sustainability assessment culture questionnaire and in the questionnaire applied only to maintenance crew.

The first questions analysed are *"Do you know if your campus has a Master Plan/Environmental Management Plan?"*, *"Do you seek to ask questions and make comments and suggestions on environmental issues at USP?"* and *"Do you seek information about the sustainability on the campus?"*. These questions come from the culture of sustainability assessment questionnaire. With the answers obtained it was possible to infer that: in general, the staff of the campus São Carlos—USP showed a low level of commitment with the theme.

Among staff, many claimed not to know if the university had an Environmental Management Plan, and most said that does not seek to clarify doubts about it or make suggestions on the subject. However, half of respondents said that they search for information about sustainability on campus, which could indicate that many employees adopt a viewer's attitude towards the university initiatives.

*"Did you took courses related to sustainability?"*. Among employees of the maintenance sectors the demand for information was mentioned several times during the interviews. According to the technical workers and to the managers, the team always search and tries to be aware about new types of technologies to implement the use of new sustainable equipments at the university, replacing the old ones that were often responsible for waste of energy.

Also according to the technical workers and managers, the university also encourages, often economically, the improvement of its employees in the area of new sustainable technologies, sending them to courses and fairs for their professional development.

*"Which environmental activities you participate/participated or promotes/ promoted on campus?"*. Lectures, programs and institutional committees or institutional boards were the most cited activities. For the employees, the importance of giving back to society and the dissemination of ideas and perspectives that promote social and environmental well being are the biggest motivators to participate in these activities.

All these responses indicate a mature commitment to the sustainability issue by employees of USP São Carlos. Even among those who do not participate in any sustainable activity the explanation for this lack of interest was minimal when compared to the justification for lack of time, information or institutional support.

In this way, the gap that exists between the community and the actions for sustainability conducted by the university is not caused by the lack of community's interest. This detachment is mainly caused by deficiencies in the communication channels, which takes away the chance of the community to participate more actively in the construction of a sustainable university.

This communication failure is exposed in the interviewee's absence of knowledge about the Environmental Policy at the University, theme of the question *"Do you know that the USP's Environmental Policy is in progress?"*.

### *5.3 Proposals Based on Gibson's Principles*

In this part of the project the objective was to made proposals to improve the use of the electrical system of the campus of USP-São Carlos. These were based on Gibson's principles of sustainability and aim to optimize the system and make it more sustainable, i.e., with minimal waste and with the use of forms of power generation that do not cause damage to the environment.

Table 1 presents these proposals together with an exploration of future scenarios and the mains advantages and disadvantages of each proposal.

### *5.4 Gibson's Principles*

The Gibson's principles for sustainable development, that served as a guide to the proposals made above, are presented in this topic, and with them will be analyzed the previous proposals. Matching the proposals with the principles. This principles are presented in (Gibson 2006a, b).

- Principle of the Ecological System's Integrity (Gibson 2006b):

Determines that relations between society and the environment should be built in a way that the integrity of the environmental systems is guaranteed, that means, without exploitation of ecological functions, as these are irreplaceable and necessary to the existence of human life.

All proposals presented above are intended to, somehow, follow this principle. They aim in saving electricity and reducing the dependence on power generation sources that are based on burning fossil fuels, which affects the health of the planet and destabilize integrity of the environmental systems.

- Natural Resources Maintenance and Efficiency Principle (Gibson 2006b):

Talks about the integrity of the environmental systems. There must be ways to ensure sustainable livelihoods for all people in order to avoid the production of waste and reduce the consumption of energy and water. The LED lighting system, the lighting automation and the use of photovoltaic panels for energy generation are ways to ensure that people continue performing and meeting their daily activities and needs, but in a less aggressive way to the environment. So, people still using the lighting, but the consumption generated by this use does not affect so drastically natural resources, as would happen if the power supply was not renewable, for example.

**Table 1** Proposals based on Gibson's principles

| Proposal | Advantages | Disadvantages | Future scenarios |
|---|---|---|---|
| Replacement of fluorescent lamps for LED lamps | – LED's efficiency is superior when compared with other lamps;<br>– LED lamps have a lifetime longer than other lamps | – High cost of the LED lamps;<br>– Long-term financial return | The replacement of the current lamps by LED lamps in the university buildings have a high initial cost due to the high number of bulbs that need to be changed (some buildings have more than 700 bulb lamps). However, for this same reason the financial return would be quickly, in addition, installation costs could be avoided thanks to the existence of specialized professionals that work for the institution itself |
| Lighting automation (using sensors and dimmers) | – Reduces waste (reduces the number of lamps that stays switched on unnecessarily and adjusts its brightness according to each context);<br>– Mostly, increases the lifetime of the lamp (with the use of dimmers).<br>– Financial return in short term (compared with LED lamps);<br>– A few equipment are needed to achieve the goal of saving (one sensor controls several lamps) | – There were no significant drawbacks in the use of sensors and dimmers, whereas that they are suitable for the activities performed in the room that they are installed | For educational buildings, occupancy sensors would be best suited for classrooms and bathrooms, because the people stay longer in this rooms and lighting is essential for the activities that are carried out in those rooms.<br>On the other hand, the presence sensors and lighting (integrated) attend to the needs of halls, as they only have transit of people, i.e., there is no need for the lights to be continuously on for a long period of time.<br>In the administrative buildings, the ideal would be the use of occupancy sensors in conjunction with *dimmers* in staff and meeting rooms. These places' lighting should be continuous during the time that people stay in the room, but the lighting can have its intensity altered depending on the type of activity performed in the room |

(continued)

**Table 1** (continued)

| Proposal | Advantages | Disadvantages | Future scenarios |
|---|---|---|---|
| Solar panels | – Uses as energy source an inexhaustible resource, solar energy;<br>– It does not emit greenhouse gases during power generation;<br>– These equipments have a long life;<br>– Is responsible for the reduce in the energy bill costs and also allows the consumer to use the credit system that can be exchanged and negotiated with the energy dealer | – Panels have high cost, the financial return occurs in a long term;<br>– Low efficiency;<br>– The production of photovoltaic cells generates pollution | The university would benefit from a set of photovoltaic panels connected to the utility grid. Thus there would not be necessary to use batteries. Also, the energy supply would be guaranteed, by the network, even in periods when the PV system does not work, for example during the night (most of the buildings have only daily activities, so the system would be well used).<br>In addition, the university could use bidirectional meters and inject energy into the grid, enjoying the credit system network |
| Consumption control (with the use of smart meters) | – Consumer would be aware of his consumption profile and also would know the network characteristics and receive informations about the quality of the energy | – The cost of equipment and installation of this technology is high | With the consumption monitoring, it would be possible to cut unnecessary network equipment, balance consumption at peak times, in general, manage more rationally and correctly the university energy spending.<br>In addition, the energy consumption reduction that the use of these devices would provide positively affects the environment.<br>After a test period, the consumption profile could be sketched and the peak time estimated. The reduction of consumption at peak times, avoid unnecessary expenses, and also avoid overloading the electrical system. That happens because the exaggerated network demand results in the use of thermal power plants to meet domestic demand and this type of generation is very harmful to the environment.<br>Still, the university community would become more conscious about their spending habits |

- Intergenerational equity principle (Gibson 2006b):

It treats about present actions that increase the ability of future generations to live in a sustainable way. Again all proposals meet this principle, not only because they deal with technologies that have a long service life, but also for allowing economy and an attitude that ensure balance in human relations with the environment so that there is still balance in the future.

This is because nonrenewable resources that are exploited on the planet for power generation (such as fossil fuels, for example) are limited and harmful not only to the environment but also to people's health. If the use of these harmful materials continue there will be a large decline in the quality of life on earth. The replacement by renewable energy sources and the use of technologies that induce conscious consumption are vital to ensure a balanced and sustainable future.

- Principle of Environmental Civility and Democratic Governance (Gibson 2006b):

Encourages the community and decision-making agents to implement in their actions the principles of sustainability. There should be a training of the people, through more efficient information channels, that encourages sustainable practices and the formation of a collective awareness on the subject.

The proposal about the power consumption control meets with this principle to provide to people the information about the use of energy so that they can reflect on bad habits they have with the environment in which they live, an example of bad habits is the waste of natural resources. With the formation of this consciousness people will be able to make decisions that follow sustainable principles, such as reducing the exploitation of natural systems.

## 6 Conclusion

The conscious use of electricity is vital to build a sustainable university. In this sense, this study provides data regarding behavior with the electricity consumption usage in the buildings studied. Therefore, these data could serve as an incentive for further progress towards sustainable development.

Smart grids were chosen in this study as a tool for change that would lead to the conscious and efficient energy consumption. These networks provide a wide participation of the people in electrical system operation. This participation takes place thanks to the information disclosure on the network that makes the consumer aware of their financial and energetic expenditure.

This technology also stimulate the use of renewable sources of energy by enabling consumers to generate energy in their own households for their own consumption or for the consumption of nearby regions. This is thanks to the two-way flow of energy in the network, which allows to consumer receive as much as inject energy in the grid system. With this new possibility people are instigated by economic advantages and concern for environmental safety using renewable energy sources in their households.

Finally, the access to information is the most important point for the change in people's behavior in relation to electricity consumption. Moreover, democratic information channels that reach all community are essential to create a sustainable university. Because only informed people can make conscious decisions, that means, only if people have the knowledge and control of how their actions impact the environment they will be in the path to sustainable development. And the control over electricity consumption is possible with the use of intelligent electric grids.

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# Recovery of a Green Area Inside the Campus of the Federal University of Santa Catarina Through Agroecological Agroforestry Systems

**Pedro Buss Martins, Luiz Fernando Leal, Ludmila Serafim de Abreu, Arthur Nanni, Anna Cecília Mendonça Amaral Petrassi, Marina Carrieri, Guilherme Augusto Fabrin, Carolina Assis Fernandes Ferreira, Gabriela Mota Zampieri, Letícia Peres and Carolina Nepomuceno**

**Abstract** The "CFH Forest" is a green area of five hectares in the UFSC campus, which shelters areas for permanent preservation of riparian forest and remaining of native vegetation. Besides the ecological function, area is a living space for university community. Over the years, the use and occupation of this area have caused negative environmental impact, generating erosion, compaction and loss of soil organic matter, leading to increased environmental degradation. The Agroecological Agroforestry Systems (Agroecological AFS) have been considered as an alternative approach for environmental recovery as it promotes efficiency and optimization of natural resources for production in an integrated form. This article aims to report the experience of this recovery project within the university campus, using Agroecological AFS, along with the principles of permaculture and the

P. B. Martins (✉) · L. Peres · C. Nepomuceno
Center of Biological Sciences, Federal University of Santa Catarina (UFSC),
Av. Vitor Lima, 222 CGA 7th Floor, Florianopolis, Santa Catarina 88040-400, Brazil
e-mail: pbmbuss@gmail.com; gestaoambiental@contato.ufsc.br

L. F. Leal
Center of Agrarian Sciences, Federal University of Santa Catarina (UFSC),
Av. Vitor Lima, 222 CGA 7th Floor, Florianopolis, Santa Catarina 88040-400, Brazil

L. S. de Abreu · A. Nanni · A. C. M. A. Petrassi · M. Carrieri
C. A. F. Ferreira · G. M. Zampieri
Federal University of Santa Catarina (UFSC), Av. Vitor Lima,
222 CGA 7th Floor, Florianopolis, Santa Catarina 88040-400, Brazil
e-mail: ludmila.abreu@ufsc.br

G. A. Fabrin
Department of Geosciences, Federal University of Santa Catarina (UFSC),
Av. Vitor Lima, 222 CGA 7th Floor, Florianopolis, Santa Catarina 88040-400, Brazil



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concept of energetic zones, through the “CFH Forest Environmental Recovery Project”, with students, teachers and technicians participation. After two years of project execution, some results are already visible, such as vegetation growth, soil recovery, erosion control and improvement of ecological awareness through education, stimulated by workshops, joint efforts and the promotion of a healthier environment.

**Keywords** Permaculture · Agroforestry · Environmental recovery
Agroecological education

## 1 Introduction

The use and human occupation of territory, both urban and agrarian, have caused large negative impact to the soil, generating erosion, soil compaction and loss of organic matter. In areas that are originally covered by tropical forests, as the case described in this report, the impacts suffered are even greater, given that, in the last two centuries, human civilization has found it difficult to combine different uses of soil, such as agriculture and urbanization, with presence of forests, seeing them only as an obstacle that hinders development. Different works have demonstrated how much the ecosystem was affected due to a disordered anthropic occupation, generating considerable problems such as loss of soil, pollution of water sources, loss of biodiversity, food insecurity and rural exodus (FAO 2015). It is important to consider that these impacts affect human civilization as well as other species, damaging the future use of these lands for other functions.

To find alternatives for a less harmful anthropic occupation that can ally this occupation with ecological resources and other components of the ecosystem without generating large imbalances have been a concern of different branches of science. In this sense, agroecology has been developed in last decades and is recognized as a true alternative for sustainable land management and food production, from small to global scale (Altieri and Nichols 2005). University campuses also generate diverse impacts, from construction to day-to-day activities, in such ways that the natural ecosystem is altered. The vegetation, the soil, and water resources are usually greatly affected. In this sense, promoting the environmental recovery of degraded campus areas becomes an important premise for universities, especially when it can serve as an opportunity to generate knowledge and skills for students and the community.

This work aims to describe an experience of agroecological environmental recovery, based on permaculture and agroforestry systems, developed within an area of the Federal University of Santa Catarina campus, known as the “CFH Forest”. This paper is important for it communicates an initiative that was effective and prone to be adapted and replicated in other contexts, providing great opportunities for both the sustainability of universities and capacity building for people. Nevertheless, as various limiting factors emerged during the project, more detailed and prolonged studies are needed in order to further analyze and present solutions to overcome those factors. Perhaps as more initiatives of this kind develop in universities, a common pathway of sustainable and intelligent land use may arise.

## 2 Context of the Environmental Recovery Project

The "CFH Forest" area is located within the University Campus of the Federal University of Santa Catarina (UFSC), in the neighborhood Trindade, SC, Brazil, and comprises approximately 5 ha (50,000 $m^2$). The CFH Forest is one of the few significant green areas remaining on the UFSC campus, being used daily by the university and surrounding community. In addition, much of the area of the Forest is characterized as a Permanent Preservation Area, due to the presence of two watercourses.

This area is located in the border between two populated and urban neighborhoods, located in the center-east of the island of Florianopolis. With the urban growth of both the neighborhoods and the campus itself, the area began to suffer great impacts, reaching an increasing stage of degradation, especially since, for some years, part of the area began to be used as parking. The intense passage of vehicles and resulting lack of vegetation cover in several places led to compaction and soil erosion. The area also comprises watercourses that meet considerable inflow of sewage and solid waste and lack of riparian vegetation in some sectors of the water streams' banks.

In this context, university students and employees, through the CFH Forest Preservation Commission and the Environmental Management Coordination of the Federal University of Santa Catarina (CGA/UFSC), in partnership with the Permaculture Study Group of UFSC (NEPerma), initiated the environmental recovery of area through the "CFH Forest Environmental Recovery Project", which started in September, 2014. Since then, recovery and environmental education actions have resulted in significant changes in the local landscape, transforming the aspect of the area and promoting advances in the awareness of the surrounding community.

The project is based upon principles and concepts of permaculture and agroecology, using agroecological agroforestry systems as a tool for landscape restoration and education. Agroforestry has proven to be an intelligent method of land use and cultivation, seeing that it promotes sustainability, allying food production, soil formation and forest recomposition meanwhile presenting great opportunities for education and training.

## 3 Permaculture as a Design Method for Sustainable Landscapes

Initially, in order to optimize the environmental recovery activities, the "CFH Forest" permaculture plan was created. The permaculture plan consists of analyzing and zoning the landscape based on the ecological features, uses and occupation of the ground. It will serve as guideline for future actions of use, management and administration of this important green area (Mollison and Holmgren 1979; Holmgren 2006). The permaculture masterplan can be used as a subsidy for a future "CFH Forest Management Plan", in case the area turns into a park. The plan was developed based on the principles of permaculture, among which is the concept of energetic zones. The methodology of energetic zoning aims at the organization of space based on the energetic needs of each location, so areas which require greater investment of energy and work in their use and management are located near the energy center, in this case represented by the project head office and CFH buildings.

In order to define the energetic zones in the "CFH Forest" area, the elements that were already present in the area were taken into account: tree species, areas of consolidated use, places of coexistence and circulation, building infrastructure, etc. Based on this analysis, sites were defined for implementation of agroecosystems according to the purpose of each energetic zone, in such a way that more intensive planting techniques are adopted in zone 1 and less intensive in areas characterized as zone 4. The proposal of uses and management for each energetic zone is described below.

Zone 0—Project head office: the head office of the Project will be established in the highest portion of the "CFH Forest", where the following will take place: reception of visitors, educational activities, community meeting center, administrative activities. The building will be built with earth and bamboo as the main materials. Zone 1—Organic garden, beginning of the didactic circuit, herb spiral, composting, worm farm: next to the head office and group reception area, zone 1 will be constituted by an organic garden, spiral of aromatic and medicinal herbs, and a space for microbial composting and worm farm. Zone 2—Orchard: mainly composed of a permaculture orchard with fruit trees and of others species of ecological interest, which will be implemented in the area currently occupied by *Eucalyptus spp.* trees. Zone 3—Agroforestry systems: zone 3 of the "CFH Forest" will be dedicated to the implementation of multifunctional agroecological agroforestry systems, which will serve mainly as a riparian forest for water streams where there is no vegetation, besides soil recovery, food production, wood, fibers and other products. Zone 4—Area of collection of products and biomass: in permaculture, zone 4 is considered a place of little intervention and management, and may be an agroforest already in an advanced stage and requiring few interventions and management. In the case of the "CFH Forest" initially zone 4 was not established, because it was decided to assign the whole area with trees as zone 5. With the future development of the agroforestry systems, it is expected that the trees and other plants require less energy and work, making it possible that some areas now treated as zone 3 might be considered zone 4 in the future. Zone 5—Common area, for inspiration and natural regeneration: constituted by areas that present vegetation already consolidated, in advanced stage of succession and by places used for rest and leisure.

## 4 Implementation and Management of Agroecological Agroforestry Systems (AFS)

After the zoning of the landscape, the main resource being used for environmental recovery is the implementation of Agroecological Agroforestry Systems (AFS). AFS constitute a method of soil management and cultivation that combine herbaceous or crawling species with shrubs and tree species, aiming for food production, environmental restoration and conservation. This system is effective for recovery of an area that is compacted and nutrient-poor precisely because it combines different species that develop environmental recovery similar to the natural process of ecological succession, although conducted and accelerated through management (Steenbock and Vezzani 2013).

Tree species are widely used in the university campus due to aesthetics, fruit production, shade supply and spaces for social interaction, leisure and rest. However, direct planting of these tree species in areas with compacted soil and nutrient-poor soil, like the CFH Forest, is ineffective without aid of other species. In this sense, legumes are a group of plants extremely useful in this context, as they usually provide high amounts of nitrogen to the soil. Pigeon pea (*Cajanus cajan*), for example, is frequently used in AFS, as it is able to develop in degraded areas and to fix nitrogen in soil (Gotsch 1994). Other species with similar function are mucuna (*Mucuna sp.*) and pig bean (*Canavalia ensiformis*). In this project we use the concept of Agroecological AFS because we implement agroforestry systems that, in addition to the aforementioned functions, meet the precepts of agroecology, promoting the biological diversity, the use of native species, partnership with the community and management without use of chemical input.

## 5 Educational Activities

Since the beginning of project, several joint efforts with participation of community were realized, aiming mainly at the planting of trees, preparation of agroforestry beds and management of existing vegetation. In the year 2016, joint efforts began to be carried out weekly. In addition, starting in the second half of 2016, the project team began to focus on educational activities, prioritizing construction of knowledge with students and community members interested in the practice of agroecology and permaculture. Six workshops were held, with the following themes: (A) reading landscape and patterns of nature; (B) permacultural planning of landscape and property; (C) agroecological management of soil; (D) agroecological agroforestry; (E) bamboo as building material; (F) water management and ecological sanitation.

Planning of workshops was based on texts related to agroforestry education, such as the “Manual do Educador Agroflorestal”, by Almeida et al. (2002). The set of workshops was planned such as to increase participation of people from the community and enable gradual construction of agroecological knowledge, through practices and sharing. In addition, workshops were developed through a pedagogical perspective of problematization of socio-environmental reality, valuing dialogue and previous knowledge of the people involved. Emphasis was placed on active construction of knowledge by individuals, “learning by doing”, encouraging practice and application of knowledge in everyday life (Peneireiro 2003).

Workshops were held in CFH Forest area, transforming it into a true outdoor classroom. During activities, in addition to nature itself as an object of teaching and learning, other materials were used, such as whiteboard, texts and hand tools for plant and earth work. A classroom in one of the university buildings was also used to display videos and other audio-visual materials. In addition, there were numerous dialogues, dynamics and joint efforts that stimulated the participants to talk and express themselves, exchanging knowledge. Facilitators were interns from the “CFH Forest Project” and other guests with experience in the themes.

## 6 Results: Restoring the Landscape with Permaculture, Agroforestry and Education

At the beginning of the project, priority areas of intervention were defined, which were in an advanced process of degradation, in order to implement agroforestry systems. Selected areas were: (a) portion of banks of streams of Forest that was without riparian forest (riparian AFS); (b) slope area, which had uncovered soil and advanced erosive process (slope AFS). Ever since, planting work has been carried out to implement agroforestry in these areas, aiming at environmental recovery, combined with production of food and other useful products, such as wood.

Agroforestry systems established during the project, to date, are presented (Fig. 1) and described below.

### *6.1 Riparian Agroforestry System (Riparian AFS)*

The agroforestry of the riparian forest is currently organized in three plots, according to the numbering shown in Fig. 2 for the “AFS riparian forest”.

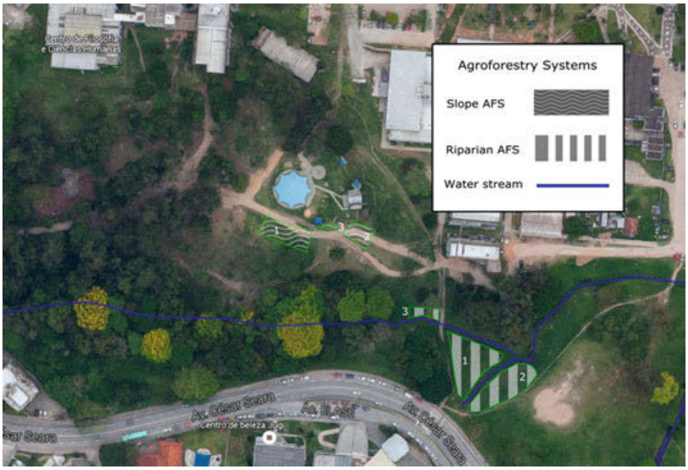


**Fig. 1** Areas of agroforestry systems implemented until April 2017

**Fig. 2** Riparian AFS—overview. Parcel 1—February 2015

Parcel 1 was the first to be implemented. The area presented little fertile soil due to the management history, with predominant presence of brachiaria grass, presence of two adult trees, one guava tree (*Psidium guajava*) and one *araçá* tree (*Psidium cattleyanum*). Previously to the project, the management of the place was carried out by the maintenance team of green areas of the University Hall of UFSC. The area was constantly mowed, preventing the occurrence of natural succession; in addition, part of the cut grass was removed from the area, which contributed to the decrease of the organic matter present in the system and soil fertility.

**Fig. 3** Riparian AFS—parcel 1 (left side) and parcel 2 (right side, still without intervention)—February 2015

The implantation process started at the end of 2014. At this first moment, fast-growing species were planted, with characteristics that make it possible to develop under conditions of low fertility, aiming at the biomass production. Lines of plants were introduced, with banana, cassava and corn. Among these, species of green manure as gray mucuna (*Mucuna sp.*) and kidney bean (*Canavalia ensiformis*) were planted (Fig. 3).

Since 2015, with the progress of the Forest Recovery Project, the parcel was densified and enriched with new species. The main species introduced were: pigeon pea (*Cajanus cajan*), mexican sunflower (*Tithonia diversifolia*), *aroeira* (*Schinus terebinthifolius*), pumpkin (*Cucurbita maxima*), ingá (*Inga edulis*), millet (various species of the subfamily *Panicoideae).* For the planting of this species, beds were constructed in the form of lines, delimited with trunks and bamboo, with compost and straw in its interior.

With the introduction of plants that were not part of the system, and with the change in the way the area was managed, natural succession could happen. Although it is a system with relatively little investment, financially and energetically, it is possible to perceive great advances in the development of the plants and the soil. Figure 4 illustrates the state of the agroforestry in May 2017, approximately 27 months after the state of the area at Fig. 2. One can notice the good development and size of the bananas (*Musa sp.*) and pigeon peas (*Cajanus cajan*), as well as the maintenance of the grass, performing its function of ground cover.

The agroforestry in parcel 2, adjacent to parcel 1, was started in May 2016, during a joint planting effort at the UFSC “Environment Week”. The planting was

**Fig. 4** Riparian AFS—parcel 1 (left) and parcel 2 (right)—May 2017

carried out in order to implement 3 rows of trees. The space between the rows were intended to produce the grass already present in the area, to be used as a source of organic matter to supply the three rows of tree with organic matter, serving as green fertilizer. The preparation of the area consisted only in mowing of the grass, which was deposited on the ground. Initially only tree seedlings were planted, in holes measuring approximately 20 cm $\times$ 20 cm, opened with a manual shovel. There was no fertilization or planting of other short cycle species. In the initial months the tree seedlings had difficulties to develop, probably due to low soil fertility, lack of irrigation and excessive sun light. As the grass grew again, the condition for the seedlings improved, because of an increase in shade and moisture preserved in the system. After a few months, the system was enriched with other species, planted close to or among the tree seedlings: banana (*Musa sp.*), mexican sunflower (*Tithonia diversifolia*), pigeon pea (*Cajanus cajan*), mucuna (*Mucuna sp.*) and yam (*Dioscorea sp.*).

Parcel 3 of the Riparian AFS is an area with grass dominance, the incidence of direct sun is lower than in the other plots, due to the greater presence of trees in the environment. In this plot, which measures approximately 48 $m^2$ (12 m $\times$ 4 m). Three rows of trees were planted, leaving the space between the rows to produce grasses, which are cut and used as mulch. Among the tree seedlings were planted, among others, mainly green manure species: pigeon pea (*Cajanus cajan*), mucuna (*Mucuna sp.*), mexican sunflower (*Tithonia diversifolia*), lab-lab bean (*Lablab sp.*), ora-pro-nobis (*Pereskia aculeata*) and banana (*Musa sp.*). The species of tree introduced were: cedar (*Cedrus sp.*), yellow jaboticaba (*Myrciaria glazioviana*), olandi (*Calophyllum brasiliense*), grumixama (*Eugenia brasiliensis*) and ingá (*Inga sp*.).

## 6.2 Slope Agroforestry System (Slope AFS)

The slope agroforestry is located in an area of slope that, before the implantation of the system, was in accelerated process of erosion. The soil on the place was extremely compacted, since part of the area was used as a walkway for pedestrians and vehicles. Currently, only a pedestrian path cuts through the Slope AFS. Initially, beds with bamboo, wood, straw and compost were built to contain the flow of water and reduce erosion. In the area, that is now considered parcel 1, some trees and shrubs species, such as mulberry (*Morus sp.*), banana (*Musa sp.*), mexican sunflower (*Tithonia diversifolia*), eucalyptus (*eucalyptus sp.*) and capororoca (*Myrsine sp.*) were present before the beginning of the project. In parcel 2 and 3, only herbaceous plants were present.

In parcel 1 the following species were introduced: pigeon pea (*Cajanus cajan*), mexican sunflower (*Tithonia diversifolia*), sweet potato (*Ipomoea batatas*), pumpkin (*Cucurbita maxima*), mucuna (*Mucuna sp.*). Garapuvu (*Schizolobium parahyba*) and Physalis (*Physalis sp.*) were some of the plants that arose spontaneously (Figs. 5 and 6).

In parcel 2, beds were built along the slope. In these beds were introduced a variety of plants, among which the main species were: pigeon pea (*Cajanus cajan*), mexican sunflower (*Tithonia diversifolia*) and ingá (*Inga sp.*). In October 2016, this parcel was enriched and densified with the following species: pitanga (*Eugenia uniflora*), olandi (*Calophyllum brasiliense*), guabiroba (*Campomanesia xanthocarpa*), king palm (*Archontophoenix cunninghamiana*), avocado (*Persea americana*), loquat (*Eriobotrya japonica*), pigeon pea (*Cajanus cajan*), maize

**Fig. 5** Slope AFS—parcel 1—March 2015

**Fig. 6** Slope AFS—parcel 1—April 2016

**Fig. 7** Slope AFS—parcel 2—July 2015

(*Zea mays*), turmeric (*Curcuma longa*), ginger (*Zingiber officinale*), ora-pro-nobis (*Pereskia aculeata*), green bean (*Phaseolus vulgaris*) and cassava (*Manihot esculenta*) (Figs. 7, 8 and 9).

**Fig. 8** Slope AFS—parcel 2—January 2016

**Fig. 9** Slope AFS—parcel 2—October 2016

Parcel 3 is a small area, in which the following species were planted: canela-sassafrás (*Ocotea odorifera*), ora-pro-nobis (*Pereskia aculeata*), ingá (*Inga sp*.), turmeric (*Curcuma longa*) and cassava (*Manihotesculenta*).

### 6.3 Workshops on Permaculture, Agroecology and Agroforestry

Workshops had good participation and were well evaluated by participants. These activities, in addition to contributing to environmental recovery of the CFH Forest area allowed exchange and practical application of knowledge related to environmental recovery and sustainability by students and people from the community.

A very diverse public attended the workshops, including undergraduate students from courses such as social sciences, geography, biological sciences, food engineering, anthropology, agronomy, architecture, environmental engineering, and design, postgraduate students, University employees and people of surrounding community.

During workshops, it was observed that the methodology of outdoor activities, which combined didactic material, dialogues and practical activities, was more effective for conducting workshops than performing classroom activities with audiovisual resources. The idea of environmental recovery ends up attracting a more practical look from participants, who were not very comfortable in a closed classroom, even when encouraged to participate. To perceive this was fundamental, since it is understood that workshops are collective constructions, that encourage participants to be active. Thus, when certain attitudes of discontent were noticed, the facilitators were open and able to modify the course of the activities, adapting to the reality of the participants. Throughout the process, there was an increase in interest and number of participants in workshops, from an average of 12 participants in first workshops to an average of more than 30 participants in last workshops.

This approach corroborates the vision presented by Peneireiro (2003), who considers active participation of members to be essential, and that the teacher should act as a facilitator. Each subject, through practice and dialogue, is able to build and exchange knowledge, enriching everyone's experiences. It is possible to draw, from this exchange of knowledge and practices, some concrete results of workshops that contributed to environmental recovery of "CFH Forest": implementation of an agroforestry system in an area of accentuated slope, erosion and hard soil; planting of an organic garden and the construction of a compost bin made of bamboo.

However, it is relevant to point out that even among some diversity the predominant public of workshops was mainly adults somehow connected with the University, which points to the need of attracting more people from outside university community, such as children and primary and secondary school students. The inclusion of these is in line with what agroecology and ethical principles of permaculture defend: care for soil; care for people, and fair sharing of resources and products.

In the educational workshops developed, the notion that the environment is formed by the social and ecological relations that characterize the space emphasized. Thus, the CFH Forest space was transformed into a place of experiences and

**Fig. 10** Workshop on agroecological agroforestry—October 2016

critical environmental education, where knowledge and practices were promoted and demonstrated the importance of agroecological agriculture. The fundamental role of humans for the conservation of nature was also discussed, not as an external agent, but as a social and natural active being in the construction of landscapes. In addition, the relationship between popular and scientific knowledge and how permaculture and agroecology allow to plan, build and maintain sustainable agroecosystems and environments were topics of debate. Thus, it is possible to conclude that the workshops met the proposed objectives, promoting socio-environmental awareness and the construction of agroecological knowledge among the participants, also contributing to the revitalization of space (Fig. 10).

## 7 Conclusion

After two years of project implementation some results are already visible. The reestablishment of ecosystems services performed by the forest are already perceived in some areas in initial stage of natural succession. In the riparian AFS, restoration of the vegetation is occurring gradually. Although many pioneer plants which assist in soil recovery are being utilized, such as mucuna, banana, Mexican sunflower and pigeon pea, the rapid growth of grasses which, on the one hand can be helpful by producing organic matter, can also be detrimental because it can suppress the growth of the tree seedlings. In this regard, areas with grasses must be managed frequently in order for it to be beneficial.

In general, it has been notorious that the planting and management of Agroecological AFS is essential for the environmental recovery of this area, providing for a more balanced and harmonious land use for the CFH Forest. Another perceived benefit has been the recovery of the soil in the areas where AFS were implemented. With this philosophy and the techniques described, it is hoped that an integral recovery may be achieved, including both the ecological and social aspects, transforming it into a healthy and useful space for the community.

During development of the project, there were some difficulties, faced by the team as challenges and opportunities for learning. The lack of soil fertility, with little organic matter and mineral nutrients, was a big limitation for the development of the AFS in "CFH Forest" area. Soil compaction was so intense in some areas that even pioneer species, such as mucuna and pigeon pea, find it difficult to develop, increasing the time for agroforestry development. In addition to ecological factors, the lack of financial resources was also a limiting aspect. An increase in financial resources would contribute to a greater efficiency in the process of environmental recovery, allowing for: more people to get involved; the possibility of buying tools that increase efficiency (chainsaws, brushcutters, small tractor); obtaining of important inputs, such as seeds, seedlings, organic matter (straw, wood) and compost.

Although the project has institutional support from the Environmental Management Coordination, some divergences were identified among the university staff, regarding the interests and objectives for the CFH Forest area. In addition to that, there has been some resistance, especially from the sector responsible for the management of green areas within the campus. This may be partly, as was concluded, due to a lack of dialogue and clarification about the project's objectives and methods of intervention (permaculture and agroforestry systems), since at various times the work has been criticized as being aesthetically inappropriate for the area.

Despite the challenges, the project has been accepted by a large part of the university community. Such acceptance could be perceived through the attendance at the workshops, as well as through encounters and dialogues during daily work and joint-efforts activities. Most people understand the principles and logic of the work and assist in process of environmental recovery. Institutional support, although limited, has also opened doors for positive relations with other public agencies and companies, which provided compost and seedlings to the project.

The whole context of the CFH Forest has great potential for future developments, both environmentally and socially. The experience of the "CFH Forest Environmental Recovery Project" has provided the university community with good experience and a solid base to advance in the recovery further improvement of the area. The advances put forth in the last two years set the stage for many possible ways of progressing to a more sustainable campus, such as the project for a community garden and "Green Park" encompassing the CFH Forest and other adjacent green areas. Furthermore, the area will continue as a space of experimentation and learning in the areas of permaculture, agroecology, agroforestry and sustainability.

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# School of Public Health, University of Sao Paulo—Marching Towards Socioeconomic and Environmental Sustainability

**Ana Maria Maniero Moreira, Wanda M. Risso Günther and Helena Ribeiro**

**Abstract** The sustainability of the earth depends largely on actions taken at universities, as they have a leading role in developing knowledge and raising awareness. The School of Public Health, University of Sao Paulo seeks to fulfill several goals in pursuance of sustainable management. Since 2009, a joint committee of students, teachers and employees endorses a Sustainability Program. Its objectives are: avoidance of natural resources depletion; waste minimization; proper waste segregation; however, its main purpose is the dissemination of environmental education and community awareness. This paper presents actions implemented and results achieved during the last eight years. Activities involve research, projects, lectures, workshops, campaigns and events regarding environmental and occupational health. Predominant actions include: avoidance of disposable products; incentives to suitable waste segregation; composting; and safe management of hazardous waste. Considering the 6.1 ton of waste monthly generated, 1.8 tons (29.2%) are carefully segregated, selectively collected, and processed through differentiated pathways. Infectious and chemical waste (5.4%) goes initially through appropriated treatment before being discarded in landfills. Confidential paper (2.5%) is shredded and goes for recycling. Other recyclables materials (18.3%) are collected by cooperatives of waste pickers and sent to the productive chain. Part of the organic waste (2.9%) is locally transformed in compost. Sustainable actions have been expanded despite the lack of economic and human resources to implement them.

**Keywords** Sustainability · Sustainable management · Sustainable campus
Solid waste · Recycling

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A. M. M. Moreira (✉) · W. M. R. Günther · H. Ribeiro
Department of Environmental Health, School of Public Health, University of São Paulo, Av. Dr. Arnaldo 715, São Paulo, SP, Brazil
e-mail: anamariainforme@hotmail.com

W. M. R. Günther
e-mail: wgunther@usp.br

H. Ribeiro
e-mail: lena@usp.br



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## 1 Introduction

With a growing population and increasing demands placed on the planet, sustainable development is one of the biggest challenges facing the world today and it is a subject of innumerable debates by politicians and business leaders (ISO 2016).

Current world development model has produced serious global and local problems such as exploitation of nature, degradation of the environment, pollution of the air, water and soil, increase of solid waste generation and deterioration of quality of life (Braun-Wanke 2017; UN-Habitat 2010).

Education and continuous learning are known to be crucial for the sustainable development. In this context, Universities are key actors in sustainable development. They generate new knowledge; contributing to the development of appropriate competencies and raising sustainability awareness (Barth et al. 2011). It is also widely known that the sustainable development not only calls for transformative research, but also for new methods that disseminate the values and principles that are the basis of sustainable development (Braun-Wanke 2017).

One of the considerable changes that occurred in higher education provision, was the incorporation of greater environmental awareness into undergraduate and post graduate level courses. These adjustments, regarded by many as an innovation, were seen like a good way of preparing students for the new world of work, where business would need to be more sustainable. Universities need to develop academic programs to integrate sustainability and to ensure that students develop the knowledge, values and competences to enable them to work with others to enhance the social and natural environment (Leal Filho et al. 2016).

The proposition must be able to give examples and encourage attitudes among students, staff and teachers not only inside the school environment, but also in real life, outside the school.

A community-based approach is effective because sustainability education is most successful when students are able to make a connection between knowledge of environmental issues gained in a classroom and personal responsibility for those issues (Rooney and Mc Millin 2010).

In this context, the aim of this paper is to present the Sustainability Program developed at the School of Public Health (FSP for its Portuguese acronym), University of São Paulo (USP), Brazil. It describes the inter-disciplinary and trans-disciplinary scenario, practices, achievements and difficulties faced since the first steps.

## 2 School of Public Health (FSP)

The School of Public Health (FSP) was created in 1918, and incorporated at University of São Paulo (USP) in 1938. It is a national and international reference in the field of Public Health. It has the mission to produce and disseminate knowledge and train human resources in public health and nutrition by means of teaching, research, and extension, contributing to improve the population health into a better condition, as well as the formulation of public policies.

FSP is composed of five departments: Environmental Health, Epidemiology, Life Cycles and Health, Nutrition, and Public Health Policy. The School is responsible for two undergraduate courses: Public Health, and Nutrition. Also offers opportunities for post graduate levels in six programs: “Public Health”, “Nutrition in Public Health”, “Global Health and Sustainability”, “Environment, Health and Sustainability”, “Public Health Entomology”, and “Epidemiology”. Dozens of specialized extension courses are also offered yearly in well-known summer and winter schools.

Currently, the FSP community consisted on approximately 1500 members, comprised of faculty professors (77), technical-administrative staff (250), undergraduate students (591), postgraduate (511), post-doctoral (27), attending specialization courses (76), and foreign students (33). Beside this population, which circulates around its dependencies on a regular basis, there are also commissioned and contracted employees, as well as a variable circulating population, composed of researchers, scholars from other units, trainees, library users, participants of several events, lectures and courses, besides patients and staff of the Primary Healthcare Public Centre, located inside the Campus area.

## 3 The “USP Recicla” Program—First Steps Towards Sustainability

Since the middle of 1990s, a Program called “USP Recicla” [USP Recycles] was implanted in several units of the University of Sao Paulo (USP), as a response to the imperative need for a change of attitude within the campuses, motivated by pressures and initiatives of the USP community itself, triggered by the increasing dissemination and concern about the problem of the exaggerated generation of solid waste in the country. At the beginning, activities were developed merely geared towards the reduction of waste and appropriate discarding of paper generated during academic and other related activities. Over the years, actions were expanded, becoming strategies to pursuit not only economic and environmental aspects, but also to contribute more intensely to the improvement of the community wellbeing, health of the neighborhood around and society’s quality of life in general.

## 4 The Socio-environmental Sustainability Program of the School of Public Health

### *4.1 Objectives*

In 2009, following the international movement that promoted greater commitment of higher education institutions in the pursuit of sustainability, the School of Public Health launched a broader program, called Socio-Environmental Sustainability.

The challenge of this new program was to give a more systemic and integrated vision to the former “USP Recicla” Program, embracing the four particular dimensions of sustainability: environmental, economic, social and cultural.

## 4.2 Methods

Strategies applied to reach this objective are presented in Fig. 1. The tool adopted is the PDCA (Plan, Do, Check & Act), advocated by Deming (1990), assisting in the planning and development of actions, evaluation of results, readjustments and continuous improvement of the plan. The program is updated every year and achievements and targets are measured and monitored adopting indicators.

## 4.3 Results and Discussion

Main results conquered during the last eight years are subdivided into topics, and presented as follow.

### 4.3.1 Constitution of a Sustainability Committee

Composed by students, professors and employees, a voluntary committee was officially institutionalized in 2009 becoming responsible for analyzing campus demands, bringing new ideas, planning, implanting and monitoring actions and communicating results achieved. Yet, the program works with the principle of co-responsibility, aiming at the decentralization and everyone’s participation.

| Health |
| --- |
| Identify and discuss campus' demand in an integrated and participatory way |
| Maintain the environmental patrimony of the campus, preserving and recovering the architectural, historical and cultural heritage of public health in São Paulo |
| Instruct students and train professionals with high quality and competence to act in the solution of socio-environmental problems |
| Develop research associated with new and existing programs on prevention of impacts and sustainability issues |
| Produce and disseminate environmental and sustainability information |
| Formulate proposals to promote more sustainable management and to strengthen co-responsibility |
| Empower and sensitize actors involved, especially by challenging for changes of attitudes |

**Fig. 1** Methods of the socio-environmental sustainability program at School of Public Health

### 4.3.2 Preservation and Restoration of the Architectural and Environmental Patrimony

Any university's environmental performance is directly influenced by the inter-connectivity between the physical environment, the campus operations and by organizational/community activities; thus, integrated strategies need to be developed. For example, sustainable landscape management may include planning for water conservation, biodiversity protection, and community-sensitive design that facilitates social engagement (IARU 2014).

The main building of the FSP was constructed in the early 1930s. Currently, it is recognized as an example of the early twentieth century public architecture in São Paulo. It was restored in 2010, when its infrastructure of classrooms, laboratories and restrooms was modernized to adapt to its prevailing and intensive use, while retaining the original features of the building. The same process was applied to the building of the Primary Health Center, located on the same ground.

In addition to architectural and cultural preservation, an area of 22,000 $m^2$ of gardens is conserved, remaining open to the inside and outside community of USP, constituting a place of leisure and physical exercise, especially for the older population living in the surroundings. In the garden, benches and tables are made of recyclable material, with a walking path on a permeable floor. However, the main elements of environmental sustainability are the garden characteristics that alleviate the climate and urban pollution, their permeability and capacity to absorb rainwater and the conservation of biodiversity. Floristic survey, carried out in 2012, indicated the existence of 648 individuals of 63 tree species, being almost half native.

### 4.3.3 Education and Research—Promotion of Disciplines and Projects

Higher education for sustainable development aims at facilitating the development of competencies to contribute to a more sustainable future. Sustainable development is not just another topic to be considered in the curriculum, but it challenges the integration of traditional discipline-oriented and participatory plus competence-oriented approaches (Barth and Rieckmann 2012).

The Sustainability Program at FSP covers three fields: (i) Research—seeking for paradigmatic solutions and generating knowledge; (ii) Teaching—training professionals to act on environmental problems and to aware citizens; and (iii) Practical actions—establishing examples of socio-environmental responsibility and preventing impacts on the environment and human health.

Several academic subjects contribute to an understanding of environmental change and deterioration, focusing on ways to face and solve these problems. The Environmental Health Department offers 15 subjects in two Undergraduate Programs: Public Health and Nutrition. Besides that, there are four other subjects ministered outside the Campus: one in Nursing and three in Environmental Engineering. The Environmental Health Department also offers 33 subjects for post

**Fig. 2** Voluntaries operating the community garden, FSP, 2014 (All pictures presented were registered by the authors)

graduate students encompassing six Programs, which are also open to any graduate level student.

Utilizing the campus as a classroom is an important part of promoting environmental literacy amongst both staff and students. The learning experience is influenced by far more than whatever is taught in classroom (Rooney and Mc Millin 2010).

Two sustainability's projects called "*Mão na massa*" [Hands-on] and "*Ecohorta*" [Eco-garden] were developed, respectively in 2009 and 2012, where children and staff of the Pre-school Day Care Center got together with students, teachers and employees of the faculty.

Since 2013, an organic garden has been voluntarily operated (Fig. 2) by students, academic and nonacademic staff, taking turns themselves in planting, watering and weeding the plots. Harvesting is free and welcome. This project also involves workshops and "chat groups" to exchange experiences and skills, aiming to environmental and nutritional education as well as social values. People are encouraged to bring nature and healthy habits to the urban environment.

#### 4.3.4 Dissemination of Environmental and Sustainability Information —Lectures, Meetings, Workshops and Trainings

Whether the goal is to reduce electricity use, increase recycling rates, or enhance student engagement across the university, the sustainability personal cannot do this alone. It needs employees and students to clearly understand what they should do and why they need to act in that way, before they will act in a positive way (IARU 2014).

Raising awareness, sensitizing, boosting interest and participation of the FSP community and the population in general represent the social dimension of this program.

Then, at the beginning of every school year since 2010, incoming students (about 120 undergraduate and 100 postgraduate) are introduced to sustainability concepts and actions developed in FSP and are also invited to participate in the activities inherent to the program (Fig. 3). Traditionally, in these occasions,

**Fig. 3** Presentation of the program to incoming students, FSP, 2012

squeezes or mugs are distributed to the students to avoid use of disposables during their academic years.

Periodically, workshops are provided to the janitors (outsourced) encompassing safe practices referring to waste segregation, handling, collection, transport and storage, besides prevention of occupational accidents and diseases caused by hazardous waste. Workshops are promoted embracing all levels of workers of the Pre-school Day Care Center and Primary Healthcare Center, which are located inside FSP area, to perform topics such as appropriate segregation/discard of recyclables and handling of hazardous materials.

Additionally, a continuous support is provided to the Hazardous Waste Management Committee of FSP, including data collection allowing the evaluation of the Program's performance using indicators.

As a way to play its role on social inclusion, in 2015, lectures regarding prevention of occupational diseases and accidents were presented to waste pickers at the facility responsible for the collection and sorting of the recyclables generated in FSP.

### 4.3.5 Reduction of the Consumption of Natural Resources

Universities face particular challenges: energy-intensive laboratories and the use of hazardous substances; they also occupy very diverse, often old, buildings that are difficult to be more energy and water-efficient (IARU 2014).

The PURE (Permanent Program for the Efficient Use of Energy) and PURA (Permanent Program for the Efficient Use of Water) are projects which monitor respectively energy and water consumption and propagate information about the importance of being aware of the sustainable use of natural resources and furthermore offer basis for planning campaigns, events, reforms and to propagate information to the community of the university.

Some examples of measures to save natural resources are: putting in place water flow reducers on taps and valves; distribution of water and energy saving guidelines (adhesives and folders); reduction of paper consumption; incentive to double-sided printing and reduction of consumption of disposable plastic cups and replacement for reusable ones.

### 4.3.6 Control and Prevention of Environmental Impacts

The underlying intent must be not only to manage environmental impact, but to educate a community who will influence corporate values and have at the end of the process graduates who will foster change beyond the university community (Rooney and Mc Millin 2010).

The 16 laboratories developing research in public health generate approximately 331 kg/month of hazardous waste, such as infectious and chemicals products, corresponding to 5.4% of the total waste generated. This kind of waste can cause serious consequences for the environment and human health if it is not safely sorted, collected, stored, transported, treated before disposed on landfills.

Used fluorescent lamps are carefully collected and sent for treatment to prevent emission of pollutants, such as mercury vapor. An average of 84 units/month of burned fluorescent lamps is safely stored and shipped for specialized treatment and recycling. Currently they have been substituted for LED (Light-Emitting Diode) lamps (without mercury on its composition) which still may be the best choice regarding light quality, energy use and environmental footprint.

Batteries and cell phones contain dangerous substances that represent threats to the environment and risks to human health. Despite acting at a local level, FSP Program tried to organize those collecting strategies that are based on social participation and citizenship. From January 2010 to December 2016, 1303 kg of batteries and cell phones generated inside and outside the university were collected at the five units that compose the so-called USP's Health-Law Campus Quarter (School of Medicine, Law School, School of Public Health, School of Nursing and Institute of Tropical Medicine). The School of Public Health contributed with about 100 kg/year of these residues which are addressed to treatment and recovery of metals.

### 4.3.7 Minimization of Waste Generation

Universities need to establish an effective process to minimize the amount of waste that is disposed at landfills (IARU 2014). An important principle required by the Brazilian National Solid Waste Policy (Brazil 2010) is concerning to the non-generation, reduction, reuse, recycling and treatment of solid waste, as well as appropriate final disposal of rejected materials. In FSP the process involves the waste minimization and recycling of different types of materials.

Total amount of regular solid waste monthly generated in FSP is around 6.1 tons. A great part of this (70.8%) is represented by regular waste (4.43 tons), sent to landfills. Arising from actions implemented by the Program was the reduction of 13.6% of regular waste generated in 2016 compared with the previous year.

The selective collection is a key point to the recovering of materials from the waste. In 2016, almost 13.5 tons of recyclables were segregated in FSP, corresponding to 18.3% of the total waste generated. In this case, the bin infrastructure becomes relevant. It must efficiently stream materials that can be recycled or reused and allow its easy access for the community members. Bins must be clearly identified to reduce incidents of cross contamination, placed in convenient areas and positioned close to the respective waste source (IARU 2014).

In FSP, suitable containers (for recyclables and non-recyclables) are strategically spread in corridors (Fig. 4), operational and administrative sectors, academic departments, classrooms, laboratories, library, Primary Healthcare Center, Pre-school Day Care Center, gardens and restaurants.

In general, demolition waste is heterogeneous and consists to a large extent of building materials but includes even small amounts of hazardous substances. After appropriate processing the major part of these materials meet the technical properties for reuse (Tränkler 1996). Since 2009, maintenance employees have been instructed to separate certain construction waste (wires, ferrous material, metal frames and others) and send them to be recycled.

All recyclables collected in FSP are addressed to a recycling sorting plant (Fig. 5), where they are separate by waste pickers who sell them to recycling industries, contributing to the social inclusion of the low-income people.

Another promising option to minimize the quantity of regular waste produced by the population is the segregation and composting of the organic parcel. In FSP, a composting project is maintained and monitored by a group of volunteers composed by teachers, effective and outsourced employees, students and trainees. Since March 2009 until December 2016, 19.4 tons of organic waste generated in FSP's kitchens (peels and leftovers of fruits and vegetables, coffee grounds) and gardens (grass and leaves) were transformed into organic compost. It means an average of 180 kg/month (or 2.9% of the total amount of waste produced). The resulting compost is distributed to the public during events or returns to the soil since it is applied to enrich the school ornamental and vegetal gardens.

The carbon emissions avoided by diverting this parcel of the waste stream from landfill has been studied in another correlated project currently in progress.


**Fig. 4** Identified containers for recyclable and no recyclable waste

**Fig. 5** Sorting of recyclables by waste pickers, 2011

**Fig. 6** Composting area, FSP, 2013

Since 2009, the composting area (Fig. 6) has received external and internal visitors and this practice has been replicated in residences and other teaching and research institutions.

Simultaneously, some other materials generated at universities require special flows and launching campaigns of collection have shown to be the best way to work around it. From 2010 to 2016, sixteen campaigns to collect unused and confidential paper collection (Fig. 7) were carried out, resulting in more than 13 tons of paper directly sent to the recycling industry. This amount is undoubtedly significant since it corresponds to 2.5% of the total waste generated in FSP.

Another successful campaign involves collection of household WEEE (Waste Electrical and Electronic Equipment). All the material collected has been donated to a recycling sorting facility specialized in disassembling electronic devices and then each component is sent to be reused or recycled.

Campaigns of printer's toners and ink cartridges collection resulted in respectively 457 and 641 items returned to manufacturers for an appropriate flow of the different components.

Software devices such as CDs, DVDs, diskettes and pen drives are periodically collected and donated to the waste pickers cooperative that is a partner of the Municipal Program of Solidary Collection of Recyclables.

**Fig. 7** Result of the confidential paper collection campaign, FSP, 2010

Permanently a special container is strategically installed at the FSP library to provide a continuous point of collection to useless writing devices such as pens, pencils, erasers, sharpeners and others. These materials are also periodically collected and sent to a recycling program sponsored by the manufacturer.

### 4.3.8 Awareness and Communication of Achievements

One of the challenges facing many organizations is determining how to improve performance through more efficient resource consumption and afterwards to communicate the effectiveness of any measures implemented. Simple and measurable performance outcomes can themselves be valuable tools for communicating a sustainability message (Rooney and Mc Millin 2010).

In 2009, the sustainable actions in FSP were a matter of a TV show called "Globo University", increasing the diffusion of the Program.

A booklet denominated "*Caminhos da Faculdade de Saúde Pública Sustentável"* [Sustainable School of Public Health Paths] containing the first steps of this sustainability Program was written in 2010 and is available for download on the FSP website.

Annual reports are published at the FSP website showing recent results, indicators and photos and calls community attention to issues that should be better explored.

Some commemorative events are used as positive sustainability approach. Every year, since 2010, varied activities are organized to celebrate ***World Environment Day*** (June 5th). The program involves lectures related to environmental health, theater plays, exposition of objects made with waste, workshops concerning reuse of disposable materials, nutrition workshops for the total utilization of aliments, guided track around FSP's gardens and composting area, distribution of booklets with recipes using peels and leftovers and samples of compost, exposition of pre-school children's drawings about ecology and examples of actions to save the planet.

Another date celebrated, since 2011, is the ***World day without a car*** (September 22th) with activities such as walking group through the Historic Center of São Paulo city and "Live parking spots"—some parking spaces are blocked to sensitize the public of the importance of the good quality of the air.

## 5 Conclusion

Despite difficulties such as lack of economic and human resources to implement some projects, results achieved so far are broad, especially in terms of community awareness and benefits of environmental preservation, which is considered fundamental to sustainability.

Internally, the program provided greater integration among the participants and sectors involved, generated knowledge on the issues addressed, with consequent implementation of actions and procedures, and instigated the FSP community to participate. These are structural and basic steps for the continuity and sustainability of the program, which has continuously implemented new actions on its agenda, always attempting to new environmental, social and economic demands. On the other hand, the evaluation of the implemented actions and the dissemination of results, based on indicators that are periodically fed into the system, gave credence to the program and legitimized its existence and improvement. More important, it has created a culture of sustainability in the school community and incentivized actions taken by various groups in different arenas: a project of rainwater reuse was put in practice by the Environmental Health Department; the concept of environmental impact of food production and of food choices was incorporated at the Nutrition course, to name a few.

Besides saving natural and economic resources by many of the actions undertaken, the restoration of the building and the maintenance of the large gardens made them attractive for the public. Students, technical staff, professors and also external public, mainly aged people from the neighborhood now use the area for leisure and recreation, contributing to their wellness.

Together with the social sphere, this program contributes to encourage and sustain the activities of waste pickers organized in cooperatives. On the other side, attracts external interest and shows enormous potential for replicability in other educational institutions. In addition, program coordinators are available for interviews and visits from stakeholders of other institutions, always with the intention of presenting successful actions, disseminating information and sustainable ideas.

There are many practices and each one of them requires different procedures, negotiations with diverse actors and constant monitoring. The publication of periodic results, based in indicators, is an incentive and motivation for the community to continue working and broaden the scope of sustainability actions. In this sense, recording all the information inherent to the Program, constitutes a differential feature and fulfill the objective of evaluating the actions implemented and make corrections to its course if necessary. It is clear, that these actions must be integrated as a part of the daily life of the community and must be continued in order to avoid retrogressions or program ending in the future.

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# Indoor Spaces Environmental Evaluation for Office Buildings at CUASO—Applicability of the BOSSA Time Lapse

**Aparecida A. Bou Ghosn, Christhina Candido, Roberta Consentino Kronka Mülfarth, Ranny Xavier Michalski, Leonardo Marques Monteiro, Lucas Barbosa Lima Lázaro, Lucas Lauton de Lima, Thaiz Fontoura Gonçalvez and Alessandra R. Prata-Shimomura**

**Abstract** This study assesses the user perception of the Indoor Environmental Quality (IEQ) of workspaces by means of application of the BOSSA Time-Lapse System—developed by the University of Sydney and University of Technology, Sydney/Australia. It is a Building Occupancy Survey System Australian (BOSSA)

A. A. Bou Ghosn (✉) · R. C. K. Mülfarth · R. X. Michalski · L. M. Monteiro
L. B. L. Lázaro · L. L. de Lima · T. F. Gonçalvez · A. R. Prata-Shimomura
Laboratory of Environment and Energy LABAUT, Faculty of Architecture and Urbanism of the University of São Paulo - FAU, USP - Rua do Lago, 876, Butantã, São Paulo, SP 03178-200, Brazil
e-mail: cidaboughosn@gmail.com

R. C. K. Mülfarth
e-mail: rkronka@gmail.com

R. X. Michalski
e-mail: rannyxavier@gmail.com

L. M. Monteiro
e-mail: leo4mm@usp.br

L. B. L. Lázaro
e-mail: lucas.barbosa.lazaro@usp.br

L. L. de Lima
e-mail: lucas_lauton@hotmail.com

T. F. Gonçalvez
e-mail: thaiz.goncalves@usp.br

A. R. Prata-Shimomura
e-mail: arprata.shimo@gmail.com

C. Candido
The University of Sydney School of Architecture, Design and Planning, Rm 587, Wilkinson Building (G04), University of Sydney, Sydney, NSW 2006, Australia
e-mail: christhina.candido@sydney.edu.au



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tool, designed to assess the IEQ of workspaces by means of a questionnaire. Supporting the current Master Plan of the Armando Salles de Oliveira University Campus (CUASO), its buildings are being used as case studies for the development of BOSSA Brazil System. The first case study was conducted at the Laboratory of Environmental and Energy Studies (LABAUT), located at the Faculty of Architecture and Urbanism of the University of São Paulo (FAUUSP). This study was conducted into two different stages. Stage 1, named BOSSA Time-Lapse Base Case, was comprised of 12 volunteers participating in a critical analysis, helping to: (1) understand the functionality of the BOSSA Time-Lapse System; (2) identify translation issues and inconsistency in the questions and, (3) adapt the BOSSA System, which was developed in Australia, to the Brazilian reality. Stage 2, named Second Application of BOSSA Time-Lapse questionnaire, was comprised of four different volunteers invited to respond to the questionnaire without any influence from the researchers. Stage 2 helped to: (1) evaluate the user satisfaction/dissatisfaction with his/her workspace; and, (2) analyze his/her relations with the environment and the building architecture, using the BOSSA Time-Lapse questionnaire. Results show that the translation issues should be reviewed, and that the building has a high level of satisfaction among its users. The dissatisfaction results show high levels of noise, lack of privacy and natural light in some workstations, mostly related to workspace layout. The questionnaire applied at stage 2 identified different results when it comes to satisfaction and/or dissatisfaction with environmental comfort issues. This analysis will contribute to the understanding of the BOSSA Time-Lapse questionnaire, and its application in office buildings in Brazil, as well as to analyze variables of the building IEQ. It will also help to understand the use and application of the BOSSA System methodology internationally.

**Keywords** Indoor environmental quality · Environmental comfort
Indoor spaces · Workspaces · BOSSA Time-Lapse

## 1 Introduction

In order to reduce the environmental impact of building, there is a need to rethink the way we build and use the urban environment. The idea of "sustainability, green building, environmental certifications, bioclimatic architecture", etc., brings us important and fundamental concepts used in architectural design processes, such as: (1) the building's suitability to the local climate; (2) impact of the building's integration with built and urban environments; (3) efficiency in the use of natural resources; (4) the quality, performance and operation of buildings; and (5) quality, comfort, health and productivity of its occupants.

The increasing use of artificial cooling in new and existing buildings, having no studies and application of passive design strategies, is one of the main factors for the increase in energy demand and use, usually from non-renewable sources. Data on natural resources shows that 60% of consumed energy on the planet pertains to operation of residential and commercial buildings (Gonçalves 2011). In addition, about 25% of primary energy consumption takes place inside buildings (Levine et al. 2007, by Gonçalves 2011).

Several factors influence the increase of district heating, heat island and the consequent use of artificial cooling. According to Gonçalves (2011) "*the micro-climatic conditions created in the built environment and open spaces are determinant for the environmental and energetic performance of buildings.*" (Translated by the authors). Gonçalves (2011) also affirmed that the cities' warming is also associated to the inert materials used on the surfaces of the built environment, and to factors such as heat transmitted by buildings, internal activities, energy consumption, lack of vegetation, and geometry of urban design.

Analysis of passive design strategies, patterns and constructive systems, architectural elements that influence the environmental conditions, as well as building operation and maintenance information, are fundamental to the evaluation of indoor environmental quality performance and building occupation quality.

According to Meir et al. 2009, *buildings are rarely revisited and reassessed once they are handed over to their users. This lack of evaluation and study stems from numerous reasons and leads to a situation in which every single building remains a unique specimen, design mistakes are repeated, and when some re-evaluation of the building as an end product is undertaken, it is often based on non-systematic troubleshooting.*

The lack of data demonstrating the real environmental and energetic performance of buildings can cause a false interpretation of passive strategies applied in building design, and they risk becoming ineffective architectural references, without any confirmation of their real effectiveness. The building's retrofit becomes a viable alternative for reducing environmental impacts, extending its life cycle and reducing consumption of natural resources, and also increasing indoor environmental quality and occupant's satisfaction.

Besides the building analyses, the occupants are also responsible for the building's environmental performance, "*since their use and occupation are directly reflected in the building's consumption, whether it has the environmental certification or not*" (Translated by the authors) (Buoro et al. 2012). While there are great efforts in obtaining building performance data, less attention—and study - has been devoted to the occupant's requirements and satisfaction.

According to Gonçalves and Marcondes-Cavaleri (2015), "*in addition to the building performance as design and construction and the prescribed efficiency of the systems, the occupant has a significant influence on the final performance of the building according to his/her activities, habits, needs and preferences*".

The Post-occupancy evaluation (POE) is a platform for systematic study of a building once it is occupied (Meir et al. 2009), allowing facility managers to identify and evaluate critical aspects of building performance (Preiser 1995).

Therefore, studying the relation between architectural design and building occupation and operation by its occupants, is of great relevance for understanding the building's real environmental performance.

It is possible to collect data on the needs of the occupants by applying an indoor spaces environmental evaluation questionnaire, and compare it with the analysis of the architectural characteristics and the workspaces layout. With the variable microclimatic measurements and the local climate analysis, it is possible to verify the occupants' satisfaction and/or dissatisfactions with these spaces. Their demands and needs are determining factors for validating design strategies, enabling the creation of new building design solutions and space adaptation by designers and several other professionals.

The building occupants are the main yardstick of the building's functionality and they are responsible for its final performance. Therefore, collection, analysis and correctly interpretation of architectural characteristics and design elements are paramount to the evaluation of indoor occupation. These analyses can support workspace requalification and create a building information database—an important tool for the application and/or validation of architectural strategies and for the building's environmental performance.

This paper aims to present an analysis of the applicability of the BOSSA Time-Lapse System evaluation tool in workspaces in Brazil, having as a baseline subject the Laboratory of Environment and Energy (LABAUT) of the Faculty of Architecture and Urbanism of the University of São Paulo (FAU/USP). This analysis will contribute to the understanding of the BOSSA Time-Lapse questionnaire, and its application in office buildings in Brazil, as well as to analyze variables of the building IEQ. It will also help to better understand the use and application of the BOSSA System methodology internationally.

## 2 BOSSA System

Since its development in 2011, the Building Occupants Survey System Australia—BOSSA, is an Indoor Environmental Quality (IEQ) assessment system for Australia's office building. Developed and managed by the University of Sydney and by the University of Technology of Sydney, Australia,[1] BOSSA is endorsed for use in the National Australian Built Environment Rating System—NABERS Indoor Environment, Green Building Council of Australia's, Green Star-Performance rating tool and the WELL Building Standard.

BOSSA is designed to overcome three methodological shortcomings identified in current POEs, as follows: (1) contextualizing POE results, (2) adding

[1]The *BOSSA System* team composed by: Professor Richard de Dear, Dra Christina Candido, Dr. Jungsoo Kim, Mr. Thomas Parkinson, Ms. Fan (Jessica) Zhang, and Ms. Nicole Maia, from University of Sydney, Australia, and Professor Leena Thomas from University of Technology of Sydney, Australia. In Brazil, the team of researches is composed by Prof. Dr. Alessandra R. Prata-Shimomura, from Universidade de São Paulo, Dr. Renata de Vecchi and Prof. Dr. Roberto Lamberts, both from Universidade Federal de Santa Catarina. http://www.bossasystem.com/bossa-brasil.html. Accessed: 11–03–2017.

instrumental data side by side to survey results and (3) producing meaningful feedback to its key stakeholders (Candido et al. 2015).

It is comprised of three independent but complementary tools: (1) BOSSA *Time Lapse*, a web-based survey tool to assess occupants' satisfaction with the IEQ performance of their office building; (2) BOSSA Nova, a mobile IEQ assessment cart equipped with an integrated array of sensors that can be used in combination with BOSSA Snap Shot questionnaire.; and (3) BOSSA Snap Shot, a questionnaire designed to provide insight into a buildings' performance matching the "right-here right now" questionnaire with instrumental measurements of IEQ variables.

For this paper, the applicability of the BOSSA Time-Lapse, the first and most conventional component of the BOSSA System is going to be analyzed.

## 3 BOSSA *Time-Lapse*

BOSSA *Time-Lapse* has been developed with an integrated, flexible branching structure based on 31 core questionnaire items. It has a systematic grouping of the building's descriptive information, allowing attribution of the occupant's satisfaction/dissatisfaction to specific characteristics of the building's design, its facilities, etc. According to Candido et al. (2015), *it is the first and most conventional component of the BOSSA System, and it is named as BOSSA Time-lapse in reference to the fact that the POE questions comprising it are summative ('Overall how would you describe…') and seasonally integrated ('…during winters…').*

The BOSSA Time-Lapse questionnaire is structured, initially on the occupant's profile, identifying the age group, gender, weekly working hours, among others. Core questionnaire items prompt building occupants to rate their overall satisfaction with key IEQ parameters, including:

1. **Spatial Comfort**: Identifies green areas in the workspace, and the occupants' level of satisfaction with the layout, furniture, etc.;
2. **Individual Space**: Identifies the spaces for each occupant, classified as individual work spaces, storage spaces for personal belongings, etc.;
3. **Indoor Air Quality**: Identifies the occupant's satisfaction or dissatisfaction with air movement, humidity, and air quality in the work space;
4. **Thermal Comfort**: Identifies the occupant's satisfaction and/or dissatisfaction with temperature, relating comfort and thermal discomfort in different climatic seasons;
5. **Noise Distraction and Privacy**: Identifies and classifies noises and distractions in the workspace layout, visual and sound privacy;
6. **Visual Comfort**: Identifies the amount of light on the workstation and the environment, glare, reflections, shading, etc.;

7. **Individual Control**: Identifies and classifies occupant's satisfaction with the control over cooling, heating, lighting, window opening and closing systems, etc.;
8. **Connection to the Outdoor Environment**: Identifies levels of user satisfaction and dissatisfaction regarding access to natural light, view of external landscapes and integration of the internal and external environment;
9. **Building Image and Maintenance**: Identifies the level of satisfaction and dissatisfaction of the user regarding cleaning, visual aesthetics and building maintenance;
10. **Environmental Quality, Health and Productivity**: Identifies the satisfaction and dissatisfaction of the occupant regarding the influence of the work area on their productivity and health, etc. and,
11. **Health**: Identifies height, weight, eventual body aches, physical activity and etc.;

The survey takes less than 10 min to be completed, and can be accessed through a link sent directly to the building's occupant. The BOSSA Time-Lapse Report is delivered to the researches via web, and according to the BOSSA System website: "*Occupants are asked to rate their overall satisfaction on a seven-point scale ranging from negative to positive (dissatisfied—satisfied, disagree—agree,* etc.*). The satisfaction graph uses the same seven-point scale to show the distribution of occupants votes for each questions. The graph also shows total of percentage of dissatisfied occupants (red box, left bottom of the graph) the mean score (gray box, center) and the percentage of satisfied occupants (green box, right bottom)*"[2] (Fig. 1).

The BOSSA System runs on the University of Sydney's IEQ Analytics online platform and questionnaire responses are logged and time-stamped by a central server (Candido et al. 2016).

BOSSA *Time-Lapse Report* summarizes the questionnaire results for each IEQ parameter, the occupant's profile and the additional comments for each occupant's responses.

## 4 BOSSA Building Metrics

BOSSA Building Metrics (BM) is a tool that aims to systematically collect the architectural information and data of the buildings where the questionnaire is applied, associating the building's information with the questionnaire responses.

The information and data collected are based on: (1) current sustainability and energy performance ratings; (2) year of construction and/or retrofit; (3) number of floors; (4) number of building occupants; (5) number of desks per floor; (6) lighting systems (including daylight and type of artificial lighting), (6) shading; (7) heating,

[2]Available in www.bossasystem.com, Accessed: 29–05–2017.


**Fig. 1** BOSSA Time-Lapse questionnaire and satisfaction graph. *Source* www.bossasystem.com. Accessed: 29/07/2016

ventilation and air-conditioning (HVAC) (including system type and personal control, if any), (8) building temperature set-points, etc. (Candido et al. 2016).

By collecting this kind of information, it is possible to conduct diverse researches relating to specific design and architectural elements that influence the thermal conditions and the building's integration with the local climate. Simultaneously, it will be possible to attribute IEQ satisfaction ratings to specific design strategies implemented in the building.

**Baseline case: Laboratory of Environment and Energy (LABAUT), Faculty of Architecture and Urbanism of the University of São Paulo (FAUUSP), Armando Salles de Oliveira University Campus (CUASO).**

This paper aims to present an analysis of the applicability of the BOSSA Time-Lapse System evaluation tool in workspaces in Brazil, having as baseline case the Laboratory of Environment and Energy (LABAUT) of the Faculty of Architecture and Urbanism of the University of São Paulo (FAU/USP). This analysis will contribute to the understanding and verification of the BOSSA Time-Lapse questionnaire, and its application in office buildings in Brazil, as well as to analyze variables of the building environmental comfort.

## *4.1 FAUUSP Building*

FAUUSP's building belongs to the CUASO complex of buildings, and has administrative rooms and departments that work as office environment. This methodology should be extended to other CUASO buildings, such as the Rectory building (Fig. 2).

FAUUSP's building was recognized by the CONDEPHAAT (Council for the Defense of Historic, Archaeological, Artistic and Tourist Heritage) as cultural

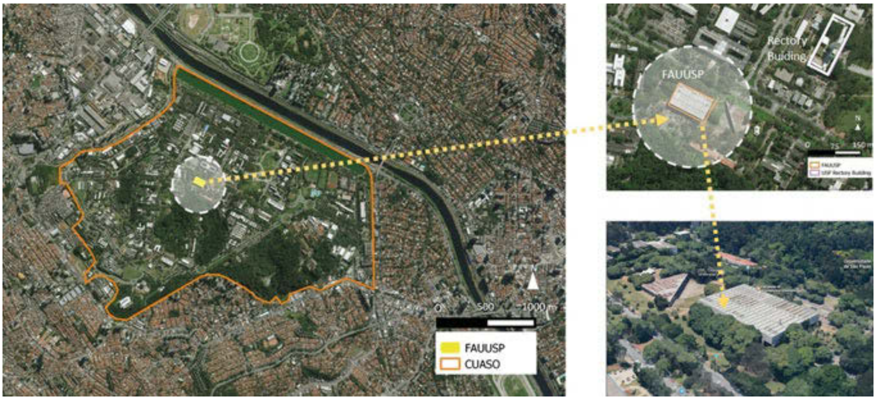


**Fig. 2** Aerial view of FAUUSP and its location within the Campus, its proximity to the Rectory building and FAU aerial view from the Northeast face. *Source* Images from—Google Maps

**Fig. 3** Views of the concrete wall supported by the trapezoids shaped columns. *Source* Images from the authors

heritage of the State of São Paulo, received national and international awards, and was designed by the architect João Batista Vilanova Artigas in 1961.

The construction was completed in 1969, and is characterized by a large concrete wall supported by trapezoids shaped columns (Fig. 3). In between the concrete wall and the columns, walls and glazed and/or open surfaces summarize the building and its form. As a solution used in different Artigas's projects, the naked concrete, glass, the simplicity of lines and forms and the integration of the indoor spaces of the building are main characteristics of the building, considered as one of the icons of São Paulo Brutalism architecture.

The space continuity is determined by the large central open space and the ramps that connect the all building's floors, each with different uses and functions. Concrete was used as technological innovation at the time. The adoption of large structural spans and the integration of indoor spaces has become the "*example for the heritage of the building environment designed for higher education*" (Simões 2004) (Translated by the authors). This philosophy was implemented in several others CUASO buildings in the 1960s, which will be the subject of research by BOSSA Brazil.

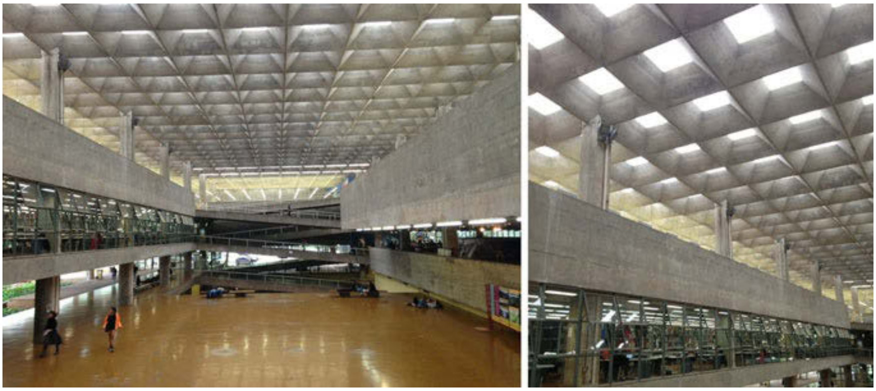

**Fig. 4** View to the open space and the ramps that connect all building floor, and the translucent fiber-glass domes on the roof. *Source* Images from the authors

The building's shape is characterized as a rectangular concrete block of 110 m × 66 m, with 08 floors interconnected by ramps, stairs and elevator, having a constructed area of 18,600 $m^2$. Its roof is designed as a concrete grid, which carries a series of translucent fiber-glass domes, which determines the zenithal lighting set at the studios (Fig. 4).

## *4.2 LABAUT—Case Study*

The LABAUT, Laboratory of Environment and Energy is located in the half-underground floors, on the northeast face. Its walls are built of fiber pressed wood panels and glass in between the rooms. The floor has a yellow epoxy, and the slab is made of concrete. The lighting is defined by fluorescent lamps, installed in metal fixtures that are fixed to the slab with a metal structure suspended at different heights (Figs. 5 and 6).

The LABAUT is designed as an open plan office space, with partitions and a fixed layout. It has 12 workstations with computers and four meeting desks. It is divided into two rooms, as shown in Fig. 7. Room 01 does not have direct access to the exterior. Many students use the workstations in room 01, characterizing it as a co-working space. Room 02 has direct contact with the exterior through pivotal windows. The windowsill is part of the half-underground floor of the building. Both rooms are divided by partitions made of fiber pressed wood panels and glass. The existing air conditioning system supports both rooms (Figs. 8 and 9).

Table 1 presents an example of LABAUT BOSSA Building Metrics.

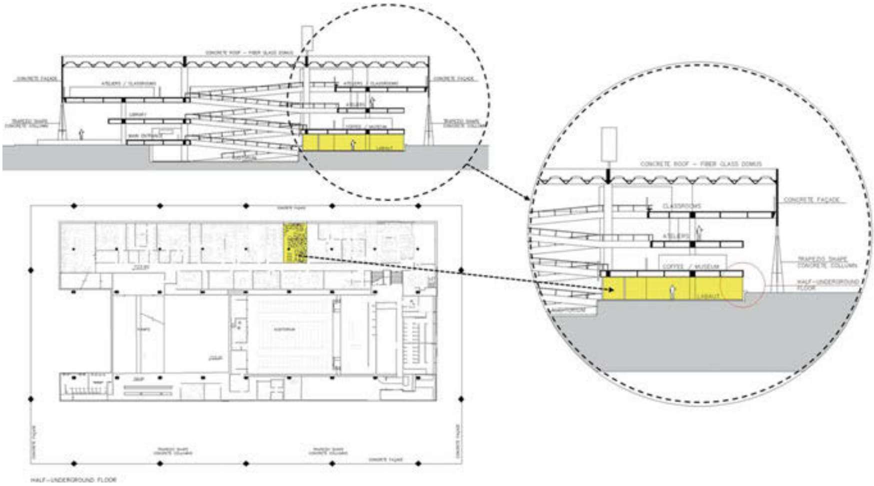

**Fig. 5** Half-Underground floor and sections highlighting LABAUT. *Source* Redesigned by the authors


**Fig. 6** Views of the concrete wall supported by the trapezoids shaped columns; indication of the LABAUT at the half-underground floor. *Source* Images from the authors

## 4.3 Application of the BOSSA Time-Lapse Questionnaire

Volunteers from LABAUT were invited to participate in the Baseline Case. Two applications of the questionnaire were carried out. The first was held on 01/27/2017, and named here as BOSSA Time-Lapse Base Case. The second was held on 04/27/2017, here named as—Second Application of BOSSA Time-Lapse.

## 4.4 Stage 01—BOSSA Time-Lapse Base Case

In Stage 1 the volunteers, most of them architects and engineers with expertise in comfort indexes and evaluation systems, answered the questionnaire with a critical


**Fig. 7** LABAUT Floor plan and pictures from the main entrance. *Source* Images from the authors

**Fig. 8** Room 1. View from the LABAUT main entrance. *Source* Images from the authors

**Fig. 9** Room 2 (Professors Room). View from the window of Room 2. *Source* Images from the authors

**Table 1** Example of BOSSA building metrics

BOSSA Building Metrics

THE UNIVERSITY OF SYDNEY UTS

| Building input | Answer | Comments |
|---|---|---|
| Building name | FAUUSP | |
| Tenant | Universidade de São Paulo - faculdade de Arquitetura e Urbanismo | |
| Address of building | Rua do Lago, 876, Cidade Universitária, Butantã, São Paulo - SP | |
| Applicant | LABAUT - Laboratorio de Conforto Ambiental e Eficiencia Energética | |
| Contact person | Professor Alessandra R. Prata Shimomura | |
| Number of survey respondents targeted (number of email addresses that the survey link will be sent to) | 16 | |
| Year of construction (building) | 1969 | |
| Has this building undergone a major renovation (e.g. façade, HVAC systems, etc)? | | |
| Year of renovation | 2007 to 2014 | |
| Building Net Lettable Area (NLA) | 18.600m² | |
| Tenant Net Lettable Area (NLA) | Auditorium and Laboratories= 3830,45m². First floor ad Museum = 4387,18m². Library = 4530,13m². Studios and classrooms= 5938,79m² | |
| Occupied floors | All | |
| Worspace fit-out | ☐ Private office<br>☐ Private office shared with other people<br>☑ Open plan office with high partitions<br>☐ Open plan office without partitions<br>☐ Other | |

analysis of the BOSSA Time-Lapse System, in order to: (1) understand the Bossa Time-Lapse System functionality; and, (2) identify any translation issues and/or inconsistencies in the questions. Twelve (12) volunteers answered the questionnaire, arranged as shown in the Fig. 10.

## 4.5 Results and Considerations for the Stage 1—BOSSA Time Lapse Base Case

Discussions among the volunteers, during and after the questionnaire application, have raised several observations:

1. The survey took an average of 30–40 min to be completed, based on the critical analysis from the volunteers;
2. Translation of terms into Portuguese need adjustments; e.g., the term "life time x work capacity" (translated form the Portuguese expression: "tempo de vida x capacidade de trabalho" shown in the survey);
3. Some questions should be reviewed regarding the indication of the work area (when related to the office space/environment), and the workplace (when related to the desk/workstation which the person occupies); facilitating the results analysis when compared to the characteristics of the buildings;
4. Some words are still in the English language, and there is a need to review their translation;

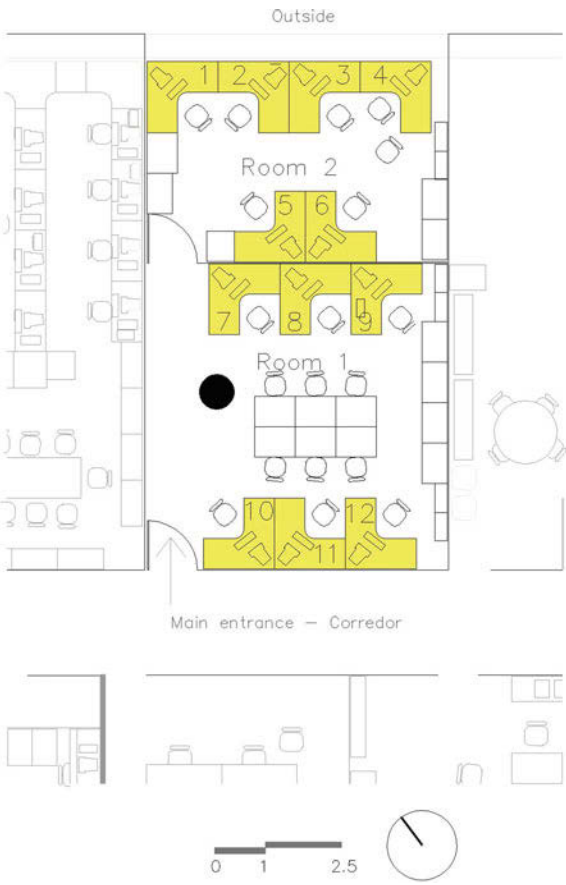


**Fig. 10** Twelve workstations occupied for stage 1, highlighted in yellow. *Source* Redesigned from the authors

5. Some multiple-choice questions require more items to fully characterize the environment. An example is the question related to the satisfaction and/or dissatisfaction with the elements of shading. Some workstations in LABAUT do not have such elements in their surroundings. It is suggested, therefore, to add the option of "Not applicable", for some questions, or to include a new question related to the existence—or not—of elements of shading;
6. The questions: "*This building provides pleasant spaces (e.g. indoor or outdoor green space, break-out areas) for breaks and relaxation*", and "*The overall indoor environmental quality of my work area influences my seat/location selection.*", both have a seven point scale of satisfied and/or unsatisfied answers. Several volunteers opted for "Yes" or "No" binary answers.

## 4.6 Stage 2—Second Application of BOSSA Time-Lapse

In Stage 2, which consists of the Second Application of BOSSA Time-Lapse, different volunteers were invited to answer the questionnaire, with no influence from interviewer and/or researcher of the BOSSA System. This second application had the aims of: 1. evaluating the occupant satisfaction/dissatisfaction in its workplace; and 2. analyzing its relations with the environment and the building architecture, using the BOSSA Time-Lapse questionnaire. Four (4) volunteers were present, arranged per highlights shown in Fig. 11.

In both stages, after the application of the questionnaire, the University of Sydney forwarded the BOSSA Time Lapse Report directly to the researchers in a PDF file. Tables 2, 3 and 4 summarize the list of BOSSA Time-Lapse questionnaire items adopted in the current analysis.

**Fig. 11** Workstations (highlighted) occupied for the second application, stage 2

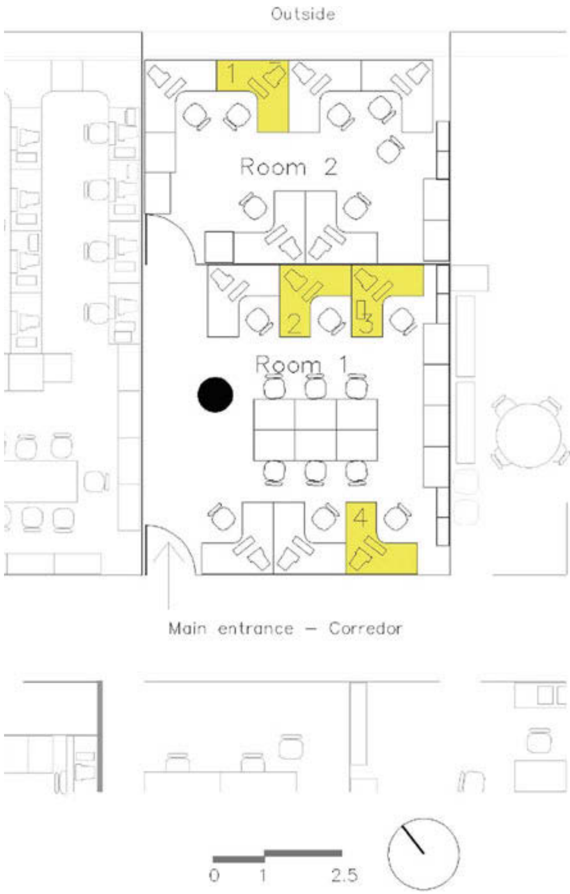

**Table 2** List of BOSSA Time-Lapse questionnaire items adopted for this paper

| Dimensions | Questions | Satisfied | Dissatisfied | Neutral |
|---|---|---|---|---|
| **Spatial Comfort** | This building provides pleasant spaces (e.g. indoor or outdoor green space, break-out areas) for breaks and relaxation | 75% | 25% | 0% |
| | Please rate your satisfaction with the visual aesthetics of your normal work area. | 100% | 0% | 0% |
| | How do you rate your normal work area's layout in terms of allowing you to interact with your colleagues¿ | 75% | 25% | 0% |
| | My normal work area can be adjusted (or personalized) to meet my preferences. | 75% | 25% | 0% |
| | The building provides adequate formal and informal spaces to collaborate with others. | 100% | 0% | 0% |
| | Please rate how comfortable your work area's furnishings are (including chairs, equipment, etc). | 100% | 0% | 0% |
| **Connection to Outdoor Environment** | Please rate your satisfaction with the external view from your normal work área. | 75% | 25% | 0% |
| | Please rate your satisfaction with the access to the daylight from your normal work area. | 25% | 75% | 0% |
| | This building provides a sense of connection between my normal work area and the outdoor environment. | 75% | 0% | 25% |

**Table 3** list of BOSSA Time-Lapse questionnaire items adopted for this paper

| Dimensions | Questions | Satisfied | Dissatisfied | Neutral |
|---|---|---|---|---|
| **Individual space** | Please rate your satisfaction with the amount of space available to you at your normal work area. | 75% | 0% | 25% |
| | Please rate your satisfaction with the amount of personal storage space available to you. | 75% | 0% | 25% |
| **Personal control** | Please rate your satisfaction level with the personal control over heating and/or cooling (HVAC system) in your normal work area. | 25% | 50% | 25% |

**Table 4** list of BOSSA Time-Lapse questionnaire items adopted for this paper

| Dimensions | Questions | Satisfied | Dissatisfied | Neutral |
|---|---|---|---|---|
| **Indoor air quality** | Please rate your satisfaction with the air movement available to you in your normal work area. | 25% | 50% | 25% |
| | Please rate your satisfaction level with the personal control over artificial lighting in your normal work area. | 25% | 75% | 0% |
| | Please rate your satisfaction level with your freedom to adapt your work area to attend your preferences.(HVAC System, lighting, windows) | 25% | 50% | 25% |
| **Thermal Comfort** | Please rate the temperatures conditions of your normal work area in winter. | 50% | 0% | 50% |
| | Please rate the temperatures conditions of your normal work area in summer. | 50% | 0% | 50% |
| **Noise Distraction & Privacy** | The work area's layout enables me to work without distraction or unwanted interruptions. | 0% | 75% | 25% |
| | My normal work area provides adequate visual privacy (not being seen by others). | 0% | 75% | 25% |
| | My normal work area provides adequate visual privacy (not being overheard by others). | 25% | 75% | 0% |
| | Please rate your satisfaction with the overall noise in your normal work area. | 25% | 50% | 25% |
| **Visual Comfort** | Please rate your satisfaction with the lighting comfort of your normal work area (e.g. amount of light, glare, reflections, contrast)? | 75% | 25% | 0% |
| | Please rate your satisfaction with shading devices (e.g. blinds, curtains, etc) of your normal work area in terms of controlling unwanted glare. | 50% | 25% | 25% |

For this paper, the focus is to analyze the relation of environmental comfort to occupant satisfaction and/or dissatisfaction. Therefore, the IEQ parameters related to Health, Productivity and Maintenance of the Building are not listed at this paper.

### *4.7 Results and Considerations for Stage 02—Second Application of the BOSSA Time-Lapse*

As listed in Table 2, the occupants show a high level of satisfaction regarding the *Spatial Comfort* and the *Connection to Outdoor Environment* parameters, having up to 100% level of satisfaction with *visual aesthetics*, *formal and informal space available* and *comfortable furnishing*. With regards to the question about the *access of daylight in the work area*, presented in the *Connection to Outdoor Environment* parameters, occupants showed a high level of dissatisfaction, probably because room 1 has no connection to external environment.

As listed in Table 3, the occupants show a high level of satisfaction regarding the amount of *personal and storage space available*, and a high level of dissatisfaction with the *personal control of air conditioning system*. The air conditioning control take place only in room 2, where there is no desk light fixtures available.

As listed in Table 4, the occupants show a high level of satisfaction regarding *Visual Comfort* parameters. Many workstations, located close to the windows, have a direct connection to external views, giving to the occupant a high level of personal control of lighting over their workstation.

The parameters with the higher level of dissatisfaction are:

1. Indoor air quality: which is assumed to be due to room 1 does not have connection to the external view and light;
2. Noise Distraction and Privacy: workstations and meeting table are located in an open plan office layout, having no partitions between them. Different activities occur simultaneously, increasing noise and distractions, hindering activities which require concentration.

Neutrality occurs only in the *Thermal Comfort* parameter, in which 50% of the occupants feel neutral and the remaining 50% are satisfied both in summer and winter. This result contradicts the additional comments presented at the end of the survey, where the 100% of the volunteers complained about thermal comfort in LABAUT, as well as about acoustics, ventilation and building maintenance.

## 5 Conclusions

Through the evaluation of the Stage 1, it was possible to observe that the BOSSA Time-Lapse questionnaire has translation issues that need to be reviewed, for some terms and/or expressions seem to be incoherent or incomprehensible in Portuguese. Multiple-choice questions require a larger number of items to characterize the environment. E.g., the question related to the satisfaction and/or dissatisfaction with the elements of shading. For a better analysis and comparison of the occupant's responses to the characteristics of the building, it is also necessary to review the translation of the term "work area" (when related to the office space/environment), and the term “workplace” (when related to the desk/workstation in which the person occupies).

Analyzing stage 2, it was observed that the building shows a high level of satisfaction by its occupants, and the IEQ parameters that presented Dissatisfaction are directly linked to the layout of the workspace, generating high levels of noise, lack of privacy and natural light in many workstation. This result shows that the Building Metrics tool can really attribute IEQ satisfaction/dissatisfaction ratings to specific design features.

On the other hand, there is an incoherence of results regarding thermal comfort. The Bossa Time-Lapse report presents a level of satisfied and neutral occupants, while the final additional comments show a high level of dissatisfaction with thermal comfort. This incoherence can result from the user’s perception of the BOSSA System, and it seems that occupants tend to use the final additional comments for complaints and/or to express dislikes rather than to express compliments to the building.

Further research will be conducted in other CUASO buildings, aiming to improve the system regarding the accuracy of the translation to Portuguese and its adaptation for the local reality. The application of the BOSSA Time-Lapse questionnaire in other buildings will allow a greater occupant feedback about the System and a greater database of different types of building, helping to better analyze the applicability of BOSSA System in Brasil with many different sample buildings. Further investigation about the statistical analyses of BOSSA System is needed when database with many sample building is recorded. In conjunction with BOSSA Time-Lapse, BOSSA Snap-Shot should assist in the measurement of the microclimatic variables in order to understand the relation between the design strategies and the environmental comfort of the buildings.

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# Regional Development in Latin America as a Way to Promote Education for Sustainable Development: The Case Study of the University of Ibague in Colombia

**Lady Johanna Peñaloza-Farfán and Alberto Paucar-Caceres**

**Abstract** Studies in Higher Education (HE) enable an individual to combine different streams of knowledge, such as the specific (subject) knowledge, customs, and experiences, into one. On one hand, this combined knowledge embedded within the cultural, socioeconomic and environmental contexts increases the importance of various social phenomena. On the other hand, the link between these different types of knowledge highlights the importance that the creation of common welfare has not only for individuals linked to HE institutions but also those outside of the university environment and processes. Therefore, we believe that in order to promote *Regional development* in Latin America, it is essential that universities define their own criteria for sustainable development in HE, which demands from them the implementation of policies and strategies aligned with their own challenges and characteristics. Hence, this study intends to gain a better understanding of the criteria for sustainable development formulated by some HE institutions in Latin America. To gain this understanding, we investigate the case study of the University of Ibagué (Universidad de Ibagué), for which we question whether this university's proposal for the *Regional development* (RD) follows the regulation for Sustainable Development Education as specified in the framework for Sustainable Development. Specifically, this study seeks to clarify the University of Ibagué's strategies for Sustainable Development Education in relation to its commitment to the *Regional development* in the Department of Tolima whose capital city is Ibague. In addition, this study analyses whether the principles that guide the strategies for the *Regional development* at the University of Ibagué are aligned with the directives issued by international agencies such as the UN and the UNESCO.

L. J. Peñaloza-Farfán (✉)
Investigator Group MYSCO, Universidad de Ibague,
Carrera 22 Called 67 B/Ambala, Ibague, Tolima, Colombia
e-mail: lady.penaloza@unibague.edu.co

A. Paucar-Caceres
Manchester Metropolitan University Business School,
All Saints Campus, Oxford Road, Manchester M15 6BH, UK
e-mail: a.paucar@mmu.ac.uk

 
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Higher education · Social commitment

## 1 Introduction

Different global concerns, such as natural disasters, global warming, increased consumption of natural resources, wars, and violations of human rights, has led to the establishment of organizations such as UNESCO, which proposes structural and policy changes in governmental, economic and environmental systems that should be applied at a global level, UNESCO (2012, 2014, 2016). The understanding of the role that universities have in increasing the awareness of these urging concerns has inspired some European Universities to adopt appropriate course of action. Some of these policies, known as Education for Sustainable Development (ESD) in the context of HE became a part of the Higher Education Institutions (HEIs)' curricula around the world, including Latin America.

However, there are other proposals that aim to generate changes in both local and regional communities. Some of them directly focus on generating sustainable development by means of improving the quality of life in a specific region. We aim to investigate in more detail how these educational processes take place and how these proposals can promote regional sustainable development targets. Hence, this study recognizes the role that organizational values and principles play in establishing the commitment of HEIs to ESD. Thus, we investigate a case of the University of Ibagué to assess the importance of the strategies and policies that this institution implements in order to ensure sustainable development. Moreover, we ask what characteristics of HEIs in Latin America allow the inclusion of ESD, in a sense of skills, training and systemic thinking gained during the university education. The linkage of this research with the University of Ibagué is due to the fact that one of the authors is a researcher of the MYSCO group at that university. For its part, the link with the University of the Andes is by reference of the mission with Regional Development.

The following extract is provided to support the motivation behind this study:

> "The HEI challenge lies in building a network that could help transfer knowledge into an action, which carries direct implications for the development". This statement interprets ESD as an institutional policy to ensure that the HEIs are managed with the objective to educate and train integral citizens able to contribute to sustainable development (Olearte-Mejia and Rios-Osorio 2015).

Therefore, "including projects that promote the analysis and understanding of environmental problems and possibilities on the local, regional and national levels, and generating a larger participation in the implementation of solutions in line with natural and socio-cultural dynamics" (Ministry of National Education of Colombia 2005), requires a broader inclusion of sustainable development methodology in the design of curricula. This is not only manifested in the universities' objectives but should also be incorporated as a form of a dialogue between different forms of knowledge gained at HEIs, in order to create a knowledge base which is formed on reality and, for that reason, it is also meaningful for learners' experiences.

When addressing the question concerning the alignment of the University of Ibagué's proposal for the *Regional development* with the regulation for Sustainable Development Education specified in the framework for Sustainable Development, we first highlight the necessity to define the university's own development criteria. These criteria aim to specify the policies and strategies for sustainable development that are suitable in the context of the university's challenges and characteristics. For this, we believe it is necessary to clarify the University of Ibagué strategies in relation to the fulfilment of its motto: "Committed to Regional Development". Following the analysis and revision focused on the issues related to ESD, we also investigate if the *Regional development* strategies that the University of Ibagué implements in the department of Tolima (Colombia) indirectly promote the awareness and the education of sustainability. Moreover, we assess whether these strategies are aligned with the directives issued by international agencies such as UNESCO and the United Nations.

This paper is structured as follows. In Sect. 2, we review the literature focusing on the following three themes: (i) Education for Sustainable Development, (ii) *Development* in Latin America and (iii) *Regional development* (RD) and Institutions of Higher Education (HEI). In Sect. 3, we outline the methodology used in the study. Inn Sect. 4, we present the initial results of a pilot survey at the University of Ibagué. This survey involved three groups of subjects: students, Administrative staff and academic staff. Finally, in Sect. 5, we summarize the results of the present study and outline its limitations.

## 2 Literature Review

Both, *Development* and *Regional development* are at the very heart of the present analysis. Since these concepts can be analysed either from the point of view of international agencies or from the point of view of Latin American countries, we first introduce some definitions clarifying the arguments made in the related literature.

First, we examine the modern definition of Development provided in the UNESCO's proposals for Education for Sustainable Development (HEAD) by Heila Lotz-Sisitka (UNESCO 2012).

Secondly, we discuss social and cultural aspects of Latin American countries as viewed from two different perspectives. The first perspective was introduced by Briceño Guerrero, who identifies the crisis in the Latin American identity in his book titled "The labyrinth of the three minotaurs" (Briceño 1994). The second perspective has been outlined by Contreras, who points out the failure of the techno-economic paradigm of *development* (Contreras et al. 2007). Further, for a more comprehensive understanding of the phenomenon of *development* and underdevelopment, we also consider the conceptual framework developed by Fuenmayor in his book titled "Sense and nonsense of development" (Fuenmayor 2000).

Finally, we consider the concept of *Regional development* (RD) as defined by two universities in Colombia. The Universidad de los Andes, Bogotá DC, concludes by noting that "the current state of sustainable *regional development* in Colombia responds to an inertial process, where political interests dominate other important dimensions" (Pineda et al. 2016). The second university, the Universidad de Ibagué located in the city of Ibagué—Tolima, proposes a commitment to *Regional development* through a range of its institutional and educational strategies (Universidad de Ibagué 2014).

Figure 1 below illustrates the relationships between the different types of knowledge defined earlier and the concepts of *development* analysed in this study. In the following sections, we develop the premises and proposals under each type of knowledge.

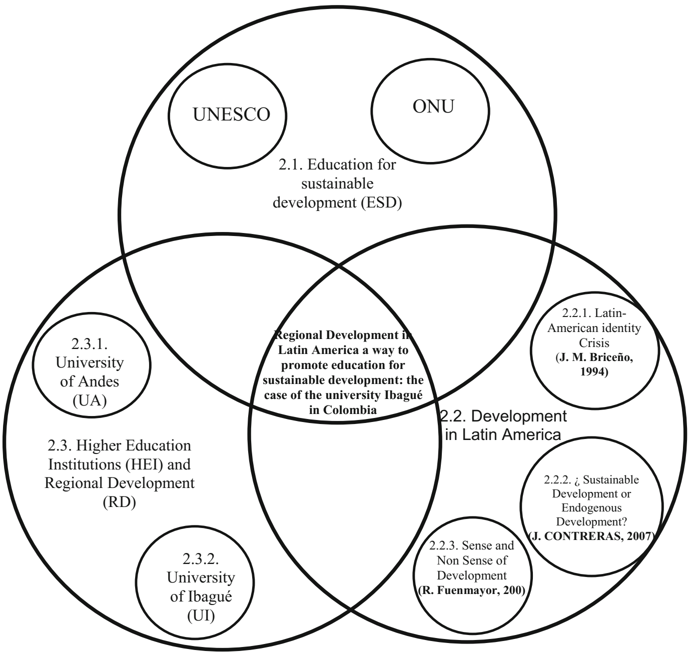


**Fig. 1** Conceptual framework based on the three fields considered in the present study (*Source* Authors)

## 2.1 Education for Sustainable Development (ESD)

As indicated in Fig. 1, we start our discussion by analysing the relationship between UNESCO's Sustainable Development Education (ESD) program by Heila Lotz-Sisitka (UNESCO 2012), and the sustainable development for HE proposal. The research paper on 'Education for Sustainable Development: An Exploratory Survey of a Sample of Latin American HEIs' (Hernandez et al. 2018) clarifies in detail the proposals for sustainable development. For instance, it is suggested that over the course of two international events education should be redirected towards SD. The UN suggests that for the sustainability discourse to e more effective, SDE should be connected with all formative levels of education. Such suggestions had been made the first time in 1992 (UN 1992; UNESCO 2014), and have been reinforced in 1997 (UN 1997) in Thessaloniki (Greece) during the International Conference on Environment and Society. Yet, to date no specific solutions have been provided as to the way in which the introduction of ESD at all levels of HE should be accomplished. Therefore, there is a need to develop educational strategies, which improve the awareness of sustainable development among students, consistently with UNESCO's Sustainable Development (UNESCO 2016).

In that context we define ESD as the knowledge and the skills "necessary to work and live in a way that protects environmental, social and economic well-being, for current as well as for future generations" (QAA 2014). One of these skills is systemic thinking, which is considered to be of great importance in achieving ESD objectives. The support of the HEIs in the implementation of ESD has been manifested since 1988 through some universities' declarations of intent; starting with the Talloires Declaration of University Presidents in which the so-called Magna Carta of European Universities for a Sustainable Future has been put forward in 1990. This document was designed to demonstrate the universities' commitment to integrate SD in their activities (Lozano et al. 2013). Although these commitments generate progress in expanding ESD in HEIs, they are not sufficient to foster a profound organizational change in HEIs' processes and in the corresponding disciplinary areas (Bekessy et al. 2007).

The curricula that have incorporated ESD greatly differ from those without consideration about ESD. ̈There is evidence that environmental education courses in HEIs have emerged since 1970 (Alonso 2010), well before the concept of Sustainable Development was established in 1987 in the Brundland report with the title "Our Common Future" (Hernandez et al. 2018). In addition to ESD, other proposals, such as the one by UNESCO should be considered, UNESCO (2014, 2016). Only in this way, one can affirm that the education of sustainable development aimed at HE students can help resolve complex problems in the areas of environment, society, culture and economy. These proposals also incentivise and encourage students to address problems in their own communities and to propose self-created and internal solutions, which could be evaluated by community members themselves.

## 2.2 Development in Latin America

The circle on the right in Fig. 1 indicates the area of *Development* in Latin America. This topic is very broad and accommodates several sub-themes. In the following, we evaluate the literature on the *development* in Latin America using the different perspectives described earlier.

### 2.2.1 Latin-American Identity Crisis

We start our discussion on the *development* in Latin America by laying down the definition of *development* by Briceño (1994). 'Development' is one of the key words used in the European discourse and the second most commonly used word nowadays. As argued by Briceño (1994), this concept "dominates the American way of thinking". This concept structured from the use of the theoretical dimension of the second reasoning (Fuenmayor 2000, 10) navigates official documents, state plans, visions and Eurocentric utopias, projects and governments. Moreover, this concept is strengthen by reasoning, modernity and progress of the real world, which accelerates the *development* through advancements in science and technology. The Latin Americans advanced this concept further in the process of identity search. This identity crisis has been shown metaphorically by Briceño (1994), who notes that the three minotaurs in his book are trapped in a labyrinth. And in this convict of the three Minotaurs two serious consequences are generated for Latin America. The first, of a practical nature, is that none of the three manages to impose themselves or to leave a survey, managing to structure coherent and successful organizations. The second, theoretically, is that Latin America fails to generate a deep-rooted thought of knowledge and reflection.

### 2.2.2 Sustainable Development or Endogenous Development?

Contreras et al. (2007), in his work titled "From the failure of *development* to sustainable endogenous development" proposes *development* to be constructed on the search and creation of sense in what is endogenous and sustainable for each region, thus, enabling to create and re-create local culture with national and universal vision. A specific case of such an interpretation of *development* could be the Constitution of the Venezuelan Bolivarian Republic. According to the author, the *development* is a historical construct in which the *development* of the region is planned by accounting for its potential, which, in turn, generates alliances with the *development* plans of other regions. Consequently, the *development* is aligned with the national plan. To make this possible, it is necessary to restructure the planning process and to stimulate development, starting from the Venezuelan State. However, if *development* is not achievable in all states, the government's lack of concern for its citizens is revealed. As shown by the author, the Venezuelan State was unable to coordinate and fully articulate *development* plans due to the institutional complexities, which should have been strategically aligned around the greater (national) purpose. Only in this way, it would have been possible to motivate the community members to promote the common welfare. In the discourse concerning the development, this concept is presented as a progressive process leading to the economic indicators similar to those obtained in the "developed" countries.

Under these circumstances, *development* becomes a way to distinguish and/or delimit the developed countries of the world from those that are not. The developed countries are those evolving more through scientific and technological advancements, and the underdeveloped countries are those countries that are at the mercy of the developed countries, or, as Contreras et al. (2007, 30) indicates, are subordinate to them. These underdeveloped countries should replicate the strategies of the developed countries. In other words, to be a developed country, a state must resemble a European country. However, an important question arises for the appropriate conduct of the state in this situation: should a community adapt to the *development* or should the *development* adapt to the community?

The failure of the *development* for the Venezuelan state is two-fold: neither enough industrialization is achieved to provide the quality of life for the population that would guarantee its well-being; nor the objective of creating a common culture is achieved. With a common culture, everyone is expected to put the common welfare at heart, and to appreciate historical events for their contributions to development. On the contrary, in order to define one's own cultural, social and cultural patterns, one must rely on other societies, cultures and economies. This is how Venezuela and its constitution from 1991 redefine the role of the *development* by emphasising the importance that diverse participation have for achieving the common good: education and work, culture and ethnicity. In the redefinition of the development, the education aims to achieve a high level of creative potential for people in work. Thus, citizen participation (through family, state and society) is indispensable in the process of education, so that a society impregnated with values of Latin American identity can be created. Such a society then becomes a transmission channel for these important cultural values.

Moreover, according to the author's suggestions, education is "an instrument of scientific and technological knowledge that must be at the service of the society" (Contreras et al. 2007, 38). This implies that every citizen has rights in and duties towards the society, and must fulfil his responsibility to promote human rights through his political and personal participations as well as through his engagement in the community. In this way, the citizen supports a democratic coexistence and social peace. From the above, the author deduces that the *development* is not limited to economic growth and formulates the concept of the *development* around the human. Sustainable Development, which addresses ecological, geographical, demographical, and political realities and includes citizens' participation, must be looked at in connection with the educational training and professional development.

This definition of *development* removes the hegemonic and one-dimensional vision of developed and underdeveloped societies. Consequently, it is possible to develop the collective identity by strengthening social work to the extent that one views the world as a web combining cultural, material, political and economic aspects with other elements in a given environment. The author concludes that *development* is the "deployment of social work in harmony with its environment" (Contreras et al. 2007, 43), and Sustainable Endogenous Development occurs in an environment in which one has the power to make decisions concerning the options for development, the local control of *development* processes, and the retention of *development* benefits in the community.

In this first part, we conclude that Latin America continuously struggles to define its own concepts of development; a *development* that re-defines the meaning of humans, education, the participation and the care for itself, its peers and its surroundings; a *development* recognised as anthropological and not as anthropocentric.

### 2.2.3 Sense and Non Sense of Development

In his book "Sense and Non Sense of Development", Fuenmayor (2000) makes an intellectual contribution to the phenomenon of *development* and Underdevelopment. He seeks to identify the conditions that support *development* and make it meaningful for the current societies. In order to do so, he applies the "holistic transcendence approach" (Fuenmayor 2000, 4).

Understanding the phenomenon of *development* in a more profound and systemic way unveils the search for the common good that hides in the term Development. However, at present the dominating and unified conception of *development* conceives a human as a creature independent of nature and with the power to consider himself a master with nature as his slave. This relationship involves other human beings as means to an end, without any consideration given to the implications of achieving the end for the society. Hence, in accordance with the unified conception, *development* is understood as the means to securing a certain degree of social welfare conditioned on the objectives set by the western cultures. This process towards sufficient conditions for *development* has hardly been discussed. However, an important emphasis has been placed on the economy and the industrialization, which are very important aspects for the society in the process of development. Yet, we note that approaching the phenomenon of *development* systemically and in a broad socio-cultural context, implies that the economy and industry are not sufficient for development.

The search for the common good defined by the author as being equivalent to the search for the global meaning of human action is the second central theme in his study. The thinking, the forms and the activities of the present societies lack the reductionist meaning in the way in which social problems are considered, which, in turn, can explain the underdevelopment in Latin America. In other words, Fuenmayor (2016) blames the loss of the holistic meaning of existence for underdevelopment. He also points out that the underlying problem of the system is the weakness and the fragmentation, which stops individuals from taking appropriate actions, as observed currently in the western societies.

According to Fuenmayor (2000), many of Latin American citizens have adopted European customs and habits, for example, in terms of food, clothing, luxury cars and modern highways, and computers. Many of them speak European languages, too. Thus, the names of the most lagging behind cultures have had important changes. For instance, “Savages” became “Primitive People”, “countries lagging behind” and “underdeveloped countries” progressed to “Developing Countries”. However, is this really development? Are companies, organizations and institutions effective enough to avert the hunger and epidemics?

## *2.3 Higher Education Institutions (HEI) and Regional Development (RD)*

The third element in the literature related to *development* in Latin America focuses on the HEIs’ attempts to trigger incentives towards regional development. Specifically, our research analyses the proposals of the University of the Andes and the University of Ibagué to promote *regional development* as a way to achieve a *development* in a specific context.

### 2.3.1 University and Regional Development (Contributions of CIDER: Regional Development Research Centre)

In its mission statement declaring “a critical and ethical training to strengthen awareness of the social and civic responsibilities, as well as the commitment to the environment” (Universidad de los Andes 2017) the University of the Andes in Colombia demonstrates a concern for equipping professionals with the capabilities to think critically and to participate in building the community. Likewise, it is evident in its “PDI 2011–2015 Integral Development Program” (the strategic plan of this university), that the university is interested in generating projects with a high impact on the environment, which in turn, “reflect commitment to the transformation, innovation and sustainability” (Universidad de los Andes 2016).

Similarly, this university’s search for conditions encouraging *regional development* is also manifested as an important vision in the handbook on ¨University and Regional Development¨. However, it is necessary to recognize that in Colombia and other Latin American countries some institutions have sought decentralization to improve people’s quality of life and, as a result, this process is called “regionalization” (Pineda et al. 2016, 135, 137).

After reviewing five *development* milestones in Colombia: Mission Lebret RAPS Corpes, Metropolitan Areas/128 of 1994, Law 338 of 1997, LOOT Law 1454 of 2011 and Law 1625 Organic of Metropolitan Areas of 2013, the information system, and inputs: Long-term planning, institutional capacity, Consensus and Resource Management, the author conclude that Colombia lacks strategies necessary for managing RD in the long term. The metropolitan areas do not have governing bodies that could facilitate the dialogue between institutions. Hence, an introduction of public policies has been proposed as a way to develop tools that allow the growth and consolidation of RD. The need to reach a consensus for dialogue among different interest groups was also recognised. Such dialogue should respect the territorial heritage of the groups and rely on regional institutions to manage resources, design projects and to implement them.

### 2.3.2 Universidad de Ibagué (UI) "Committed to Regional Development"

The University of Ibagué in Colombia constitutes a specific case of *development* initiatives related to HE. In response to its motto "Committed to Regional Development" (Universidad de Ibagué 2014), this institution aims to form future professionals and to equip them with the skills that would allow them to design and implement projects, which could address complex social problems of the region, while simultaneously taking into account different forms of knowledge and cultural norms of the country. Based on the motto, the university develops educational strategies related to teaching, research and social projects. Thus, by fulfilling its mission, this university advances its proposal for educating the new generations "with a solid scientific and professional training, rooted in ethical and moral principles, and committed to social, cultural and economic *development* for regions" (Universidad de Ibagué 2014, 15). In this way, this university wants to contribute to the harmonious *development* derived from critical analyses and creative spirit of reality, thus, assuming the personal and social responsibility and commitment. For these reasons in the UI Plans for 2028, ̈RD lies at the core of its strategic considerations ̈ (Universidad de Ibagué 2014, 27).

The UI views HE as a strategy and an opportunity for personal improvement and for fulfilment for those who want to assist in the transformation of their environment for the benefit of the regional community and society in general. In addition, HE promotes the integral educational *development* of the community in the search for the recovery of the essential individual values without having harmful effects on people's dignity, and the conservation and reproduction of ecosystems.

Within economic values, labour is considered as a source of wealth and personal transcendence. These values entail democracy, respect for human rights, equity, justice and the affirmation of regional and national identity. To carry out the regional programs, various external aspects must be consulted. These aspects include the current level of *development* in the region, its projections and, preferably, the needs of the regional community and those of companies and entities in the region. These aspects should be considered together with the economic, social and cultural regulations in the country (Universidad de Ibagué 2014, 16). In its mission, the UI expresses its commitment to the integral training of leaders and entrepreneurs with solid scientific and professional knowledge, with deep ethical and moral principles, and with commitment to the social, cultural and economic *development* at the regional level. The UI promotes the integral *development* of the human being, and it takes care of the region and the community. In this context, care is understood as the appropriate use of regional resources that contributes to the society's well-being and to the conservation of the environment.

The subject "Context and Region: Introduction to Systemic Thinking" (CRIPS) was included as an educational strategy to ensure high quality in the universities' provision of training in the country and region's *development* (Universidad de Ibagué 2014, 20). This course is aimed at students enrolled in various programs, yet attending their first semester of study. This course seeks to develop students' skills for Systemic Thinking. CRIPS is included in the new curriculum as a subject in the Basic Common Cycle, which entails the total of five subjects in the first semester. All the programs at the University of Ibagué have these five subjects in common. "The purpose of the first-semester curriculum for all programs is to provide common training that accounts for the academic and socio-cultural profile of the students" (Chaparro 2016). This competence is considered indispensable in the training of professionals interested in the promotion of RD. The course implements different approaches developed from the study of reflection, action, analysis and continuous evaluation, all being promoted by the teaching team.

In line with the mission of the UI, these approaches promote the creation of the atmosphere for dialogue, which allows the co-construction of activities to promote RD, as well as a joint construction of capabilities and competencies needed to face one's own problems. The above arises as a mean of taking care of oneself and others from a holistic perspective. This approach recognizes that *development* depends on the context (which involves constant adjustments in its structure), and it is relational, non-linear and reactive. From this perspective, *development* is understood as a system that requires feeding back relevant information and has historical dynamics that provide the foundations for solving problems (Aldana and Reyes 2004).

Another strategy to promote *development* in HE is the introduction of the idea of "Peace and Region in the last semester of study (independently of the subject studied). In accordance with this idea, young people should live with colleagues from other disciplines in a municipality of their department for one semester, in order to help the regional administrators in solving problems that hinder development" (Universidad de Ibagué 2014, 12). In terms of teaching, the University proposes projects to "qualified academics with academic and research vocations, who are committed to the *development* of the university and the region" (Universidad de Ibagué 2014, 17). The academics are encouraged to "disseminate and apply the scientific knowledge for problem solving" (Univeresidad de Ibagué 2014, 18) and together with the students to maintain the search for academic excellence for the progress and *development* of the community".

It is important to highlight that in the past UI had 33 research groups that studied problems within their disciplines. These were reorganized into twelve groups that focused on problems relevant to the *development* of the Region¨ (Universidad de Ibagué 2014, 13). "The University is also leading the revision process of the Vision Tolima 2025 programme and has been actively involved in the formulation of projects related to royalties. In addition, the university has consolidated its participation in boards, committees and other events concerned with the discussion and policy design for the *development* of the Region" (Universidad de Ibagué 2014, 14).

The opening of the first Business Development Centre (CDE) in Tolima was inaugurated in April 2017 with the objective to adopt the University of Texas' methodology known as Small Business Development Centre (SBDC). This centre aims to increase the productivity and the competitiveness in micro, small and medium-sized enterprises, by lying down greater emphasis on productive units belonging to vulnerable population and victims of conflict (RSI News, nd). This centre also promotes business growth, innovation, productivity and profitability through proposals that strengthen administration, management, production, technological development and access to credit. The students participating in the Peace and Region idea also engage the CDE methodology to develop projects in the areas of international business administration and financial administration, in order to meet the most urgent needs of the population.

This chapter outlined the institutional vision of the UI in promoting RD. Specifically, we described this institution's educational strategies aimed at encouraging RD. These strategies are aligned with the values of social development, solid scientific and human foundations, and concrete practical training.

## 3 Methodology

The present research aims to define the criteria for development, *regional development* and sustainable *development* which will encourage to design policies and strategies designed to match the challenges and characteristics of HEIs. Taking into consideration the fact that the aspects which enable the ESD are transversal in different areas and in different parts of the curriculum, an interdisciplinary approach is fostered in order to broaden the comprehension and the analysis of the natural and human phenomena further. Likewise, the cross-cultural congregated in HE brings together different types of knowledge, including the subject-specific knowledge, customs, and experiences, which account for historical particularities in different regions. Given the need to articulate learning in this context, the cultural, socio-economic, and ecological-environmental aspects influence the values of academic education by increasing the awareness of common welfare and encouraging the care for others and the environment.

Therefore, in the first instance we considered it appropriate to develop the literature review that links to the *development* (as sustainable development) as proposed by UNESCO and the UN. Second, we discussed *Regional development* in the Latin American context, and third, we investigated the connections between Higher Education Institutions (HEIs) and *Regional development* (RD). In this way, we intended to clarify the strategies of the University of Ibagué in relation to the fulfilment of its motto "Committed to regional development". Moreover, from surveys and interviews that record the students, academics and Administrative staff of the University of Ibagué (UI)' perceptions of Regional Development, of students, we constructed micro theories "anchored" in the specific contexts of experience (the so called Grounded Theories) as highlighted by Glaser and Strauss (Glaser and Strauss 2006).

Considering the last objective, we employed software NVivo. This software enables to construct a word cloud and a hierarchical map so that the relevance of the categories that influence the specific perception can be assessed. Finally, after analysing the specific objectives outlined earlier in a comparative way, we consolidate micro theory by contrasting the proposals for ESD derived from UNESCO and UN and in the face of information provided about the HEIs in Latin America and Regional Development, UNESCO (2012, 2014, 2016). This comparative analysis will determine how aligned the principles orienting the strategies for Sustainable Development at UI are.

### 3.1 Questions to Investigate, Sample Size and Sample Frame

With regards to the characterization of *Regional development* at the University of Ibagué, the sampling strategy addresses the following three questions:

(1) What words do you associate with *Development*?
(2) For you what is *Regional Development*? And
(3) What *Activities or Actions* at the University of Ibagué do you associate with *Regional Development*?

### 3.2 Variables Explored in the Survey

The variables we considered are: Development, *Regional development* and Activities that promote Regional Development.

The sample size is 200 students who generate 600 values to categorize, 20 academic members of staff who generate 60 values to categorize, and 25 Administrative staff who generate 75 values to categorize, with a total of 735 values to categorize.

# 4 Initial Results of the Pilot Study: Perceptions of Students, Administrative Staff and Academics of the University of Ibagué

The main variables investigated, as explained in Sect. 3.1, are Development, *Regional development* at the UI and the activities that promote RD at the University. As indicated above, at the beginning of our pilot study we presented to the agents a series of questions to identify the sample comprised of the three types of university agents (students, academics and administrators). The questions asked concerned the activities related to *regional development* proposed by the UI, and were addressed with the purpose of obtaining concepts or ideas that these questions were associated with among students, academics s and administrators. In the following, we illustrate the answers given by these three groups of agents using two types of graphs. The first type is a word chart that highlights the most frequently used words; the second is a map of hierarchies of different categories, which allows to compare and understand the patterns and references generated by the participant's perceptions on the problem.

## 4.1 Perception of Students

In the word map in Fig. 2, one sees the relevance that students assign to the word "region" (50 repetitions out of 929), 26 repetitions of "development", 25 for "progress", 20 for "advancement", 18 for "growth", 17 for "projects", 15 for "social", 12 for "education" and 11 for "people", when asked about the associations with *Development* and *Regional development.*

**Fig. 2** Perception of students

### 4.1.1 Development

In the next illustration focusing on hierarchy (see Fig. 3), six major categories, such as prosperity, knowledge, quality of life, growth, commitment and social, are distinguished. Prosperity is the largest of the categories and entails the following subcategories: progress, solution, advancement, process, overcome difficulties and project. Knowledge category includes training, information, preparation, and within training, we also consider a category labelled compliance. The category Quality of Life includes subcategories such as empathy, entrepreneurship, create, conceive and change. Further, the category Growth has two subcategories: goal (objective) and maturity. Situated in the blue area, the category Commitment contains responsibility and collaboration. Finally, Social is associated with union, expansion and politics.

The solar projection captured in Fig. 3 tells us that each ring or circle indicates a level of hierarchy, so that each category shows that some of the elements contained in it are more relevant than others are, thus enabling the identification of the most relevant categories. The relevance of each category related to the total number of elements for the administrative staff members will be emphasized in Sect. 4.2, and for academics in Sect. 4.3.

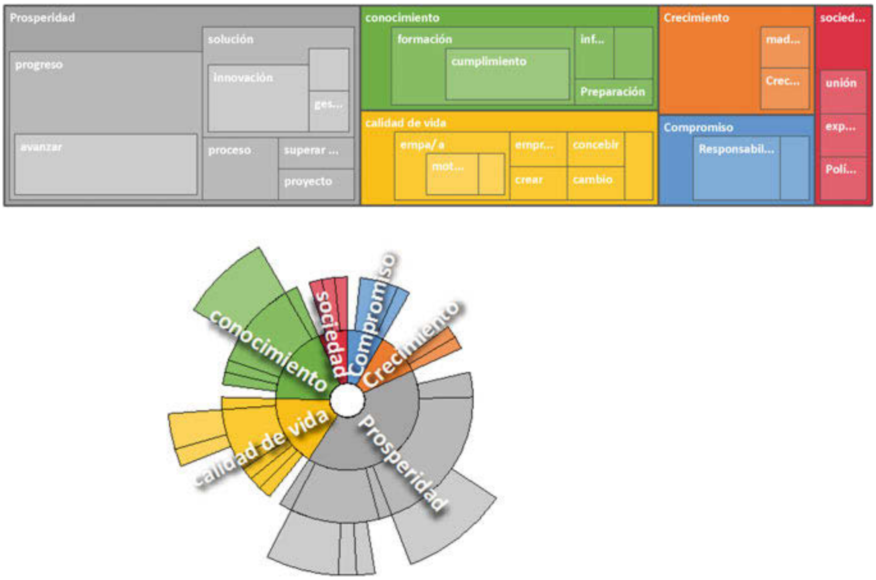


**Fig. 3** Hierarchical map of categories and solar projection: students' perceptions of development

#### 4.1.2 Regional Development

Students' perception of *Regional development* is linked to the categories such as Progress, Projects, Process, Commitment, Community and Region. As shown below (see Fig. 4), the category of Progress has more subcategories than other categories, and it is associated with evolution, advancement, innovation and education. Moreover, as illustrated in the solar projection below, this category is characterized by the highest number of associations.

#### 4.1.3 Promotional Activities of the University of Ibagué in the Context of RD

The following map demonstrates the hierarchy of university's activities aimed at promoting RD. The hierarchy is categorized as follows: Activities related to support for society and people in need and to the integration of the entire population and the business sphere. The second category entails Context and Region, which is linked to the identification of problems in the region and to the realization of projects with the purpose of providing solutions that favour the interests of the community. The next category, Integral Professionals focuses on high quality training for professionals, people and citizens. The category Reinforce Learning is built on reinforcement of reading and writing, and creation of language centres, conferences, lines of communication and other relevant classes. Finally, the most relevant category in Fig. 5, includes the activities and training for integrity of professionals.

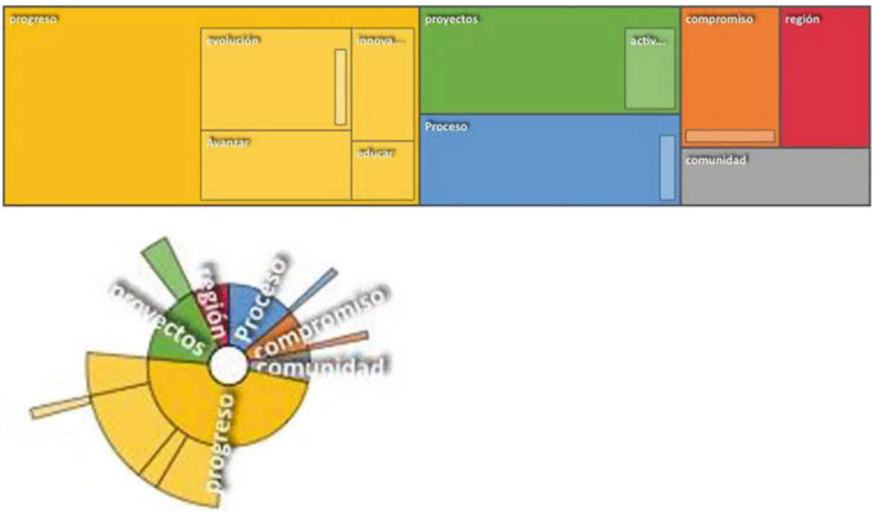


**Fig. 4** Hierarchical map of categories and solar projection: students' perceptions of *Regional Development*

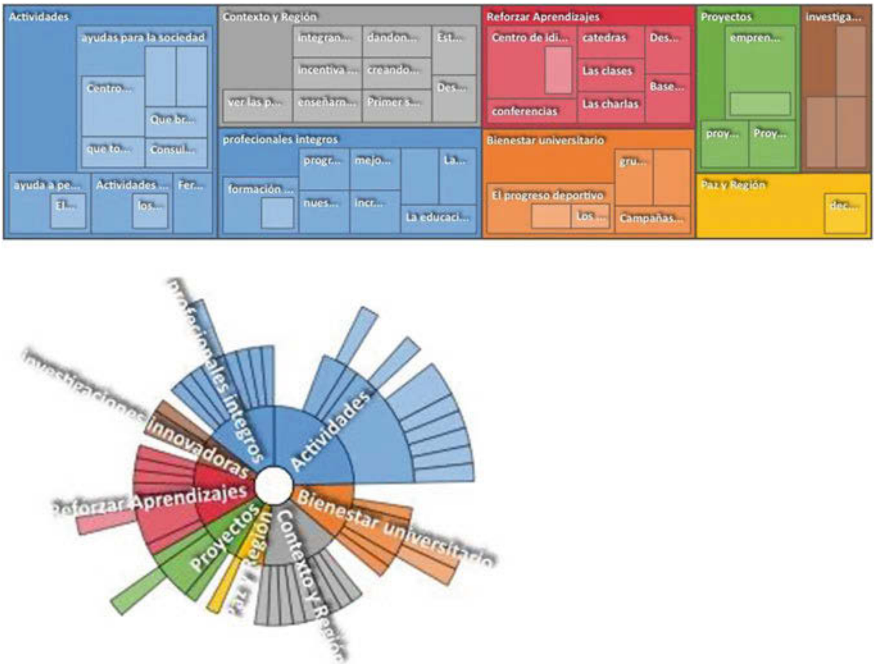


**Fig. 5** Hierarchical category map and solar projection: students' perception of UI proposals for *Regional Development*

## 4.2 Perception of the Administrative Staff (Administrative Members of Staff)

As can be seen from Fig. 6, 303 responses of Administrative staff account for the word "region" 14 times, "projects" 7 times, "research" 6 times, "university" 6 times, "evolution" 5 times, "people" 5 times, "life" 5 times, and "community" 4 times. Words such as community, evolution, vision and education are less frequent, but still relevant.

### 4.2.1 Development

The administrators' perception of *Development* illustrated in Fig. 7, embraces five broad categories: Growth, Processes, University of Ibague, Prosperity and Progress. The subcategories of Growth include evolution, changes, progress and improvement, and constitute the broadest category as shown in Fig. 7. The category Processes entails construction, recognition, profitability, goal, logistics and

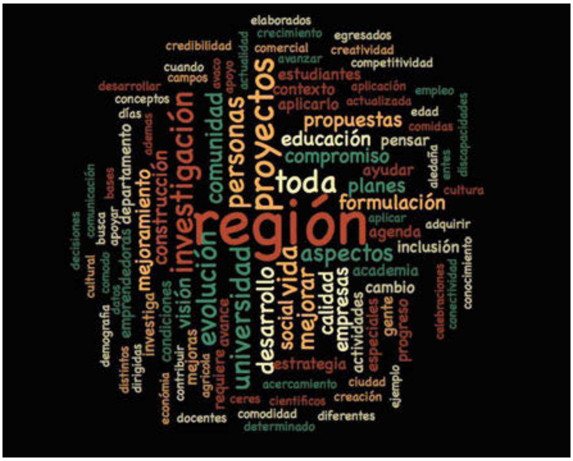


**Fig. 6** Perception of administrators

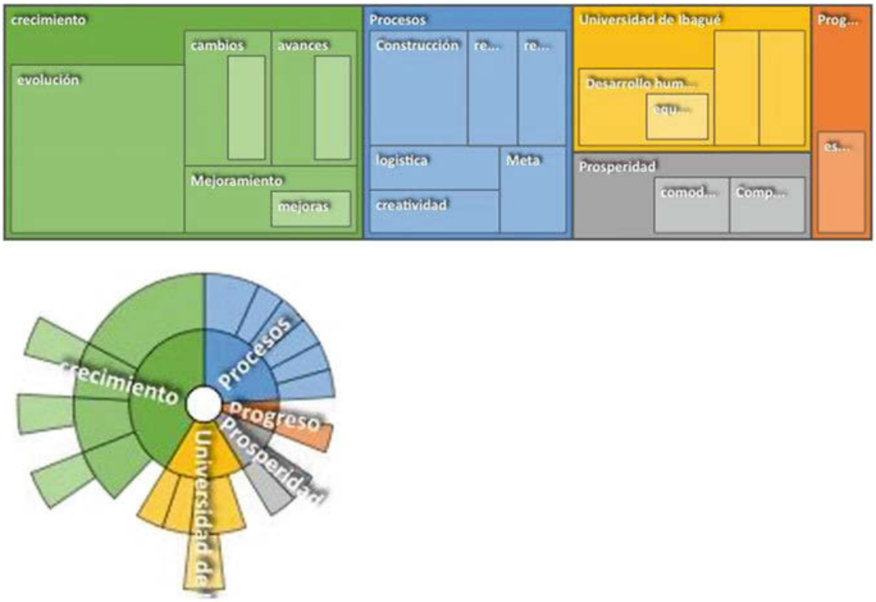


**Fig. 7** Hierarchical category map and solar projection: administrators' perception of development

creativity. The University of Ibague category includes sustainable human development, equity, context and sustainability. While community and commitment are subcategories of Prosperity, Progress has only one subcategory, which is effort (also see the solar projection on the next page).

#### 4.2.2 Regional Development

The perception of the *Regional development* by the Administrative staff at the University of Ibagué, can be summarized using seven categories (see Fig. 8). Construction of the Region is the category most indicated in administrators' responses, as shown by the solar projection below. The other categories include Region, City progress, Context, Aspects, Projects and Contribution to Education. The Construction of the Region relies on the large subcategory called Improvement of the conditions related to culture, education, society and economy, which increase the quality of life of people living in the region. The category Region captures information concerning population, place, department and city, The Progress of the City describes the work done in a specific place that aims to boost its cultural and natural wealth.

#### 4.2.3 Promotional Activities of the University of Ibagué in the Context of RD

According to the perception of administrators, the activities promoting *Regional development* in the university consist of inclusion activities (children, senior

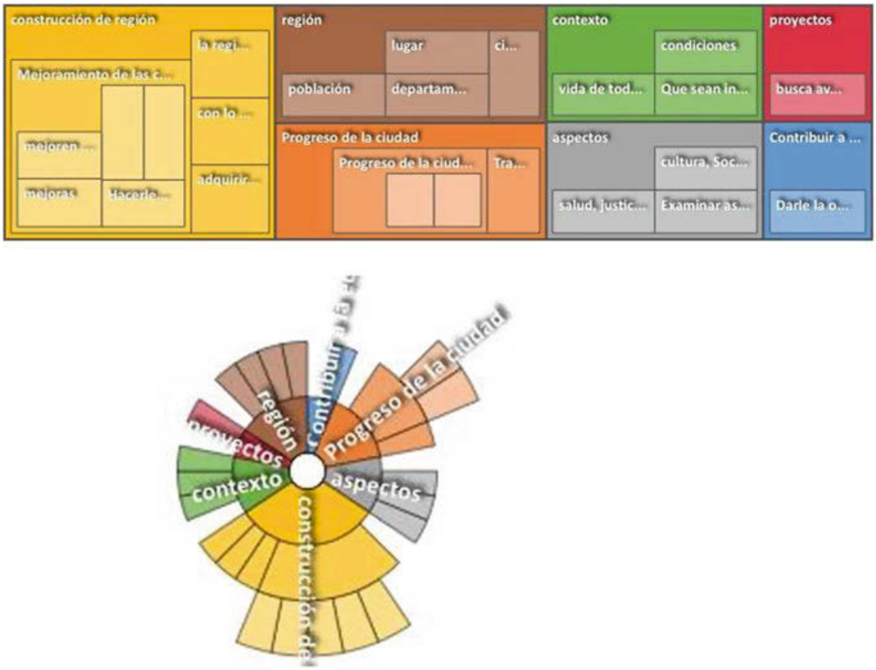


**Fig. 8** Hierarchical category map and solar projection: administrators' perception of *Regional Development*

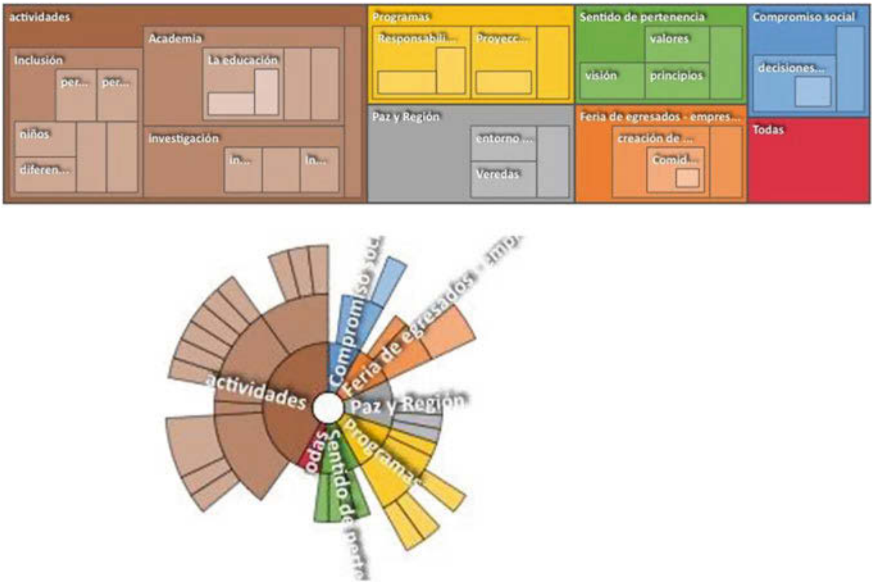


**Fig. 9** Hierarchical category map and solar projection: administrators' perception of UI proposals for *Regional Development*

citizens, (GBLT) community, people with disabilities); academic and research activities, programs of responsibility and social projects as well as the subject Peace and Region, which influences the regional environment (municipalities and sidewalks). Moreover, the Sense of Belonging emphasising the values, mission, vision and principles of the university are included. The Graduates Fair which focuses on the creation of companies and on the promotion of employment for graduate students, is the next category. The category Social Commitment describes the political decisions of the university related to the formulation of proposals concerning the regional environment. The final category called '*Todos*' links all the activities and strategies of the University. The number of responses for each category is illustrated in the solar projection below (Fig. 9).

### *4.3 Perceptions of Academics*

For academics at the University of Ibagué, the word "Region" is the most frequently used (27 times) in connection with *Regional development* and *Development* (see Fig. 10). Other concepts appearing in that context are "territory" (17 times), "for" (18 times), which here indicates a purpose. Other words which play a role in the context of *Regional development* are "social" (15 times), "community"


**Fig. 10** Academics's perceptions of UI proposal for *Regional Development*

(13 times), "development" (12 times), "process" (11 times), "growth" (9 times), "projects" and "research" (also 9 times), "needs" and "programs" (both 8 times), and "university" (7 times). The total number of associations used by the academics, amounts to 851.

### 4.3.1 Development

Academics link the *Development* with four main categories, including Globalization, Welfare, Region and Human Being. The category Globalization can be further divided into subcategories, such as transformation, capitalism, evolution, inequitable, unidirectional, imposition, organization and planning. The subcategories learning, improving the quality of life, sustainability, hope, autonomy and joy belong to Welfare. Equity and community make up the Region category, while the category Human Being entails the person and the values, which are shaded grey in the solar projection, as indicated in Fig. 11.

### 4.3.2 Regional Development

Academics perceive *Regional development* through categories, such as Common Project, Social, Communities, Identity, Growth and Region (see Fig. 12). The first main category, Common Project, can be further subdivided into Strategies that address actions designed with the purpose of strengthening the region. These strategies are directed towards promoting appropriate policies, the *development* of the vision of work, and talent discovery. They also stretch to economic, educational, employment, and equality dimensions, which focus on individuals. The next category, Social, is linked to individuals. However, this category also encompasses


**Fig. 11** Hierarchical category map and solar projection: academics' perception of development

relationships, synergies, human terms, collective (work and local entrepreneurship), universality, and refers to the harmonious balance between all human beings and nature. The category Communities is split into subcategories such as autonomy, communities, collectivism, convergence, culture, territory and people.

Another rich category is Identity, which encompasses government, integrity, improvement and growth for the region (beyond economic and political aspects), potential of the region, and finally, the quality of knowledge that is relevant for achieving harmony between nature and culture. The subcategories of Growth include access to basic services with the implications for quality of life, health care and recreation. The ultimate category in this section, Region, centres on the territory and the local.

### 4.3.3 Promotional Activities of the University of Ibagué in the Context of RD

The main activities outlined in Fig. 13 are Educational Strategies, Research, Social Projects and Responsibility, Disseminating Knowledge, University Welfare, and Incorporation of Regional Entities. These categories are subdivided accordingly. For instance, Educational Strategies include common cycle, academic programs, peace and region, curriculum, conferences, CERES and the connection between

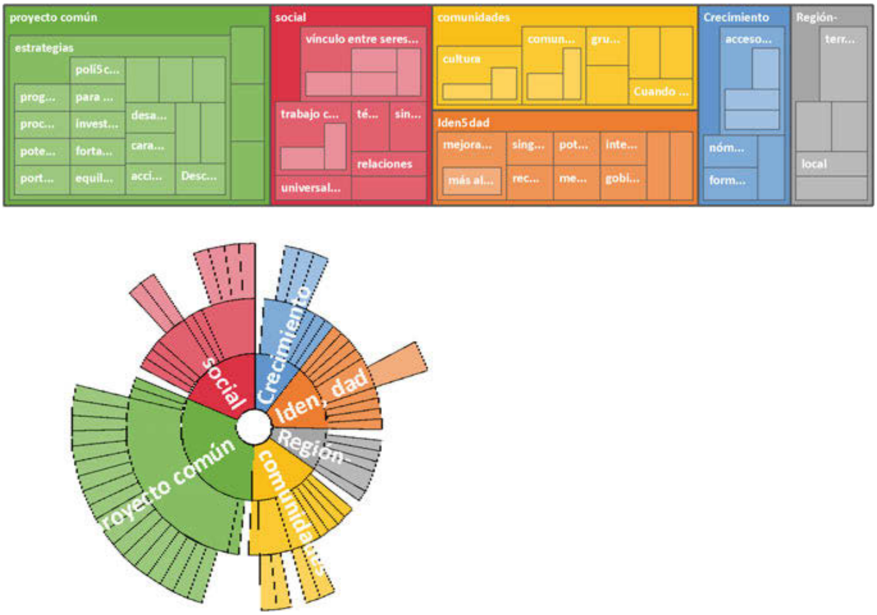


**Fig. 12** Hierarchical category map and solar projection: academics' perception of *Regional Development*

students and territory. Similarly, Research comprises of aspects oriented to the region, such as technology and finance. The idea of Social Projects relies on entrepreneurship, mobility and community agreements. In contrast, Social Responsibility focuses on social inclusion, projects and areas of special interest. Another important category is Dissemination of Knowledge, which takes place via production of editorial manuscripts as well as creation of forums. University Welfare is defined through students' support, university development, the so called orange economy, as well as defining and preserving regional music.

The solar projection below highlights the relevance of educational strategies in promoting Regional Development.

## 5 Initial Conclusions

This study intends to compare the results of the initial survey at the University of Ibague with the guidelines for Education for Sustainable Development proposed by the international agencies. We compare our results with the outcome of a similar investigation that has been conducted in Manchester, titled "Education for Sustainable Development: An exploratory survey of a sample of Latin American

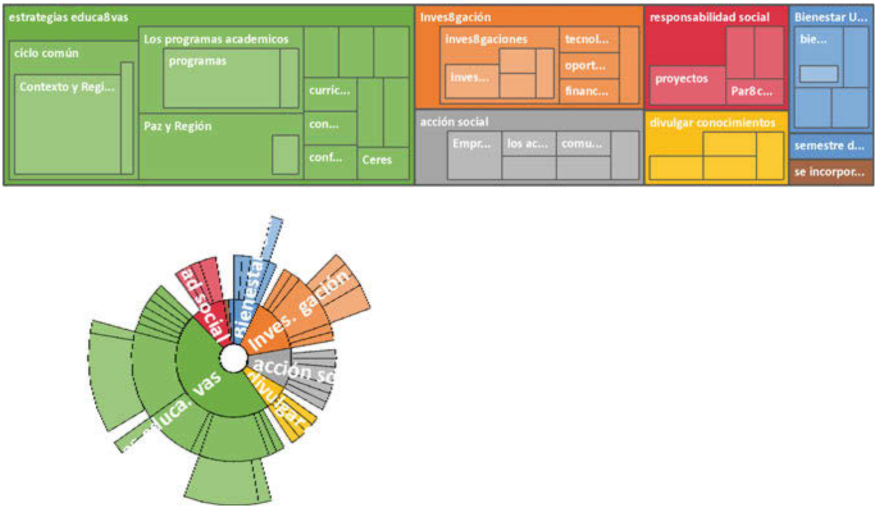


**Fig. 13** Hierarchical map of categories and solar projection: academics' perceptions of UI proposals for *Regional Development*

HEIs". This comparison enables us to identify whether the course curricula at Manchester Metropolitan University are equally aligned with the guidelines and proposals of UNESCO and the UN.

We believe that it is important to evaluate the results of this comparison, independently of whether these results turn out to be positive or negative. In this way, we can identify whether it is necessary to include appropriate subjects in the curriculum, and whether each university should introduce its own strategies toward sustainable development. Hence, we want to examine whether each university should create its own action plan for sustainable development, by taking into account its own particularities, challenges and characteristics in the context of the UNESCO (2012) proposal.

Based on the analysis of agents' perceptions of *Development* at the University of Ibagué, our study supports the UNESCO and UN guidelines, recognizing the importance of various aspects, such as economy, improved quality of life, as well as social and ecological issues. In the context of sustainable human development, academics also emphasize the need for equity in communities, the recovery of key values, and the importance of human beings.

The hierarchy unravelled through the evaluation of Regional *development* by the three types of agents at the University of Ibagué gives importance to (in this order): progress, projects, community, region—being understood as territory or locality, and the commitment to the community project "construction of the city and the region". The identity of a community and the relationship between those not involved in the *development* process also play an important role.

Participants perceive that the educational strategies designed to promote *Regional development* at the University of Ibagué are those of the Basic Common

Cycle, which includes the course Context and Region: Introduction to Systemic Thinking, as well as academic programs, such as CERES: Centros de Desarrollo Regional (*Regional Centre for Higher Education).* Other elements perceived by subjects in the context of educational strategies designed to promote RD are regional research projects, which contribute to the improvement of technology, the programs of Action, Accountability and Social Projection implemented in the region, the program Peace and Region that connects students with the municipalities and the Tolima department. Other important factors include Integral training for professionals, citizens and people, the dissemination of knowledge and the links with graduates and students.

As shown in this study, different approaches and strategies can be implemented to promote ESD with numerous variations for multiple subjects. "The HEI challenge lies in building a network that could help transfer knowledge into an action, which carries direct implications for the development". This statement interprets ESD as an institutional policy to ensure that the HEI are managed with the objective to educate and train integral citizens able to contribute to sustainable *development* (Olearte-Mejia and Rios-Osorio 2015).

It is worth noting that the results reveal a concern about individual training and the relationship between this individual and the environment, his values, being a person, and comprehensive training as a professional and a citizen. As Contreras et al. (2007, 43) states, in order to achieve human development, it is necessary to "deploy social work in harmony with its environment", which is not limited to the economic growth, but rather is a result of personal development.

Following the previous results of our analysis (Sects. 4.1.3, 4.2.3 and 4.3.3); the perception of *Regional development* activities in the UI seems to show that the connection with the community and the environment is not fully understood. However, the UI's concern for a scientific and professional formation, rooted in ethical and moral principles, can be seen as driven by a position that challenges the *unifying* conception of a man-nature relationship, in which the role of humans is seen as masters and nature as the slave. UI aims to form its professionals in a way they are aligned with a view of *development* anchored in a *diversifying* position; a view advanced by (Fuenmayor 2000). The *diversifying* conception of the notion of *development*, bases its challenge to the *unifying* position, on the use of the concept of 'Self-Generative capacity of a culture' (Fuenmayor 2000, 51). National *culture* has an important role in *development* and, according to Fuenmayor, should be understood as life that emerges from a process of dynamic interrelations with the environment and self-generative of its beings, its changes, and transcendent forms.

Following Contreras (Contreras et al. 2007) and the results obtained at the University of Ibagué, we think that *development* must re-shape to account for interrelations between humans, education, the participation and the care of itself, its peers and its surroundings. We believe that this requires the implementation of practices focused on the improvement of personal relationships and consequently of the relationship between an individual and the environment.

Finally, we want to emphasise that the present study is a result of a collaborative effort between the University of Ibagué and Manchester Metropolitan University.

For this collaborative study, we adopted the slogan of the University of Ibague 'commitment to social development' as an indirect way of investigating whether this motto influences the process of learning about sustainable *development* of various groups at the university (stakeholders) and also those from the environment. We are aware of the limitations that employing this motto as a proxy for our examination, in addition to the limited sample size we have for our results. Thus, we emphasise that the present examination is still in progress and we hope to extend it further by increasing the sample size through the incorporation of other Latin American and European universities. In this manner, we could explore the similarities and differences in the extent to which the two regions follow the directives of international agencies concerned with promoting the Education for sustainable development.

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# An Experience of Participatory Construction of Solid Waste Management and Environmental Education Indicators on a University Campus

**Antonio Carlos Merger Jr., Daniela Cássia Sudan and Evandro Watanabe**

**Abstract** The increase in the production of solid waste is related to serious impacts on climate change of the planet owing to emission of greenhouse gases, such as methane ($CH_4$). Therefore, indicators, which are tools developed to evaluate and maintain control over a process of interest, can be used to measure how relevant these impacts are or can be. There are many initiatives, results and challenges in the solid waste management and environmental education areas in high education institutions, but there are just a few studies about structured indicators that were implemented in a systematic way. Considering these facts, this study aims to contribute to the topic of indicators, focusing in domestic solid waste. To do so, we will present: a research of scientific productions about this topic, at international and national levels; domestic solid waste management and environmental education indicators under development on the University of São Paulo's campus in Ribeirão Preto city. The adoption of indicators is relevant to broaden the possibilities for evaluation and reflection on the impacts of what is implemented in the high education institution, reverberating in the improvement and enhancement of actions and results to achieve the sustainability in universities.

**Keywords** Indicators · Solid waste management · Environmental education University

A. C. Merger Jr. (✉) · D. C. Sudan
Environmental Management, University of São Paulo,
Ribeirão Preto, São Paulo, Brazil
e-mail: antonio.merger@usp.br

E. Watanabe
School of Dentistry of Ribeirão Preto, University of São Paulo,
Ribeirão Preto, São Paulo, Brazil



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## 1 Introduction

The symptoms of climate change are evident, and they reflect the accumulated mountains of solid waste with their characteristics and dangers that impact societies and their living environments (Padilha 2016), offering unequal risks to populations, such as the generation of slurry that can contaminate water and soil if it is not properly treated, and the creation of shelters for vectors of disease (Jacobi 2007).

The report prepared by The World Bank (2012) presents a survey of solid waste generation by region. According to the data, the member countries of OECD (Organisation for Economic Co-operation and Development), such as United States, United Kingdom, Spain, Australia, Canada, Chile, Germany, are the largest solid waste generators, totaling 572 million tonnes of waste per year with a 2.2 kg/capita/day average. Latin America (20 countries) and the Caribbean region, in which Brazil is included, generates around 160 million tonnes of solid waste per year with a 1.1 kg/capita/day average. This same region also stands out as the greatest social inequality one, considering that its waste generation ranges from a mere 0.1 to 14 kg/capita/day (The World Bank 2012) (Fig. 1).

In 2008, in Brazil, there were still 2906 open dumps in 2810 Brazilian municipalities (IPEA 2012). Therefore, it is spent to land potentially recyclable materials and, moreover, illegally. For example, 25% of the gravimetric weight of discarded domestic waste is composed of paper. This material is deposited with organic matter (which comprises 65% of this gravimetric weight), packagings and tailings in landfills, making it infeasible for reuse or recycling (IBAM 2001).

With the enactment of the law N. 12,305, art. 3, XVI of the Brazilian Solid Waste Policy (2010), Brazil has made a leap, even if delayed, towards the regulation of its solid waste management and associated actions to eliminate open dumps and support cooperatives of recyclable waste pickers (Brasil 2010).

However, the promotion of actions to achieve sustainability still suffers long delays in practice. Contemporary societies have become the locus, in the course of time, of significant causers of global problems, such as the accelerated industrialization, exacerbated population growth, extraction and use of non-renewable resources, and environmental deterioration (Philippi Jr. et al. 2005).

Disregard for environmental issues is progressively aggravated by the standards of present-day society, which encourage the practice of exacerbated consumerism and unnecessary, irresponsible discarding, strongly allied with media stimuli.

Agreeing with Padilha (2016, 46):

> We start from the premise that our cravings for commodities are created and manipulated by direct and indirect advertising, and this is fundamental to the consumer society make consumers more and more persuaded and motivated to consume. Capitalist industries, definitely, do not depend on people's spontaneous and genuine desires. Otherwise, ads would not be as necessary as they are (Translation by the authors of this article).

Also associated with the mountains of waste is another aspect of consumer society, according to Padilha (2016), called planned obsolescence. "Together, advertising

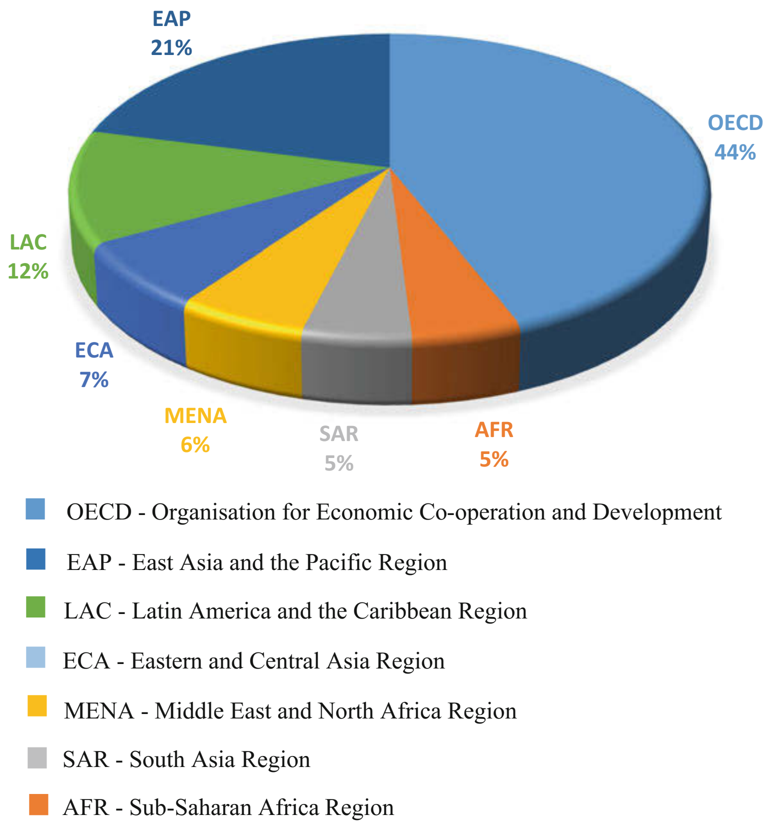


**Fig. 1** Waste generation by region (*Data source* The World Bank 2012, pp. 8–9)

and planned obsolescence are essential fuels to keep the production-consumption cycle working—more production, more consumption by our capitalist society" (Padilha 2016, 47). The products are lasting less (let us remember, in a planned way), then disposability increases, fueling the cycle that goes on through the quest to buy more and more, increasing merchant, manufacturer sales and consumers debts. In this context, the author asks whether this productivist-consumerist model is ethical, destroying "the environment forever" (Padilha 2016, 47). Besides, she places the following challenge to waste management programs: "more than just discussing the 3R (reduce, reuse and recycle), which are also important, it is necessary to rethink urgently the model of economic growth that we have followed in the last 200 years (p. 48).

In the university context, Tonso (2011) reports that since the Tbilisi Conference in 1977, organized by UNESCO, the incentive and encouragement for inserting the environmental dimension in university curricula have been promoted, since higher education institutions (HEI) are important spaces for discussion and reflection on the most diverse subjects. However, aversion to this topic in university communities is still present (Tonso 2011).

As a reflection of this, when we collected data on both sustainability and solid waste management policies and its indicators in universities (Table 1), we found out a significant absence of articles and other scientific works focused on indicators presentation, elaboration or implementation directly related to sustainable issues in HEI.

To make Table 1, a research for articles was elaborated in some databases and in a specific journal—Journal of Sustainability in Higher Education. The surveys were directed to sustainability indicators, solid waste management indicators and environmental education indicators, all at the university level, in the last 20 years.

The theme related to sustainability is current and exhaustively explored. Based on the parameters presented in the surveys, we tried to focus on the main aspects relevant to our project: indicators for solid waste management and environmental education. Some papers that we found and consider relevant were reported in more detail below. In particular, the work carried out by the National Health Foundation of Brazil (2016), in collaboration with the researcher Gina Rizpah Besen, which reports the elaboration of indicators for urban waste selective collection and for cooperatives of collectors. It has been of great significance for the project development, and we intend to study it with more attention in future works.

In this sense, the objectives of this article are to gather existing works on solid waste management and environmental education indicators in universities, as well as to report the initial experience of building sustainability indicators focused on solid waste management at the University of São Paulo, on the campus of Ribeirão

**Table 1** Survey of articles related to indicators in universities around the world

| Scientific libraries | Researches | | |
|---|---|---|---|
| | Sustainability indicators in universities | Solid waste management indicators in universities | Environmental education indicators in universities |
| SCIELO | 1 | 0 | 1 |
| CAPES | 284 | 7 | 41 |
| ERIC | 46 | 70 | 46 |
| Journal of Sustainability in Higher Education | 14 | 17 | 8 |

Survey made in May 2017

Preto city. These indicators, under construction, will have the purpose of strengthening and achieving the objectives of shared management of domestic solid waste determined by the University's Permanent Program, USP Recicla.

## 2 Current Situation in Other Universities

Among the programs and initiatives observed during the research presented in Table 1, the Produção Mais Limpa project (P+L—Cleaner Production project), implemented by "Júlio de Mesquita Filho" State University (UNESP) on the campus of Bauru city. P+L, acronym used to designate the project, is an integrated environmental strategy for production processes with the objective of optimizing spent resources, such as water, energy and raw materials, encouraging their reduction (CNTL-SENAI 2003, 10). Therefore, the Faculty of Engineering of UNESP used the project principles, adapting them for implementation in the university context, in order to analyze the situation of solid waste generated on campus (Battistelle et al. 2011). Some of the indicators analyzed are presented in Table 2.

At the international level, we highlight the University of Michigan, United States. This institution offers incentives for recycling and energy reduction costs programs in its buildings, alternative ways of locomotion through the campus, as well as promoting the dissemination of the sustainability concept through the academic courses offered (Marans and Callewaert 2017). The university has its own indicators mechanism called Sustainability Cultural Indicators Program (SCIP), whose main objective is to measure and identify the evolution of sustainable culture within the institution through annual surveys involving students and staff (Marans and Callewaert 2017).

The Universitas Indonesia (UI) has also performed an international ranking since 2010, called UI GreenMetric Ranking, which evaluates both environmental and sustainable policies and conditions applied at participating universities. The institutions are assessed according to indicators related to infrastructure, energy and

**Table 2** Main indicators based on the P+L project

| | |
|---|---|
| Indicators | Energy efficiency |
| | Rational use of waste and plastic |
| | Rational consumption of paper |
| | Consumption of organic waste |
| | Consumption of building materials |
| | Rational consumption of chemical and electronic waste |
| | Discharge of fluorescent lamp |
| | Metals consumption |

*Data source* Battistelle et al. 2011, 315

**Table 3** Top 10 universities in relation to waste indicators in 2016

| Ranking | University |
|---|---|
| 1 | Nanhua University Taiwan |
| 2 | Notthingham Trent University |
| 3 | University of Bradford |
| 4 | Georgia Institute of Technology |
| 5 | Universite de Sherbrooke |
| 6 | Freie Universitaet Berlin |
| 7 | Dublin City University |
| 8 | Wageningen University & Research |
| 9 | University of Nottingham |
| 10 | University of California Davis |

*Data source* Universitas Indonesia 2016

climate change, waste, water, transportation and education (Universitas Indonesia 2016). The indicators related to waste category analyze the existence of programs to reduce the use of paper and plastic, to recycle the waste produced by the university, to treat toxic, organic and inorganic waste, and to disposal sewage. The best ranked institution was Nanhua University, Taiwan. In 2016, University of São Paulo was ranked 316th in terms of waste indicators, while it was ranked 176th in 2015. However, the university has several initiatives in the field of sustainability, such as the USP Recicla program itself. We believe that the decay presented in the ranking is due to the lack of an efficient evaluation of these initiatives, mediated by appropriate indicators. Thus, it is possible to produce regular results to be used.

In the energy and climate change category, which assess indicators such as energy efficient appliances usage that are replacing conventional appliances, smart building implementation, renewable energy produce inside campus, electricity usage per year and greenhouse gas emission reductions program, University of São Paulo was ranked 386th, and the best ranked institution was Trier University of Applied Sciences, Germany (Universitas Indonesia 2016) (Table 3).

## 3 USP Recicla Program and Indicators

The USP Recicla Program is a permanent program of the University of São Paulo, founded in 1994 and applied to 7 of the 11 university's campuses (Sudan 2013). The program has a strong socio-environmental mission in the university community:

> To contribute to the construction of sustainable societies through actions aimed at reducing waste generation, conserving the environment, improving the quality of life and training committed people. (University of São Paulo 2011)

This program aims to encourage the incorporation of social environmental values in the university community, which is its priority public, as well as collaborate in the policy establishment for the reduce, reuse and recycling of materials and to improve environmental education through educational actions such as workshops, courses and speeches.

One of the main objectives of the program is developing a shared and integrated management for domestic solid waste. The Ribeirão Preto campus, however, has challenges in the strict measurement of data from actions related to the disposal, collection and reuse of domestic solid waste generated on campus. This deficiency exists, among other reasons, because of the absence of solid waste management indicators, that should be developed according to the needs presented, and the difficulty in collecting data in a public institution.

According to Hammond et al. (1995), indicators are defined as follows:

> As commonly understood, an indicator is something that provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable (p. 9).

de Souza Minayo (2009) treats the indicators as quantified or qualitative parameters that are used to detail if the objectives of a proposal are conducted correctly (process evaluation) or if they have been achieved (results evaluation).

Thereby, indicators can be understood as important tools for a system or a process management, assisting in pointing out situations that must be changed or carried forward in order to achieve the initially proposed objective.

When choosing indicators, it is necessary to have a in-depth knowledge about the process in which it will be used, since the process complexity determines if an indicator will be able to evaluate it completely. Moreover, the indicators do not point to absolute certainties in relation to the results, they point only to trends: indicators are instruments, do not operate by themselves, indicate what they should indicate (de Souza Minayo 2009).

USP Recicla program has developed some studies, such as this one, on a specific set of indicators[1] to maintain a continuous control of what is and how much is produced and disposed to relation of domestic solid waste in the campus faculties, allowing a more accurate assessment about the efficiency of the waste management initiatives, whether they are or are not providing the expected effects and what needs to be modified to improve them.

USP Recicla program, through the Environmental Management Superintendence of the University of São Paulo, actively participated in the elaboration of the USP Solid Waste Policy[1], between 2012 and 2015, based on the work of a Working Group. The Policy developed by the University's staff aims to promote the proper solid waste management produced by different faculties of the campuses.

The Ribeirão Preto campus is the second largest USP campus, with about 14,000 people in its community. It has 10 faculties of teaching, extension and research in the

[1]The USP Solid Waste Policy is being analyzed by the university rectory.

areas of biological sciences and health, humanities, and exact sciences, as well as the management and administration units of the campus. USP Recicla program has been operating on this campus since 1997, accumulating results in terms of education and environmental management. Particular emphasis is given to: continued residue minimization projects in the university restaurant; delivery of durable mugs to each person linked to the university to avoid the generation of plastic waste; installation of compost heaps of organic waste in nine faculties; promotion of selective collection (30 tonnes per month of recyclable waste), collected by a cooperative of recyclable waste pickers, produced by the faculties themselves and those brought by external agents and deposited in the containers distributed throughout the campus. However, the control over what is produced on the Ribeirão Preto campus and their respective amounts are inaccurate data until now.

The implementation of quantitative indicators on this campus could, then, contribute to a greater reliability survey of the data related to the amounts generated by the university community and to a continuous monitoring of the performed activities, which are deficient actions in the current state lived by the University. Qualitative indicators, which will be the objects of future studies, would have the role of stimulating the greater participation of the university community in the socio-environmental issues of the institution and beyond.

## 4 Method and Development

As previously mentioned, the project aims to develop a tool to measure and evaluate, both qualitatively and quantitatively, the generation of recyclable solid waste from campus faculties in Ribeirão Preto, as well as the educational initiatives associated to solid waste management within the permanent program USP Recicla.

It is necessary to be attentive to the fact that this tool is in its initial stage of development. In its first phase, a questionnaire already applied by USP Recicla program in 2004 was taken as a basis, being updated and reviewed collectively by the USP Recicla's commissions. This questionnaire was elaborated to carry out a survey about the current situation of the campus faculties regarding their domestic solid waste management, as well as the environmental education initiatives of the program. The questionnaire, after being reviewed by the invited groups, will be directed to the USP Recicla's Commissions on the campuses. The Commissions are composed by professors, undergraduate and/or graduate students and technical staff of the University. They actively work in the faculties to disseminate the program, its intervention proposals and educational activities among the university community.

The mechanism was initially divided into 3 stages, according to the theme addressed in the questions. The stages and the type of questions made in each of them are presented in Table 4.

**Table 4** Stages and subjects approached in the questionnaire to be evaluated

| Stages | Subjects approached |
|---|---|
| Composition and engagement of USP Recicla's Commissions | How many members make up the Commissions |
| | How many members are active and sporadic |
| | How many members are involved in other campus commissions |
| | The internal organization of the roles of these members |
| | The recording methods used in meetings |
| | How the communication with the faculty directorate occurs |
| | Initiatives that are currently employed, or those that have already been used and interrupted |
| | Data collected about waste management |
| | Dissemination of results to local staff |
| The activities carried out by the commission in the faculty in which it operates | Collaboration of the cleaning teams that assist in the collection of waste |
| | The provisional storage given for the waste until the selective collection is carried out |
| | The efficiency of the cooperative work that collaborates with the campus in the collection of the segregated materials |
| | Difficulties found in promoting the proper functioning of the program |
| Suggestions from commissions to promote the improvement of the program on campus | Suggestions to improve its operation, taking into account the difficulties pointed out |
| | The main points that commissions consider relevant to start measuring in the selective collection process and environmental education |

The faculties are not currently able to provide concrete data in relation to quantities produced and/or destined for selective collection, since continuous weighing of discarded materials can not be performed. The proposal, based on quantitative indicators developed by Besen and Ribeiro (2006), is to continuously apply indicators that evaluate the coverage of the selective collection on campus, as well as the recovery rate of recyclable waste and the amount of tailings produced. It is believed that the application of this form can cause a search, by the USP Recicla's Commissions, for improvements in the monitoring of the waste situation in the faculties, and so they can jointly elaborate intervention proposals and improve the measurement mechanisms over time.

We have the proposal to develop the questionnaire in a participatory manner before properly applying it. Therefore, the content of the questionnaire was evaluated by members of the Commissions themselves who will suggest modifications to it. This method has been chosen so that the mechanism in construction can be in agreement with the opinions of all, or at least the majority, of those who will make use of it. We were inspired by the fundamental concepts of participant research that, according to Brandão and Borges (2007), constitute projects of commitment and mutual involvement between the groups involved in its elaborations. Usually, participant research is used in a perspective of social reality experienced by the individual and collective participants in the development process (Brandão and Borges 2007).

To promote more easily member participation in the mechanism formulation, the form was introduced on an online platform (Google Forms). The platform has the function of collecting information of the respondents and passing them to the administrators, facilitating even further analysis of data.

Only after completion of the adjustments, the questionnaire will be properly applied. From the first data obtained, the main points that need intervention or continuous evaluation for its maintenance will be evaluated.

The form was sent to representatives of 11 USP Recicla's Commissions on campus, which were: College of Nursing of Ribeirão Preto, School of Physical Education and Sport of Ribeirão Preto, Faculty of Pharmaceutical Sciences of Ribeirão Preto, Faculty of Law of Ribeirão Preto, Faculty of Economics, Business Administration and Accounting of Ribeirão Preto, Faculty of Philosophy, Sciences and Literature of Ribeirão Preto, Faculty of Medicine of Ribeirão Preto and School of Dentistry of Ribeirão Preto, besides the Superintendency of Environmental Management of Ribeirão Preto and the Prefecture of the campus of Ribeirão Preto.

## 5 Evaluation Results

The representatives of the commissions had access to the questionnaire introduced in the online platform. Those who reported difficulties in accessing it received the questionnaire via e-mail. Thus, we had a total of 6 reviews returned (55%) with positive and negatives notes and suggestions.

The main points of the evaluation have been organized and are presented in detail in Table 5.

According to some of the evaluations presented in Table 5, the mechanism is deficient in quantitative issues. This is mainly due to the difficulty in collecting data within a large institution, with hierarchical instances and computer systems that do not interconnect, making it impossible to elaborate an initial set of data. Measurements made so far make up inaccurate data sets due to the difficulties in making a team sufficiently specialized to perform this task and reliably storing of the data collected, as well as their easy availability for queries. Therefore, the process needs to be started again with improvements so that the proper adjustments can be applied.

A significant point of the evaluations was the fact that some participants requested more open answers on some questions. This suggestion came as a surprise to the coordinators who thought that working mostly with multiple choice

**Table 5** Notes and suggestions made by the Commissions

| Positive notes | Negative notes | Suggestions |
|---|---|---|
| The form, in its entirety, was considered an important tool to promote improvements in USP Recicla program on campus | It is not clearly specified what external collaborators, questioned in the first stage of the questionnaire, mean | Identify who are the professors, staff and students members of the Commissions |
| The issues were considered to be relevant and they have key components for understanding the functioning of the Commissions | Many questions are formulated in a qualitative way, not allowing exact answers, only those based on impressions | Identify quantitatively how many members are also on other campus Commissions and who they are |
| The mechanism is very significant, since it does not require a large sum of money to be realized, taking into account the current economic recession of the University | – | Identify how many are active and sporadic members with percentages, rather than whole numbers |
| – | – | Open space for more detailed answers. This could improve the analysis of the data later |
| – | – | Organize the obtained data in graphics and tables to produce a report of the current situation of USP Recicla program |

*Source* questionnaire applied to the 11 commissions of USP Recicla on Ribeirão Preto campus from March 30 to May 10

method be a way to facilitate and encourage the participation of Commissions members by optimizing the time taken to answer the topics. For the application stage, we must review the response options given to the respondent, in order to allow more complete and detailed answers, which will allow us to have a broader view of the points.

Another point that needs to be thought for future applications is a way to encourage all Commissions members to participate in. Only nearly 55% of the invited group participated by submitting their assessments about the questionnaire. This data can probably be justified by two main occurrences: the size of the form and the chosen application medium. The form is relatively large, containing a total of 23 questions, 5 of them containing sub-items. This can make the response process tiring and/or time consuming, resulting in a lower participation rate. In addition, we chose to share the mechanism through a virtual platform with which not everyone knows and masters, and it may cause strangeness and consequent withdrawal if guidelines are not given.

## 6 Partial Considerations

The non-development of quantitative indicators in an old waste management program makes us believe that the answer to this problem is more complex than we initially imagined, involving organizational issues that still merit further study.

However, the involvement of a broader group with different experiences within the USP Recicla program proved to be a valuable method to promote a survey of possible changes in the questionnaire, since it allowed us to have different views on the same points. This will give us more possibilities of improvement until its effective application.

Therefore, we conclude that the first contact was of extremely important to show us the points that need to be corrected, and that we are investing in a necessary and relevant mechanism to promote the evolution of the program on campus and begin a change in how to evaluate the shared management of the waste we produce and the changes brought by environmental education in the university community.

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# Design and Waste Upcycling from Tree Pruning and Fallen Trees at the USP Campus (University of São Paulo)—Potentialities

**Cyntia Santos Malaguti de Sousa**

**Abstract** One of the remarkable characteristics of the USP campuses is the abundance of trees. Their regular cleaning and pruning generate a lot of waste, and its management is done by the University Mayor. These activities are getting more complex because of the summer heavy rains and the consequent increase of fallen trees. On the other hand, a significant part of this waste could, eventually, be benefitted and employed in artifacts production, that could be used on-campus, or as input for research and extension design activities. The results of an exploratory research are presented here, aimed at identifying: through bibliographic research, the theoretical fundamentals for sustainable design and wood waste upcycling and the history of USP Campus afforestation; through institutional documents consulting and interviews with the responsible personnel, the main characteristics of the existing trees species, the guidelines for their use, the current monitoring activities and required conditions for this wood harnessing; and through the university database access, finished researches devoted to this waste exploitation in artifacts production. Some municipal experiences on this waste management in Brazil were also analyzed, in order to complete the argumentation for the proposal of an experimental design research project in partnership with the University Mayor.

**Keywords** Waste recovery · Design · Urban afforestation · Tree pruning Fallen trees

## 1 Introduction: Design, Sustainability and Wood Waste Upcycling

C. S. M. de Sousa (✉)
Technology Department of the Architecture and Urbanism College,
University of São Paulo, Rua do Lago, 876,
Butantã, São Paulo, SP 03178-200, Brazil
e-mail: cyntiamalaguti@usp.br



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> The planning-designer is responsible for almost all our products and tools as well as for almost all our ecological mistakes. He is responsible in bad-faith or for carelessness; for having disregarded his/her responsible creative possibilities, for not wanting to get into trouble, or for wanting to move forward no matter what. (Papaneck 1977, 58)

Already in the beginning of the seventies, Austrian Victor Papaneck, considered one of the first designers to worry about social and environmental issues, severely criticized the action of his professional category, placing it among the main articulators of the consumption and waste society, which contributes significantly to the planet's degradation and to the depletion of natural resources. On the other hand, by defining design as "the conscious effort to establish a significant order" (Papaneck 1977, 19), he highlighted that this concept should replace qualifications that are usually associated to words such as "beautiful", "ugly", "dim", "disgusting", "realistic", "obscure", "abstract" and "pretty", typical of a superficial perception of design. This is how he defended that design should be responsible vis-a-vis ecology and society, dedicating itself to nature's minimum effort principle, i.e., making the maximum using the minimum, meaning consuming less, using things for a longer time and doing material recycling, for example. With these principles in mind, he conceived the term eco-design, linked to the idea of eco-efficiency. "According to this approach, the environment is as important as the technical feasibility, cost control and market demand" (Kazazian 2005, 36).

With the advance of thoughts on environmental sustainability, understood as the "systemic conditions according to which, at a regional and planetary level, human activities should not interfere in the natural cycles on which all that the planet's resilience allows, is based" (Manzini and Vezzoli 2005, p. 27), guaranteeing the right to the same natural capital for each human being (equity principle), as well as for the future generations, the concept of design for sustainability eventually emerges. According to Manzini and Vezzoli (2005, 23):

> Proposing the development of design for sustainability therefore means promoting the production system's capacity to respond to the social pursuit for well-being, using a number of environmental resources greatly smaller than those currently in use. This demand coordinated management of all instruments available (products, services and communication), granting unity and clarity to one's own proposals.

In this case, it is necessary to have a strategic approach, to involve planning, prospection and prior compared assessment activities, of the different environmental issues' solutions, across all the life cycle. This approach is known as Life Cycle Design. Without ignoring the concern with a product's environmental performance (the core focus of eco-design), design for sustainability searches a more systemic look at the articulation between the meeting of human needs and the social and environmental balance.

One of design for sustainability's guidances is to carry out production, consumption and discard processes that are biocompatible, i.e., that employ natural renewable resources, without, however, surpassing the reproduction limits of the ecosystems which support them; in addition to reintroducing resources such as totally biodegradable waste and separated according to their decomposition and reintegration possibilities. The principal idea would be to organize these processes "as transformation chains (bio-cycles), integrated to the natural cycles as much as possible" (Manzini and Vezzoli 2005, 33).

Among mankind's mostly used natural renewable resources, for numerous purposes and from ancient times to this day, is wood, and in Brazil it hasn't been different, even before the arrival of the Portuguese. However, the unscrupulous and unlimited extraction of wood generates many interconnected environmental problems, starting by deforestation, which also led many native Brazilian species to the threat of extinction. Different measures have been progressively adopted to regulate these activities, from the banning of the threatened species' commercialization, to the spreading and certification of the forests' sustainable management techniques. On the other hand, also the production segments, which used wood as main raw material, have been starting to search for solutions to better use the material, avoiding waste in the manufacturing processes and searching for secondary uses or adequate destinations for the discarded residues.

And how does design interact in this context? In some cases designers have been taking part actively in this effort, adjusting furniture projects and civil construction components to reach such goals, including the support of digital tools; in other occasions, designers act independently, in their own workshops, using certified wood as raw material (given they come from sustainable management areas), wood shavings/chippings (scrap) from the timber industry or wood derived from pruning activities, fallen branches, leaves, seeds or even trees. In other occasions, as a form of social integration and income generation, designers or artists develop products from industrial chippings or from forest waste, together with groups of people living in neighboring areas or sensitive communities. We can mention, as examples, the works of Hugo França, reutilizing dead trees to produce unique garden furniture sculptures (benches and tables); Danilo Blanco, who innovated the aesthetic pattern of solid inlaying using wood waste (from carpentry shops, demolition and logging companies) and sharing his experience in company courses and workshops, education and capacity building programs for youngsters at risk; Ricardo Afiúne, from Araucari Arte, who works with fallen branches; and Carlos Motta, who develops furniture with demolition wood.

Recently some works with this type of approach have been valued in Brazil by public agencies such as São Paulo's city government, which has been supporting initiatives such as Hugo Françaś's in the Ibirapuera Park and other parks, flowerbeds and city squares, usually in the form of donations and partnerships with the private sector. Environmental organizations such as Friends of the Atlantic Rain Forest Biosphere Reserve Institute, include, among its objectives, the support to sustainable actions and businesses associated to small and medium community businesses as a form of strengthening income generation alternatives that contribute to this biome's conservation; these institutions' "products of biodiversity" catalogues feature several crafted objects made of forest waste such as fibers, barks and shells, seeds and even wood. These objects are considered samples of the biome's biodiversity as well as of the social and cultural heritage wealth of the people who inhabit these areas (Mercado Mata Atlântica 2008).

## 2 Cidade Universitária Armando Salles de Oliveira—CUASO Afforestation

The USP campus located in the West zone of the city of São Paulo, was inaugurated in 1968 and named *Cidade Universitária Armando Salles de Oliveira—CUASO*. Today it occupies an area of approximately 3,650,000 $m^2$ (Universidade de São Paulo 2014).

The initial land plot was a donation from the Butantã farm property. Because it was a coffee farm (Miranda 2015), much of the original vegetation of the place had been removed. Professors who joined USP by that time say it had no trees. Some also add that on the stretch of land close to the margin of the *Pinheiros* river, one of the land-plot's limits and considered floodplain, very long ago there were *Jerivá* palm trees and large *Araucária (the Brazilian pine tree),* giving origin to the name of the river. Since the creation of the *Cidade Universitária Campus* in 1934, "preparing the entire property in the form of a pleasant and recreational park" was part of the conditions established (Pinto and Buffa 2006). The campus' architectural and urbanization projects were developed by more than forty architecture firms coordinated by the university's Technical Office. Two types of urbanistic projects were implemented.

> In the foregrounds, a small part of the campus was designed with clear influence of the City Company projects, which had been developed for the city of São Paulo, neighborhoods such as the Jardim América, Jardim Paulista and others. The sinuous and organic plot, contouring squares and green areas, in the style of English garden cities[1], is outstanding in this little area of the Cidade Universitaria entrance. Eventually the option became more pragmatic and two way boulevards began to cut the campus on both directions: rapid avenues, with no crossings, broad and straight.

According to different historical reports, the plants were effectively brought over and planted in the context of an urban afforestation. In both the mentioned urbanization models, the chosen plants followed the trends of the sixties: privilege was given to ornamental species regardless their origin. The *Tipuana* or Rosewood, for example, with its origin in Bolivia and Argentina, is very common in the campus and is also very much present in the Jardins neighborhoods. Also, the availability of seedlings at the time was not very big. The layout of the trees makes some scholars believe that there had never been a well-structured landscaping

[1]1 According to Wolff (2001 apud Limnios 2006) the concept of garden city, originated in England by the end of the 19th century, is applied to "urban nucleus" that try to live independently from other cities". Such approach stemmed "from a planning perspective with broad social purposes and a spirit which searched to join city and field in an organic whole".

project at USP. In fact (Miranda 2015), as each institute is responsible for the care and maintenance of its plants, many of these were chosen by the directors, professors or staff, individually or in small groups.

In a quick walk across the Cidade Universitária, entering through Gate 1, one may see a line of palm trees along the main boulevard; it is said that they were planted in the sixties by one dean. With their origin in Australia, they were brought because of a fashion of the time, the reproduction facility and their exotic beauty. They stand side by side with *Tipuanas*, one of the predominant arboreal species in the campus, while large *Sibipirunas* were placed along Rua do Matão. As the *Tipuanas*, in the blossoming season they present small yellowish flowers, which color the ground as they fall. On the other hand, in the traffic circle in front of the Oceanography Institute and thanks to the initiative of one of the institute's directors, we find many *Ipês,* a reference to the native cerrado's vegetation.

Nowadays the existing arboreal set of the CUASO, features both native and exotic species. Nevertheless, the campus is considered a Green Nucleus with high ecological, socio and cultural worth, encompassing 924,836 $m^2$ of common green and landscaped areas, hosting about 22 thousand trees. Although the registration files are not updated and do not count the trees per species, the variety is great, including: *Tipuanas, Angicos, Quaresmeiras, Manacás da serra, Paus Ferro, Sibipirunas, Ipês rosas, Ipês amarelos, Ipês brancos, Eucaliptos, Pinus, Goiabeiras, Ingás, Aroeiras, Erytrinas, Espatódeas, Amoreiras, Uvaias, Guapuruvus, Paineiras, Paus Brasil, Araçás, Jambolões, Pitangueiras, Jacarandás mimosos, Mangueiras,* and others (Verhalen 2017). Their distribution is varied, but there are, however, large concentrations of ornamental species along the main boulevards, such as the *Tipuanas*, the Palm trees, the *Sibipirunas* and the *Jacarandás*.

## 3 Monitoring Activities and Required Conditions for Wood Harnessing at CUASO

The afforestation of public roads, the creation of green areas, as well as their suitable management are being increasingly considered important activities in the realm of urban governance. They provide very positive impacts on the local climate and environmental conditions, making the urban soil more permeable and mitigating the formation of "heat islands" as well as protect the fauna. In addition, they promote significant effects on the landscaping, creating more scenic beauty, shadow zones, resting and contemplation environments. Nonetheless, "afforested areas, created artificially and in the adverse conditions of cities, require continuous attention and necessary actions" (Santos et al. 2015, 12).

At CUASO these activities are in charge of the Social and Environmental Management Technical Division. It was expected that in 2015 an Urban Afforestation Master Plan would be implemented, to regulate the local afforestation and promote continuous management improvement. The starting point would be a qualitative and quantitative arboreal inventory, identifying and localizing species and concentrations, as well as allowing health monitoring and, therefore, possible risks of falling. Eventually, little by little, the exotic species could be replaced by native ones, in conjunction to tree planting and landscape planning programs.

Although it wasn't possible to obtain more precise information about that Master Plan, some specific procedures are adopted regarding pruning and removal of fallen trees, as well as characterizing and measuring the existing status, in a still preliminary mode. The tree pruning can only take place with the authorization of the Butantã Regional Municipal Government and of the Department of Parks and Green Areas—DEPAVE of the Municipal Government. Before the removal of fallen trees and/or large branches, it is necessary to draft a report and inform the municipal environmental agencies.

According to the Municipal Government's Technical Manual for Tree Pruning, adopted by USP (Santos et al. 2015, 10), "pruning" is the partial removal of branches of a plant, modifying its structure and consequently its development stage. "In urban trees, pruning is basically the timely elimination of branches on one part of the plant, to provide its healthy development, compatible with the physical space it occupies".

At USP the pruning season for trees in the common areas usually starts in April and lasts about six months, given the complexity of the procedures involved and the large number of trees. Once a year, the University Government—PUSP-C, also does the pruning and cut of trees in USP's units, after an inspection to check the conditions in place and request the environmental agencies and the Municipality for the necessary authorizations. In reference to the falling of trees or large branches, due to strong winds and rains that occur in the city—mainly in summer—, the Waste and Natural Resources Service establishes that the units should: take pictures of the fallen tree or branch before the removal to prove environmental agencies that the tree or branch fell due to the rain and not because of the cut or pruning; inform the location and date of the fall; inform if the fall interrupted or affected services of the unit or surroundings, including sidewalks, roads or parking lots. This data subsidizes the drafting of the report sent to the Municipal Government, avoiding charges and searching to accelerate the removal processes. With this information, the Municipality may trigger its Emergency and Risk sector, to intensify inspection in the location, aiming at foreseeing new accidents and speeding up services such as prior pruning and cuts.

Management and disposal of both wastes are made by outsourced firms, which must operate according to guidelines defined by the Technical Division in charge (Mellucci 2017). Also the "pruning of trees and bushes, cutting of trees and grass, transplant of trees and gardens' pest control" (Mellucci et al. 2015, 6) are made by outsourced firms, managed by the Technical Environmental Management Service—SVGA. The service may be performed by green area maintenance firms, which take the removed material to grinding and composting; or by a wood commerce and recycling firm, Made Vila, which operates removing dumpsters rented by PUSP-C.

In this last case, the waste removed is treated for chips production, then dried (10–23% humidity) and compacted in the shape of pellets to be used as fuel (energy).

It is estimated that around 90 $m^3$ of pruning waste is removed from the Campus monthly, or 18 dumpsters of 5 $m^3$. The average fall of trees is of 25 per year, depending on climate circumstances and the phytosanitary conditions of the subject (Mellucci 2017). The greatest fall champion is the Tipuana,[2] followed by the *Jacarandá,* the *Quaresmeira* and the *Manacá da Serra. Eucaliptos*, *Guapuruvus* and *Paineiras* are more of a problem due to the falling of branches and not of the entire tree (Verhalen 2017).

From the preliminary information gathered it is undeniable both the dimension and complexity involved in the management and execution of the described activities. From the perspective of the problem's global treatment, there is a coherent and articulated response. But, however part of this waste could have another type of destination in the Campus itself, to respond to the learning, research and extension demands, or even for the physical infrastructure, although this alternative could make the system's management more complex.

## 4 Understanding Something About Pruning Waste and the Characteristics of Some of the CUASO Species

Pruning waste may be classified following different criteria (Nolasco 2000; Meira 2010) such as origin, species and plant component which originated them, generating factors, hazards, chemical composition, physical features, dimensions, quantity, seasonality, spatial dispersion and form of management. This analysis is very important for the choice of a suitable destination, making the best of its peculiarities.

In terms of generating factors, it may come from clearance pruning and urban afforestation maintenance, due to falls caused by natural phenomena, by senescence or human pillage (Meira 2010). It consists of branches, twigs, leaves, seeds, fruit and stems. In the case of the removal of arboreal samples, there are also roots and the trunk. This waste may be classified according to their diameter (Cortez 2011)—leaves and thin twigs with up to 8 cm diameter; branches with diameters ranging from 8.1 to 15 cm; branches of 15.1 to 25 cm diameter; and branches with diameters above 25 cm.

From the hazard perspective, both the National Solid Waste Policy (Brasil 2010), and the Brazilian Technical Norms' Association (ABNT 2004), consider them nonhazardous, solid urban cleaning waste, and the latter, includes them in

[2]The presence of fungi and termites is an important risk factor associated to tree falling. In the case of the *tipuana tipu*, it is a fast-growing exotic species, brought to several neighborhoods of the city of São Paulo, developed by the City Company in the first decades of the 20th century. They suffer a lot with the rotting by fungi caused by trunk injuries from incorrect pruning or vandalism (Brazolin 2009)

Class II A—non-inert waste, because they are biodegradable. In terms of chemical composition, it is organic material, composed of about 50% carbon, 6% hydrogen, 44% oxygen and 1% nitrogen (Silva 2005). This waste is composed basically of cellulose, hemicellulose and lignin—responsible for the hardness and rigidity of the cell wall, driving the commercial use of wood.

Regarding the potential use of wood waste from the Cidade Universitária Campus' trees, based on Rizzini (1978), Lorenzi (1998), Zenid (2009) and Brazolin et al. (2014), information on the seven species pointed out as the most subject to fall and breaking of branches (Tables 1 and 2) reveal interesting opportunities.

Most of the species subject to falling are ornamental, except for the eucalyptus. Regarding the origin, only the eucalyptus and the *tipuanas* are not Brazilian. In terms of dimension, those trees that mostly fall are medium sized; however, *tipuanas* are thicker than the rest. Those whose branches fall a lot, are larger and thicker as well, except for the eucalyptus. Three of them—*tipuana*, *manacá-da-serra* and the eucalyptus—are very much attacked by termites. The tree with greater durability is the *jacarandá mimoso.* Nevertheless, a deeper research would be necessary to learn the physical, chemical and mechanic characteristics of each species, and from then on prospect potential destinations to better value the pruning and fall waste. In any way, it should be highlighted that all of them offer potential applications in the creation of daily use objects; furniture, internal civil construction and interior decoration elements, as well as boxes and packaging. Undoubtedly this potential may vary, depending also on the health of the tree at the moment of pruning or fall, demanding that there be specific procedures in place during the activities.

## 5 Some Other Experiences and Researches on These Waste Management in Brazil

In an exploratory research the following practices were identified and analyzed: the Concessionária AES Eletropaulo (electricity utility) in 24 municipalities (Burani et al. 2009); the city administration of São Paulo/SP, Guarulhos/SP (Rocha et al. 2015), Campinas/SP Maringá/PR (Martins 2013) and Florianópolis/SC (Chaluppe 2013). And also some particular initiatives were found of interest: Serraria Ecológica in Guarulhos (Rocha et al. 2015), "Companhia Melhoramentos da Capital"—COMCAP, for Florianópolis (Chaluppe 2013), the Composting plant of AES Eletropaulo (Burani et al. 2009), for the Metropolitan Region of São Paulo, and the "Madeira Urbana" (urban wood) Project (Madeira Urbana 2017).

In most of the situations, researches point that there is a lack of a more adequate methodology to manage tree pruning and fall waste. Nowadays most of it goes to landfills, sometimes, even burned in open air. Meira (2010) points out that in many cases the waste ends up in water sources, generating risk of fires and landscape

**Table 1** Tree species of great occurrence at USP and more susceptible to falling down

| Scientific name | *Tipuana Tipo (Benth.) O. Kuntze* | *Jacaranda mimosifolia* | *Tibouchina granulosa* | *Tibouchina mutabilis* |
|---|---|---|---|---|
| Popular name | Tipuana, acácia-argentina, pau-de-mocó, petirica-gaçu, tipa-branca | Jacarandá mimoso, flamboyant azul | Quaresmeira, quaresma, flor-de-quaresma | Manacá-da-serra, cuipeúna, jacatirão, flor-de-maio |
| Family | Fabaceae | Bignoniaceae | Melastomaceae | Melastomaceae |
| Habitat | Origin: Bolívia and Argentina | Forest formations from Atlantic complex: SP and MG | Pluvial Forest from Atlantic slope; BA, RJ, SP, MG | Pluvial Forest from Atlantic slope; RJ till SC |
| Average dimensions | 9–12 m high; > 12 m; 1.6 m $\phi$ | 12–15 m high; 30–40 cm $\phi$ | 8–12 m high; 30–40 cm $\phi$ | 7–12 m high; 20–30 cm $\phi$ |
| Morphology | Shaft nearly rectilinear and light-brown outgoing bark, with vertical grooves and transverse greases | Thin and grey bark | Smooth and whitish bark. Dense, full bodied, globular and short treetop, with many branches | Thin bark |
| Wood | Slightly heavy, indistinct heartwood and sapwood; uniform white-yellowish. Little shiny, medium texture, right and irregular grain, little rough surface to touch. Weak natural resistance to termite attack | Clear, very hard, heavy, compact, long lifecycle but fragile | Slightly heavy, tough, low durability when exposed to inclement weather | Slightly heavy: 0.66 g/cm$^3$, soft, very much attacked by termites |
| Uses | Light packaging, pan of panels and doors for interiors | Toys, boxes, furniture, musical instruments, lining, carpentry; seeds in bijou and crafts | Light objects, toys, boxes, etc. | Beams, rafters, internal work, posts, mainstay and mourners for dry places |

degradation. Sometimes the material ends up being auctioned, but only small amounts.

Two main categories were mentioned regarding the reuse of wood waste: non-energy and energy use. The first one as fertilizer or organic compost, extraction of oils, resins, reconstituted wood; the second, with technologies related to physical processes (briquetting and palletization), thermochemical processes (combustion, pyrolysis and gasification), or biological ones (anaerobic digestion) (Chaluppe 2013).

**Table 2** Tree species of great occurrence at USP which branches more often break

| Scientific name | *Eucalyptus grandis* | *Schizolobium parahyba* | *Ceiba Speciosa* |
|---|---|---|---|
| Popular name | Eucalipto-grandis | Guapuruvu, bacurubu, guapiruvu | Paineira-rosa, barriguda, barriguda-de-espinho |
| Family | Myrtaceae | Fabaceae Caesalpinioidae | Malvaceae |
| Habitat | New Zealand; BA, ES, MG, GO, MT, SP, PR, RS | Atlantic forest, RJ to RS | BA, ES, MG, GO, MT, MS, PB, PR, RJ, RS, SC, RS, DF |
| Average dimensions | 30–40 m high; till 30 cm ϕ | 10–20 m high; till 100 cm ϕ | 15–30 m high 120 cm ϕ |
| Morphology | Rose- beige sap-wood; light brown-rose core; low brightness, imperceptible smell and taste; soft to touch, right grain, fine/medium texture | Smooth grey bark, smooth bark, light transversal marks in relief | Straight trunk and very thick in its middle third; rough bark |
| Wood | Light: 0.42 $g/cm^3$ Moderate durability (attacked by fungi and termite). Heartwood difficult to deal with; permeable sapwood | Light white-yellowish, silky smooth surface, half glossy; in general light and soft; tannic bark | Light: 0.26 $g/cm^3$, soft, thick texture, right grain, low mechanical resistance, little durable |
| Uses | Clapboards and light internal structures. Wall footers, door trims, linings and lickings, scaffoldings. Laminates, furniture, plywood, pallets, packaging | Boxes, linings, clipboards, toothpicks, canoes, paper pulp; aeromodelling, toys, games, seeds for decoration and bijou | Plywood core, doors, linings, boxes and cellulose. Feather from the seeds for pillows and mattresses filling |

For Rocha et al. (2015, 137) "the most sustainable and efficient alternatives are using trunks to generate wood utensils, fences and other objects, as well as composting branches and leaves". They suggest that waste from large parts of wood be employed in artisan work (production of furniture for squares, gardens or other public use) or in fences.

Martins (2013) corroborates this vision, highlighting that this waste can be source of raw material for the manufacturing of solid wood products (furniture, doors, mountings, beams, floors and other), small objects (toys, tool handles, decoration in general), and power generation by fabricating charcoal. Analyzing sample characteristics of the three most frequent species in the Municipality of Maringá—*Sibipiruna*, *Tipuana* and *Ipê Roxo*—he concluded that thanks to its high density, the *Ipê Roxo* provides mechanical resistance for the production of structural elements; the *Sibipiruna*, given its medium density, may be applied in small objects production. The *Ipê* and *Sibipiruna* are also appropriate for charcoal.

Nevertheless, the most articulated project observed was the “Urban Wood”, launched in 2010 by the Brazilian Tropical Forest Company—CBFT, during the Architecture, Decoration and Landscaping Show in Campinas—Campinas Decor, organized by the “Instituto Agronômico”—IAC. The objective was to certify products that used wood originated from reuse, fall, authorized pruning or cuts of trees which composed the urban and rural landscape. At Campinas Decor, they presented the ambience setting of a restaurant placed inside a greenhouse protected by the Campinas Historical Heritage, whose tables, chairs, sofas, benches and other objects were constructed with wood deriving from trees pruned and dead in the city, such as *Sibipirunas*, *Abacateiros* (Avocado trees), *Ficus* and even *Araucária* pine trees. Furniture was designed by two architects, one engineer and one designer, and manufactured by three carpentry shops, licensed to receive and use the Program’s certified wood for production. Thus, the pieces show a stamp containing a specific code for on-line consultation that allows to “trace the story of the wood being used, with information and images of the pieces, as well as the permits, dates and even the exact location where the fallen or pruned tree stood, or otherwise the demolished site which originated the reused wood” (Madeira Urbana 2017). The initiative dialogues with the municipal law (13,737; 12/4/2009), aimed at reusing products resulting from tree extraction and pruning in public areas, reducing $CO_2$ emissions in the atmosphere.

As the author of this article became aware of this initiative, she oriented a Design course final work (Arruda 2011) using wooden slates, to produce an exposition shelf system, of *Fícus* deriving from the program. With the support of IPT (São Paulo Technological Research Institute) and the models and prototype workshop of the University, it was possible to characterize and treat the wood, eliminating fungi, to obtain a light modular system, mounted with fittings, which explored the potential of more than one type of very common wood in the urban afforestation.

## 6 Experimental Researches in the Production of Artifacts and Components

The resulting findings of two of USP’s exploratory researches strengthen this article arguments. The first was part of a master’s degree course at the Escola Politécnica (Gallego 2015), and the second, was found in a Doctorate thesis developed at the “Luiz de Queiróz” School of Agriculture’s Furniture construction and Forest Waste Lab (Meira 2010).

Gallego (2015) analyzed two types of very specific arboreal waste, present in the CUASO Campus: the stem leaves of the bamboo (FCB) and the palm tree leaf sheath (BFP). Her objective was to explore the use potential of this waste in the production of decorative laminates, for interior coating of buildings. The experimental phase of the work crossed the following stages: (1) waste characterization, in terms of humidity level, water absorption capacity, porosity; chemical analysis of loss to fire and thermal gravimetrical analysis; (2) waste pre-treatment, including collection, washing and drying methods, rectification of leaves, chemical and thermomechanical tests; (3) molding/casting of waste through different mechanisms, and application of tests with three types of substrate and three types of coverings; (4) characterization trials of coverings in contact with different adhesives, chemical characterization analysis, optic microscopy and scanning electron microscopy. Furthermore, abrasion, cleanability and perception trials. In her first results Gallego concluded that: this waste's thermomechanical behavior is ideal for the application in the production of decorative laminates with Kraft paper substrate; in the pre-treatment phase, the thermomechanical rectification of leaves is ideal to conserve the waste surface; and finally, the molding of the kraft substrate coating, also shows the best visual and aesthetic performance.

Meira's study (2010), although prior, was more encompassing, and its objective was the quantification, characterization and design of a management model for the urban afforestation waste, using the municipality of Piracicaba as case study. She also tried to assess the viability of using material in the production of solid wood products (sawn wood, furniture, small wooden objects), in composting with other available waste in the cities, and as source of energy (firewood and charcoal). At the end of the study the management plan proposed three action courses: generation reduction, waste upcycling and final disposition in emergency cases. Regarding the second course, waste upcycling, the author tried to first know the waste from samples of different diameters, determining their density, humidity level, color, fixed carbon quantity, ashes, etc.

> …these variables indicate if the waste can be dismembered into boards or transformed into small wooden objects, furniture, urban equipment, frameworks to use in low-income housing; their energy potential to use as firewood, charcoal, briquettes or pellets; the possibility to produce organic compost among other forms of upcycling. In doing so, it's possible to separate the material for different destinations, obtaining maximum economic, social and environmental return (Meira 2010).

According to that research, as other experiences showed, composting is a good strategy for it is encompassing. The wood waste of some species, however, can be better used in other ways such as in the manufacturing of small objects in the furniture constructing industry (*Sibipiruna* and *Chapéu de sol),* or in the manufacturing of urban equipment such as pergolas and benches. The diversity of colors and patterns of these waste's legno may also be explored.

In the laboratory where Meira developed her thesis, other experiences continued and two approaches were identified for the development of wood pruning products: the early processing of branches and trunks, turning them into boards; or using the waste in its natural form, valuing shapes, textures and colors of each species, preserving rusticity, the bark, avoiding varnishes or dyes. As of the second approach, several artifacts were created—toys, fitting games, office appliances, etc., —composing a portfolio which could be used as reference for social municipal social programs to build the capacity of people excluded from the labor market, and/or use in schools, nurseries/kindergartens and parks. According to reports of the time, this research also deployed into the offering of a capacity building training for municipal public officers to design plans for the urban afforestation waste management, which would take place in each regional administrative unit of the State of Sao Paulo.

## 7 Final Considerations

The intention of this article was to raise the attention to the importance of systematic research, learning and extension activities, for the Design Course at the School or Architecture and Urbanism of this university—FAU, to explore the potentialities for the upcycling of arboreal waste of the CUASO Campus, in creating objects and building components. As this article showed, the amount and characteristics of this waste offer good perspectives in this way. The experiences and researches mentioned also revealed that, more than a potential (as shown in Tables 1 and 2) the wood waste from pruning, can effectively have useful and sustainable destinies other than turning it all into organic compost; even that from ornamental trees.

The implementation of such idea, nevertheless, requires a different and more complex approach, involving waste pruning selection, evaluation, treatment and experiments. On the other hand, the use of these resources inside the Campus, as urban equipment for instance—such as benches, paths and support for signaling systems—could help in humanizing the overall environment, as well as represent, if not an economy, at least an exemplar attitude towards a circular economy. Award schemes could be organized to stimulate these initiatives. That could be enhanced with the identification of the upcycled woods with stamps or other signaling system, so that its origin and history can be told or recovered, such as it was done by "Madeira Urbana" Project. And thinking optimistically, eventually a new service could be implemented in CUASO Campus, where selected pruned wood could be identified, cut, treated following some guidelines, and stored for some planned use. Another possibility that emerges is the planning of researches in partnership with the private sector to develop some kinds of panels and composites such as those Gallego (2015) did, from the fallen leaves or smaller particles.

The use of wood waste as a raw material in disciplines of the Design Course such as "Materials and Production Processes", "Urban design", "Furniture design" or "Toys Design" could also be an interesting learning experience. In fact, this was already done by this article's author, with very good results in the design and prototyping of tridimensional puzzles by the students when they were studying wood connections, in the context of the first discipline mentioned.

So, based in these findings, a new design research is already in course at FAU. Given the pruning period at CUASO, and with the help of a design student scientific research, samples of pruned branches of different dimensions and conditions have been collected; its characterization is being done; at the FAU Models' Lab, these pieces will be dried under controlled conditions while some wood treatments and appareling methods will be studied; some of these will be applied to the samples and the results analyzed; the prepared samples will finally be employed in different artifact prototypes, according to its characteristics, conditions and their fitting to the demands of the mentioned disciplines.

Depending on this research final result, the next step shall be a major research, in partnership with other USP unities and the University Mayor, in order to analyze the implementation viability for an arboreal waste management system which allows other types of destination in addition to those of today.

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## Author Biography

**Prof. Dra. Cyntia Santos Malaguti de Sousa** holds a Bachelor degree in industrial design from ESDI - UERJ (1980) and received her Ph.D. in architecture and urbanism from FAUUSP (2000). She is professor and researcher at the Department of Technology at FAUUSP. Specialized in design management and design for sustainability, develops researches in fields such as reverse logistics, material culture and raw-materials for design.

# The Sustainable Management of Special Waste at UFSC—Work and Environment

**Carlos Alberto Rodrigues, Ariane Laurenti, Laerte de Souza Jr. and Bruno Eduardo dos Santos Silva**

**Abstract** Waste management is an activity of public interest. Higher Education Institution's (HEI) waste is generated from teaching and research laboratories, as well as from social assistance services where hazardous and non-assimilable substances are present. This type of waste needs to be precisely defined and classified once generators need special care in handling it. In this sense, this paper analyzes Job Health and Safety aspects of a special waste diagnosis at the Federal University of Santa Catarina (UFSC). In the scope of the study carried out at the UFSC, it was verified that many of the special waste handling activities are carried out by students. It was also identified the lack of internal regulation that guarantees the protection of health and safety of all members of the university community involved in special waste operations. In universities in general, laboratories producing chemical waste have a potential exposure of workers to risks and, therefore, should be the object of the university management attention. The project described in this paper was important to inform the university managers about the

C. A. Rodrigues (✉)
Departamento de Atenção à Saúde – PRODEGESP, Federal University of Santa Catarina – UFSC, Trindade, Florianópolis SC 88040-900, Brazil
e-mail: carlos.alberto@ufsc.br

A. Laurenti
Centro de Ciências Da Saúde – Departamento PTL, Federal University of Santa Catarina – UFSC, Trindade, Florianópolis, SC 88040-960, Brazil
e-mail: ariane.laurenti@ufsc.br

L. de Souza Jr.
Departamento de Engenharia Sanitária E Ambiental – CTC, Federal University of Santa Catarina – UFSC, Trindade, Florianópolis, SC 88040-900, Brazil
e-mail: laertesouzajr@gmail.com

B. E. dos Santos Silva
Rua João Pio Duarte Silva, 404/101 B, Córrego Grande, Florianópolis SC 88037-000, Brazil
e-mail: bruno.silva@rotaria.net



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involvement of students in internal waste collection activities, which is not an activity of the academic structure. It was not intended to determine the best way to solve this problem, but rather to contest the issue and induce a debate regarding the lack of a specific Brazilian legislation to address this problem. The study also showed that it is important for the University to develop internal regulations about this subject. A sustainable waste management system needs to contemplate and regulate the working conditions of students in laboratory activities for safety and protection of their health.

**Keywords** Chemical waste · Waste management · Job health and safety

## 1 Introduction

Waste sustainable management should be an object of public interest and, therefore, of involvement and responsibility. In HEIs, sustainable management of its waste is an obligation, which is justified by the characteristics and finality of the activities that are carried out inside of a campus. For this obligation to become an example of management for society and to produce new knowledge, political and socio-cultural attitudes—which presupposes a sustainable and fair society—it is important for the principles and practices of sustainability to become incorporated into the institution.

Sustainability initiatives in HEIs in Brazil and in the world, when related to environmental issues and health and safety aspects of work in the management of special waste (chemical and biological), are often presented as isolated practices. When they appear as institutional strategies, they present some degree of difficulty in their implementation (Tauchen and Brandli 2006; Zhang et al. 2011; Ioja et al. 2012).

Institutional structures have security responsibilities at every level. This responsibility includes acquiring hazard recognition skills, assessing the risks of exposure to hazards, minimizing the risks of exposure, and addressing laboratory emergencies (ACS 2012).

Safety in the realization of functional attributions is one of the components of workplace well-being, and it increases life quality of individuals exposed to risks (Silva and Ferreira 2013). Therefore, the lack of special health care for these individuals, in addition to generating a sense of insecurity and lack of motivation at work, does not meet the fundamental principle of sustainable waste management (WHO 1995).

Within the HEIs, occupational health and safety aspects are linked to activities in teaching, research and extension laboratories or other sites that handle and manage chemical and biological substances. HEIs have the obligation to offer study and work conditions capable to guarantee the information, training and sanitary surveillance of all teachers, students, technicians and employees.

Any activity performed with special waste and products should consider occupational exposure as a possible source of acute poisoning and chronic diseases.

Environmental and biological monitoring are tools to protect and monitor this exposure. These tools represent a special health care by the employers in relation to the individuals exposed to these agents (OSHA 2007).

The levels of risk in waste management can be diverse and therefore demand diverse safety conditions. Anyone who works in a laboratory, being a teacher, researcher, student, technician or visitor, should always care about their health and other people's. In addition, the person also needs to care about environmental issues (discharges, waste treatment, etc.) in order to preserve the characteristics and health of the natural environment in general (reduction of the volume of reagents used, development of low-impact technologies, etc.).

In HEIs, among individuals exposed to chemical risk conditions are students (undergraduate, graduate, and trainees). These, because of the fact that they are not part of the institution staff team, are not covered by labor legislation or statutory legal regime. Therefore, it is essential that these members of the university community also become adequately protected by regulations, in relation to health and safety, to carry out their activities. This issue is faced in many ways and with different understandings. These differences appear in the treatment given to students in regulations that deal with the management of laboratories and their waste.

In general, HEIs regulations establish the organizational structure, roles, and responsibilities of all parties involved in safety management. They also establish the rules of protection and emergency to be applied and observed by all those at risk. In some cases, students are considered workers, even without explicit mention, and therefore also responsible for performing extra tasks. In some waste management regulations, this is possible as long as they have the necessary PPE, training and qualification (Oliveira Jr. 2012; Università degli Studi dell'Insubria 2012); in a second situation, the student must know and have access to all safety standards and procedures and handle the waste only in the internal generation sites, not having any external responsibility to the laboratory (UNAM 2012; UFOPA 2016). In a third case of regulation, this possibility is not totally clarified (UNICAMP 2005; Universidad de Los Andes 2009). Finally, in a fourth possibility there is no regulation that contemplates this situation. The last case is the one observed at UFSC and several other HEIs.

Concerned with the reality of laboratories producing chemical and special waste, and with the safety and health of its users, UFSC in 2014 developed the Institutional Development Project called "Management of Chemical and Special Waste at UFSC: From Production to Final Disposal". This project addressed many aspects of this issue, but the present paper will deal only with those related to the manipulation and exposure of members of the academic community to chemical substances, with attention to internal waste collection. Health is a key factor for people's life quality and the sustainability of any human activity. Thus, the lack of institutionalized special health care for workers exposed to risks impairs the sustainable management of waste, as well as it generates a feeling of insecurity and workers demotivation.

The importance of the project described in this paper was to show, through the data obtained that, although the internal collection of waste is performed by students (undergraduates and post-graduates), this activity is not regulated as part of the university academic structure. The data obtained should be an alert to the university managers, and reveal several aspects that should be prioritized by public managers regarding the student community. It is also important to stimulate both the debate on the subject and subsidized effective actions in the scope of administration to improve the conditions of waste management.

## 2 UFSC's Support to Health and Safety at Work

Teachers and technical-administrative staff have a working relationship established through Laws 8112/90 and 8745/93, which deal with the federal public service. In its organizational chart, UFSC has a specific sector to deal with health and safety issues. The Department of Attention to Health of the Staff (DAS), linked to the Office People Management Development (PRODEGESP), develops actions of expertise, promotion, and surveillance in complementary health. There was only one internal regulation on work safety (Ordinance Normative 58/2015/GR) which provides for the granting of additional insulation, hazardous, and Ionizing Irradiation and Gratification by X-ray works.

Although UFSC does not have a specific regulation, many initiatives related to its waste have been promoted: Portaria nº 0320/GR/97[1] and nº 002/GR/2005[2]; Resolution Nº 009/CUn/2006[3]; the development of a manual of basic safety rules in laboratories and for the management of chemical residues[4]; The MWMP of the University Hospital[5]; and, more recently, the waste sector has been structuring itself in a more professional way, with qualified workers who have elaborated the institution's waste plan, among other initiatives.

Student community at UFSC is formed by elementary school students from the Child Development Center (NDI), high school students from College of Application, and undergraduate and postgraduate students from UFSC, whose activities are developed in the field of teaching, research, and extension.

Graduation activities are regulated at UFSC by Resolution nº 17/CUn/97 (UFSC 1997) and Resolution nº 76/CUn/2016 (UFSC 2016); the Extension activities by Resolution nº 03 CUn/09 (UFSC 2009); and Research activities under Resolution nº

[1]Implementation of the Chemical Waste Management System, with the collection and final disposal of waste carried out by the company Proactiva.

[2]Discipline the use of chemical substances in the development of teaching and research activities of UFSC.

[3]Resolution that concerns about the need to comply with health and safety standards in research activities with potential risk.

[4]Manual elaborated by teachers Nito A. Debacher, Almir Spinelli and Maria da Graça Birth of the Department of Chemistry/UFSC.

[5]In 2011 the University Hospital/UFSC prepared its Medical Waste Management Plan (MWMP) and revised it in August 2013.

47/CUn/2014 (UFSC 2014). In none of them it is possible to identify any reference to health and safety issues. However, students receive special attention to health in the Health Care Service of the University Community (SASC) of the University Hospital (HU).

Although many advances have been made in the administrative structures of the University, as mentioned before, there are still many difficulties.

In addition to the need to create a strong safety culture and provide appropriate material and normative instruments for the protection of HEIs workers (technicians and teachers), special attention must be paid to students. It is essential to emphasize the educational importance of waste management for student formation as a citizen (Abreu and Iamamoto 2003). It is not enough that the university simply relies on regulations in the field of safety and health of its dependents and the surrounding environment, it also must guide its institutional planning and its ethical and moral actions (ACS 2012).

## 3 Waste Diagnosis at the Federal University of Santa Catarina

This study was carried out at Florianopolis campus of the Federal University of Santa Catarina (UFSC), located in the city of Florianopolis—state of Santa Catarina, Brazil. It covers an area of more than 20 million square meters, with a community of approximately 40,000 members. UFSC Campus in has eleven (11) Educational Centers, as well as a few administrative and service sectors.

For the project described in this paper, it was considered nine (9) Educational Centers, one (1) University Hospital, (1) "Colégio de Aplicação" (elementary education), one (1) University Press.

Based on a concept of integrated systemic analysis (Alshuwaikhat and Abubakar 2008), as well as on the experiences of other universities, this project' authors accomplished a diagnosis of the current situation of special and chemical waste at UFSC. Considering the complexity and quantity of generators at the university, a specific methodology was developed for this acquisition, processing and presentation of qualitative-quantitative data (Laurenti 2016). It was possible to identify 304 laboratories, of which 182 were producing this type of waste.

## 4 Data Acquisition

This project research was based on an exploratory-descriptive process; exploratory in the sense of providing flexibility in data comprehension, which is effective in the diagnosis of unknown situations (Zikmund 2000); and descriptive, to allow a deeper analysis of the system characteristics and, eventually, make it possible to establish relationships between variables (Gil 2008). Based on that, the data collection technique applied was the use of a structured questionnaire form and a field observation script, both executed during field interviews. Marconi and Lakatos (2007) define “interviews” as the meeting of two people so that one of them obtain information on a certain subject, through a conversation in a professional nature.

The form presented itself as a guide for the interviews, as well to record information collected and observed. It was applied to every research and extension laboratory, once the University did not have reliable data regarding the spatial location and precise quantity of generators. 304 potential generators were visited, with spatial data reported through spatial references and geographical location via GPS, later registered in a Geographic Information System. This system was later made available for the University Waste Management sector.

The form was structured in a logical order, providing information about the lab main characteristics (users, activities), segregation of chemical waste, characterization of waste (variety and quantity), waste treatments applied, packaging, identification, waste storage, collection (internal and external) and, especially for the object of this paper the aspects related to job health and safety, as well as legislation related to it.

Three people were sent for each interview, being two undergraduate students and one UFSC staff supervisor. Each one of them would fill an individual form observing aspects related to Collective Protective Equipment, and the provision of waste storage and packaging elements.

In the described aspects, 47 quantitative and qualitative questions were applied, six (6) of them directly related to Occupational Health and Safety. These six questions related to: access to MSDS (Material Safety Data Sheet); occurrence of accidents in the laboratory; emergency plans; safety equipment; collective protection equipment; training of laboratory users; and user’s knowledge on waste legislation.

After the interview, the responses were compared and a single version was recorded on a digital table. When controversies were to be found, the lab interviewee would be contacted and, when necessary, the place would be visited again. Once in possession of a single, digitized form, data could be forwarded for analysis and processing.

## 5 Data Processing

Considering the large volume of data without standardization, a few methodological procedures were applied to make it ready for analysis.

First, the project team created an integrated workbook containing index functions, database and statistical analysis tool, as well as information related to the person who compiled data, facilitating future verification. The worksheet first tab contained a code for each lab, which would make data analysis easier. In this same table was also made the distinction between laboratories that generate chemical and/or special waste.

A second tab was created containing the original answers given by lab generators. It had the function of "database" for quick queries, which sometimes became necessary during the processing and analysis of information. The other data tabs were related to the treatment and analysis of data.

Several concept and nomenclature criteria for data standardization were used, these related to its validity and applicability (Laurenti 2016). In this sense, the form questions were analyzed in terms of "categories" of answers within a "variable" under analysis. For example, a variable would be "system of waste internal collection" and its categories would include "hand" and "specific transport container".

Variables were often related to each other and, for this reason, to analyze health and safety issues, it was also necessary to analyze variables linked to other sectors of waste management.

## 6 Data Analysis in the Aspect of Job Health and Safety

Following the idea of interdependence between variables, job health and safety aspects were connected to the variables of waste collection (logistics), explored in this section as an example for the process of data analysis applied to all the questions.

Regarding waste collection, this research focused on the survey of aspects of sustainability and safety during internal collection, since it was intended to study the reality in which waste collector staff were developing this activity.

Once it was verified that waste collection at the university takes place in two moments, the nomenclature proposed by NBR 12807 (ABNT 2013) was adopted: "internal collection" and "external collection". "Internal collection" was specifically interesting for aspects of job health, being the act of collecting waste already conditioned at the generator site and moving it to an external area far from the generation site, either for internal temporary storage or for external temporary storage, for later collection by the company responsible for its final disposal. In this sense, the treatment of this variable was continued.

Firstly, the waste generators that did not have internal waste collection were excluded from the sample space. In this way, it was obtained the information that 81 generators were performing internal collection.

## 7 Results and Discussion

Among activities carried out in Higher Education Institutions (HEIs), research and teaching activities are the one that involve the largest number of members of the University Community (Faculty, Student and Technical-Administrative Staff), which are diversified in their assignments, at risk situations, particularly in laboratories (CSB 2010).

Risks in a laboratory involve factors such as: hazardousness of materials, such as toxic substances, biological agents, radioactive materials, flammable substances; dangerousness of equipment such as high voltage, high-speed centrifugal, pressure systems; restricted spaces, insufficient staff training, and the generation of waste.

Although the amount of such waste generated is generally small, the worrying is the variety of toxic waste and persistent in the environment (Nolasco et al. 2006).

In this sense, the management of special waste in a university must be part of an institutional environmental policy that provides support for actions ranging from segregation to the waste final destination.

During the diagnosis of the conditions for the management of chemical and biological waste (special waste) at UFSC, several problems related to job safety were identified. Among several issues, special attention was drawn to "internal waste collection" due to: high student involvement in this activity; precariousness or lack of training for this activity; precariousness in the signaling of emergency telephones; little knowledge and availability of the MSDS (Material Safety Data Sheet); low rate of demands by the heads of examinations for unhealthy or dangerous job functions; inadequate location of collective safety equipment (like fire extinguishers); and the precarious provision of personal protective equipment.

Despite being an elementary operation, internal waste collection poses risks to the worker's health and safety, and it is possible to identify potential chemical risks (contact by air, skin, eyes), ergonomic (weight, posture, container handling, packaging, etc.) and accidents (building conditions, packaging, work organization). At UFSC, chemical waste collection process takes place in two stages: internal collection, which consists of the removal of waste from the generator and storage in another temporary place, which is performed by internal staff; and the external collection, which consists of the removal of waste from the place of temporary storage and transportation to the destination, and it is carried out by a contracted company.

The UFSC special waste generators considered in this analysis (182) consist of laboratories that carry out teaching, research and extension activities, or a combination of these three (Fig. 1).

Among the 182 generators, the largest number of laboratories is research (77) and only 14 are related to teaching. Although the number of laboratories conducting research or in combination with other activities was much higher than those of educational, it was not possible to determine if the quantities of waste generated in these places were higher than those generated in the didactic laboratories, since many variables interfered with this evaluation.

The internal collection of chemical waste is performed in 81 generators of this sample space. In other places, the collection is performed directly by the outsourced company, thus characterizing external collection. Therefore, the lab does not have external storage and the waste remains at the generating site until the time of external collection. In 65 of labs (91.55%), the person performing this activity has other functions, and in 06 generators (8.45%) the worker responsible for waste collection exclusively performs this activity.

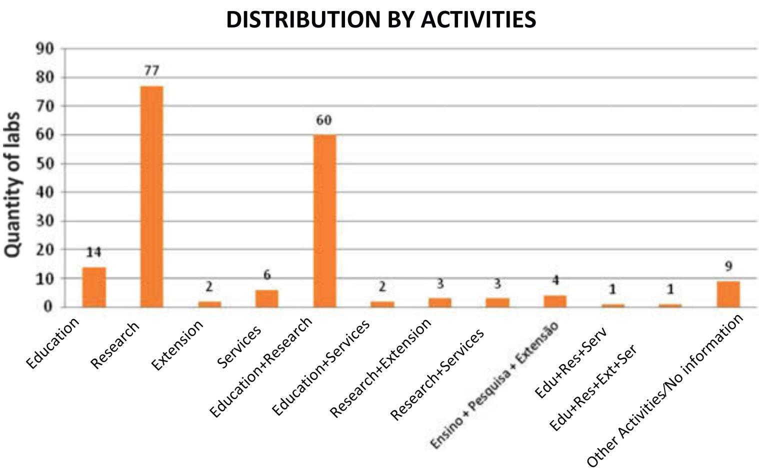


**Fig. 1** Special waste generating activities at UFSC. Sample = 182 generators

In most of the generators surveyed, the internal collection of waste is carried out by students, being 33 places of undergraduate students' responsibility and 8 post-graduate students' responsibility. In 24 generators, the internal collection is performed by laboratory technicians, in 6 generators it is performed by UFSC staff (not specialized technicians), in 02 generators it is carried out by teachers and 02 generators couldn't inform about it (Fig. 2).

Figure 3 displays the distribution of internal waste collection within UFSC sectors and Education Centers.

In this context, it stands out the Chemistry course of Physics and Mathematics Center (CFM), which has 15 generators, which internal collection is carried out by undergraduate and graduate students (51.85% of the total generators in the CFM); and the Biological Sciences Center (CCB), with 11 places where undergraduate students perform this activity (68.75% of the total generators in the CCB analyzed within the internal collection category).

As previously said, the collection of special waste is an activity that exposes the collector to chemical, ergonomic and accident risks. These risks require careful attention to the protection measures established in legislation. Thus, the revealed evidence—that in a large number of generators, the internal collection of waste is carried out by students (undergraduates and post-graduates)—should be an alert to university managers, since this type of activity does not fit As one of the academic activities inherent in your student community.

As also mentioned, graduation, extension and research activities have internal regulations of the institution, but these do not contemplate in their texts the protection of health and safety in the student context. Faced with this situation, it is recommended that internal regulations be established in universities to frame the role of students within the universe of special waste management. It should be emphasized that the institutional decision basically consists of the answer to at least

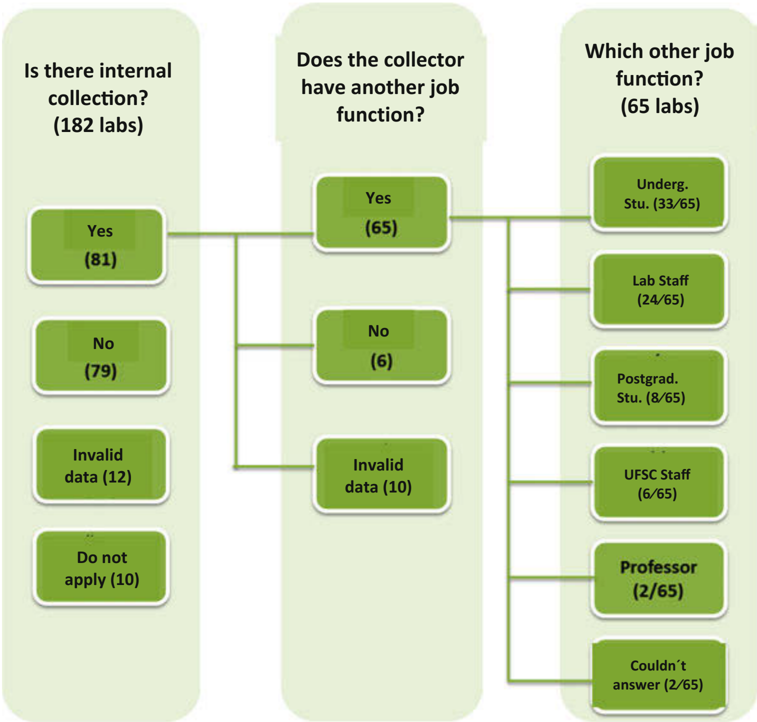


**Fig. 2** Waste internal collection analysis process

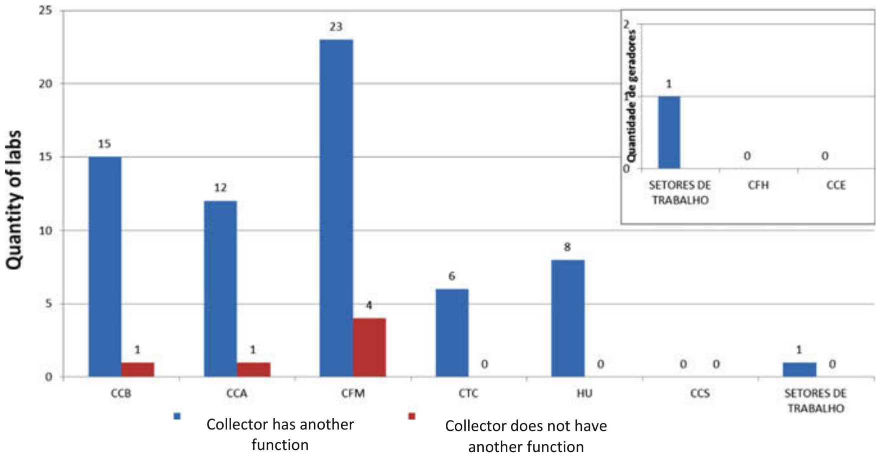


**Fig. 3** Distribution of internal waste collection within UFSC sectors and education centers

two questions: Will students be allowed to perform tasks external to the laboratory, within the waste management plan? If so, how will the protection of health and safety at work be institutionalized?

From the verification of the high number of generators in which the collection of waste was carried out by students, it was sought to analyze other aspects related to safety in the execution of this task as: training, personal protective equipment, health care and information on waste hazardousnes, as shown in Fig. 4.

Regarding the provision of training to the staff that performs the internal collection of waste, only 14 (18.19%) of the surveyed sites reported receiving training, whereas the vast majority, 63 sites (81.81%) do not receive institutional training to carry out the task.

Trainings are intended to instruct workers on the aspects to be observed before and during the execution of their tasks so that the risk exposure to their health and safety is the smallest possible or even nonexistent.

The lack of specific training to perform the internal waste collection function increases the risk of accidents during the activity. In addition, it hampers the establishment of safe conduct standards (standard operating procedures) which can be a great opportunity to review and improve the effectiveness of the activities performed and the continuous improvement of the safety conditions of the laboratories.

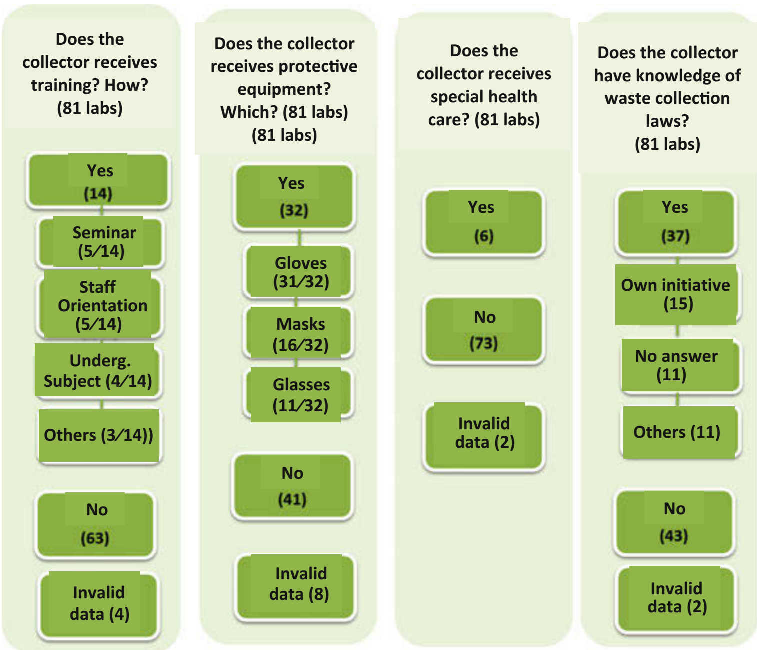


**Fig. 4** Analyzed aspects related to safety in the execution of internal collection

In spite of the fact that there was no procedure established for the acquisition, supply, training and inspection of the use of PPE within the institution, data obtained indicated that 34.93% (32 generators) receive the equipment to carry out the internal collection of the waste. On the other hand, it is worth noting that 65.07% (41 generators) do not receive any type of equipment (Fig. 5).

However, the fact that the material is not specifically provided for the task, which would compromise the protection of the physical integrity of the collectors at their most basic level, does not mean that individual protective equipment is not used. What happens is that the material is not exclusive to the function and that in the execution of the task the equipment is used for the activities of research and didactics.

Although 32 generators have been identified that provide PPE to the collectors, only 9 of them provide glove, mask, and glasses; and 15 of them only provide gloves (Fig. 6).

In this way, it is perceived that there is an important organizational failure that can act in detriment of work safety. The fact that there is variability in the supply of PPE to the waste generators shows the lack of institutionalization of the procedure. Personal Protective Equipment must be provided by the employer whenever general measures are not sufficient to protect the worker from the risk agents present in the workplace.

Since internal collection is an activity that poses risks to health of the waste collector, special precautions are recommended, such as periodic specific medical and laboratory tests.

In data related to health care within the collector, it is highlighted the fact that in 73 generators (92.40%), there are no periodic examinations against only 6 sites (7.60%) in which the collectors receive some special attention on health care (Fig. 7).

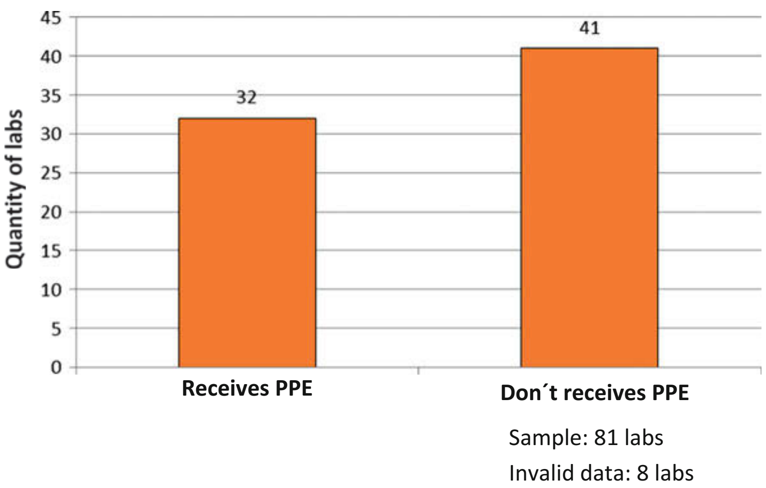


**Fig. 5** Distribution of labs regarding the reception of PPE

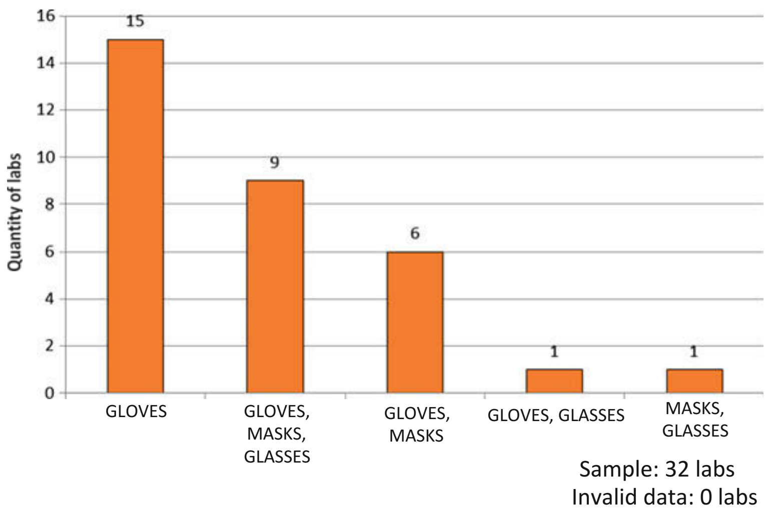


**Fig. 6** Distribution of types of PPE provided to internal waste collectors

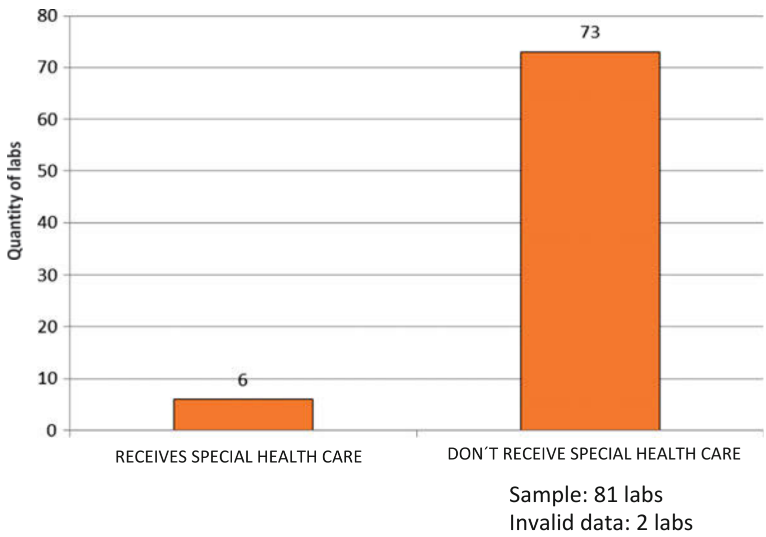


**Fig. 7** Distribution of health care reception by laboratory users

The occurrence of occupational accidents is an indicator of problems in the management of health and safety at work, although, even if there are no acceptable rates of accidents for a given activity, the possibility of them happening always exists.

In order to verify the incidence of accidents in the UFSC, it was not considered only the collection of waste and for that reason it was used the entire study sample, 182 special waste generators (chemical and infectious).

Data on the occurrence of accidents at generators show that in 59 places (34.50%) there was some type of accident at or near the workplace, involving occupational activity but not necessarily related to waste, while in 112 sites (65.50%) there was no occurrence record (Fig. 8).

It should be pointed out that non-registration does not necessarily mean the absence of accidents at all, because some laboratories informed that not all events are recorded, especially when the degree of severity is low. Sustainable waste management should provide for awareness-raising for the recording and analysis of accidents and continuous actions to reduce the frequency and severity of occurrences.

Thee generators who registered some kind of accident reported a variety of types of accidents. In addition, the diversity of agents causing accidents indicates the presence of numerous risk factors in the workplaces surveyed.

One of the important factors of accident minimization is the degree of information offered/received by the individual exposed to the accident risk. In this sense, information on the potential hazards offered by waste, based on their intrinsic hazard characteristics and on the basis of exposure is fundamental.

In relation to the chemical substances that make up the waste generated in the institution, it has been verified that 82 of them can be characterized by their MSDS as dangerous, toxic, flammable, explosive, reactive, and harmful to health.

MSDS is a document standardized by the Brazilian Association of Technical Standards (ABNT 2010), which contains information on a chemical, as regards protection, safety, health and the environment, and must accompany chemical products when they are marketed.

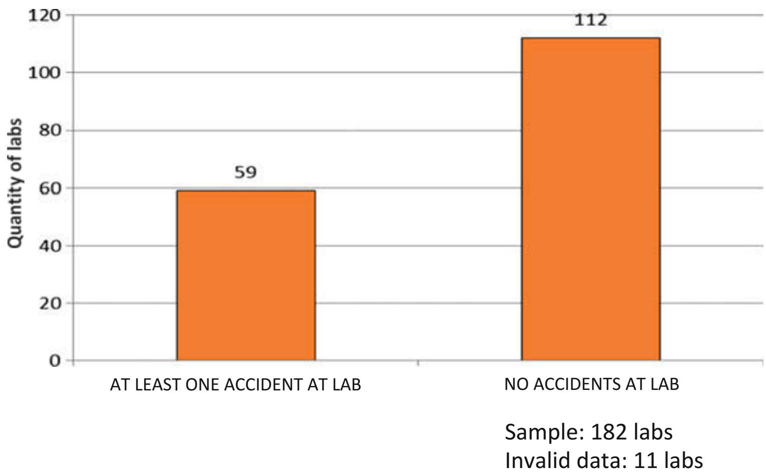


**Fig. 8** Distribution of occurrence of accidents at labs

The MSDS is an important source of information for the reagent handler and its waste, as it contains recommendations on the product and the measures in case of occupational or environmental exposure. According to the current legislation, it should be kept available to workers, so it is imperative that those involved with chemical waste have these sheets easily accessible even in printed form, so that they can be consulted when necessary.

For the evaluation of the collector information on the chemical characteristics, via MSDS, the sample space was 178 generators. This number corresponds to the total of 182 generators subtracting 4 of them that generate only biological waste.

Figure 9 shows that only 28% (47) generators have the MSDSs available in their work environments while 72% (119) of them claim not to have them physically available in the workplace and of these 118. From the 47 generators who reported having MSDSs, only 12 of these sites (25.53%) identified collectors who knew the functionality and purpose of these tools.

Considering that these datasheets are available on the websites of the chemical waste traders/representatives and that in all laboratories there are computers for students' access and use, this situation seems to show not only the lack of MSDSs in chemical handling environments and the lack of information of the members who manage them, but above all the certainty of the inefficiency of the current actions of training and orientation that are being conducted within the Institution.

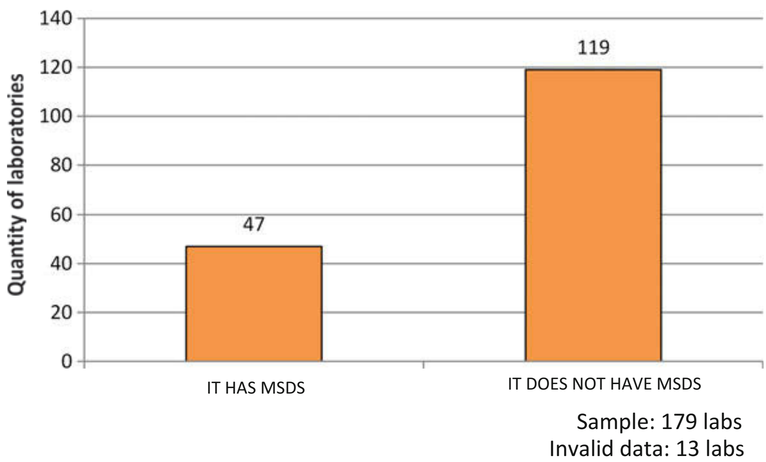


**Fig. 9** Distribution of laboratories which have or do not have MSDS

## 8 Conclusion

This project data highlight aspects that should be prioritized by university managers regarding health and safety conditions in the management of special waste, with special attention to the role of students in this process.

Undoubtedly, in the case of the Institution where the project was applied, the exposition of students to risk in activities related to the management of chemical waste is the most important situation to be registered, since there is no regulation or legislation in Brazil to deal with the subject. The importance of this research was to alert university managers that the activity does not fit and is not regulated as an inherent function of the student academic plan.

There are different ways of approaching this topic in universities in different parts of the world, so this study was not intended to determine the best methodology, but to present the issue and induce a debate concluding that, since there is no established legislation, internal regulations will be (and are necessary to be) applied in universities.

Basically, the initial question to be asked is: In which ways are students supposed to be involved in activities related to chemical waste management? Although many improvements have been made in UFSC administrative structures related to waste management, there are still some unique aspects that need to be dealt with immediately:

(a) the low institutional investment in the waste area;
(b) the absence of an institutional environmental policy that integrates and encompasses the management of the whole generation of waste;
(c) the lack of a multidisciplinary team established to manage a special waste system and maintain the continuing education of the university community, which is necessary to guarantee the efficiency and safety of the process;
(d) the lack of initiatives that emphasize Environmental Education in general and in particular within the academic curricula.

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## Author Biographies

**Carlos Alberto Rodrigues** is an administrative technician in education - a technical job security position in the Health Care Department of the Federal University of Santa Catarina (UFSC) since 2010. He holds a degree in building construction technology from the Federal Institute of Santa Catarina (IFSC) and work safety technician by the Liberato Salzano Technical School Foundation Vieira da Cunha since 2005. He worked in the footwear industry in worker safety, focusing on training and follow-up of Accident Prevention and Fire Brigade Commissions.

**Professor Ariane Laurenti** lecturers on Toxicology (Department of Pathology) at the Federal University of Santa Catarina (UFSC) since 1997. She has a major in Chemistry (Bachelor and Licentiate) from UFSC and a Ph.D. in Environmental Sciences from Università Degli di Venezia —Italy (1993). Ariane also holds the position of Socio-Environmental Management Advisor at UFSC since 2013, representing this institution in environmental matters involving government agencies and the Federal Public Ministry. Currently, her activities are focused on the didactic-pedagogical field, with the development of research projects and actions in the environmental area.

# Multidisciplinary Project Applied to the Restaurant of the University of São Paulo—An Energetic, Ecological and Economic Analysis

**Mateus Mota Morais, Choi Wang Dzak, Clinton Henry Colaço Conegundes, João Gabriel Monteiro Mendonça, Sarah Emanuelle Ferreira Matias and Wesley Gustavo Takaessu Domingos**

**Abstract** The present work is the result of a multidisciplinary project of the following mechanical engineering courses: Environmental Management for Engineers; Thermal Power Systems; Modeling and Simulation of Thermal Systems. The objective of the project was to apply the knowledge of thermal graduation courses to a campus sustainability problem. The object of study chosen was the steam generation and distribution system of the restaurant of the University of São Paulo—São Carlos campus, used for cooking food and washing dishes. The optimization proposal was to transform the open system into a closed system by reducing leaks and installing a condensate return line to the boiler. The current system and the optimized system were mathematically modeled using thermodynamics, heat transfer and fluid mechanics equations. The savings and benefits of the project were compared to the installation costs for evaluation of econometric data. As a result, an annual saving of

M. M. Morais (✉) · C. W. Dzak · C. H. C. Conegundes · J. G. M. Mendonça
S. E. F. Matias · W. G. T. Domingos
Department of Mechanical Engineering, University of São Paulo at São Carlos School of Engineering, Avenida Trabalhador São-Carlense 400, São Carlos, SP 13566-590, Brazil
e-mail: mateus.morais@usp.br

C. W. Dzak
e-mail: choiwangdzak@yahoo.com.br

C. H. C. Conegundes
e-mail: clintonhenrycolaco@gmail.com

J. G. M. Mendonça
e-mail: joao.gabriel.mmendoca@gmail.com

S. E. F. Matias
e-mail: sefmatias@gmail.com

W. G. T. Domingos
e-mail: wesley.domingos28@gmail.com



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13,000 L of diesel and 331,000 L of water was forecasted, resulting in a savings of R $ 46,000 and an emission reduction of 34,600 kg of $CO_2$. The payback period of this investment was forecasted to take only 8 months.

**Keywords** Sustainability · Economic viability · Heat transfer · Steam

# 1 Introduction

The present work is the result of a multidisciplinary project of the following mechanical engineering subjects: Environmental Management for Engineers; Thermal Power Systems; Modeling and Simulation of Thermal Systems.

Originally, each subject demanded an independent project, according to their respective topics. However, adopting a multidisciplinary point of view, the project team decided to perform a single integrated project, which could be applied in a real life problem at the University of São Paulo (USP)—São Carlos campus and which could also be relevant for the learning process of each individual subject. In order to do so, the following objectives were proposed for the project:

- Propose a solution for a real sustainability problem at the USP—São Carlos campus I.
- Apply thermodynamics, heat transfer and fluid mechanics knowledge in a project related to an electric, thermal or mechanical energy generating system.
- Evaluate the economic viability of the proposed system, using tools from econometric data analysis.

The chosen study subject was the university restaurant (known as "Bandejão") from the USP—São Carlos campus I, which currently serves, on average, 3100 daily meals. The choice was influenced by the its large heat consumption (steam used for cooking food and also for cleaning silverware). The project aimed to understand the current operating mode of the restaurant and propose more economic and ecological alternatives. This paper highlights how undergraduate students can contribute significantly to improve sustainability on campus using knowledge learned on classroom.

# 2 Methodology

## 2.1 The Actual System Configuration

The first stage of the project consisted in understanding the "Bandejão" operating mode, in order to obtain sufficient data for mathematical modeling. To accomplish this, visits to the restaurant, consultations with professors, technicians, restaurant staff and with the original system designer were performed. The system consists of a diesel fueled boiler, which generates steam, and a distribution line which feeds three industrial pans and a dishwasher. A diagram for the system is shown in Fig. 1.

The fire-tube boiler uses diesel oil as fuel. The technical data, which is shown in Chart 1, was obtained from the boiler's structure and from the manufacturer's catalog.

The boiler runs for 14 h a day (from 6 am to 8 pm). Every morning, it takes approximately 20 min until its temperatures stabilizes and it can enter the functioning regime. This time is increased to 35 min on Mondays, since the boiler is not used on Sundays. It runs steadily through a control system which keeps its pressure between 500 and 700 kPa (all pressure values in this paper are given in terms of relative pressure). When the system is being used, the pressure decreases faster and the control heats the boiler. When there is low usage, the pressure decreases slowly,

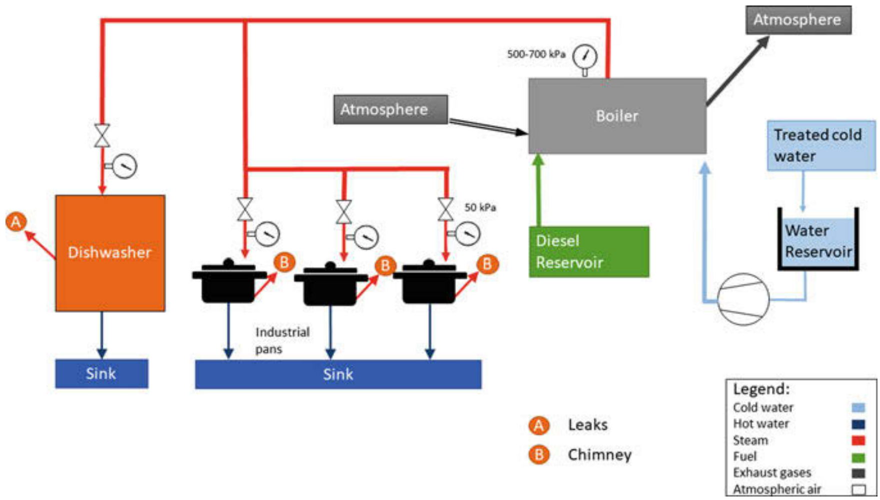


**Fig. 1** Restaurant actual system

**Chart 1** Boiler datasheet

| | |
|---|---|
| Manufacturer | Ecal |
| Model | VMI 513 |
| Nominal power | 600 kW |
| Fuel type | Diesel |
| Fuel consumption per hour | 60.3 kg/h |
| Saturate steam production per hour (with 20 °C water) | 800 kg/h |
| Heating surface | 28.6 $m^2$ |
| Working pressure | 800 kPa |
| Date of manufacture | 1990 |

and less fuel is used. According to the restaurant's management, there is an average fuel consumption of 2000 L every 2 weeks.

The steam distribution line was also analyzed. The steam line is external, over the roof of the restaurant. It is composed of steel pipes (1 inch, schedule 40) covered with glass wool insulation (thickness of approximately 0.08 m), which are wrapped by an aluminum sheet.

The pans have capacity of 300 L and a nominal steam consumption of 36 kg/h (Fig. 2). They run for an average of 10 h/day. Each pan contains a pressure reduction valve, in order to work with steam at 50 kPa (relative pressure). They have double walls, in such a way that the steam involves all its inner surface, therefore heating the food. The pans also have a steam trap, which eliminates the condensate, and a chimney that releases steam (Fig. 3).

It was observed that there is no condensate return line. Therefore, the hot water which leaves the pans, through the steam trap, is wasted. Besides that, the steam is continuously discharged by the chimney, being discarded into the atmosphere. In this open system configuration, useful water and energy are wasted resulting in higher operation costs.

The last element of the system is the dishwasher. According to the manufacturer's catalog, the nominal steam consumption is 56.7 kg/h. The dishwasher only runs for 6 h a day. Next to the dishwasher, several steam leakages (in the pipeline, in the register and even through the floor drain) were found, even when the machine was not being used. Leakages represent a direct waste of resources.

**Fig. 2** Picture of one of the restaurant's industrial pans

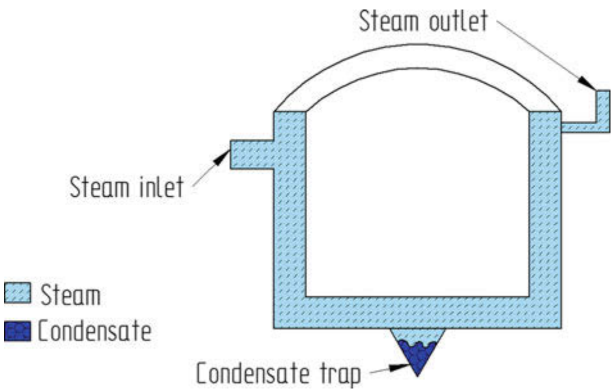


**Fig. 3** Pan configuration diagram

## 2.2 *Optimization Proposal*

As an optimization proposal, a condensate return line was evaluated. In this proposal, the condensate would be collected directly from the steam traps, in the bottom of each pan. Instead of being discarded, the condensate would return to the water reservoir which supplies to the boiler (Fig. 4). The dishwasher water return was not considered because food debris would contaminate the steam. Therefore, cold water should be added to the tank to maintain the required amount of water. In this partially closed system configuration, there would be water and energy savings.

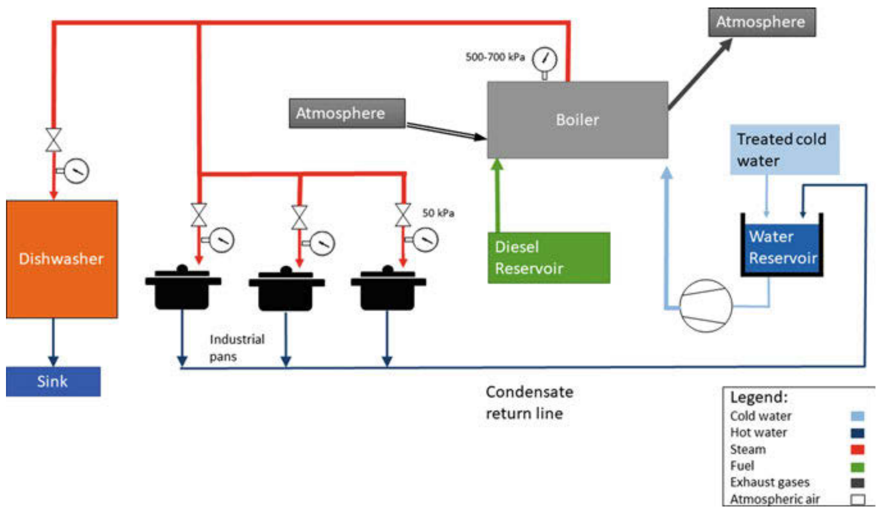


**Fig. 4** Condensate return line system

The water used in the boiler is treated, which leads to the assumption that no additional treatment would be necessary for it to be used again. However, the contact with the pipes and with the bottom of the pans might contaminate the water after some cycles. The evaluation of the water quality after repeated use was not performed. If the quality of the water decreases, another stage of treatment may be necessary before the water is recycled.

One of the objectives of the project was the analysis of the economic viability of the ecological solution. For this reason, operating data and purchasing costs of the necessary elements for the solution implementation were collected. The parameters used for the viability analysis were: required investment, monthly savings, payback period, net present value (NPV) and the internal rate of return (IRR). To evaluate the ecological improvement of the solution, the resources use (water and fuel) and the pollutants emission ($CO_2$, $NO_x$ and ashes) of both configurations were compared.

## 2.3 Mathematical Modeling and Simulation

To model the current system, it was decided to perform a simulation without considering the steam released in the atmosphere and the dishwater leakages. These leakages are difficult to measure directly, but they can be estimated by comparing simulations result with the actual consumption data.

The fuel consumption in the boiler was assumed to be directly proportional to the quantity of heat produced. The water inlet temperature adopted was 20 °C. The heat generation in the boiler is used to heat the water and generate saturated steam. Using thermodynamics knowledge, the heat produced can be calculated through the energy flow difference of what enters (cold water) and what leaves (saturated steam) the boiler (Eq. 1).

$$\dot{Q}_{boiler} = \dot{m}_{steam} * \left(h_{steam}@P_{sat} - h_{liq}@20\,^{\circ}\mathrm{C}\right) \tag{1}$$

where

$\dot{Q}_{boiler}$ Heat produced in the boiler (kW)
$\dot{m}_{steam}$ Steam flow produced (kg/s)
$h_{steam}$ Enthalpy of saturated steam at boiler pressure (KJ/kg)
$h_{liq}$ Enthalpy of cold liquid water entering the boiler (kJ/kg).

The steam consumed in each industrial pan was considered to be 36 kg/h and in the dishwasher as 56.7 kg/h, according to the nominal values. The total daily consumption was calculated, considering the operating hours of each component.

For the evaluation of the pressure loss in the steam distribution line, the Müller-Steinhagen and Heck correlation for two-phase pressure drop was used (Thome 2004b). This correlation calculates the friction factor based on the Reynolds number of both the liquid and the vapor phases (Eqs. 2–9). The momentum pressure drop was neglected, since there is minimum quality vapor change.

$$\dot{M}_{total} = \rho * V_m \tag{2}$$

$$Re_L = \frac{\dot{M}_{total} * D_{int}}{\mu_L} \tag{3}$$

$$Re_v = \frac{\dot{M}_{total} * D_{int}}{\mu_v} \tag{4}$$

$$f_L = \frac{0.079}{Re_L^{0.25}} \tag{5}$$

$$f_v = \frac{0.079}{Re_v^{0.25}} \tag{6}$$

$$A = \left(\frac{\partial P}{\partial x}\right)_L = f_L * \frac{2 * \dot{M}_{total}{}^{\wedge}2}{D_{int} * \rho_L} \tag{7}$$

$$B = \left(\frac{\partial P}{\partial x}\right)_v = f_v * \frac{2 * \dot{M}_{total}{}^{\wedge}2}{D_{int} * \rho_v} \tag{8}$$

$$\frac{\partial P}{\partial x} = (A + 2(B - A) * x) * (1 - x)^{\frac{1}{3}} + B * x^3 \tag{9}$$

where

| | |
|---|---|
| $\dot{M}_{total}$ | Mass velocity of fluid (kg/m$^2$ * s) |
| $\rho$ | Fluid density (kg/m$^3$) |
| $V_m$ | Average fluid velocity (m/s) |
| $D_{int}$ | Inner tube diameter (m) |
| $Re_L$ | Reynolds number of liquid phase (−) |
| $Re_v$ | Reynolds number of vapor phase (−) |
| $\mu_L$ | Dynamic viscosity of liquid phase (Pa * s) |
| $\mu_v$ | Dynamic viscosity of vapor phase (Pa * s) |
| $f_L$ | Friction factor of liquid phase for $Re_L > 2000$ (−) |
| $f_v$ | Friction factor of vapor phase for $Re_v > 2000$ (−) |
| $\rho_L$ | Liquid phase density (kg/m$^3$) |
| $\rho_v$ | Vapor phase density (kg/m$^3$) |
| $A$ | Frictional pressure gradient for all the flow liquid (Pa/m) |
| $B$ | Frictional pressure gradient for all the flow vapor (Pa/m) |
| $\frac{\partial P}{\partial x}$ | Pressure drop per meter (Pa/m) |
| $x$ | Vapor quality (−) |
| $\mu$ | Dynamic viscosity of the phase (Pa * s). |

To evaluate the heat transfer in the distribution line, the global heat transfer coefficient was calculated considering: external convection, heat conduction on insulation and pipe, and internal convection. In order to calculate the heat conduction, the steel and insulation thermal conductivities were adopted to be 44.97 and 0.07 W/m * K, respectively.

For the convection coefficients related to the internal side of the pipeline, Dobson and Chato method for annular flow condensation of pure vapor in a horizontal tube was used (Eqs. 10–15) (Thome 2004a).

$$Re_{Ls} = \frac{\dot{M}_{total} * D_{int} * (1 - x)}{\mu_L} \tag{10}$$

$$X_{tt} = \left(\frac{1 - x}{x}\right)^{0.9} * \left(\frac{\rho_v}{\rho_L}\right)^{0.5} * \left(\frac{\mu_L}{\mu_v}\right)^{0.1} \tag{11}$$

$$Ga_L = \frac{g * \rho_L * (\rho_L - \rho_v) * D_{int}^3}{\mu_L^2} \tag{12}$$

$$Fr_{so} = 0.025 * Re_{Ls}^{1.59} \left(\frac{1 + X_{tt}^{0.039}}{X_{tt}}\right)^{1.5} * \left(\frac{1}{Ga_L^{0.5}}\right) \tag{13}$$

$$Nu_{int} = 0.23 * Re_{Ls}^{0.8} * Pr_L^{0.4} * \left(1 + \frac{2.22}{Xtt^{0.89}}\right) \tag{14}$$

$$Nu_{int} = \frac{h_{int} * D_{int}}{k_L} \tag{15}$$

where

$Re_{Ls}$ Superficial liquid Reynolds number (−)
$X_{tt}$ Martinelli parameter for turbulent flow in both phases (−)
$Ga_L$ Galileo number (−)
$g$ Gravitational acceleration (m/s$^2$)
$Fr_{so}$ Froude transition number for $Re_{Ls} < 1250$ (−)
$Pr_L$ Prandtl number of liquid phase (−)
$Nu_{int}$ Nusselt number on inner side (−)
$h_{int}$ Internal side convection coefficient [W/(m$^2$ * K)]
$k_L$ Thermal conductivity of liquid phase [W/(m * K)].

For the convection coefficients related to the external side of the pipeline, the Churchil-Bernstei correlation for crossed flow in the pipes, considering wind speed as 3.8 m/s (smooth breeze) was used (Eqs. 16 and 17) (Bergman et al. 2015). The wind speed was selected based on São Carlos's average wind speed retrieved from Instituto Nacional de Meteorologia (INMET 2017).

$$Nu_{ext} = 0.3 + \frac{0.62 * Re^{\frac{1}{2}} * Pr^{\frac{1}{3}})}{\left(1 + \left(\frac{0.4}{Pr}\right)^{\frac{2}{3}}\right)^{\frac{1}{4}}} * \left(1 + \left(\frac{Re}{282,000}\right)^{\frac{5}{8}}\right)^{\frac{4}{5}} \tag{16}$$

$$Nu_{ext} = \frac{h_{ext} * D_{ext}}{k_{int}} \tag{17}$$

where

$Nu_{ext}$ Nusselt number on the outer side (−)
$h_{ext}$ External side convection coefficient [W/(m * K)]
$k_{ext}$ Thermal conductivity of the fluid at the outer side [W/(m * K)]
$D_{ext}$ Exterior tube diameter (m).

The global heat transfer coefficient is calculated considering each of the contributions (internal convection, conduction on pipeline, conduction on insulation and external convection). With these values, the steam condensation rate in the pipeline can be calculated (Eqs. 18 and 19) (Bergman et al. 2015).

$$\frac{1}{U} = \frac{D_{ext}}{h_{int} * D_{int}} + \frac{D_{ext} * \ln\left(\frac{D_{tube}}{D_{int}}\right)}{k_{int}} + \frac{D_{ext} * \ln\left(\frac{D_{ext}}{D_{tube}}\right)}{k_{ext}} + \frac{1}{h_{ext}} \tag{18}$$

$$\dot{Q}_{tube} = U * A * \Delta T = \dot{m}_{cond} * h_{lv} \tag{19}$$

where

$\dot{Q}_{tube}$ Heat dissipation in the tubes (W)
$A$ External pipe area ($m^2$)
$U$ Overall coefficient of heat transfer ($W/m^2 * K$)
$\Delta T$ Temperature Difference (C)
$D_{tube}$ Outside diameter of tubing without insulation (m)
$\dot{m}_{cond}$ Condensate flow rate (kg/s)
$h_{ls}$ Difference of enthalpy between liquid water and steam (kJ/kg).

To model the system optimized by the condensate return line, it was considered that the hot water condensated would be recycled to the boiler, and the cold water would be added in order to compensate the dishwasher losses. The return line was considered to be of the same tube type of the steam distribution line.

For the evaluation of the pressure loss in the steam distribution line, the Petukhov correlation was used (Bergman et al. 2015). This correlation calculates the friction factor based on the Reynolds number of the fluid (Eqs. 20, 21 and 22) (Fox et al. 2014).

$$f = (0.79 * \ln(Re) - 1.64)^{-2} \tag{20}$$

$$f = \frac{\frac{\partial P}{\partial x} * D_{int}}{\frac{\rho * V_m^2}{2}} \tag{21}$$

$$Re = \frac{\rho * V_m * D_{int}}{\mu} \tag{22}$$

where

$f$ Friction factor of return line fluid (−)
$Re$ Reynolds number of return line fluid (−)
$\rho$ Return line fluid density (kg/m$^3$)
$V_m$ Average fluid velocity (m/s)
$\mu$ Dynamic viscosity of the fluid (Pa * s).

To evaluate the heat transfer in the return line, the global heat transfer coefficient was calculated on the same way as on the distribution line (using Eqs. 16–19). The only difference is for the convection coefficients related to the internal side of the pipeline. The Gnielinski correlation was used to calculate the Nusselt number on the inner side (Eqs. 23 and 24) (Bergman et al. 2015).

$$Nu_{ret} = \frac{\frac{f}{8} * (Re - 1000) * Pr}{1 + 12.7 * \left(\frac{f}{8}\right)^{\frac{1}{2}} * \left(\mathrm{Pr}^{\frac{2}{3}} - 1\right)} \tag{23}$$

$$Nu_{int} = \frac{h_{ret} * D_{int}}{k_{ret}} \tag{24}$$

where

$Pr$ Prandtl number of the return line fluid (−)
$Nu_{ret}$ Nusselt number on the inner side of return line (−)
$h_{ret}$ Internal side convection coefficient on return line [W/(m$^2$ * K)]
$k_{ret}$ Thermal conductivity of the fluid on the inner side on the return line [W/(m * K)].

The simulations were performed using the software EES (*Engineering Equation Solver*). This program also provided the values for the fluid properties (viscosity, density, Prandtl number, enthalpy…), in function of temperature and pressure. The results were obtained solving the previous equations simultaneously. The different system configurations were then compared, in order to evaluate resource consumption, pollutant emission and costs. The diesel oil price adopted was of 3.00 R$/L, the average cost from August to October 2016, according to the National Petroleum Agency, Agência Nacional de Petróleo (ANP 2017). The water and sewer cost of 11.66 and 8.16 R$/m$^3$, respectively, were adopted based on the municipal tariff obtained of Serviço Autônomo de Água e Esgoto in October 2016.

The tariff was selected for commercial category with an average monthly consumption between 41 and 60 $m^3$.

## 3 Results

The current system water and oil consumptions (considering leakage), the results of the simulations without leakages and with the condensate return line can be compared in Table 1. Expenses related to two weeks were compared.

It is observed that the biggest return can be obtained by decreasing leakage, with the additional benefit of using the return line. From a sustainability point of view, the installation of a condensate return line would be advantageous considering the water and fuel use reduction and the consequent decrease of pollutant emission. The water savings would be of 81% (36.8 $m^3$/month); the fuel consumption would be reduced by 46% (1460 L/month), which is equivalent to a monthly reduction of 3847 kg of $CO_2$.

The use of the energy can be better visualized in the Sankey diagram of the energetic flow of current system (Fig. 5). In this diagram, it is evident that the biggest losses are a consequence of the leakages.

The results of operational costs, related to fuel, water and sewer consumption, for two weeks, are presented in Table 2.

Considering the installation costs, a preliminary evaluation of the costs to adapt the current system (elimination of leakages and installation of the return system) was made. The estimation considered the price of new steam traps, new pressure reducing valves, pipes, insulation and labor. The total investment was forecast to be R$ 31,000. To implement the proposals, a deeper market research with the manufacturers is necessary, in order to obtain the specification of the components and their current prices.

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Comparing the installation costs with the operation savings, it is possible to make an econometric evaluation (Table 3). Only the 9 operating months per year of

**Table 1** Use of water and fuel in different configurations (2 weeks)

| Configuration | Diesel (L) | Water ($m^3$) |
|---|---|---|
| Actual (with leakages) | 2000 | 22.6 |
| Simulation without leakages | 1402 | 15.8 |
| Optimized (with condensate return line) | 1272 | 4.2 |

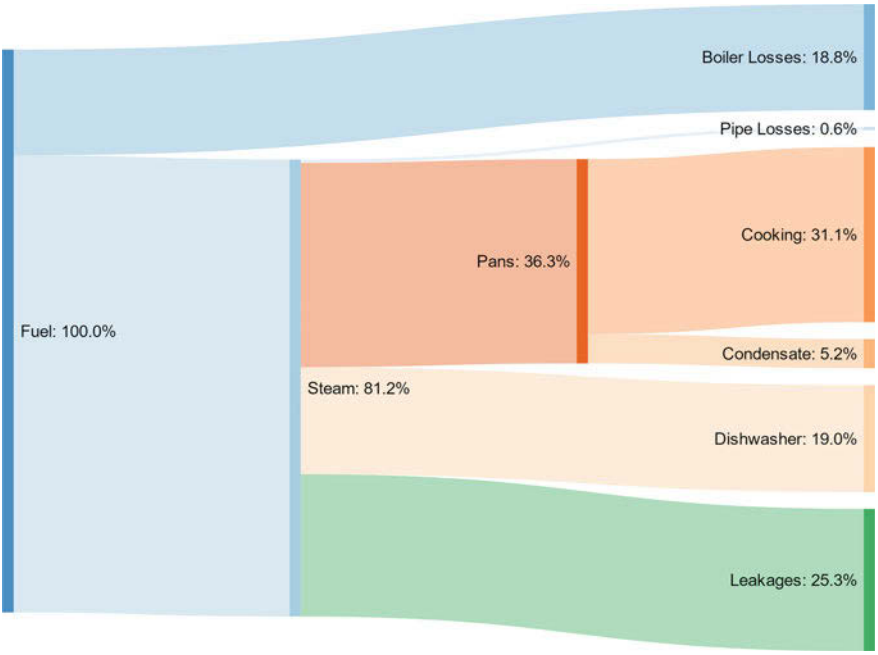


**Fig. 5** Sankey diagram of energy flow of current system

**Table 2** Operational costs (2 weeks)

| Costs | Current (R$) | No leakages (R$) | With return line (R$) |
|---|---|---|---|
| Diesel | 6000.00 | 4206.18 | 3815.46 |
| Water | 447.90 | 313.19 | 83.57 |
| Total costs | 6447.90 | 4520.17 | 3899.03 |
| Savings | 0 | 1927.73 | 2548.87 |
| Savings (%) | 0 | 30% | 40% |

**Table 3** Econometric data

| | |
|---|---|
| Investment | R$ 31,000 |
| Monthly savings | R$ 3800 |
| NPV | R$ 134,500 |
| Payback | 35 weeks |
| IRR | 147% |
| Accumulated cash flow (first 5 years) | R$ 244,440 |

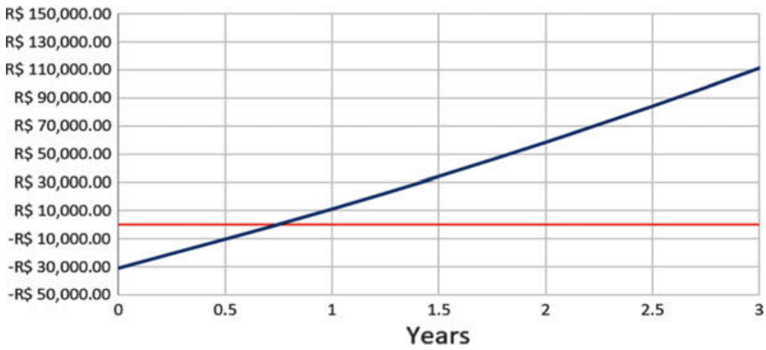


**Fig. 6** Accumulated cash flow in the first three years

the restaurant were considered (the vacation period was not considered since the restaurant operates with reduced capacity).

In order to calculate the NPV and IRR, a 5 year period and an interest rate of 12% (Brazilian public debts securities rate in the end of 2016) were considered. The evolution of the economical return can be observed in Fig. 6.

## 4 Further Considerations

The results obtained point out the feasibility of the project. Because they are obtained through mathematical modeling, the results need to be validated in the future by more accurate measurements of the actual system.

As a next step, the mayor of the campus and the management company of the restaurant were contacted to initiate an action plan to implement the improvement proposals. The contact and negotiation with suppliers and service providers must be carried out to update the budget and economic projection.

The study of restaurant improvements is not exhausted by the current work. Giantaglia (2016), another campus student, in his graduation final project, conducted a feasibility study of cogeneration applied to the university restaurant. In this proposal, generators would provide energy for the north area of the campus and thermal energy for the restaurant. In this assessment, the initial investment would be R$ 7,400,000 with an estimated 6 years return. This assessment points out that there are other alternatives to the current system that might be economically advantageous in the long run.

## 5 Conclusion

The economic evaluation indicated that the reform of the steam system in order to reduce leaks and losses as well as to reuse the condensate brings economy in operation and benefits for the environment. A modest investment (<R$ 40,000) would have a fast return (8 months) with lasting benefits.

The initial objectives of the interdisciplinary project were satisfactorily achieved. The initiative of the project team to integrate and apply knowledge from different areas proved to be relevant and pointed out feasible solutions to a real sustainability problem on campus. The project developed the technical skills of the engineering course, but also encouraged a concern about the environmental problems of the campus. Thus, the students experienced personal growth and, if changes were applied, there would be improvements to the campus and to the environment.

The initiative and participation of undergraduate students can contribute significantly to the solution of local campus problems. Graduation plays an important role in developing a mindset that can impact society in the future. Universities and teachers have the role of encouraging and supporting students through projects that can be applied to real problems of society, especially the question of sustainability.

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# Development and Implementation of the Sustainable Logistic Management Plan of the Federal University of ABC

**Giulliana Mondelli, Silvana Maria Zioni, Cássia Gonçalves de Souza, Ulisses Demarchi Silva Terra and Vanessa Soraia Sales dos Santos**

**Abstract** This work describes the experience of the Federal University of ABC in the development and implementation of its Sustainable Logistic Management Plan (*Plano de Gestão de Logística Sustentável—PLS/UFABC*), with the objective of diagnosing and improving the Institution's actions regarding sustainability. This process started in 2015, guided by a Brazilian Federal Regulation of the Ministry of Planning, Budget and Management (Normative Instruction N$^{o}$ 10, of November 12th, 2012, MPOG). The committee that developed the PLS/UFABC thought beyond simple compliance of this Normative Instruction, and launched the "Sustainable UFABC" Program (*UFABC Sustentável*), with future concern to put into practice actions and demands described and raised, and incorporate the sustainability aspects in the daily life of the Institution. PLS/UFABC was published in book format and today, it is being accompanied by the Advisory Committee on the Sustainability of the UFABC (*Comissão Consultiva à Sustentabilidade—CCS*).

G. Mondelli (✉)
Engineering, Modelling and Applied Social Sciences Centre,
Federal University of ABC, Avenida dos Estados 5001,
Santo André, SP 09210-580, Brazil
e-mail: g.mondelli@ufabc.edu.br

S. M. Zioni
Engineering, Modelling and Applied Social Sciences Centre,
Federal University of ABC, Alameda da Universidade, s/nº,
São Bernardo do Campo, SP 09606-045, Brazil
e-mail: silvana.zioni@ufabc.edu.br

C. G. de Souza · V. S. S. dos Santos
Federal University of ABC, Avenida dos Estados, 5001,
Santo André, SP 09210-580, Brazil
e-mail: cassia.souza@ufabc.edu.br

V. S. S. dos Santos
e-mail: vanessa.sales@ufabc.edu.br

U. D. S. Terra
Federal University of ABC, Alameda da Universidade, s/nº,
São Bernardo do Campo, SP 09606-045, Brazil
e-mail: ulisses.terra@ufabc.edu.br



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CCS is composed by professors, students and managers, which seek to encourage academic activities, as research, extension and innovation, in addition to introduce new management practices. In order to integrate different areas of the Institution, PLS/UFABC comprises: Water and Sewage; Energy; Consumption materials and Sustainable Bidding; Waste Management, Spaces, Displacement of Personnel and Urban Mobility; Implementation, Dissemination and Communication. This paper provides how the PLS/UFABC was created, developed and is now being implemented, serving as a study case for other Institutions, public or not, educational or not, Brazilian or not.

**Keywords** Sustainable development · Public institutions · Education

## 1 Introduction: The PLS/UFABC Creation

Today, the Federal University of ABC (*UFABC—Universidade Federal do ABC*) is composed by two campuses, in expanding process, located at Santo André and at São Bernardo do Campo municipalities,[1] whose built area is respectively 70,000 and 26,000 $m^2$. At the Santo André campus, the expansion includes the construction of an "annex", called "Tamanduatehy Unit", with 34,000 $m^2$ of constructed area, in addition to the other blocks under construction on the main unit, totaling 142,632.70 $m^2$ of constructed area when completed. For São Bernardo do Campo campus, it is intended to reach about 70,000 $m^2$ when all the buildings are completed. In January of 2017, the institution had 12,626 of undergraduate students, 1428 graduate students, 679 professors, 761 managers and 275 outsourced employees, distributed on both campuses.

The academic organization of UFABC is based in three centers: Center of Natural and Human Sciences (CCNH—*Centro de Ciências Naturais e Humanas*), Center of Mathematics, Computing and Cognition (CMCC—*Centro de Matemática, Computação e Cognição*) and Center of Engineering, Modeling and Applied Social Sciences (CECS—*Centro de Engenharia, Modelagem e Ciências Sociais Aplicadas*).

On June 6, 2012, the Federal Government published the Decree N° 7,746 (Brasil 2012a), establishing general criteria, practices and guidelines for the promotion of national sustainable development and it established the Interministerial Commission for Sustainability in Public Administration (CISAP—*Comissão Interministerial de Sustentabilidade na Administração Pública*). The article 16 of this decree establishes that any Federal Public Administration, autarchic and foundational, as well as the state-owned companies must prepare and implement a Sustainable Logistic Management Plan (PLS—Plano de Gestão de Logística Sustentável).

[1]Municipalities which are part of the Metropolitan Area of São Paulo.

In compliance with this determination, the Secretariat of Logistic and Information Technology of the Ministry of Planning, Budget and Management (SLTI/MPOG—*Secretaria de Logística e Tecnologia da Informação/Ministério do Planejamento, Orçamento e Gestão*) published the Normative Instruction Nº 10 in November, 2012 (Brasil 2012b). It establishes the preparation of the PLS as a planning tool, which will allow the entity to establish practices of sustainability and rationalize expenses and processes in the Public Administration.

According to this request and concern for sustainable development established in the Institutional Development Plan (PDI—*Plano de Desenvolvimento Institucional* 2013–2022) (UFABC 2013), the Rectory of the UFABC, through Rectory's Ordinance Nº 080/2015, established the Management Committee for the elaboration of the Sustainable Logistic Management Plan (*CPLS—Comissão Gestora da elaboração do Plano de Gestão de Logística Sustentável*) (UFABC 2015). The committee had competence to deliberate, coordinate and supervise the activities required to formulate the PLS/UFABC. The promotion of sustainable actions, programs and projects in the use of resources by UFABC was the strategic axis of the work of this Committee, in compliance with the guidelines of the PDI, specifically in item 7.3—Planning for Institutional Development: "The institutional planning of public organizations must establish sustainable and consistent priorities, in the sense of using public resources in actions that bring effective benefits to society" (UFABC 2013).

So, CPLS developed the PLS/UFABC toughing beyond the simple compliance of the Normative Instruction Number 10, and launched the "Sustainable UFABC" program (*UFABC Sustentável*), with future concern to put into practice actions and demands described and raised, and incorporate the sustainability aspects in the daily life of the Institution. PLS/UFABC was published in 2016 (UFABC 2016a) and today, it is being accompanied by the Advisory Committee on the Sustainability of the UFABC (*ComissãoConsultiva à Sustentabilidade—CCS*) (UFABC 2016b).

This paper share the diagnosis and the experience obtained during the development and implementation of de PLS-UFABC, with the following objectives:

- Diagnose the sustainable activities already started, completed and in progress at the University;
- Raise the impressions that the university community has on this subject;
- Establish goals, targets, actions, monitoring indicators, deadlines and costs for each axis studied;
- Develop a collective conscience of sustainable commitment with the resources available at the University;
- Encourage research on institutional sustainability;
- Promote quality of life for the University community;
- Consolidate itself as a Sustainable University.

So, this paper is important because it provides how the PLS/UFABC was created, developed and is now being implemented, serving as a study case for other Institutions, public or not, educational or not, Brazilian or not.

Finally, the making limitations of the work and constraints of the paper was to reorganize and integrate people involved during the elaboration of the Plan with that one is now implementing the Plan, passing for a good communication and transitional time with interested ones.

## 2 Methodology: The Collective Construction of PLS/UFABC

The construction work of the Plan was coordinated by the Management Committee for the elaboration of the Sustainable Logistic Management Plan (CPLS—*Comissão Gestora da elaboração do Plano de Gestão de Logística Sustentável*). In compliance with Decree N° 7,746, of November 5th, 2012, and Normative Instruction N° 10, of November 12th, 2012, the PLS was structured in seven axes: Water and Sewage; Energy; Consumption materials and Sustainable Bidding; Waste Management, Spaces, Displacement of Personnel and Urban Mobility; Implementation, Dissemination and Communication.

During the 1st Sustainability Forum of UFABC: Building the Sustainable Logistics Plan,[2] held on March 30, 2015, at the Santo André campus, the axes were developed by working groups, with the participation of students, professors and managers of the University. For two and a half months, the groups made the diagnosis, through bibliographical/documentary research and data collection: interviews, opinion surveys and internal consultation, in the latter case, in order to verify which sustainability initiatives were already in progress.

Based on the diagnosis of each axe, there were developed the targets, potential actions, monitoring indicators,[3] deadlines, estimated costs and respective responsible for implementing these actions. All this information was organized in a Plan of Action from 2016 to 2022 (UFABC 2016a), an indispensable instrument for the implementation and control of a project like that. In this context, the indicators were developed considering the specifics of UFABC, national and international experiences, such as: programs and projects of teaching and research institutions that already address sustainability in the management of their campuses.

Before the writing end of the PLS/UFABC, the draft document was made available for Public Consultation, through which the community had the opportunity to participate once again in the construction of this important institutional project. On 06/23/2017, the official launch of the Plan occurred, published in book format (UFABC 2016a). In the same year, the "Sustainable UFABC" Program was instituted, having the PLS as part of a set of sustainable actions developed inside and outside the University campuses.

[2]Available at: https://www.youtube.com/watch?v=_zngZ9z43KE.

[3]An instrument that makes it possible to monitor, evaluate and report on the current situation/action and its progress.

The management of the PLS is under the responsibility of the Advisory Committee on Sustainability of the UFABC (CCS),[4] with the support of thematic advisory groups and the Pro-Rector of Planning and Institutional Development—ProPlaDI. As provided in the Rectory's Ordinance N° 246/2016 (UFABC 2016b), the duties of the CCS are:

I. Resolve matters involving changes into the Plan, its committees and working groups;
II. Issue opinions about the Sustainability subject;
III. Ensure the implementation of the Sustainability Policy of the UFABC;
IV. Contribute to the transparency of information.

# 3 Development: The Sustainable UFABC Axes

## *3.1 Water and Sewage*

One of main objectives of the Water and Sewage axis was to identify and raise actions concerning to drinking water use reduction, as rainwater harvesting by collection and sewage segregation and treatment for reuse. These measures aimed to promote processes to reduce impact on water resources. For that, preventive maintenance, current infrastructure adequation and future buildings (in Project or licensing phase) might be occur.

As a new University, UFABC's hydraulic system has been projected separately, i.e., water is provided in two different pipes according to their use: potable or non-potable. Beyond that, campus project rainwater harvesting in different areas, as roofs and sidewalks covers in both campuses. A wastewater treatment plant for water reuse (ETERA—*Estação de Tratamento de Efluentes para Reúso de Água*) is projected to complement rainwater harvesting and supply to Santo Andre campus. In both campuses were already installed a dual flush system in most useful toilets to reduce fresh water use. To decrease even more fresh water consumption, PLS recommends: another ETERA construction at São Bernardo do Campo, the installation of recirculator water pumps in lac destillators, scientific studies of alternative sources of water viability, continuity of preventive maintenance program of hydraulic network and consumption monitoring in each building through hydrometers.

An important objective to guarantee water resources quality was to eliminate the inadequate practice to discharge laboratorial effluents in common sewage network. As action to promote this sustainable habit, it was proposed the elaboration of guidelines to environmental friendly procedures in the labs, as also a list of chemical that might be neutralized, and then discharged normally.

[4]Composed of students, professors and managers of the University.

## 3.2 Energy

Reduction of electrical energy consumption was the major goal of the Energy axis. Then, PLS/UFABC looks for identify actions to guarantee racional and quality consumption at the University Campuses, reducing waste and aiming to implement an efficient system of energy management.

UFABC has multimeters installed in its buildings, however, it is necessary to install new equipment in order to establish a procedure to measuring energy in a systematic way. The internal lighting of the buildings is mostly designed to receive tubular Fluorescent lamps, mainly, by high pressure steam lamps. The use of diesel generators is a solution adopted by the University to continuously maintain the supply of energy to places where it is indispensable, such as Laboratories.

Associated with this goal of consumption reduction, the cost reduction can be achieved by diversifying the local energy matrix. Although UFABC consumption does not exceed the maximum level for reactive energy use by consumer, depending on the active energy consumed established by the regulator (ANEEL—*Agência Nacional de Energia Elétrica*), it is necessary to seek the continuous improvement of consumption patterns.

Management and monitoring of energy consumption standards is also a goal of sustainability. With respect to the construction factors that lead to improvements in the environmental management system of the energy part, the Santo André campus demands more use of artificial lighting and air conditioning than the São Bernardo do Campo Campus, where buildings favor the efficient use of lighting and natural air conditioning. At the Santo André Campus, administrative areas, laboratories, classrooms and teachers require the use of air conditioning, however, not all equipment is in accordance with efficient standards of energy consumption. At the São Bernardo do Campo Campus there is the use of air conditioners only in specific environments, such as laboratories. As measures to improve management and reduce the University's energy consumption, effective control is recommended of consumption per unit, rational use of elevators through diagnosis of use, correction of technical failures in electrical networks, installation of natural gas generators and chillers, creation of an Internal Energy Conservation Commitee (CICE—*Comitê Interno de Conservação de Energia*) and a local energy matrix diversification program.

Regarding the tariff charge, it was verified that UFABC does not pay for Reactive Energy. This means that the average power factor is within the limit allowed by ANEEL. As for the tariff model, the University is hour-seasonal and the determination of the power factor is hourly and not by average monthly, as in the conventional tariff.

## 3.3 Consumption Materials and Sustainable Bidding

The objective of the Consumption materials and Sustainable Bidding axis was to analyze the consumption dynamics of the materials cited in Normative

Instruction N. 10, of November 12th, 2012 and to suggest sustainable actions that lead to the critical reflection of the community onto preservate such resources. With regard to the issue of Sustainable Bidding, the objective was to select a specific group of Bids for contracting services/works and to analyze in which phases of bidding it is possible to adopt sustainable attributes and clauses.

UFABC acquires various types of consumption materials, which are essentially related to the activities of teaching, research and extension. In consultation of the Transparency Portal[5] (*Portal da Transparência*), it was found that such materials, for example, range from glassware and laboratory reagents to structured cabling materials.

Considering the variety of consumption materials acquired by the University and the pressing need for the elaboration of PLS, CPLS monitored, in this first phase of the implementation of the Plan, the materials established in Normative Instruction N° 10, article 8, item I: paper, print cartridges and disposable cups (Brasil 2012b). In relation to the Sustainable Bidding, were selected the Public Notice of public works and project management, the services of: surveillance, cleaning, telephone service provider, administrative support (janitor, reception, kitchen maid, driver) and building maintenance.

### 3.3.1 Consumption Materials

The PLS diagnosis identified that the University does not have an institutional program of sustainable consumption, however it is emphasized that there are important initiatives in progress, which contribute to a better management of the natural resources available to the community.

As example of sustainable initiatives already implemented can be cited: the Integrated Management System (SIG/UFABC—*Sistema Integrado de Gestão*); the badge printing system; the "islands" of printing, the obligation of the contracted companies to collect the empty printing supplies and refer them to the due process of recycling, among others.

PLS/UFABC foresees the achievement research on some "theories" found in the literature ("recycled paper pollutes less than white paper" and "hot air hand dryers are more sustainable than paper towel"), which need to be applied to the reality of the Institution; with the intention that future measures are adopted with safety and reliability. There is also a feasibility study for adherence to the Information Electronic System (SEI!—*Sistema Eletrônico de Informações*).

It is also suggested that periodic awareness-raising campaigns be developed with a view to developing a sustainable institutional culture, because if the community is not instigated to think sustainably much more than the concept of saving "financial resources" of government, certainly will not be effective the modification of

[5]www.transparencia.gov.br

systems and procedures, the distribution of durable mugs, rather than the use of disposable cups etc.

### 3.3.2 Sustainable Bidding

PLS/UFABC identified that the UFABC already determines some sustainable clauses in the Public Notice of public works and services, especially in the execution of the contract. However, in view of the lack of normative definition, establishes which documents/certificates may be required in the bidder's qualification. PLS developed the targets and actions aligned in two aspects: the continuous improvement of the bids organized by the Institution, in order to increase the demand for more sustainable products and services, through the specification of the object. The following actions are suggested: provision of training courses for the applicant areas, the dissemination of guides and guidelines, the qualitative change of the terms of reference elaborated by UFABC etc.; Gradual changes in the execution of services already contracted, for example, elaboration of the institutional policy for the use of telephone services.

## *3.4 Waste Management*

The objective of Waste Management axis was to identify, promote and propose actions concerning to municipal solid waste (MSW) and hazardous-waste generation, segregation, adequate destination and reduction in both campuses.

In 2011, an extension project called "Solid Waste Management in UFABC: implementing selective collection" was carried out, with objective to destinate adequately MSW, to aware university community about solid waste management importance, manage and sustainably implement a selective collection program in UFABC. Furthermore, UFABC is registered as a Voluntary Collection Point (PEV) of batteries from domestical use and has construction maintenance waste segregation (construction and demolition waste, bulbs, wires, oil and grease). Print toners are collected by specialized company to recovery and recycling. This is collection, treatment and adequate destination of chemical and biological hazardous waste by contracted companies.

To decrease the MSW generation, PLS/UFABC suggests the elaboration of a quantitative and qualitative diagnosis of waste generation and its final destination, besides continuity of activities as composting of the organic waste generated by the restaurants in both campuses. Regarding management improvement, it was suggested the purchasing of adequate packages for the storage of the chemical waste generated in the laboratories. Also, PLS proposes the elaboration, disclosure, and implantation of a Health Service Waste Management Plan and nominee a committee to adequate the destination of Electronic Waste.

### 3.5 Spaces

The main objective of the Spaces axis was to promote improvements in the quality of life in the work environment, from the more rational use of spaces that support the various activities inherent to the University—didactic, research, extension and administrative—as well as those necessary to harmonious coexistence of the community, with the vision to achieving a better fulfillment of the demands of these activities and the reduction of everyday conflicts.

During the UFABC foundation time, 30,000 $m^2$ were available for the University use, when it housed 932 undergraduate students, 96 postgraduate students, 113 professors, 92 administrative technicians and 64 outsourced employees. In 2015, there were 12,116 undergraduate students, 1170 undergraduates, 564 professors, 742 administrative technicians and 410 outsourced employees, distributed at the both campuses.

During the last years, the conditions of occupation and development of the activities showed a great improvement, however, it is still possible to observe situations of improvisation and conflicts about the use of the spaces. It is possible to say that there are three questions that stand out there: the adequacy of the spaces of leisure and coexistence; Rationalization in the use of spaces; and issues related to environmental comfort.

The aspects of integration and coexistence have been discussed in a specific commission, called "Conviva UFABC", which has conducted questionnaires, workshops and exposition of proposals and is discussing the implementation of coexistence and leisure spaces on campuses. The University also created the "Permanent Commission of Physical Space", which is responsible for mapping, evaluating and suggesting ways to rationalize the occupation and use of the spaces, also thinking about how the information in these spaces can be strategically manage.

One innovation of UFABC is the distribution and sharing of the research laboratories, which are classified into three categories: Multiuser Laboratory, Multicenter Laboratory and Research Groups Laboratory. Also, stands out the Multiuser Experimental Center, a complex that includes medium and large equipment in the areas of Physics, Chemistry, Biology and Engineering. This center is available to faculty and students of the University, as well as collaborators and researchers from institutions in the region.

In order to improve the use of the University spaces, it is recommended to create a Master Plan to carry out a complete diagnosis on the characteristics of environmental comfort in all UFABC spaces. It main goals include: to design a project to restructure the spaces with inadequacy; to adopt measures for evaluation and control of air quality in air-conditioned environments; expansion of Multi-user Centers; balance of activities and use of the spaces; and creation of a virtual campus map.

## 3.6 Displacement of Personnel and Urban Mobility

The objective of the Displacement of Personnel and Urban Mobility axis was to identify and carry out actions related to the improvement of the mobility and conditions of urban mobility of the university community, especially covering intra and inter-campus accessibility and rationalization of the sustainable transport systems.

In 2015, approximately 13,000 people traveled daily to the campuses, in their home-to-work and studies travels, from different backgrounds, facing the challenges of urban mobility in the ABC region.

Although the Santo André and São Bernardo do Campo campuses are located close to mass transit systems and circulation corridors of the São Paulo metropolitan region, the conditions to access, as critical as those that affect the rest of the metropolitan population, are aggravated by the characteristics of the educational institution, which attract many people in concentrated hours throughout the day, and the fact of having its structure installed in more than one campus, which implies a greater number of trips during the working days and studies.

Because of this, UFABC has been offering transportation services between the both campuses (private shuttle) and between the main transportation terminals of the two host cities (Santo André and São Bernardo do Campo). In addition, there are vehicular transport services to support the administrative and academical activities. Some indicators have shown that the accessibility conditions are inadequate due the great demand for charter services and for the parking areas. Evidences that question whether the existing modal transportation alternatives correspond effectively to the needs and characteristics of urban mobility of the UFABC community.

Faced with this diagnosis and in line with the development of the PLS, the working group structured the six major objectives for the improvement of Urban Mobility and Displacement of University personnel, such as: improving mobility and interaction between campuses; improving the conditions for municipal and regional mobility; improving the conditions for local mobility and micro accessibility; the rationalization of cargo transportation generated by UFABC; the reduction of $CO_2$ emissions; and the development of benchmarking of sustainable mobility strategies.

To achieve these objectives, five structuring points were defined: the development of an extensive diagnosis of the accessibility infrastructure and the urban mobility conditions of the academical community; the development of a benchmarking with the aim of comparing the performance and solutions of different entities and organizations in the promotion of sustainable urban mobility actions; the actions of partnerships for sustainable mobility with other local and regional bodies and institutions to improve the mobility of the academical community; the rationalization of transportation and mobility in UFABC in relation to passenger and cargo transportation services and the requalification of accessibility within and around the campuses; and the development of a Mobility Information System that allows the entire academical community to know the best forms and modalities the access both campuses, times and ways of travel, bus schedules, location, etc.

With the definition of these objectives and actions, is intended to deliver a series of products, among which stand out: the establishment of an Intermunicipal Line between the two Campuses; the purchase of an adapted vehicle to transport people with disabilities; the development of a new Intercampi Ride Program; the construction of an Intercampi Bicycle lane integrated of the others municipal bicycle lanes; the implementation of a future CPTM UFABC Station; the construction of a pedestrian access gate to the Anchieta highway; the construction of a connecting walkway of the Tamanduatehy Unit (Annex) to the center of the municipality of Santo André; the full accessibility in the campuses with the installation of tactile signage in the floor and communication in Braille; the accessibility of the sidewalks and route around the campi; the construction of chartered buses station; and the development of a benchmarking of sustainable mobility strategies.

## 3.7 Implementation, Dissemination and Communication

The objectives of the implementation, dissemination and communication axis were: to plan and carry out actions that favor the implementation, monitoring, analysis and disseminations of the PLS/UFABC elaboration process; to support the activities proposed by the working groups; to promote the development of strategies for the dissemination of knowledge related to sustainability; and mapping of the sustainable actions practiced at the University.

The actions and activities developed by the group, during the process of elaboration of the PLS, aimed to detect initiatives, impressions and expectations of the community on the subject, as well as establishing an easy and agile channel of communication between the CPLS and the community. During this process, it was noted that the sustainable actions promoted by the community are, in general, attentive to the expansion and promotion of knowledge, interaction and social integration, optimization of resources and cost reduction. Regarding the actions proposed for the implementation phase, the PLS suggests: the institution of the CCS as a deliberative advisory body for the actions of the Sustainable Logistics Management Plan and the establishment of an institutional area responsible for implementing, monitoring, evaluating and disseminating PLS/UFABC, aiming at the development of the UFABC's Sustainability Policy.

For effective implementation, monitoring and dissemination of the PLS, it is also recommended: to establish communication processes; to monitor and revise pertinent legislation; to hold the Sustainability Forum annually; to group and analyze PLS implementation indicators; to conduct periodic surveys of the community; to disseminate Monitoring and evaluation results of PLS; and planning awareness and dissemination campaigns.

## 4 Implementation of the Sustainable UFABC Program

The management model for the implementation of the PLS/UFABC was defined according to the Rectory's Ordinance Nº 246/2016, which, in addition to effectively approving of the PLS/UFABC, as a planning tool for UFABC's Sustainability Policy, established the Advisory Committee on the Sustainability (CCS). This act of the Rectory established (Article 2) that the management of the PLS/UFABC is delegated to the CCS and its thematic advisory groups, considering the support of the Pro-Rectory of Planning and Institutional Development (ProPlaDI—*Pró-Reitoria de Planejamento e Desenvolvimento Institucional*) (UFABC 2016b).

The institution of the CCS reinforces the strategical nature of the plan, since in addition to taking care of the essence of the PLS/UFABC, CCS assures its commitment to the PDI, always deliberating on new demands involving any of the axes of actions presented in the scope of the Sustainable UFABC program.

The CCS is formed by representatives of the Rectory, Pro-Rectorates and areas responsible for the management of the physical structures and of human resources management, like: Community Affairs and Affirmative Policies; Extension and Culture; Planning and Institutional Development; Communication and Press Office; Campus Administration and Superintendency of Constructions; Superintendency of People Management; as well as representants of the researchers and students.

Regarding the attributions of the CCS, mentioned in the methodology, there is highlighted the ones related to stimulating, promoting and disseminating the culture of sustainability, with the dissemination of sustainable actions to the UFABC community and the holding of the Annual Sustainability Forum.

The management support guaranteed by ProPlaDI is given in particular by: monitoring the committees and thematical advisory groups suggested in the initial diagnosis; coordinating the preparation of the work plan by the partner areas and thematical groups; contributing to the articulation and communication between areas and respective sustainable projects; supporting the holding of the UFABC Annual Sustainability Forum; and coordinating the preparation of a report to monitor the activities, in order to seek to align the current sustainable practices with those established by the Federal Government and reaffirmed in the PLS/UFABC.

The implementation of the PLS, already in its first year of validity, has been suffering the effects of Constitutional Amendment Nº 95, 2016 (Brasil 2016), that instituted a New Fiscal Regime in the country. This is a limitation to the growth of Brazilian government expenditure over the next 20 years, including Federal Higher Education Institutions. Thus, when confirming one of the potential risks for the implementation of PLS/UFABC (UFABC 2016a, 117), the reduction of budgetary resources, it became even more necessary to update the diagnosis of sustainable activities, as initially proposed in the PLS/UFABC document.

Therefore, the management structure of the Sustainable UFABC Program is now being demanded to review the diagnoses of each axis of action and the respective working plans, specially regarding the first year of implementation of the PLS/UFABC. These procedures imply updating the execution schedules specific to each axis, in order to adapt them to the new scenario, characterizing the process of constant monitoring and adjustments of the planning guidelines. However, some actions have been implemented and therefore deserve attention.

## 4.1 The First Year of Implementation of the Sustainable UFABC

During the first year of implementation of the PLS/UFABC, it was planned to carry out an expanded diagnosis of each of the axes as well as to support the sustainability actions already ongoing in the Institution. This is what happened, especially with the Urban Mobility axis.

UFABC signed a Scientific Technical Collaboration Term with the WRI Brazil, a non-profit organization, in 2016. This partnership promoted an extensive research about the urban mobility habits of the academical community. The research experience enabled a comprehensive travel database for all members of the academical community: undergraduate and graduate students, faculty, administrative staff, and outsourced staff. The data of origin and destination of the trips of a significant sample of the academical community was georeferenced, allowing diverse analyzes and to draw a profile of the patterns of displacement produced by the UFABC: time of route, modals used, distance, use of the campuses, other origins and destinies beyond the residence, etc. In addition, to improving the diagnosis, the research explored guidelines for sustainable mobility, observing possibilities or tendency to ride, collective transportation and bicycle transport.

Another outstanding action in the process of PLS/UFABC implementation refers to the Energy axis. At the end of 2016, ANEEL published a priority project call for energy and strategic efficiency in Research and Technological Development in Energy. The objective of the Call for Proposals to promote energy efficiency and minigeration in public higher education institutions met the PLS/UFABC guidelines and the University's latest architectural project, which provides for two large roofs with photovoltaic panels at the São Bernardo do Campo Campus expansion area. A team made up by professors from the University's energy area and engineers and architects from the construction sector presented to ANEEL and Eletropaulo—partner concessionaire in the bidding process—a project to deploy a photovoltaic system in existing buildings, with a generating capacity of 331 kWp at the Santo André Campus and 269 kWp at the São Bernardo do Campo campus. With the project approved, it is expected that, by the end of 2017, UFABC will have photovoltaic systems installed in the buildings of both campi and that, at times and days of lower consumption, the University will produce energy beyond what is necessary to its consumption by exporting it excess to the local power grid.

Regarding waste management axis, the University runs two projects involving students and professors in 2017: the first one to develop a system for the recycling of organic matter produced by the university restaurants, using the vermicomposting method; and the second one to promote environmental education for selective collection inside and outside the campuses. Also, in April 2017 it was carried out the 1st Workshop on Waste Management of the UFABC, promoted by the Waste Management Committee (CoGRe—*Comissão de Gestão de Resíduos*).

As for the knowledge and development of a sustainable culture in the institution, the University will promote the qualification of its employees in a sustainable bidding course promoted by the Federal Government's School of Finance. The objective of training is to improve purchase and contracting procedures with a view to specifying more sustainable, socially responsible products, services and works.

Also noteworthy is the implementation of an Integrated Management System of UFABC (SIG/UFABC). With modules for the most diverse areas of the University, SIG-UFABC offers operations for the management of the units responsible for finance, equity and contracts of the University with the objective of integrating actions related to requisition of materials, provision of services, supplies, control of infrastructure and control of the internal budget. In addition to improvements in public management and mapping of administrative processes, this action has seen the reduction of paper consumption, information processing time, process transportation, etc.

## 5 Conclusion

This paper had the challenge to resume all the seven axes studied and developed during the PLS/UFABC elaboration (Water and Sewage; Energy; Consumption materials and Sustainable Bidding; Waste Management, Spaces, Displacement of Personnel and Urban Mobility; Implementation, Dissemination and Communication) and to present the institutional tools used to transpose a theoretical document for its practical implementation.

Until now, the experience in the elaboration and implementation of the PLS/UFABC has been proportionated an intense process of knowledge of the different areas and competences of the UFABC. An individual and a collective effort of the University community are necessary to implement this Plan. The large number of actions, goals and indicators proposed by PLS/UFABC demands responsibility and awareness of the various areas, which need to talk to each other.

A management structure (CCS and ProPlaDI) was needed to administer, monitor, promote and develop guidelines in the expectation of carrying out the proposed actions. The internal community and the different administrative areas presented limitations in recognizing, understanding and disseminating their sustainability initiatives and identifying them as such were identified.

Dissemination and implementation of the PLS/UFABC is always necessary, but has been suffering the effects of Constitutional Amendment Nº 95, 2016. Due the reduction of budgetary resources, it became even more necessary to update and review the diagnoses of each axis of action and their respective working plans, as initially proposed by the PLS/UFABC document. These procedures imply updating the execution schedules specific to each axis, in order to adapt them to the new scenario, characterizing the process of constant monitoring and adjustments of the planning guidelines. In view of this, frequent discussion forums with the internal and external community of UFABC seem to be not only necessary, but very timely.

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### Author Biographies

**Professor Giulliana Mondelli** is Civil Engineer and has spent her last 17 years researching, teaching and consulting in Civil and Environmental Engineering and related areas. She received your doctoral degree in Geotechnics (University of São Paulo) in 2008, when she researched subsoil pollution caused by municipal solid waste disposal, then consulted, researches and teaches about sanitary landfills projects, contaminated sites investigations and solid waste classification and characterization. She joined to the Center of Engineering, Modeling and Applied Social Sciences at Federal University of ABC in 2014 and soon coordinated the PLS/UFABC elaboration. She would like to thank the Rectory and all the professors, technicians and students who have collaborated with the PLS/UFABC and that today participate of the CCS, using their creative visioning and for providing the inspiration for this paper. In special, we acknowledge Victor Hugo Argentino, to collaborate with the translation and revision of this text.

**Professor Silvana Zioni** is architect and urban planner (University of São Paulo), master's and PhD in urban and regional planning (University of São Paulo). Her professional experience includes municipal companies and consultancy, particularly in the area of urban planning and transportation. Previously a professor at the School of Architecture at Mackenzie's (São Paulo). She joined the Center of Engineering, Modeling and Applied Social Sciences at Federal University of ABC in 2010, and also linked to the post-graduate program in planning and management of territories. She collaborated with the elaboration of the questions of Mobility with the PLS-UFABC, and presently she coordinates the CCS of UFABC Sustentável.

**Cássia Gonçalves de Souza** is Technologist in Environmental Control, graduated by the State University of Campinas (UNICAMP) in 2013 and specialist in Environmental Management. She develops professional activities at the Federal University of ABC since 2014, working in the area of chemical waste management, battery waste and environmental education. Participated as member of the Management Committee for the elaboration of the Sustainable Logistics Management Plan (CPLS/UFABC).

**Ulisses Demarchi Silva Terra** is Architect and Urbanist by the State University of Campinas (UNICAMP). He is PhD Student in Planning and Territorial Management of the Federal University of ABC (UFABC) and Master in Architecture Technology by the Faculty of Architecture and Urbanism of the University of São Paulo. He is specialist in Housing and City by the School of the City Association (AEAU) and is consultant in urban and housing planning with experience in the area of architectural projects, sustainability and construction management. He researches parametric architecture, architecture of collective spaces and transport technology. Participated as member of the Management Committee for the elaboration of the Management Plan for Sustainable Logistics Management (CPLS/UFABC).

**Vanessa Soraia Sales dos Santos** is Public Administrator, graduated by the São Paulo State University (UNESP) in 2006 and specialist in Government Audit. She develops professional activities since the implementation of the Federal University of ABC—UFABC in 2007, working in the following areas: Management of Services and Processes, Finance and Budget, Biddings. She is bound to the Rectory of the UFABC and participated as member of the Management Committee for the elaboration of the Management Plan for Sustainable Logistics Management (CPLS/UFABC).

# Recovery of EACH-USP Organic Waste as an Instrument for Achieving Sustainability

**Gabriel Pires de Araújo, Fernanda de Souza Bueno and Ednilson Viana**

**Abstract** The large generation of urban solid waste in Brazil has as one of its characteristics the predominance of the organic fraction. When disposed in landfills, this fraction can cause public and environmental health problems, increase the emission of greenhouse gases and contribute to a reduction in the landfills' lifespan. Considering that university restaurants are great generators of organic waste, this research tries to approach how the valorization of these wastes using the biodigestion process would contribute to the increase of the sustainability at the campus EACH-USP. This management model avoids the disposal of organic waste in landfills (reducing emissions from the transport of waste to landfills), can generate electric energy and can provide a by-product with potential fertilizer. For this approach, organic waste generation data on campus were analyzed, also was estimated the energetic potential of this waste and the avoided $CO_2$ emissions, through the adaptation of the GHG protocol tool. The results indicate that the management of organic waste is very important for sustainability in the context of university campuses, since its valuation focuses directly on the environmental issue.

**Keywords** Urban solid waste · Organic waste · Recovery of organic waste
Biodigestion process

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G. P. de Araújo (✉) · F. de Souza Bueno · E. Viana
School of Arts, Sciences and Humanities, University of São Paulo,
São Paulo, Brazil
e-mail: gabriel.pires.araujo@usp.br

F. de Souza Bueno
e-mail: fernanda.souza.bueno@usp.br

E. Viana
e-mail: ednilson.viana@usp.br



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## 1 Introduction: The Problematic of the High Generation of Solid Waste and the Environmental Impacts of the Disposition of the Organic Fraction in Landfills on a Brazilian Context

Most human activities end up generating solid waste. The implementation of programs and projects that reduce the generation and the impacts of these wastes becomes something challenging for the whole society. To overcome these challenges it is necessary for both managers and the general population to have a different look at what is erroneously termed “junk”, understanding that often this “junk” may actually be something with potential for profit (Demajorovic and Lima 2013). In this list of residues with the possibility of recovery, the organic fraction of Urban Solid Waste (USW) stands out in this chapter.

The latest report available from the Brazilian Association of Public Cleaning and Special Waste Companies (ABRELPE) provides information that, in 2015, Brazil generated 218,874 tones of municipal solid waste per day, equivalent to 1071 kg per inhabitant every day (ABRELPE 2015). Of this value, half is composed of organic waste (IPEA 2012), and even this fraction that has possibility of use is also discarded in landfills. This occurs because this is the predominant management model in most Brazilian municipalities, that is, a model that values the landfill rather than the use of waste (Gonçalves et al. 2013).

Grounding of organic waste is one of the main anthropogenic sources of methane emission (Baird and Cann 2011), which is a cause for concern when addressing the issue of climate change, since methane is a major greenhouse gas (GHG). For Baird and Cann (2011), “when one considers the period of one century after its emission, one kilogram of methane is still 23 times more effective in raising the temperature of the air than the same amount of carbon dioxide”, justifying use of anaerobic digestion process as an important path for the energetic use of organic waste in the mitigation of the climate change (Ostrem 2004). This strategy has great relevance when seeking to reduce the environmental degradation imposed by today society, since “… under the historical prism of the development process, it is not possible to think of many reversals of environmental damages if the climate issue is not addressed concomitantly” (Veiga 2010).

A low-carbon development still presents an uncertain future in the Brazilian scenario (Lucon et al. 2013). This fact opens up precedents for institutions such as universities to seek innovative methods for Brazil to reduce its GHG emissions. Such a search is of great importance, whereas that if there is no effort to mitigate GHG emissions, global temperatures can rise from 2.6 to 4.8 °C by the end of the 21st century (compared to 1986–2005), resulting in socio-environmental and economic adverse effects (IPCC 2014).

Within the context exposed in this introduction, this chapter will address the recovery of organic waste within the university campus as a sustainability tool. The study will be conducted based on the collection of data from the School of Arts, Sciences and Humanities of the University of São Paulo (EACH-USP), where it is proposed the valorization of organic waste generated by the university's restaurant of the unit through the biodigestion process.

## 2 Environmental Impacts of Universities and Their Role in the Search for a Sustainable Development

The combination of population growth, the increase of natural resources consumption, and the consequent environmental degradation require more intensive corrective actions. To reverse the environmental situation in which the world finds itself, it is necessary to develop collective ecological consciousness. One of the steps to achieving it is through education that can be done by universities (Tauchen and Brandli 2006). Nowadays, many universities teach environmental practices in different courses. This is very important because universities also cause impacts, such as the production of waste, since organic that are most common until chemistry waste.

Due to the concern with the adequacy of the universities in favor of environmentally correct practices (Tauchen and Brandli 2006), it can be said that the pursuit of sustainable development is one of the major commitments of the universities to the society in which it is inserted (Gonzáles and Rincón 2012a)—considering that the attribute "sustainable" of development within universities is seen as "(…) a posture capable of responding to social and environmental problems through management actions and environmental education in its university community, with economic efficiency" (Amaral et al. 2012, p. 496). This commitment to sustainable development has become more relevant when universities came to be considered as impact generators, such as those arising from the generation of solid waste, the generation of liquid effluents, the consumption of natural resources, among others (Tauchen and Brandli 2006). These impacts go beyond the area in which the campus is inserted, since universities are open systems with input and output of matter and energy (Gonzáles and Rincón 2012b).

Higher education institutions must always strive for innovation and technological development, in addition to preparing and qualifying their graduates so that they include the environmental issue in their professional practices. In order for this to happen, it is necessary for them to practice what they teach, and it is pertinent for university campuses to present models and practical examples of sustainable management, going beyond the theoretical field (Tauchen and Brandli 2006).

It was from the 1960s that higher education institutions started to include the environmental issue in their management systems. These first experiences occurred in the United States of America, increasing in the 1970s. In the 1980s, the approach to the environmental issue in universities focused on the development of specific waste management and energy efficiency policies (Tauchen and Brandli 2006). As early as 1990, the Declaration of Talloires, signed at the time by about 30 universities, emerged from the perception that educational institutions are an active part of global environmental problems, since often the campuses have management unsustainable practices and passive attitudes about environmental problems. Thus, it is necessary that higher education institutions assume their leadership role in overcoming the environmental challenge (Engelman et al. 2009).

In the Brazilian context, there are still few studies about the commitment of higher education institutions to environmental issues and the relationship between influence and actions in the community in which these institutions are located (Engelman et al. 2009). Some of the educational institutions surveyed by Engelman et al. (2009) indicate that although there are initiatives regarding environmental practices, many of them are not carried out due to an immediate vision of the search for cost reduction and also for lack of capital for investment, these problems being recurrent in organizations located in developing countries.

Due to the impacts mentioned in the introduction of this paper, the use of organic waste generated by the operation of university restaurants is an important point to confer an environmental and sustainable attribute to a higher education institution. As an example of universities in Brazil that have studies of estimation of potential energy for the valorization of its organic residues from the restaurant through the process of anaerobic digestion, we can mention the Federal University of Juiz de Fora (Rocha 2016) and the School of Arts, Sciences and Humanities of the University of São Paulo—EACH-USP (Bueno et al. 2016).

Regarding EACH-USP, an approach will be taken on the energy potential of the organic waste generated by the university campus restaurant in 2015, as well as the potential of equivalent $CO_2$ emissions avoided with the adoption of the valorization of this waste through the biodigestion process.

## 3 The School of Arts, Sciences and Humanities of the University of São Paulo: The Valorization of the Organic Waste from the University Restaurant as a Tool in the Search for a More Sustainable Campus

Ancient demand of the population of the eastern region of the municipality of São Paulo, the Arts, Sciences and Humanities of the University of São Paulo was inaugurated in 2005, with the aim of promoting the educational development of the region (Rollemberg 2005).

Due to its pedagogical project, which proposes the resolution of problems through an interdisciplinary approach—and also for courses such as the baccalaureate degree in environmental management and the postgraduate course in sustainability—EACH-USP has an important role to play in the pursuit of sustainable development, especially with regard to society (Penin 2005).

**Table 1** Adapted from Bueno et al. (2016) about average data obtained in the literature

| | |
|---|---|
| Average generation of biogas | 100 $Nm^3/t$ => 11.2 t/month × 100 $Nm^3/t$ = 1120 $Nm^3$/month |
| Average concentration of $CH_4$ in biogas | 60% => 1.120 $Nm^3$/month × 60% = 672 $Nm^3$/month |
| Lower calorific value of $CH_4$ | 9.97 kWh/$Nm^3$ => 672 $Nm^3$/months × 9.97 kWh/$Nm^3$ = ~7000 kWh/month |
| Generator efficiency | 30% => 7000 kWh/month × 30% = ~2000 kWh/month |

The university campus restaurant in question caters to many users, ranging from students to employees, which ultimately generates a large amount of organic waste that is disposed of in landfills, an incorrect destination when you take into account the negative environmental impacts that this type of destination causes (Bueno et al. 2016).

Through an exploratory research to follow the frequency of users in the university restaurant in the month of September 2015, Bueno et al. (2016) reached the value of 16 $m^3$ of organic waste generated per month, corresponding to about 11.2 tons. By means of data obtained in the literature (Table 1), the authors reached an average generation of 2000 kWh/month.

In addition to energy generation, the energetic use of organic residues generated on campus through the anaerobic digestion process would have a great contribution to avoiding GHG emissions. This decrease would occur through the non-circulation of pickup truck of organic waste from the EACH-USP to the landfill; because the generation of energy in the campus itself decreases the amount of energy to be consumed from other sources; and finally, by the non-emission of $CH_4$ during the process of degradation of organic waste sent to landfill.

Aiming to present an estimate of GHG emissions that would be avoided if the anaerobic digestion process was adopted for the recovery of organic waste in the year 2015, it was decided to adapt the methodology of the GHG Protocol, which converts GHG to a unit of measurement called $CO_2$ equivalent.

For the estimation, it was evaluated the fact that the organic wastes generated by the campus restaurant are destined for a landfill called "CDR Pedreira". This landfill is located about 26 km from the campus, when using the highway Ayrton Senna and BR-381 road. In the case of using the organic waste on the campus itself, it would not be necessary to transport the waste to the landfill, which is collected and destined three times a week by AMBITRANS (Bueno et al. 2016). Thus, 0.240240 t/month of $CO_2$ equivalent would be avoided, considering that a heavy-duty diesel-powered vehicle emits 770 g/km of $CO_2$ (Álvares Jr. and Linke 2012).

Starting from the value of 2000 kWh/month of electricity to be generated by the biodigestion process at EACH-USP (Bueno et al. 2016), the amount of $CO_2$ emissions equivalent to being avoided by the use of an alternative energy is 0.2488 t/month. For this calculation was considered data from the Ministry of Science, Technology and Innovation of Brazil, which says that the average $CO_2$

**Table 2** Estimation of the hypothetical potential of avoided GHG emissions per month in the year 2015, through the use of Biodigestion of the organic residues of the EACH-USP

| | |
|---|---|
| Emissions avoided by the non-circulation of the truck collecting organic waste | −0.240 $tCO_2$eq./month |
| Emissions avoided by the generation of own electricity | −0.2488 $tCO_2$eq./month |
| Emissions avoided by non-emission of methane from organic waste | −1.35 $tCO_2$eq./month |
| Total emissions avoided | −1.83904 $tCO_2$eq./month |

*Source* Adapted from ISWA & Climate and Clear Air Coalition Secretariat (2016)

emission factor equivalent of the National Integrated System in the year 2015 was 124.4 $gCO_2$/kWh.[1]

Regarding the emission of $CH_4$ due to the anaerobic degradation of the organic residues of the university restaurant of EACH-USP, Bueno et al. (2016) estimate that the amount of $CH_4$ to be generated is about 0.45 t/month.[2] Considering that $CH_4$ is about 23 times more effective in causing global warming than $CO_2$ (Baird and Cann 2011), it is possible to estimate an emission of about 1.35 t/month of $CO_2$ equivalent to be avoided.

Based on the "Manual for the Management of Organic Waste in Schools", by the International Solid Waste Association (ISWA) and the Climate and Clear Air Coalition Secretariat (2016), the following table was prepared (Table 2) to The data on the equivalent $CO_2$ emissions avoided through the application of the biodigestion process as a management strategy for the organic waste of the university restaurant of EACH-USP, are presented in a synthetic and clear way.

It should be noted that the emissions that would be avoided in the year 2015 are relatively significant, reaching a total of 1.83904 $tCO_2$eq./month estimated through the adaptation of the tool. This value indicates the importance of addressing the issue of waste generation and its link with GHG emissions, considering that the issue of global climate change is something that must be tackled by a campus that aims to be sustainable.

The concept of sustainable development goes beyond environmental aspects, including issues related to education (Lenzi 2009). For this reason, it is important to mention the pedagogical gains derived from the valorization of organic waste by means of biodigestors. A biodigestor that takes advantage of organic waste generated on campus and generates energy has great potential to draw the attention of the university community and the surrounding society to environmental issues and existing technological solutions. The biodigestor also has the potential to be a pedagogical tool so that the students of the campus have contact with the techniques of sustainable management of organic residues and to learn of practical way on subjects approached in a theoretical way.

[1]Information available at: www.mct.gov.br/upd_blob/0241/241068.htm

[2]The data of Bueno et al. (2016) indicate the value of 672 $Nm^3$/month. This value was converted to kilogram (and later tons) through the website: www.linde-gas.pt/en/news_and_media/tool/gas_calculator/index.html

It is also important to highlight the benefits of an economic nature, since, according to Gasi and Ferreira (2006), this is an important criterion to be evaluated in a management model. In Brazil, the cost of collecting, transporting and disposing of waste in a landfill is on average US $ 86 per ton, which corresponds to a monthly cost of about US $ 963 for the grounding of EACH organic waste, a waste with potential of use. With the implementation of the proposal presented in this article, the tendency is that in an optimal scenario, the collection, transportation and disposal costs will be zeroed, contributing to the university's progress in the economic sustainability of campus activities. In addition, there is also the cost avoided by the treatment of leachate generated by organic waste in the landfill, which should also be considered as a positive factor in this type of analysis. Furthermore, Bueno et al. (2016) converted the value of the energy produced by organic waste in money to check how much it would be economized and how long it would take to the amount saved by the utilization of biogas to compensated the amount spend buying the biodigestor. Their conclusion was that it would happen in 56 years or less. Therefore, beyond environmental advantages the campus would have economic advantages soon.

## 4 Conclusions

A waste management model that allows the valorization of organic residues through the biodigestion process proves to be a tool of great importance for the achievement of sustainability in the context of a university campus, since this type of valuation presents environmental gains, for combating the problem of global warming, economic, for reducing the costs of final disposal of waste, and pedagogical, due to its potential to generate knowledge. Emissions avoided with the recovery of organic waste from the university restaurant demonstrate the importance of this type of practice in the context of sustainability. In addition, considering the fact that problems in the university environment, and universities have a duty to provide and practice solutions to the problems faced by them as well as by society, it does not make sense that a teaching institution such as EACH-USP (that seeks to be sustainable) continue to take actions such as grounding your organic waste, being fully aware of the negative impacts that this type of action produces. With this in view, this article aimed to propose the decision-making in the construction of models Management of organic waste to the university environment in general. EACH-USP also has an organic waste valorization center, a big step to the sustainable development. Some things that still can be done is to develop a pilot plant biomethane production and a project to utilize biodigester effluent as biofertilizer in university campus gardens.

It should be mentioned too that developing countries' universities have less money to invest in science and technology. That's why the impact resulting by universities from the called Third World countries needs more attention than the ones from wealthy places.

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## Author Biographies

**Gabriel Pires de Araújo** Enabled as an Environmental Technician (2013) by the State Technical School Júlio de Mesquita—State Center for Technology Education Paula Souza, Gabriel Pires de Araújo is currently graduating in the Bachelor of Environmental Management course at the School of Arts Sciences and Humanities—University of São Paulo (EACH-USP). He is a Researcher of Scientific Initiation at the University of São Paulo through the Unified Scholarship Program, where he develops research on the recovery of organic waste in small and medium scale. He is a volunteer in the “Projeto SustentABC”, which aims to disseminate sustainability practices on a regional scale through environmental education. It has as an area of interest the Environmental Management, Public Policy Management, Sustainability and the Valorization of Solid Waste.

**Fernanda de Souza Bueno** Bachelor’s Degree in Environmental Management at the School of Arts, Sciences and Humanities at the University of São Paulo, Fernanda de Souza Bueno also participated in the PBL2016 International Conference, where she published, together with her colleagues, the article “Evaluation of biogas production and energy potential of organic waste from the university restaurant of EACH-USP”. Currently, research in his work of conclusion of course on the use of mathematical models to verify the dispersion of pollutants in urban scenarios. It has areas of interest such as Waste Utilization, alternative and sustainable sources of energy, and those related to the concentration and dispersion of pollutants.

**Professor Ednilson Viana** graduated in Biological Sciences from UNESP in SJ do Rio Preto (1991), holds a master’s degree in sciences from the Institute of Chemistry of USP São Carlos (1994), and a doctorate in Hydraulics and Sanitation from the School of Civil Engineering (1999) and postdoctoral degree from Universidade Nova de Lisboa (2013). He currently teaches the Environmental Management course at EACH-USP, where he coordinates and develops research that covers the environmental, economic, social, legal and health aspects of the Sustainable Management of Solid Waste, with special attention to the recovery of organic waste.

# Sustainability and Higher Education in the Amazon: A Study Based on the Institutional Development Plan (IDP) of the Federal University of Western Pará

**Luís Alípio Gomes and Tania Suely Azevedo Brasileiro**

**Abstract** Environmental concerns have become a challenge for society since the scientific and technological advances. The article presents the results of the research in progress that has been developed in the Ph.D. Course Environmental Sciences in the Postgraduate Program in Society Nature and Development at Federal University of Western Pará. It is a qualitative research that relied on bibliographical and documentary research (Lakatos Marconi 2003; Gil 1999). The Federal University of Western Pará (Ufopa), located in the North of Brazil, in the Amazon region. The Institutional Development Plan (IDP) and annual reports served as the basis of these document analyses. The adoption of 'sustainable development' is presented in the IDP, along with specific actions for campus greening, but it also was necessary to consider the conceptual, philosophical and epistemological aspects of this term. This paper is important because these analyses pointed to the need for further study of and attention to curricular greening, as discussed in this study's conclusions.

**Keywords** Sustainability · Sustainable development · Education
Higher education

## 1 Introduction

The article discusses environmental problems global concerns directly affecting the quality of life on the planet due to the scientific and technological advances of the countries in the last 50 years of 20th century. It discusses strategies that have been

L. A. Gomes (✉) · T. S. A. Brasileiro
Society Nature and Development Program, Federal University of Western Pará (PPGSND/UFOPA), Vera Paz Street, Santarém, Pará 68035-110, Brazil
e-mail: luisalipiogomes@hotmail.com

T. S. A. Brasileiro
e-mail: brasileirotania@gmail.com



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adopted among the different nations as a way to restrain or mitigate environmental damages. The role of education, specifically, by universities and the concept of curricular greening was analyzed in the context of raising people's awareness of the environment. More specifically, this article presents the results of a research in progress that was developed in the Ph.D. in Environmental Sciences within the Postgraduate Program in Society Nature and Development in Federal University of Western Pará. It discusses the emergence of the concept of sustainable development and the role of education in relation to environmental issues. These results highlight the responsibility of universities in training professionals who will work in society and therefore the need for greater attention to curricular greening. The articles concludes by proposing an approach to curricular greening at Ufopa. This paper is important because it discuss the higher education role in sustainability in the Amazon region, and discusses the implications of this conceptual approach to curricula greening for Ufopa as well as for other universities.

## 2 Environmental Agenda

The environmental problems always comes accompanied by dense reports, studies, research that demonstrates the impacts generated by these problems are not always friendly to human being the environment, or human-environmental relations. Air, water, soil and the every existence of living beings still go through a series of threats caused by deforestation, pollution, degradation among so many and varied forms of aggression to nature and existence of all species.

Society has been informed through newscasts about numerous disasters and excessive use of natural resources, in the use of substantial changes to the environment (deforestation, natural disasters, climate change, contamination) that has generated environmental problems in every country in the world, especially the industrialized ones (Bolea et al. 2004). Reigota (2007) asserts that since the Second World War and the advances of science and technology has generated more strongly and accentuated environmental problems. Such situation provocated the environment scientific from the political, ethical and epistemological criteria in producing science. Gadotti (2004, p.385) mentions that "with the desire to dominate the Earth, the human being was moving away from its house, its ship, breaking the bonds of coexistence with other beings, interdependence and solidarity".

Concern for the environmental was gradually inserted in the agenda of the governments in different nations. Sometimes priority or not, the fact is that today the development of any nation can not fail to consider the debate and concerns about environmental issue and the impact generated by the various enterprises. In regard to institutions that are responsible for scientific research, there are numerous questions about the purpose of that research, how this research is, focused, financed, carried out and whether would aggravate or soften the environmental situation on the planet. In synthesis, from the second half of the twentieth century, with the advances of science and technology, had to consider the binomial development and environment.

## 3 From the Paradox to Sustainable Development

In 1962 Rachel Carson's book "Silent Spring" was published. The author reported the harmful consequences of the use of pesticides and chemical-synthetic insecticide for humans and the environment. This aroused people's concern for the harm to human health from the use of chemicals in pest and disease control. Since then, many others have presented equally important facts concerning: loss of biodiversity, species extinction, progressive ozone depletion and effects of exposure; global warning and its multiple effects (e. g. climate, surface temperatures, glaciers, polar ice, sea level rise); world population growth and associated settlement, development, and consumption patterns; other forms of pollution; and the quantity and quality of drinking water (Kraemer 2004).

Conventions, conferences, agreements, charters, international treaties and a series of legal frameworks were elaborated in the second half of the 20th century and the beginning of the 21st century as a way to restrain, discipline, regulate, prevent and mitigate exploitation of the natural resource. Ciurana and Leal Filho (2006) listed several international conferences and meetings that have shown concern about the environment: Stockholm Conference, 1972; Belgrade Charter of 1975; Intergovernmental Conference in Tbilisi, 1977; International Meeting of Experts on Environmental Education in Paris, 1982; The Moscow Conference, 1987; Rio Conference, 1992; World Congress on Education and Communication for Environment and Development, 1992; Conference of Thessaloniki, 1997; World Summit on Sustainable Development (Rio + 10) in Johannesburg, 2002. All of these international events had the capacity to mobilize nations around the world to discuss, agree and establish strategic actions to help restore the balance between development and environment.

In these events, an important role was assigned to education recognizing its potential to educate present and future generations regarding the environment (Sáenz and Benayas 2012; Beringer and Adomßent 2008). It is understood that formal and informal education focuses directly on the creation of new attitudes, conceptions in the relation between human being and nature because its awareness educative process (Gadotti 2004).

At the end of the 20th century, humanity lived a paradox: on one hand, there was much wealth and abundance in the world, while on the other hand, misery, environmental degradation, and pollution was increasing. The idea gained strength because it was not enough to produce wealth and economic development paying a high environmental cost, it was fundamental not to lose sight of the ecological limitations of the planet (Kraemer 2004). In 1972 the United Nations convened a Conference on the Human Environment held in Stockholm. The understanding was that mankind had reached a point in history where it should shape its actions around the world with greater attention to the environmental consequences. Ignorance or indifference can cause massive and irreversible damage to the environment including the life and well-being of the people. It would be possible of conquering a better life for the present generation and for posterity, with an environment in harmony with human needs and hopes. Defending and improving the environment for present and future generations has become a fundamental goal for humanity.

It was no longer possible to pursue the development at any cost because the historical moment required actions to try to reverse damage to the environment. In this sense, a declaration was approved at the end of this Conference in Stockholm, that was known an Environmental Document that listed 26 principles that should guide the conduct of society and its relationship with the environment. In the beginning, there is an explicit recognition of the strategic role of education, which is now considered to be indispensable, especially in environmental matters, aimed to the young and adult generations, and that the less privileged population should be given attention in order to consolidate the basis of a well-informed public opinion, and to conduct individuals and the community in improving the environment in every human dimension.

In 1983, Dr. Gro Harlem Brundtland, former Prime Minister of Norway, was invited by the UN Secretary-General to chair the World Commission on Environment and Development, resulting in the publication of the document "*Our Common Future*" in 1987, it was also known as the Brundtland Report. Lozano (2006) says that after to its publication of "*Our Common Future*" the concept of sustainable development became world famous. Alongside education, another term has gained strength to secure the future of the next generations: sustainable development. The 96th Plenary Meeting of the United Nations General Assembly on December 11, 1987 presents the concept of sustainable development as one that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brunacci and Philippi Jr. 2005).

According to Brunacci and Philippi Jr. (2005), the term sustainable development was incorporated into official rhetoric and enriched the academic discourses, the proposals of politicians and entrepreneurs, the ideas of professionals and environmental activists. Due to the repercussion it had on the media, it began to be part of the everyday language of the most different segments of society. The concept of SD, even though it is criticized for the fact that current use has become synthetic and generic, has become quite widespread in the literature. The use of the sustainable development has been consolidating and gaining strength in several fields (Brunacci and Philippi Jr. 2005).

The focus on concepts such as education for sustainable development, education for sustainability and education for sustainable societies got visibility in the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992 (Sáenz and Benayas 2012). Gadotti (2004) asserts that process of sustainable living as a way of educating for planetary citizenship promoting a sustainability culture that proposes a set of knowledge and values, such as education to think globally, with feelings, simplicity and stillness. Education is necessary to form the earthly identity and to understand it. The sustainability culture need to reconceptualize the curricula, but not only this, it is important to impregnate it with the themes of life. Without a sustainability by education, the Earth will continue to be considered only as a space for our sustenance and technical-technological domination. Sustainability is a guiding principle of education, curricula, objectives and methods (Gadotti 2004).

Many have recognized the importance of the role of higher education in advancing sustainability. One of the early statements was the Talloires Declaration, a ten-point action plan composed at a conference in France in 1990, which has been signed by more than 500 university leaders in 50 countries. More recently, Lozano (2006) pointed out that future leaders, decision-makers, and intellectuals of the social, political, economic sectors are formed and shaped within the world's higher education institution. Gough and Scott (2007) asked about "what is the purpose of a university?" They answers that "the purpose of a university is to help society meet its skills needs for the future; and it might do that both by teaching established skills to students and by carrying out research that elaborates new technological and socio-economic responses to meet the future problems and opportunities we expect to face" (p. 8). The authors argue about the possible tool for thinking about higher education's role in building the future, while talking account of its personal, societal, economic and environmental implications, is in terms of benefit to society as a whole rather as simply benefit to the student. If the university community does not pay special attention to its role and mission in society there is a serious risk in becoming an 'ivory tower' according to Gough and Scott (2007). Kraemer (2004) corroborate this idea and emphasizes that role higher education prepare for life, in order to guarantee employability and aptitude for work, to enable the individual to respond to a rapidly evolving society with the advent of technology and, finally, to be able to respond to the search happiness, well-being and quality of life. Institutions of education and, specifically, the university, act directly in the preparation of the generations for a viable future due to its multiplier effect, since from the conviction of each student for good ideas of sustainability and the capacity of influence the whole of society in different areas (Kraemer 2004).

Guerra and Figueiredo (2014) suggested that the relevant role of higher education highlights their responsibility in building a fairer, egalitarian and ethical society, as well as inserting the environmental dimension in teaching, research, outreach and management. The challenge of SD finds in the university the capacity of exercising a leadership role once its tradition and mission is the teaching and training of decision makers of the future and citizens more qualified for decision making (Kraemer 2004). According to Cortese (2003):

> Higher education institutions bear a profound, moral responsibility to increase the awareness, knowledge, skills, and values needed to create a just and sustainable future. Higher education plays a critical but often overlooked role in making this vision reality. It prepares most of the professionals who develop, lead, manage, teach, work in, and influence society's institutions, including the most basic foundation of K-12 education. Besides training future teachers, higher education strongly influences the learning framework of K-12 education, which is largely geared toward subsequent higher education.(p. 17)

Due to the importance assumed by the universities, in Table 1 it is exhibited the documents produced from 1972 to 1992 by the United Nations (UN) in which mention the education towards sustainable development through university.

The Table 1 indicates that education and universities have gradually assumed responsibility for SD. The Various measures could be triggered by universities such as the formulation of multi or bilateral agreements, cooperation and technology transfer, configuration of science and technology programs, production of scientific knowledge, development of programs in environmental education and development. One of the actions has been the subject of scientific research is the process of curricular greening in the universities.

**Table 1** The UN and universities in the field of Sustainable Development (1972–1992) adapted from Kraemer (2004)

| Document | Objectives | Recommended Measures |
|---|---|---|
| United Nations Conference on Human Development (1972) —Stockholm Declaration (Principles 9 and 24) | Prevent and/or mitigate damage to sustainable development | Formulation of multi- or bilateral agreements or other forms of cooperation (including technology transfer) |
| United Nations Conference (1991) Report of the Preparatory Committee | Involve everyone in education for sustainable development | Involvement of decisions in the government, specialists who advise them in universities, research institutes, etc. |
| United Nations Conferences (1992) Rio Declaration (Principle 9) | Strengthen capacity building for sustainable development | Exchange of scientific and technological knowledge. Development, adaptation, diffusion and transfer of technologies, including new and innovative Technologies |
| United Nations conferences (1992) Agenda 21 (Chapters 31, 34, 35 and 36) | Clarify the role of science and technology in sustainable development | (Re) design of national science and technology programs in order to clarify sector contributions to sustainable development and identify roles/responsibilities of the sector in human development |
| | Generate and disseminate knowledge and information on sustainable development | Produce long-term scientific assessments of resource depletion, energy use, health impacts and demographic trends, and make public in widely understood ways |
| | Educate everyone for sustainable development | Development of education programs in environment and development (accessible to people of all ages). Incentives from countries to universities and establish network |

Geli de Ciurana and Leal Filho (2006) assets that the origin of curricular greening was the result of the efforts of researchers from several countries in the formation of the Curricular Greening of Higher Education Network, ACES, acronym in Spanish. According to the authors, this network was formed in 2002 in the Program of Higher Education Curricular Greening: proposal of interventions and analysis of the European Union process. Five European universities, six Latin American universities, three of which were Brazilian universities (Universidade Estadual Paulista—UNESP, State University of Campinas—UNICAMP, Federal University of São Carlos—UFSCAR), participated in the program, making a total of eleven universities that had the objective to elaborate methodologies of analysis to evaluate the degree of curricular greening in Latin America and Europe.

Bolea et al. (2004) understand the curricular grenning as the introduction of environmental and sustainable knowledge, criteria and values in university studies and programs. It supposes the inclusion in the teaching plans of concepts and instruments capable of understanding and appreciating the environment and its complexity, which represents a radical change in the conception and explanation of many subjects that are taught at university. Nóbrega and Cleophas (2016) emphasize that the process of curricular greening occurs when there is socio-environmental practices in the school or university with a wide participation of different actors. Wemmenhove and de Groot explain that "greening the universities is the general catchword for the response of universities to the global challenge of environmental responsibility and sustainable development" (2001, p. 267). Curriculum greening means representing the same content under different theoretical and methodological approaches, ensuring that interdisciplinarity acts in curricula directly from the insertion of socio-environmental themes in a transversal way (Nóbrega and Cleophas 2016).

In short, the curriculum greening, although not a new idea, has the sense of inserting in the university:

> conceptual, methodological and attitudinal innovations, but also structural and organizational, that allow an interdisciplinary approach in the curriculum, which facilitates a global planning of objectives and contents, which approximates the comprehension of the complexity and the planetary vision that facilitate the decentralization and flexibility of the curriculum necessary to adapt to the environment and provide answers to their concerns (Muñoz p . 37, 1996).

In an analysis of the contribution of environmental education to science and sustainability in Brazil, Reigota (2007) reviewed research on the state of art of Brazilian environmental education from 1984 to 2002, and found that 1 high level theses, 45 Ph.D. theses and 264 dissertations had been produced. According to him, this 'cartography of Brazilian environmental education,' revealed a migration movement from a perspective derived from social movements and biological sciences, mainly in the area of education (Reigota 2007).

Curricular greening is a process that is produced by a combination of the efforts of universities themselves to define the conception of this type of curriculum, sustainability, and the design and implementation of practical actions aimed at incorporating sustainability into higher education (Ciurana and Leal Filho, 2006). Therefore, it is not only desirable but necessary to investigate curricular greening efforts in the universities. One of the reasons why the focus is on the university is related to the role it plays in society:

> … preserves, memorizes, integrates and ritualizes a cultural heritage of knowledge, ideas and values, because the university is responsible to re-examine it, update and transmit the knowledge, which ends up having a regenerative effect … The university has a mission and function through the centuries that goes from the past to the future; the universities has mission beyond national borders to preserve the knowledge, because it has an autonomy that allows to carry out this mission, despite the nationalist closure of modern nations. (Morin 2004, p. 15)

The university has this historical mission to produce knowledge, ideas and values. Nowadays, the discussion about university includes social responsibility and sustainable development (Casanova and Troiteiro 2013) as well as other subjects that are under its tutelage. In any case, it is necessary to unravel the role that universities inserted in the different contexts. Regarding the regional context, Rolim and Serra (2009) assert that in the region where the university is located, it demonstrates a strong impact on the regional development process, it is more propitious to overcome issues considered problematic, besides contributing to the improvement the standard of the population's life through the training of professionals, the researches and community outreach.

## 4 Research Methodology and Questions

This research took place at the Federal University of Western Pará (Ufopa), headquartered in the municipality of Santarém, Pará State, Brazil. This municipality is located in the north of Brazil, in the Baixo Amazonas region, in the interior of Pará State (Santarém 2013). Santarém is considered a polarizing center of the western Pará State because it covers an area of 22,358 km$^2$ and home to twenty-seven municipalities. Ufopa was implanted with a strong appeal for regional development, mainly considering its location in the interior of the Amazon.

In 2008 and 2009 the population of Santarém was estimated at 275,571 inhabitants and 276,665 inhabitants, respectively. Official information from the Brazilian and Geography Institute Research (IBGE) released in April 2011, records that the population was estimated at 294,580 inhabitants. The implantation of Ufopa was a result of Federal Government Policy and the Decree No. 6,096, 4/24/2007, which established the Program for Support to Restructuring and Expansion Plans of Federal Universities (REUNI) and gave a new dynamic for the emergence of new federal institutions of higher education in Brazil. Ufopa was created by the Law No. 12,085, 11/5/2009, and it was the union of the Federal University of Pará—UFPA and the Rural Federal University of Amazonia—UFRA. In spite of being a new university, there was already an experience of higher education in the municipality. The institution gained a projection for being considered the first federal institution of higher education in the interior of the Amazon. The creation of the university was considered strategic in terms of regional development. The Amazon, considered one of the great Brazilian biomes, is a region that has faced, throughout its history, several challenges, as well as other regions of the country. But what differentiates this region from others is the exuberance of its biodiversity, that makes it unique (Fig. 1).

It would not be unusual if the university leaders raised the following question: how can we effectively and efficiently incorporate SD into the university's policies, education, research, outreach and campus operations? How can we ensure that SD [Office1] becomes an integral part of the university culture and creates a multiplier effect within the institution and in society, in the short-and long term? Lozano (2006) claims these questions came from a large percentage of university leaders and faculty members have done little or nothing to incorporate SD principles in their courses, curricula, research and outreach. Shriberg (2002) presents an evaluation of different assessment tools for sustainability in higher education where it is analyzed recent efforts to measure sustainability in higher education across institutions. In short these assessment tools are: National Wildlife Federation's State of the Campus Environment, Sustainability Assessment Questionnaire, Auditing instrument for sustainability in higher education, Higher Education 21's Sustainability Indicators, Environmental Workbook and Report, Greening Campuses, Campus Ecology, Environmental performance survey, Indicators Snapshot/Guide, Grey Pinstripes with Green Ties, EMS Self-assessment (Shriberg 2002). Lozano (2006) defends a different kind of tool called Graphical Assessment of Sustainability in Universities (GASU). The limitation of this work and constraint of this paper is that it didn't used a particular assessment tool, but only bibliographies and accompanying documents.

The research questions that drove and guided this study were: (1) How is the sustainability and higher education is considered in Ufopa?; and (2) How does Ufopa express its commitment to sustainable development in its Institutional Development Plan (IDP)? To respond these questions we adopted bibliographical and documentary research. The bibliographical research has the purpose of providing theoretical basis. In this sense, the present research included a variety of materials on sustainability and higher education found in books, journals, theses, dissertations, annals of scientific events available both physically and via world wide web. Documentary research is based on materials that have not received analytical treatment and can be harnessed according to research objectives (Gil 1997). It involves all materials that can serve as information for scientific research and are found in public or private archives, as well as in statistical sources compiled by official and private corporation (Lakatos and Marconi, 2003). In our case, the main source for documentary research was the Institutional Development Plan of Ufopa and its additive as one of the most important document to a higher education institution in Brazil. We consulted the Annual Reports of Activities (2015a) and Management Report Department of Environment (UFOPA 2015b), in order to understand how actions are developed focused on the environmental issue on campus. There is a legal requirement regarding to the Institutional Development

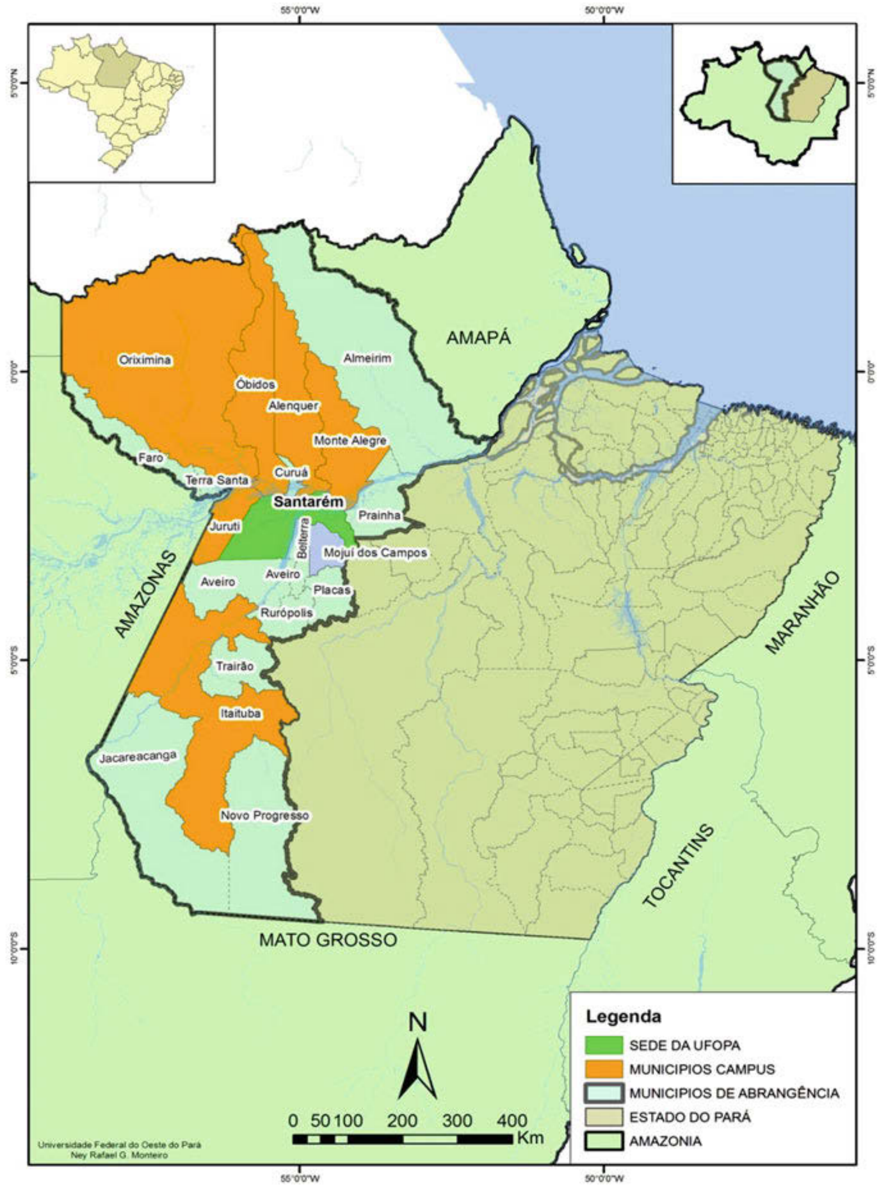


**Fig. 1** Coverage area of the Federal University of Western Pará located in Municipality of Santarém in Pará State from Pro-Rector of Planning and Institutional Development (UFOPA 2015c)

Plan, because it contains formally the intentionality, vision, mission, values and principles that higher education should follows. We used as descriptors the terms sustainable and sustainable development that appear in the IDP.

## 5 Sustainability and the UFOPA Institutional Development Plan

The elaboration of the Institutional Development Plan (IDP) is a requirement of the Brazilian legislation, the Law of National Education (LDBEN), Law 9,394/1996; Law No. 10,861/2004, which established the National System for the Evaluation of Higher Education; Decree No. 5,773/2006 that provided regulation, supervision and evaluation of Higher Education Institutions and the National Education Plan (PNE —2011–2020), Law Nº 13,005/2014. The UFOPA IDP is structured in the following sections: Institutional Profile, Strategic Agenda, Implementation and Development Schedule of the Institution and Courses, Administrative Organization, Student Assistance Policy, Infrastructure, Evaluation and Monitoring the Institutional Development, Financial and Budget. The IDP elaboration process began in June of 2011 and extended until the year 2013 (UFOPA 2012). Before the Plan expired, it was revised and added, justifying that "the adjustments were to improve the planning of the activities of the University for the proposed period", allowing "more effective monitoring of the goals outlined" (UFOPA 2015c ).

In the introduction the IDP includes a citation from United Nations document related to Education for Sustainable Development, showing that the university should play an important role as a vector for transformation and induction of changes in society, search for sustainability development. In the Strategic Agenda the IDP demonstrates is commitment to "ethical and democratic values, social inclusion and sustainable development" by "expanding opportunities, reducing poverty and inequities while respecting the environment" (UFOPA 2012). There is an explicit reference to "The university as a greening space: Campus GREENING and the ECO Tourism with the implementation of the Professional Masters and Tourism Observatory". the structural programs. In the Institutional Profile there is a strategic goal of "attracting qualified researchers, that is, human resources with the necessary skills, abilities and attitudes to promote regional sustainability development" (UFOPA 2012, p. 77). The other references only relate to financial sustainability, as it can be observed in the sections on Evaluation and Monitoring the Institutional Development and Financial and Budget Aspects.

In the revised of IDP in 2014 there was a review of the strategic planning of the institution that generated the addition in the framework of goals and indicators. The revised document used terms of sustainability in the following sections (Table 2).

**Table 2** Sustainability references from the Institutional Development Plan (IDP) (2012–2016)

| Section | Text | Page |
|---|---|---|
| UFOPA Strategic Indicators | Strategic aim: to contribute to the *sustainable development* of the region<br>Strategic action: elaborate the Sustainable Logistics Plan | 38 |
| Philosophical and technical-methodological principles | They are guiding principles of UFOPA training: social and public responsibility, scientific, artistic and social relevance, justice and equity, innovation, interaction and interactivity, articulation and pertinence. Concerning about pertinence the institution is committed to reduce inequalities and the integral development of society, as well as to strengthen local capacity for innovations that promote *sustainable* use of Amazonian biodiversity | 50 |
| Extension Policies | Activities aimed enhancing cultural and environmental diversity, commitment to human rights, respect for differences in race, ethnicity, beliefs and gender, ethical principles, promotion of social inclusion and/or *sustainable* and regional *development* | 61 |
| Schedule of implementation and development of the institution and courses (face-to-face and distance) | Implementation of the Course on Society, Environment and *Sustainable Development* in the face-to-face modality for 2011. Situation: already implemented and concluded | 87 |
| Academics Units | Institute of Biodiversity and Forest (Ibef) that offers courses in Agricultural Sciences and Biotechnology appears in the IDP with the commitment to develop high level human resources for innovation, prospecting opportunities for the *sustainable development* in Amazonia involving partnership with the local productive sector and society | 113 |

The revised IDP added an innovation compared to the first version in creating a the Environmental Management and its department. The Department of Environment (DMA) had two coordinations: Coordination of Conservation and Cleaning and Environmental Management Coordination. The IDP did not introduce to the attributions of this board and its coordinations, mentioning only the actions that should be developed. The actions are characterized in temporal and permanent action. Consulting the Annual Reports of Activities (UFOPA 2015a) and Management Report (UFOPA 2015b) from the Department of Environment (DMA), the main assignments of this board are as follows:

- Participate in an integrated way the units and sectors that make up UFOPA, in the planning, execution and/or operation phases of projects, programs and works focused on water supply system, collection system, transportation and effluent treatment, management solid waste management, rainwater management and drainage, environmental regularization, environmental education and environmental comfort;
- Support and promote sustainability in the management of the various sectors that make up UFOPA, seeking the environmental sustainability of its processes and environmental aspects;
- Promote the awareness of the academic and technical-administrative communities in the preservation, conservation, recovery and maintenance of the environment;
- Subsidize environmental actions, projects and programs in the areas of teaching, research and outreach;
- Develop partnership with environmental agencies in other government institution, as well as with non-governmental organizations and communities in general about sustainability.

The Institutional Environmental Awareness Program developed by the DMA was successfully by reducing the consumption of input materials (plastic cups, paper, electricity and water, developed the distribution on graphic material of environmental awareness campaign “All for Sustainability” such as folders, posters, stickers and banners. In 2016, according to the Management Report (2016), the Department of the Environment (DMA) was extinguished, and only the Environmental Management Coordination (CGA) was maintained in the administrative structure responsible for the environmental management of the institution.

## 6 Conclusion

The university is responsible for providing the highest degree of education aiming the qualification of citizens in the resolution of problems that most afflicts the society as the environmental problems.

Federal University of Western Pará since its implantation there has been a formal statement regarding sustainable development. However, by reading the document in detail, it was observed that issues related to sustainability and sustainable development are not sufficiently addressed in the construction of the IDP. The terms sustainability and sustainable development are used indiscriminately without reference to the conceptual, philosophical and epistemological issues. Sterling (2002) argues that sustainability does not simply require an add-on to existing structures and curricula, but implies a change of fundamental epistemology in our culture and hence also in our educational thinking and practice, it means, sustainability is a gateway to a different view of curriculum, of pedagogy, of organisational change, of policy and particularly of ethos. Due to the relevance of this document, the location in the Amazon of this university there should be a deeper about the curricula greening. It is necessary to update IDP about the sustainability considering the curricula greening because it can offer important contributions to the consolidation of sustainability in higher education specially in UFOPA because its location in the Amazon.

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## Author Biographies

**Luís Alípio Gomes** is a Ph.D. Student in Nature and Development Society—PPGSND/UFOPA of the Line of Research Management of Knowledge and Innovation for Sustainable Development. Master in Education—PPGE/UFOPA Research Line History, Policy and Educational Management. His degree is in Pedagogy from the Federal University of Para—UFPA. He was Municipal Secretary of Education in 2012 in the municipality of Santarém-PA. Membership of the Forum Education in Santarém city. He has been working on the following themes: Educational Systems, Municipal Education Plan, Teaching Methodology, Educational Policies, Interdisciplinarity and Higher Education.

**Tania Suely Azevedo Brasileiro** is a graduate in Psychology from the Federal University of Rondônia (1996), a postgraduate degree in Psychology from the Federal University of Rondônia (1997), a postgraduate degree in Physical Education from Universidade Federal de Juiz de Fora (1978), a postgraduate course at Pedagogy from (2004), Master's in Pedagogy of Human Movement from Gama Filho University (1989), master's at Educational Technology from Rovira i Virgili University (2001) and Ph.D. She has experience in Education, focusing on Educational Technology, acting on the following subjects: historical-critical pedagogy, school management, teaching learning process, social transformation and democratic management.

# Impact of Groundwater Supply in Brazilian Energy Sector, Case of Study: The Main Campus of University of São Paulo Cuaso

**Débora dos Santos Carvalho and José Aquiles Baesso Grimoni**

**Abstract** The study aims to investigate the impacts of groundwater supply in the Brazilian energy sector, the dynamics of decision making in water management and Brazilian energy management, and to point out where actions for sustainability in groundwater pumping should be taken. Power generation, consumption and management interact in many ways with water resources, yet surface water management differs from groundwater management. About 2.6% of Brazilian energy consumption is used for groundwater supply. Actions for energy efficiency in this sector can bring energy savings.

**Keywords** Groundwater · Pumping · Energy eficience · Water Supply
Extreme event

## 1 Introduction

This project aims to investigate the impacts of groundwater supply in the Brazilian energy sector. It also aims to study the dynamics of decision-making in water management and Brazilian energy management, to identify the demands of groundwater and electric energy and to point out where actions for sustainability in pumping groundwater must be taken. Groundwater depends on rainfall for the recharge of the spring, the electric energy in Brazil, is also strongly tied to the amount of rainfall, and is therefore dependent on hydrology. There is no way to exploit underground water without energy, and the scarcity of it, makes more efforts to reach it.

The interrelationships between energy and water have been gaining international prominence in recent years with the increasing demand to use both resources and governments continue to strive to ensure reliable supply to meet sectoral needs. As almost all energy generation processes require significant amounts of water, and

D. dos Santos Carvalho (✉) · J. A. B. Grimoni
University of São Paulo, Av. Prof. Luciano Gualberto Travessa 3, n° 158,
São Paulo, SP CEP 05508-010, Brazil
e-mail: debcarvalho@alumni.usp.br; debcarvalho@gmail.com

 
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water requires energy for treatment and transportation, these two resources are inseparable. This relationship is the nexus of energy water (Rodriguez et al. 2014).

The literature review shows a constant theme of stress and water scarcity, as well as the expectation that they will increase over time. The impact of intersectoral competition on energy and water underscores the need for a more integrated approach to planning for the use of both resources (Rodriguez et al. 2014).

Global pumping of groundwater, notably for irrigated agriculture, is a major energy consumer, and much more effort needs to be put into reducing inefficient energy use due to the depletion of aquifers and the inadequacy of artesian well projects.

The complexity of water resources systems requires methods for integrating technical, economic, environmental, legal and social issues at the basin scale within a framework that allows the development of efficient and sustainable water use strategies (Pulido et al. 2003) apud (Pulido-Velázquez et al. 2006).

Groundwater in Brazil has been progressively exploited for the supply of cities and urban centers, as well as for industry, irrigation and tourism. It is estimated that there are at least 416 thousand wells in the country, with an annual increase of 10.8 thousand new catchments, serving 30–40% of the population. This exploited volume is still very small when compared to the potential of its renewable reserves of 42 thousand $m^3/s$ (4). Despite its significant contribution to the socioeconomic development of many regions of the country and their ecological role in maintaining the base flow of bodies of water, groundwater management is still incipient and does not reflect its current and strategic relevance. The lack of public policies for the sector is evident in the lack of knowledge about the stage of use and potential of aquifers, as well as the risks of anthropogenic contamination to which they are subject and which affect their quality.

Integrated Resource Planning (RIP) is the combined development of electricity supply and demand side management options (DSM) to provide energy services at the lowest cost, including social and environmental costs. This type of planning incorporates the effort to account for the resource potential in energy use improvements with the same rigor used to inventory energy supply resources (de Martino Jannuzzi and Swisher 1997). Generation, consumption and management of energy interacts with the groundwater domain in surprisingly varied ways. As a consequence, specific inputs of hydrogeological science are needed to understand these links, and for risk assessment and effective management of interactions. To facilitate the discussion it is useful to classify the interactions under the sustainable exploitation of renewable energy resources, the impacts of groundwater exploitation on non-renewable water and energy sources, and energy consumption for pumping groundwater (Hipel et al. 2015).

The effects of drought are devastating agricultural activities and hydroelectric generation in populated areas. With the persistent reduction of precipitation in these areas, lakes dry up, river outflows decrease and potable water supply is reduced, the same author also states that the impacts are greater in less resilient nations, which do not have the capacity to absorb the changes in their social, economic and agricultural systems (Centro de Ciências do Sistema Terrestre 2009). Recognition of the need to address the effects of fragile water governance structures (Jønch-Clausen 2010) convinced many countries that a new parameter of water management is needed.

Surface water management differs from groundwater management, and it would be a great misconception to treat both similarly, but both resources are interconnected and poor management of one source can cause damage and overloads to the other source (Pulido et al. 2003).

In 1997 in Brazil, Law No. 9,433 was implemented, known as the Water Law, which establishes the National Water Resources Policy and the management instruments regarding the quantitative and qualitative aspect of the water sources and its objectives are to ensure the quantitative and qualitative control of water use and the effective exercise of access rights to water (Prates et al. 2015).

In Brazil, 39% of municipalities are supplied only by groundwater, 14% use mixed water supply (groundwater and surface water) and 47% only use surface water (Agência Nacional de Águas 2010). In São Paulo, Paraná and Rio Grande do Sul, more than 50% of the municipalities, mostly located in the western states, are also supplied exclusively by groundwater (Agência Nacional de Águas 2010).

The Brazilian Law number 10,257 of July 10, 2001, called the statute of cities, determines in one of its guidelines that it is the responsibility of municipalities to protect, preserve and recover the natural environment, among others. However, until then this Law has not contributed to reduce the accelerated urban processes of groundwater degradation in Brazilian cities (Boldrin and Cutrim 2011).

More than two percent of Brazil's total electricity consumption is consumed by sanitation service providers in 2008, equivalent to 8.3 billion kWh/year, 90% of which is consumed by the motor-pump assemblies. It is estimated that this consumption can be reduced by at least 25% in most water systems (Rede Nacional de Capacitação e Extensão Tecnológica em Saneamento Ambiental—ReCESA 2008).

Water losses are directly related to energy consumption, as it takes about 0.6 kWh to produce 1 $m^3$ of drinking water. This shows that hydraulic efficiency and energy efficiency are fundamental to the proper management of water supply systems (Rede Nacional de Capacitação e Extensão Tecnológica em Saneamento Ambiental—ReCESA 2008). The country's electricity consumption in 2016 was 460,001 Gigawatt-hours (GWh) (EPE—Empresa de Pesquisa Energética 2017).

It is estimated that 20% of rainwater infiltrates the soil, constituting huge underground reserves, i.e. renewable reserves (Macintyre 1997), and, of this amount, the exploitable reserves represent 20% of the renewable reserves (Agência Nacional de Águas 2005).

To facilitate the study of groundwater, Brazil was divided into homogeneous regions, forming 10 hydrogeological provinces. The boundaries of these provinces do not necessarily coincide with those of the hydrographic basins (see Figs. 1 and 2), represented in these provinces are regions where aquifer systems have similar conditions of storage, circulation and water quality (Agência Nacional de Águas 2005).

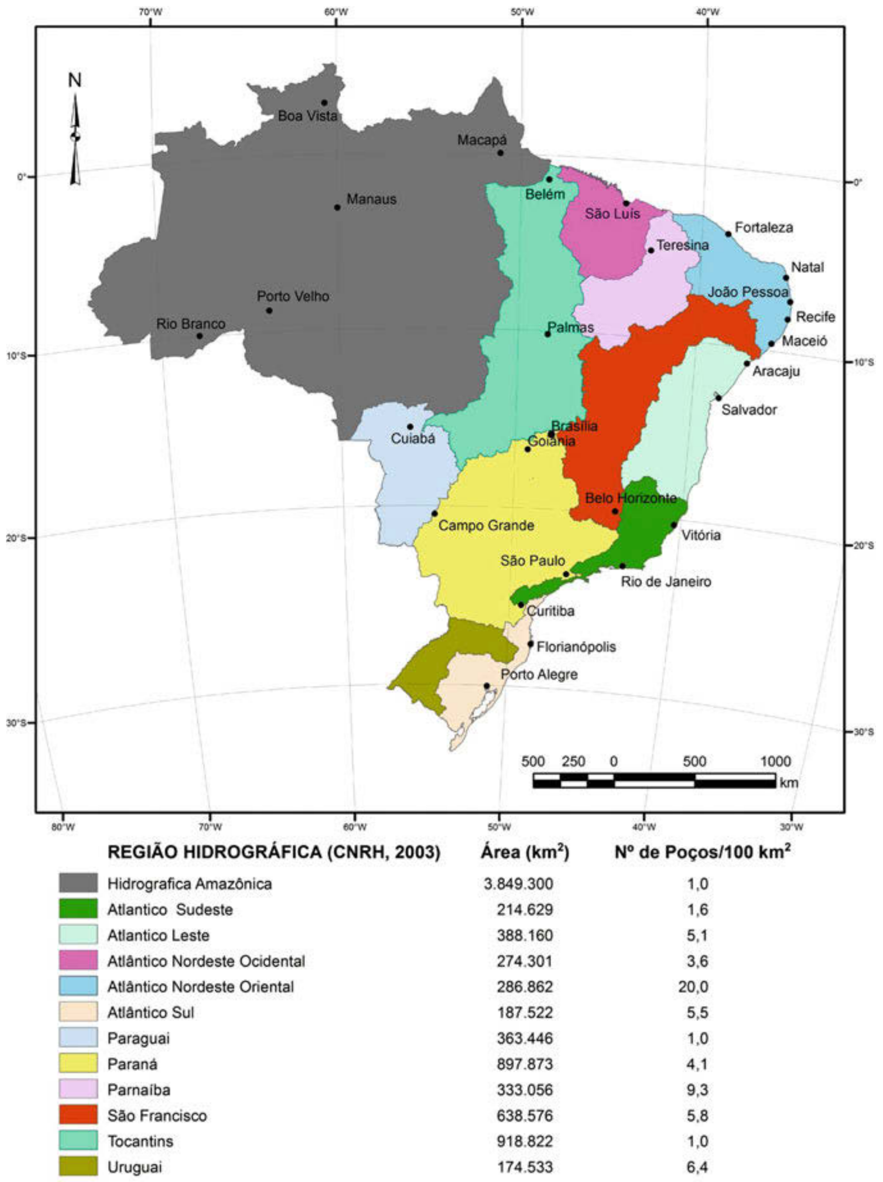


**Fig. 1** Distribution of wells by hydrographic region of Brazil—Diniz et al. (2014)

Much is discussed about the volume of groundwater present in Brazilian aquifers, on the volume of supply and demand of groundwater, but for it to be extracted, electricity is needed. Considering the amount of more than 2000 Brazilian municipalities are supplied only by groundwater, a study of the impact of this policy on the Brazilian energy system is necessary (see Fig. 3).


**Fig. 2** Schematic representation of the main Brazilian aquifers and their extensive recharge areas (Agência Nacional de Águas 2005)

According to the European IEC 60034-30/31 classification of engines for performance, from January 1st 2017 all engines with a rated power between 0.75 and 375 kW must not have efficiency levels below IE3 or meet at IE2 level and be equipped with a frequency inverter. The European Union directive 640/2009, based on standard 60034-30, establishes the "ecodesign" requirements for the placing on the market of engines (da Costa Cleto 2012). Already available in the market motors of class IE4, Super Premium Efficiency.

Brazil has been making efforts to conserve energy since the mid-1980s when two national programs were created: PROCEL (electricity) and CONPET (petroleum products). Although previous initiatives had taken place, these two programs were the major expression of the interest of the federal government and a favorable manifestation of establishing a public policy for the area of energy that incorporated the need to control energy demand. A third example of actions that favor the advancement of energy efficiency (de Martino Jannuzzi 2015): From 2001 a national fund was created called CTENERG. This fund has a strategic guidelines document available on the website of the Ministry of Science and Technology where it is verified that it is another source of funds to finance not only the development of more efficient technologies that our industry may be manufacturing but also to finance efficiency programs of public interest, intelligently complementing the activities that companies may be doing within a more commercial vision (de Martino Jannuzzi 2015).

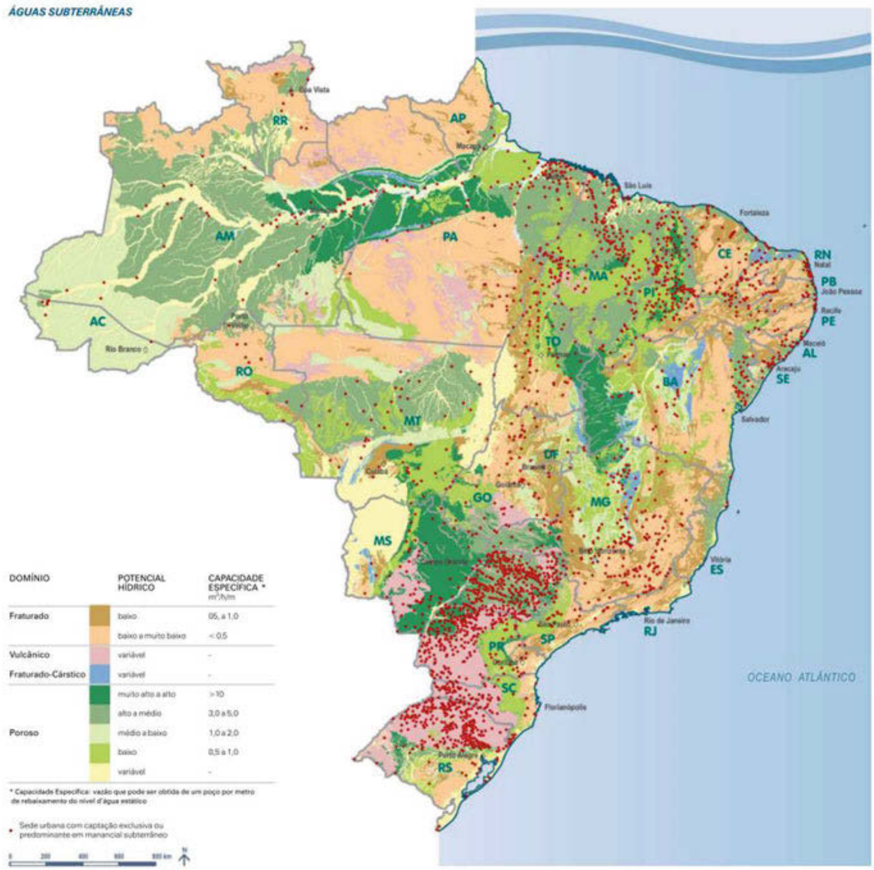


**Fig. 3** Municipalities of exclusive supply by groundwater in Brazil (Agência Nacional de Águas 2010)

Due to the considerations considered here, the present work is of importance for the study of the preservation and the efficiency of the use of natural resources, as it is proposed to reduce the impacts of extreme events in large urban centers, thus proposing more resilient cities.

The works dealing with the economic aspects of the exploitation of groundwater are still scarce. In this way, some works will be introduced that discuss, in a less specific way, the relevance of the consumption of electric energy in the abstraction/ production of water (Simonato 2013).

The aquifers perform two different functions: the one of reservoir and the one of conduction of the water. Thus, the pores as a whole behave either as a reservoir or as a conduit that transports the water between two points under a hydraulic gradient, as can be seen in Fig. 4. The water contained in an aquifer is displaced, consequently, under conditions of hydraulic flow similar to those of a “reservoir in


**Fig. 4** Schematic representation of groundwater distribution (Barbosa Jr. 2000)

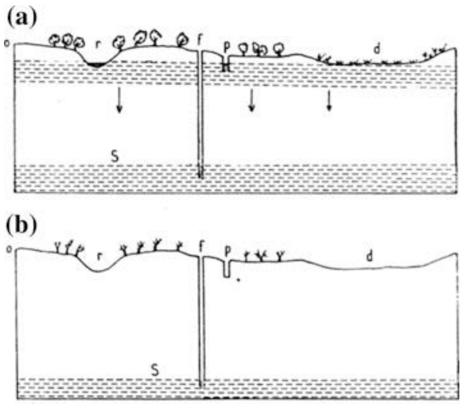


**Fig. 5** Seasonal variation (Pimienta 1980)

operation". The efficiency of an aquifer as a source of water supply depends on properties closely linked to the two functions it performs. The properties related to the reservoir capacity are porosity and specific production (or specific supply), while the properties associated with the water conduction function are hydraulic conductivity (or permeability) and transmissivity (Barbosa Jr. 2000).

There is a significant seasonal variation in each aquifer, which differs in times of drought and rainy seasons, as can be observed in Fig. 5.

The drought of 2014 that reached the city of São Paulo in Brazil was an exceptional event, unprecedented in the long historical series of observations. The average flow rate to the reservoirs of the Cantareira System in 2014 was the lowest in the series of 85 years (Sabesp 2015).

Figure 6 illustrates the increasing losses in pumping as the groundwater level is lowered due to groundwater exploitation and also due to dry periods of the year.

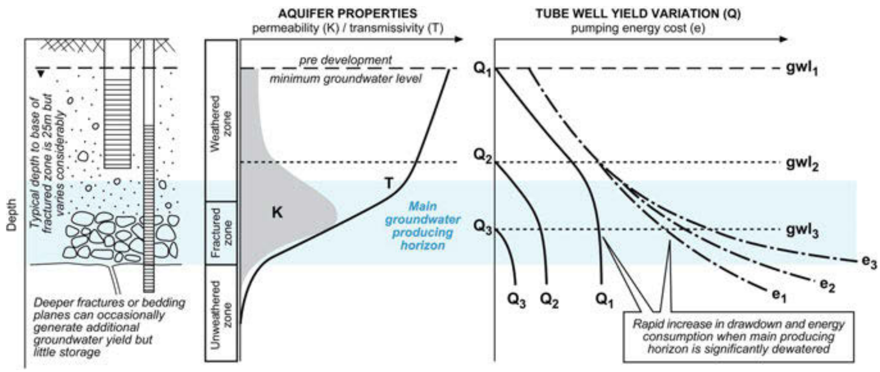


**Fig. 6** Increasing losses in pumping according to aquifer conditions (Grant 2015)

Pumping produces the depressions of the water level of the aquifer (or of the piezometric surface, in case of artesian), constituting the so-called "cone of depression". The radius of this cone, called the radius of influence, is a function of the pumping rate, and also varies with the pumping time. The influence radius, as well as the level depression, grows with the pumping time, at decreasing rates, until the capacity of recharging of the aquifer is balanced with the pumping rate (Barbosa Jr. 2000).

For the sake of water use, the saturation zone is the most important. It can be considered as a vast reservoir, or a set of natural reservoirs, whose storage capacity is defined by the total volume of pores in the rocks that are completely filled with water in this area (Barbosa Jr. 2000).

The most serious consequence of excessive groundwater pumping is that the groundwater below which the soil is saturated with water may be reduced. For water to be withdrawn from the soil, water must be pumped from a well below the water table. If groundwater levels decline too much, then the well owner may have to drill down the well, drill a new well, or at least try to lower the pump. In addition, as water levels decrease, the rate of water the well can produce may decrease (Perlman and USGS 2017).

As the depth to the water increases, the water must be lifted higher to reach the earth's surface. If pumps are used to lift water (as opposed to artesian wells), more energy is needed to drive the pump. Using the well can become prohibitively expensive (Perlman and USGS 2017).

## 2 Methodology

The purpose of this study is to study the impacts of supply policies in the Brazilian energy sector and will involve the study of strategies for the use of groundwater for public supply, capable of maximizing economic returns through a proposal that considers sustainability, the flexibility and resilience of a water system. In general, the methodology will involve the determination of the electric energy consumption in each Brazilian Aquifer System based on data from wells registered and comparison of available data. Data on the exploitation of groundwater are scarce and sometimes conflicting.

The 2014 Water Crisis brought about a paradigm shift, since until then the records indicated that 1953 had been the most critical year in history, when an average flow of 24.6 $m^3/s$ was recorded, more than double that of 2014 (Sabesp 2015). Due to the entire context of the water crisis in the Metropolitan Region of São Paulo, it was chosen for a more detailed case study.

To obtain the annual energy consumption related to the pumping of groundwater, some hypotheses were adopted. First, we studied the aquifer systems and their respective withdrawal rates. Of these flows it was defined that 60% of the withdrawal would be groundwater. The data of the average flows and their average depths of each aquifer system were combined. Based on these data, it was projected which ideal power of the motorbomba group would be most appropriate for the characteristics of each system and how many of these groups would be required to meet the withdrawal flow of groundwater. It was considered a 50% increase in the ideal power, considering the losses with incrustations in old wells and non-efficient materials.

## 3 Results

The increasing population growth of the world population, economic and social development, technological evolution, the consequent pressures arising from the need for greater food volume, attendance to current consumption paradigms and land use and occupation models have been the responsible for increased water stress, caused by excessive exploitation rates and/or water contamination (Simonato 2013).

Of the amount of rainfall, one-fifth renews groundwater bodies, and exploitable reserves make up 20% of renewable reserves. Therefore, in a scenario of surface water crisis, groundwater is late, but strongly affected, since only 4% of the volume of precipitation effectively composes the exploitable reserves.

### *3.1 Consumption of Energy*

More than two percent of Brazil's total energy consumption is consumed for pumping groundwater, which is equivalent to 12 billion kWh/year, that is 12,007 GWh/year, as can be seen in Table 1. Table considered a normal scenario, with the water demands available in Agência Nacional de Águas (2005), when there was no water crisis.

**Table 1** Consumo de energia por ano para bombeamento de água subterrânea

| Aquifer Sistems of Brazil | Consumption of energy per year to pumping groundwater (GWh/year) |
|---|---|
| Solimões | 22 |
| Alter do chão | 221 |
| Boa Vista | 11 |
| Parecis | 153 |
| Jandaíra | 133 |
| Açu | 126 |
| Itapecuru | 204 |
| Corda | 87 |
| Motuca | 38 |
| Poti-Piauí | 208 |
| Cabeças | 76 |
| Serra Grande | 156 |
| Barreiras | 1.218 |
| Beberibe | 13 |
| Marizal | 97 |
| São Sebastião | 25 |
| Inajá | 10 |
| Tacaratu | 59 |
| Exu | 10 |
| Missão Velha | 5 |
| Urucuia-Areado | 338 |
| Bambuí | 860 |
| Bauru-Caiuá | 1.874 |
| Serra Geral | 4.322 |
| Guarani | 1.155 |
| Ponta Grossa | 369 |
| Furnas | 219 |
| Total | 12.007 |

In a scenario of surface water crisis, with regard to rainfall precipitation or withdrawals greater than the region's carrying capacity, or works that alter local hydrodynamics, the groundwater is reached with a delay depending on the hydrogeological characteristics of each aquifer system. Actions to remove water from larger depths, or from unsaturated zones, added by a greater exploitation of the aquifer system, due to the scarcity of surface resources, only increase these values of energy consumption for pumping groundwater. Many scenarios are possible to predict, considering the total withdrawal flow being supplied by groundwater, there would be a 59% increase in energy consumption, for example.

In the long term, Brazil will have the challenge of including a new 30 million inhabitants and 39 million new homes. In addition to the quantitative expansion, the PNE 2050 scenario estimates that the per capita income growth of the Brazilian population will put it at a level between the current levels of Spain and France (EPE—Empresa de Pesquisa Energética 2014) and analyzing separately the 14% increase in population, would represent the same increase in water demand for the year 2050, and with that we would have a 22% increase in energy consumption for pumping.

## *3.2 Case of Study Main Campus of USP—CUASO*

The main campus of University of São Paulo located on the west side of the biggest city in Brazil, has since 1998 the monitoring of water demand. The campus is nominated CUASO (Cidade Universitária Armando de Salles Oliveira).

Several programs were implemented to try to decrease the water consumption across the years in the campus. One of the most known is the new PUERHE-USP.

Created by Portaria GR-6,632, dated 4/3/2015, the Permanent Program for the Efficient Use of Water and Energy Resources at USP (PUERHE-USP), which unified the work already carried out by the PURA (Permanent Program for the Efficient Use of Water) and PURE (Permanent Program for the Efficient Use of Energy) programs, which did work separately since 1997, is intended to implement a set of measures that aim to encourage and promote the management of water and electricity use in all University facilities through actions of a technological and behavioral nature (USP—Universidade de São Paulo 2015).

To save water, inspections are carried out to prevent and correct leaks immediately after detection, monitoring the water consumption of the units and their buildings; installation of faucet and toilet models; maintenance and regulation of sanitary equipment. In the area of energy, there are reforms of lighting systems aiming at the use of economical lamps and high efficiency luminaires, campaigns for lighting shutdown and air conditioning at times when they are not used; management of contracts and invoices seeking to find the best cost/benefit relation with the energy concessionaires; online monitoring system of energy consumption in the Capital campus (in deployment); and development of new specifications that follow energy efficiency standards (USP—Universidade de São Paulo 2015).

But something stands out. In the year 2014 CUASO experienced the highest rate of reduction of water consumption, according to Table 2, of 18%. In this period, the Metropolitan Region of São Paulo experienced the greatest shortage crisis in its history, and this rate refers to the awareness of the population to save water along with the actual lack of water.

Observing Fig. 7, we can see that PUERHE-USP's actions have been successful in reducing water consumption since 1998 in CUASO.

In this opportunity, it was considered to reactivate the groundwater wells of USP (Jornal do Campus 2015). Of the six wells, five existing wells are shown in the

**Table 2** Comparisons past years of water consumption at main Campus USP—CUASO

| Year | Demand ($m^3$/month) CUASO | Regarding year before (%) | Comparing with 1998 (%) |
|---|---|---|---|
| 1998 | 137,881 | | |
| 1999 | 116,850 | −15 | −15 |
| 2000 | 107,980 | −8 | −22 |
| 2001 | 94,364 | −13 | −32 |
| 2002 | 93,748 | −1 | −32 |
| 2003 | 91,183 | −3 | −34 |
| 2004 | 80,743 | −11 | −41 |
| 2005 | 79,623 | −1 | −42 |
| 2006 | 82,315 | 3 | −40 |
| 2007 | 82,946 | 1 | −40 |
| 2008 | 76,533 | −8 | −44 |
| 2009 | 66,507 | −13 | −52 |
| 2010 | 70,531 | 6 | −49 |
| 2011 | 78,821 | 12 | −43 |
| 2012 | 80,983 | 3 | −41 |
| 2013 | 81,005 | 0 | −41 |
| 2014 | 66,247 | −18 | −52 |
| 2015 | 57,785 | −13 | −58 |
| 2016 | 58,818 | 2 | −57 |

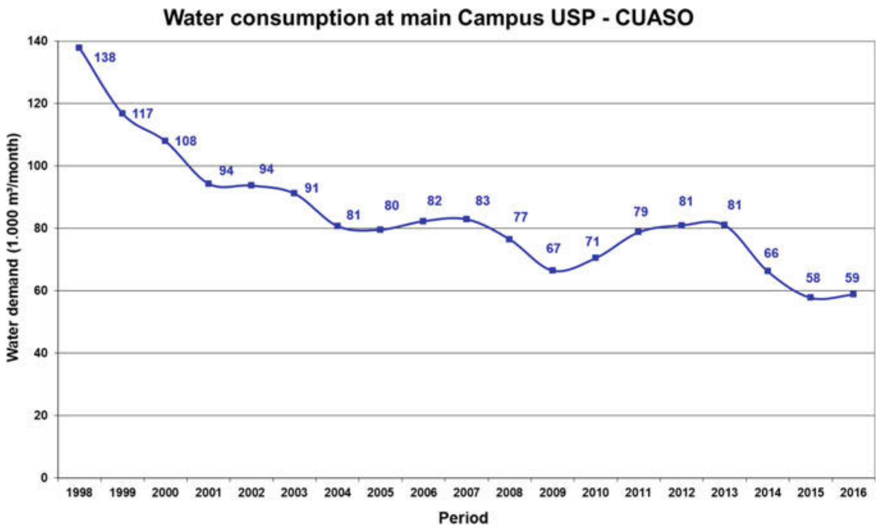


**Fig. 7** Water consumption at main Campus USP—CUASO


**Fig. 8** Location of the groundwater wells in Campus CUASO (Jornal do Campus 2015)

Fig. 8, three of them would be reactivated. Tests have been carried out, but the wells needed to be granted use by the DAEE, Department of Water and Electric Power of the State of São Paulo, according to Brazilian legislation, and this bureaucratic process lasts since 2015 more than two years, so that it was not possible to reactivate the wells at the height of the water crisis in 2014 (Costa 2017).

The wells, which were required the granted are PA1, PA2, PA3.

The adoption of some statements (hachured cells) like the working hours and the some depth of the pumping are decisive values. The subtotal amount of energy consumed by pumps, which already have the grant required in the DAEE, is 6877 kWh/month. It means 82,520 kWh/year, i.e., 0.082 GWh/year (Fig. 9).

In the year 2014 it was consumed 146,000 MWh (146 GWh) at all Campuses of the University. Since the data of the Table 3, the implementation of the groundwater pumping at CUASO would represent 0.06% of the total among of energy consumption of the USP.


**Fig. 9** Evolution of the yearly energy consumption at all Campuses of USP between 2010 and 2014 (USP—Universidade de São Paulo 2017)

**Table 3** Consumed energy of the implemented and simulated best option pumps with hachured value estimated

| Wells | Status (COSTA, 22 mai. 2017) | m3/h (DAEE - Departamento de Águas e Energia Elétrica do Estado de São Paulo, 26 out. 2015) | Work hours a day (DAEE - Departamento de Águas e Energia Elétrica do Estado de São Paulo, 26 out. 2015) | Work days (DAEE - Departamento de Águas e Energia Elétrica do Estado de São Paulo, 26 out. 2015) | m3/month | Deph (DAEE - Departamento de Águas e Energia Elétrica do Estado de São Paulo, 26 out. 2015) | Pump model (COSTA, 22 mai. 2017) | Power (kW) (COSTA, 22 mai. 2017) | Energy (kWh/month) |
|---|---|---|---|---|---|---|---|---|---|
| PA1 | Grant required | 37.89 | 20 | 22 | 16,672 | 64 | EBARA, BHS 516-05 | 6.7 | 2,938 |
| PA2 | Grant required | 20 | 20 | 22 | 8,800 | 47.5 | EBARA, BHS 512-05 | 5.6 | 2,462 |
| PA3 | Grant required | 4.44 | 20 | 22 | 1,954 | 152 | EBARA, BHS 411-08 | 3.4 | 1,477 |
| SUBTOTAL | | 62.33 | | | 27,425 | | | 15.6 | 6, 877 |
| PA4 | Grant not required | 2.88 | 20 | 22 | 1,267 | 88 | EBARA 4BPS3-15 | 1.49 | 656 |
| PA5 | Grant not required | 16.36 | 20 | 22 | 7,198 | 88 | EBARA 4BPS18-14 | 5.59 | 2,460 |
| PA6 | Grant not required | 6.54 | 20 | 22 | 2,878 | 88 | EBARA 4BPS8-13 | 2.98 | 1,311 |
| TOTAL | | 150.44 | | | 38,768 | | | 25.7 | 11,303 |

However this little increase of 0.06% in the energy consumption, the gains with obtaining groundwater are considerable, because, in the year 2016 CUASO used 58,818 $m^3$, and the implementation of groundwater pumping, just with the three pumps to its were required the governmental grants would give 27,425 $m^3$ year, it means 47% of the yearly water consumption.

If all six existing groundwater wells were reactivated, that would have an increase of 0.09% in the energy consumption of the USP and a supply of 66% of water demanded at the CUASO.

It is possible to adopt the photovoltaic generation of energy to reduce the costs with energy, and being more sustainable, using a renewable resource.

## 4 Conclusion

Through induced progress, measures can be suggested to safeguard energy, such as sectoral energy efficiency programs, exchange for more efficient equipment and other technologies such as alternative and sustainable pumping and from renewable sources that do not use electricity from the electricity grid. These measures would not only relieve the electrical system, but also leave the groundwater pumping system more resilient, decoupled and independent of any event that interrupts the supply of electric power, giving water security to the population.

The Campus CUASO is located besides on of most polluted river of Brazil, Rio Pinheiros, and its area could do a great influence in the groundwater of the Campus CUASO. The further works will revel if this water of the campus CUASO is potable or if it should be at least useful for another uses, like use in the toilets, washing buttons or other uses not noble as drinkwater.

The further studies too will dedicate themselves to discovery if in a cenario of extreme drought, as hold on 2014, would have enough groundwater to pump, how many time after the extreme event would reach the groundwater and which could be the lowest depth and the lowest flow that the exploitation could be feasible.

However, this work try to show some sustainable solution regarding water and energy for the Campus CUASO USP.

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## Author Biographies

**Débora dos Santos Carvalho**

Place and year of birth: Porto Alegre/RS, 1981.
Location and year of graduation/graduation: Gradações Novo Hamburgo, 2006; São Paulo, 2015/Master's Degree in Freiberg, Germany 2014; Master's Degree, São Paulo 2017.
Professional experience: Environmental Engineer from the University of São Paulo, where she also participated in the short course with Harvard University on sustainable cities (2015). She was awarded a Scholarship for Academic merit by the Sciences without Frontiers Program, where she obtained a Master of Science in Geological Engineering and Hydrogeology from the Freiberg Mountain Technical University in Germany. She holds the first degree in Advanced Course of Technology in Industrial Automation by the State University of Rio Grande do Sul (2006). Has experience in the area of Water Resources and Sanitation, trainee in Germany in a company of Environmental Engineering and Geotechnics. She intends to develop an international career focused on solving Brazilian water, hydrogeological and energy problems. She speaks fluently German, French and English.

**José Aquiles Baesso Grimoni**

Place and year of birth: Lorena/SP, 1958.
Location and year of graduation/post-graduation: Graduation São Paulo, 1980/Post-Graduation São Paulo, 1988 and 1994.
Professional experience: Has a degree, master's and doctorate in Electrical Engineering by the Polytechnic School of USP in 1980, 1988 and 1994 respectively. He has been a professor at the Polytechnic School of USP since 1989. He was vice-director of the IEE-USP from 2003 to 2007 and from 2007 to 2011 respectively. He is the coordinator of the Permanent Program for the Efficient Use of Water and Energy Resources at the University of São Paulo (PUERHE-USP) since 2015.

# Sustainable Management Analysis of a Contaminated Area on USP Capital Campus

**Fernanda Bertaco Bueno, Wanda Maria Risso Günther and Arlindo Philippi Jr.**

**Abstract** Although remediation technologies solve environmental and public health issues caused by soil and groundwater contamination, they can also generate negative environmental externalities such as energy and natural resources consumption; imbalance of water cycle; and greenhouse gas emissions. Due to recent occurrence with contaminated areas at the University of São Paulo—USP the paper aims to present a sustainable management analysis of a contaminated area on USP capital campus as part of the process of elaborating a sustainable management plan. The research methodology was based on literature review about sustainable remediation and construction; and qualitative analysis of actions, sustainable practices and lessons learned from case studies of contaminated sites management. Preliminary results showed selection of USP Leste site as case study, selection of 48 sustainable practices that were classified regarding the objectives of USP Working Groups and identification of sustainable actions adopted on case study. As a result, an analysis of sustainable management practices was carried out to assess intervention measures that need to be improved and how some sustainable management

F. Bertaco Bueno (✉) · A. Philippi Jr.
University of São Paulo, Av. Dr. Arnaldo, 715, São Paulo
SP 01246-904, Brazil
e-mail: fbb85@hotmail.com

A. Philippi Jr.
e-mail: aphij@usp.br

F. Bertaco Bueno
Secretaria do Verde e do Meio Ambiente of São Paulo, São Paulo, Brazil

W. M. Risso Günther
School of Public Health at University of São Paulo, Av. Dr. Arnaldo, 715,
São Paulo, SP 01246-904, Brazil
e-mail: wgunther@usp.br

W. M. Risso Günther
Environmental, Health and Sustainability of University of São Paulo,
Av. Dr. Arnaldo, 715, São Paulo, SP 01246-904, Brazil



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practices could be applied on case study to maximize potential benefits. This analysis will provide subsidies for the development of a sustainable management plan which is expected to be completed in 2017.

**Keywords** Contaminated areas · Sustainable management · Sustainable remediation · Sustainable construction · Campus

## 1 Introduction

The presence of contaminated areas represents a major challenge for sustainable urban development, since hazardous substances in soil and groundwater may bring risks to human health and ecosystem, compromise water as drinking water, and reduce economic value and social function of the land.

According to the List of Contaminated and Rehabilitated Sites of the state of Sao Paulo from December/2014, published by Companhia Ambiental do Estado de São Paulo—CETESB, the regulatory agency for contaminated areas of the state of São Paulo, 4771 contaminated areas were identified in the state. The main contamination sources of the state were: (i) the activity carried out by gas stations; (ii) industries; (iii) commerce; and (iv) waste disposal facilities (CETESB, 2015).

Although it is not common the presence of contamination source in university campuses, that are institutional places focused on teaching and research, four contaminated areas have been identified on the University of São Paulo—USP.

In the management process of contaminated areas it is necessary implementation of emergency measures, engineering or institutional controls, remediation technologies and/or monitoring for environmental restoration of contaminated sites (CETESB 2007).

Although remediation technologies solve environmental and public health issues, they can also generate negative externalities such as energy and natural resources consumption; imbalance of water cycle within hydrological regimes; soil erosion; nutrient depletion; and greenhouse gas emissions such as carbon dioxide, nitrous oxide, methane; as well risks to local workers and to economic feasibility of the project for future reuse of the site (SURF 2009).

Given these impacts originated from management of contaminated sites and the recent occurrence of contaminated areas in universities, the inclusion of sustainability in land restoration becomes an alternative to reduce adversities and a challenge to find new solutions for safe use by local workers and students.

Considered an important center of excellence in knowledge production with a consolidated academic reputation, the USP capital campus has four contaminated areas, which are in the process of environmental management: two disabled gas stations, a former industrial area considered unclaimed inheritances and the land occupied by the School of Arts, Sciences and Humanities of University of Sao Paulo where there was waste disposal in the past.

In case of universities, initiatives related to the perspective of a sustainability model depend mainly on the adoption of an environmental policy that contains guidelines for the development of research and sustainability actions (Philippi et al. 2012).

Regarding to sustainability, USP has been adopting initiatives related to the perspective of a sustainability model and developing an environmental policy with guidelines for improving and expanding campus articulations with the Academic community and society in general.

In 2014, the Prefecture of University of Sao Paulo capital campus—PUSP-C developed the Sustainable Campus USP Program, whose objectives included: planning and developing sustainable projects; articulating research, education, culture and extension to sustainability; and create management tools based on sustainability principles for improving quality of user's life on campus and surrounding areas (Lima et al. 2015).

In 2015, the Sustainable Campus Program became part of Environmental Policy Program, coordinated by the Environmental Management Superintendence—SGA of USP.

By means of an internal ordinance, 12 Working Groups—WGs were defined with the aim of developing public management models based on the new parameters of sustainable for improving quality of life of society (SGA 2016). This article aims to present a sustainable management analysis of a contaminated area located on USP capital campus based on preliminary results for the development of the sustainable management plan. In addition, the process of elaborating a sustainable management plan and the concepts of Sustainable Remediation and Green Building are presented in this article in order to have a greater familiarity with the theme.

It should be clarified that, in the present work, the term sustainable management is adopted as a process focused on integrating sustainability principles in the management of contaminated sites in order to obtain possible environmental, economic and social benefits. The elaboration of the plan considered local specificities on sustainable practices to be implemented, according to the needs and guidelines of USP.

## 2 Process of Elaborating the Sustainable Management Plan

The methods adopted of elaborating the sustainable management plan included literature review, documental research and case study. The detailed procedure for developing the sustainable management plan consisted in the following steps, as shown in Fig. 1.

All of these steps illustrated in Fig. 1 provided subsidies for the development of a sustainable management plan for a contaminated area.

**Steps adopted for developing the sustainable management plan**

1. Literature Review - Existing tools for implementation and design of sustainable remediation and green building including sustainable management practices
2. Documental Research - Characterization of four contaminated areas located on USP capital campus
3. Case Study - Selection of a contaminated area located on USP capital campus
4. Literature Review – Papers and scientific articles about sustainable practices applied on international and national cases of contaminated sites
5. Selection of cases of contaminated sites with sustainable practices adopted
6. Identification of main sustainable management practices and green building practices and qualitative analysis of actions, practices and lessons learned from selected cases of contaminated areas with sustainable practices
7. Survey of practices identified in each case of contaminated area with sustainable practices in the listings of sustainable management and building construction practices provided by SURF-UK and MMA
8. Selection of sustainable practices
9. Classification of practices regarding the objectives of USP Working Groups (WGs)
10. Analysis of existing management practices in the case study
11. Specification of sustainable practices that could be applied in the case study (Successful case practices selected and practices recommended by EPA)

**Fig. 1** Steps adopted for developing the sustainable management plan. *Source* The authors

Step 1—Firstly, in search of greater familiarity with the theme, a bibliographical review was carried out on the existing international tools for the implementation and design of sustainable remediation and green building demonstrated by LEED (Leadership in Energy and Environmental Design) certification that includes aspects such as conservation and efficiency practices for water and energy use; materials reuse; local generation of renewable energy; among others.

Step 2—By means of consultation with the administrative and technical documents in PUSP-C; Superintendency of Physical Space; and Environmental Company of State of São Paulo—CETESB, a research of secondary data such as environmental studies and technical reports about contaminated areas located on USP capital campus was carried out during the period from March/2015 to July/2015. The research considered the sites that contamination was already delimited by environmental assessments.

The characterization of the areas located on USP capital campus encompassed data such as assessment of land use; physical environment properties; types of contaminant; current stage of environmental management; future land use; intervention measures; remediation technologies; and recommendations and restrictions of regulatory environmental agency.

Step 3—Based on this characterization, one of these areas was selected for elaborating a sustainable management plan that includes integration of remediation and construction design phases.

The criteria for selecting an area for case study were based on the variety of contaminants; associated risks; and the possibility of construction of sustainable buildings on site. Therefore, an area was appropriate to elaborate a sustainable management plan when there was a need of remediation implementation to manage risks and the possibility of building construction with sustainable elements on the redevelopment site project.

Step 4—The bibliographic review was also used to conduct a research of papers and scientific articles related to sustainable practices applied on successful national and international cases of contaminated areas. Sources for the consultation included electronic virtual library of USP and CAPES (SIBI 2015; CAPES 2015), websites from *USEPA—Contaminated Site Clean-Up Information* (USEPA 2015), SURF USA (SURF 2015), SURF UK (CL:AIRE 2015); brownfield redevelopment and revitalization winners of the 2007, 2011 and 2012 Phoenix Awards (THE PHOENIX AWARDS 2015), and the cases presented in the dissertation "Recuperation of contaminated sites: a new challenge for landscape design" by Carlos Morinaga (Morinaga 2007).

Step 5—In these cases of contaminated areas with sustainable practices, the selection criteria were applied and the cases considered as the basis for this study were defined. The selection criteria were: (i) characteristics similar to those in the case study area, such as previous use; current or future use; the contaminant group; presence of methane gas; remediation technology; and (ii) application of sustainable construction elements.

Step 6—After selecting the cases, the main sustainable management practices and sustainable construction practices were identified and a qualitative analysis of the actions, practices and lessons learned from the selected cases of contaminated areas with sustainable elements was elaborated.

Step 7—Based on the analysis of the cases and the main practices employed, a survey was made in order to identify which practices of the cases of contaminated areas correspond to the practices on the listings of management practices and sustainable construction developed by United Kingdom's Sustainable Remediation Forum—SURF-UK (CL:AIRE 2014) and the handbook of the Sustainability Training in Public Administration of the Ministry of the Environment—MMA (MMA 2013).

Step 8—After identifying which practices of the cases of contaminated areas were in the listings of SURF-UK and MMA, the corresponding practices on the listing of SURF-UK and MMA were selected.

Step 9—The selected sustainable practices were classified according to the objectives of the Working Groups (WGs) of the Environmental Management Superintendency - SGA of USP in order to verify if the practices were in accordance with the guidelines of the university.

Step 10—After the classification of the practices, an analysis about the area of the case study was elaborated in order to assess the practices already applied on the case study and the reasons for some practices have not been implemented yet.

Step 11—From this analysis, it is expected the specification of selected sustainable practices by describing how they could be applied in the selected area for case study based on the survey of all practices implemented in selected successful cases of sustainable management of contaminated areas and some practices recommended by the United States Environmental Agency (USEPA 2016).

Thus, based on the necessary interventions, sustainable management practices that could be applied according to USP management guidelines will be listed, so that sustainability could be included in the contamination management of the USP campus area.

## 3 Sustainable Remediation and Green Building

In the context of management of land contamination, when a contaminated area requires interventions such as implementation of remediation technologies for risk management, the effects can be both positive to solve environmental and public health problems as negative for energy and natural resource consumption; greenhouse gas emissions; impacts on local communities and on the cost-effectiveness of the project for the future land use (SURF 2009).

An alternative to reduce these adversities is the inclusion of sustainability in the management of land contamination, an initiative carried out in 2002 by the European network called CLARINET—Contaminated Land Rehabilitation Network for Environmental Technologies, whose objective is to develop principles contaminated land management for ensuring the safe use of land, minimizing pollution and risks associated, and ensuring the functionality and proper conditions of ecosystems.

Subsequently, a complementary approach to the sustainable recuperation of *brownfields*[1] was developed by a network composed of environmental experts from Europe, called CABERNET—Concerted Action on Brownfield and Economic Regeneration Network (COMMON FORUM 2015).

Based on these principles, the concept of sustainable remediation emerged in the United States in 2006, developed by an organization of remediation professionals known as the Sustainable Remediation Forum—SURF, in order to establish a framework that incorporates sustainable concepts throughout the remedial action process while achieving standards regulatory. According SURF, sustainable remediation comprises soil and groundwater risk-management actions that are selected, designed, and operated to maximize net environmental, social, and economic benefits.

In addition to protecting human health and environment from hazards of contaminated areas, the adoption of sustainable practices on cleaning up process results in environmental, social and/or economic benefits, such as reduction of air pollutants emissions, creation of employment opportunities and reduction of costs associated with remediation processes (USEPA 2008; SURF 2009).

Several tools and methodologies for assessing sustainability into remediation projects have been developed to assist managers, stakeholders and environmental

[1]Abandoned or under-used industrial and commercial sites where expansion or redevelopment is complicated by real or perceived environmental contamination (USEPA 1999)

consultants for identifying impacts associated with remediation activities and analyzing treatment alternatives with low carbon footprint.

In the literature there are several scientific studies comparing remediation technologies through the use of sustainability assessment tools (Lesage et al. 2007; Fevre-gautier et al. 2010; Cappuyns and Kessen 2012; CL:AIRE 2013; Beames et al. 2014; Huysegoms and Cappuyns 2017). However, the lack of studies that contain a general approach of each tool in a comprehensive way for sustainability assessment in remediation technologies makes it difficult to choose the tool that should be adopted in each case.

Based on the indicators categories and sustainable principles, SURF-UK has developed a set of 166 Sustainable Management Practices[2] to encourage sustainable thinking, decision-making and actions that could be incorporated into associated activities to the management of land contamination to improve the environmental, economic and social performance of the land redevelopment project. Sustainable Management Practices are not necessarily new actions to be implemented in a contaminated area, but rather suggestions for measures and actions to reduce costs, natural resources consume and negative impact on communities or on the environment.

SURF-UK developed this set of Practices according to best practice guides of sustainability assessment on land contamination and other sectors in the UK and abroad (Bardos et al. 2016). Some examples of practices listed by SURF-UK and respective sources were shown in Table 1.

According to Bardos et al. (2016), the use of these practices improves environmental, economic and social benefits on a redevelopment project; as well it helps to achieve sustainable gains in the remediation and construction phase of the project.

The United States Environmental Agency—USEPA also has fact sheets about best management practices that could be applied to site investigations and common remediation technologies. Nevertheless, these practices are related to Green Remediation, focusing on reduction of environmental footprint from remediation activities (USEPA 2008, 2016).

The combination of land contamination management and buildings construction design on planning stages can be considered an alternative on site recuperation to incorporate sustainability in contaminated land redevelopment, avoiding unnecessary use of energy, material and financial resources, such as the installation of a renewable energy plant on site for remediation technology, and subsequently for future energy supply of the site.

The concept of green building incorporates elements to use less materials, energy and water in building's life cycle. In this case, green buildings can also be referred to as sustainable buildings, because the design of these buildings has

[2]The complete list of 166 SURF-UK Sustainable Management Practices is available at www.claire.co.uk/surfuk (CL:AIRE 2014).

**Table 1** Examples of sustainable management practices identified by SURF-UK

| Sustainable practice | Applicable SURF-UK indicator category | | | Source |
|---|---|---|---|---|
| | Environmental | Economic | Social | |
| Evaluate carbon footprint for major activities and implement a $CO_2$ emissions reduction plan | X | | X | DEFRA (2009) |
| Consider use of cleaner fuels and additives (e.g. ultra low sulphur diesel) for non-road plant | X | X | X | USEPA (2010) |
| Divert runoff away from stockpiles | X | X | | EA (2012) |
| Control and mitigate noise, vibration, dust (etc.) | | | X | ITRC (2011) |
| Develop/implement a plan to communicate project issues and progress with external stakeholders | | X | X | ITRC (2011) |

*Source* CL:AIRE (2014)

broader economic, social and ecological implications than a regular construction (Norte Arquitetura e Urbanismo 2015).

One of the certification tools for green building widely used internationally is the Leadership in Energy and Environmental Design—LEED developed by the U.S. Green Building Council—USGBC (Hernandes 2006).

This tool encourages the adoption of practices such as conservation and efficiency of water and energy use; reuse of buildings materials; local generation of renewable energy and innovative design in buildings in order to gain points toward LEED Certification for a redevelopment project (GBC BRASIL 2015; USGBC 2015).

In LEED there is no list of sustainability practices; this tool works with credits that are based on categories that encompass water, energy and materials. The list of Sustainability Practices of the Ministry of the Environment that could be adopted in the building construction also considers the same issues and elements of LEED as

**Table 2** Examples of management practices related to green building available from the Ministry of the Environment

| Management practices—green building |
|---|
| 1—Use of economical, fluorescent or light emitting diodes (LEDs) lamps |
| 2—Implementation of water reuse systems for energy saving |
| 3—Implementation of rainwater harvesting systems for water saving |
| 4—Implementation of solar water heating systems for energy saving |
| 5—Implementation of renewable energy systems (wind or solar) for energy supply |

*Source* MMA (2013)

energy efficiency, use of materials with minimal environmental impact and optimization of construction stages. Examples of such practices include implementation of water reuse systems and renewable energy systems (wind or solar), as described in Table 2.

## 4 Preliminary Results for the Development of the Sustainable Management Plan

As described in the process of elaborating the sustainable management plan, four contaminated areas are located on the USP capital campus: (i) a disabled gas station located on campus "Armando de Salles Oliveira"; (ii) a disabled gas station located on PUSP-C; (iii) a former industrial area considered unclaimed inheritances; and (iv) the land occupied by the School of Arts, Sciences and Humanities of University of Sao Paulo, known as USP Leste, where there was waste disposal in the past.

Based on information such as media impacted, type of contaminants, risks associated and future land use, an area was selected for the case study. Among all the contaminated areas characterized, the land occupied by USP Leste was selected for the case study, since the area has a greater variety of organic and inorganic compounds, and the size is significantly larger than the other sites, facts that would provide a more comprehensive study on sustainable practices that could be implemented.

In addition, sustainable alternatives could be studied for methane gas control, since methane gas generation from the decomposition of organic matter in the site may persist for years or decades. It should also be noted that although the environmental agency allowed the use of USP Leste site as education center with some restrictions, incorporating a project with sustainable practices and enhancements in interventions would result in an improvement in quality of user's life on campus and surrounding areas.

a. *Qualitative analysis of cases of contaminated areas with sustainable practices*

In order to provide support for the elaboration of the Sustainable Management Plan, national and international cases of contaminated areas were analyzed regarding the sustainable management practices and sustainable construction practices applied.

Based on the cases analysis, 7 cases of contaminated areas were selected, considering characteristics similar to those in the case study area and application of sustainable construction elements. The selected cases were: (i) Victor Civita Square (Motta et al. 2007; Morinaga 2007; Praça Victor Civita 2015); (ii) Ohlone College Newark (Ohlone College 2015); (iii) Dutch Rail Yard (SURF 2015); (iv) Pharmacia & Upjohn Company Llc (USEPA 2015; Pharmacy & Upjohn Company Llc Site 2015); (v) Former industrial area with fertilizers (USEPA 2015); (vi) Operating Industries Inc. Landfill (USEPA 2015); and (vii) "*Case Study on the Evaluation and*

*Implementation of Green and Sustainable Remediation Principles and Practices During RCRA Corrective Action Cleanup*" (Petruzzi 2011).

In each case, contaminants, remediation technologies and sustainable practices were listed for developing the plan for the contaminated area of USP Leste.

In all cases of contaminated areas, the option in situ thermal treatment for contaminated soil was studied as an alternative instead of excavation and disposal to landfills, except in the case of Petruzzi (2011). In addition to being economically viable, in situ thermal treatment could be a sustainable solution for contaminated soil remediation, since it avoids transportation large volumes of soil to landfills and, consequently, it minimizes costs, transportation energy requirements and air emissions of trucks and other vehicles, and surroundings impacts on communities near by landfills.

The qualitative analysis of the actions, practices and lessons learned from 7 cases of contaminated areas with sustainable elements allowed the identification of benefits generated, sustainable gains, and 77 sustainable management practices applied on many stages for the management of land contamination.

Among the various environmental, economic and social benefits identified in each case, it can be highlighted: reduction of energy demand and electricity consumption and reduction in the rate and the volume of groundwater extraction after renewable energy systems installation for electricity supply; reduction of long term costs related to energy consumption; and increase of quality of life in communities in the surrounding regions.

b. *Selection of sustainable practices*

The reproduction of the 77 sustainable management practices applied on the cases of contaminated area would be a simplistic solution for the campus site, as it does not consider local challenges and characteristics. For the elaboration of the sustainable management plan, it was intended to standardize the practices applied on the cases studied, starting from the 166 sustainable management practices developed by SURF-UK (CL:AIRE 2014) and 13 sustainable construction practices available in the handbook of Ministry of the Environment (MMA 2013).

Based on the analysis of the 6 cases of contaminated area and the 77 sustainable management practices identified, a survey was made in order to identify which practices of the cases of contaminated areas correspond to the practices on the listings of SURF-UK and MMA.

As a result, 48 practices were selected from the total of 179 sustainable management and construction practices (166 from SURF-UK and 13 from MMA). Examples of such practices are described in Table 3.

c. *Classification of practices regarding the objectives of USP Working Groups (WGs)*

The Environmental Policy Program coordinated by the Environmental Management Superintendence—SGA of USP has established 12 Working Groups (WGs) to promote studies in accordance with legislation and best practices; collect

**Table 3** Examples of sustainable practices selected from SURF-UK and MMA

| Sustainable practices |
|---|
| *Management* |
| Use cleaner fuels and additives (e.g. ultra low sulphur diesel) for non-road plant<br>Identify drainage systems and implement measures to mitigate risks of contamination<br>Adopt measures to prevent access and damage to protected areas<br>Minimize vehicle transportation |
| *Sustainable construction* |
| Implement of rainwater harvesting systems for water saving<br>Use sustainable drainage systems<br>Minimize water consumption |

*Source* Adapted from MMA (2013), CL:AIRE (2014)

information and consult the university community, related to the group's theme; and prepare documents that will be part of USP's Environmental Policy (SGA 2016).

With specific objectives, the Groups that comprise the program are: (i) Mobility; (ii) Environmental Education; (iii) Sustainability in Administration; (iv) Energy; (v) Sustainable Buildings; (vi) Territorial Use and Occupation; (vii) Solid Waste; (viii) Fauna; (ix) Reduction of Greenhouse Gases and Pollutant Emissions; (x) Green Areas and Ecological Reserves; (xi) Water and Wastewater; and (xii) Environmental Policy.

In order to align the university guidelines with the sustainable management plan for the USP Leste site, the 48 selected sustainable practices were classified according to the objectives of the USP Working Groups.

d. *Sustainable actions adopted in USP Leste site*

The initiatives adopted by the university administration with the aim of integrating the principles of sustainability into the management of the site were considered as sustainability actions applied at USP Leste site, according to the internal documentation. Examples of these actions related to contamination management and building construction include: (i) methane ventilation system instead of removing of soil containing decomposed organic matter; (ii) sewage treatment plant; (iii) rainwater harvesting system; (iv) creation of a Technical Group and an Environmental Commission composed of USP administration and students to monitor actions related to environmental management on USP Leste site; (v) organization of two seminars for students and workers of campus about the actions of land contamination management by the USP administration; (vi) measures to prevent access and damage to contaminated areas; and (vii) restriction of groundwater use as intervention measure after completion of environmental assessments.

Regarding the specific objectives of the WGs, it can be seen that the sustainability actions applied at USP Leste site fit into 6 Working Groups, as can be seen in Table 4.

**Table 4** Sustainability actions applied at USP Leste site regarding the specific objectives of the working groups

| Working groups | Actions applied at USP Leste site |
|---|---|
| Environmental education | • Organization of two seminars for students and workers of campus about the actions of land contamination management by the USP administration |
| Sustainable buildings | • Rainwater harvesting system |
| Territorial use and occupation | • Measures to prevent access and damage to contaminated areas;<br>• Restriction of groundwater use as intervention measure after completion of environmental assessments |
| Solid waste | • Methane ventilation system instead of removing of soil containing decomposed organic matter |
| Water and wastewater | • Rainwater harvesting system from 3 buildings for reuse in bathrooms and garden irrigation |
| | • Sewage treatment plant |
| Environmental policy | • Creation of a Technical Group and an Environmental Commission composed of USP administration and students to monitor actions related to environmental management on USP Leste site |

## 5 Analysis of Existing Management Practices Related to Sustainable Principles on Case Study

Based on the classification of the sustainability actions applied at USP Leste site according to the objectives of each WG, an analysis was conducted in order to assess the reasons for some practices have not been implemented yet on USP Leste site.

Although there is no established number of sustainable practices to define how sustainable a campus is, it can be stated that the more sustainable practices are employed, the more the campus will be recognized as a sustainability model. In this research, it was studied that a list of 48 sustainable practices could be adopted on USP Leste site; however, only 7 sustainable practices associated with land contamination management and buildings construction were identified on campus.

Despite USP has adopted some sustainable actions, it cannot be affirmed that the campus is sustainable, since the term sustainability includes integrated actions that generate environmental, economic and social benefits. In this case, the USP Leste site has adopted actions such as rainwater harvesting system and sewage treatment plant that generate mainly environmental benefits. These actions could have already been expanded to all buildings, not just some campus buildings.

Regarding the seminars for students and workers of campus about the actions of land contamination management, communication could have been more effective and more transparent since the beginning of the identification of environmental problems, not after these issues had already been widely exposed on the media. Therefore, if there had socio-cultural events, newsletters and workshops about contamination issues, the university would have generated social benefits such as improvement of public image and enhancement of social responsibility.

Another initiative adopted by USP Leste site that communicate project issues and progress with external stakeholders is the creation of Technical Group and Environmental Commission to discuss and monitor actions related to environmental management on USP Leste site. Although these actions promote dialogue with stakeholders, there are records of meeting minutes of these groups by August 2014 on university website, not indicating frequent meetings of these groups. Dialogue among all stakeholders is critical to broadening and reinforcing linkages between campus, community and the city.

Another example of sustainable practice that could be adopted, it is the creation of classes on environmental issues to disseminate the history of the place and invest in research about green building and sustainable solutions for contamination management, such as life cycle of an assessment and remediation project; and/or development of pilot renewable energy systems.

As stated in the case of Ohlone College, the USP administration could disseminate the history of the place, lessons learned and results for having a better interaction with students and community.

One of the actions implemented on USP Leste site is the installation of a methane ventilation system instead of removing of soil containing decomposed organic matter. Despite being more economic, this solution could be improved with sustainable practices to avoid accumulating methane inside the buildings. Project alternatives could be studied such as electric energy supply from renewable energies to the ventilation system, in order to minimize costs of energy consumption, reduce natural resources consumption and reduce air pollutants emission.

The main purpose of USP Leste site location is to increase the population's access to teaching and research. However, there is lack of infrastructure in the surrounding areas, given the number of poor communities in the region without basic sanitation and some abandoned contaminated areas near the campus without appropriate management. The function of the university is not to provide infrastructure to the region, but as an educational institution it could promote research, development of private public programs and partnerships to create opportunities for recuperating surrounding areas near the campus. Just as stated in the case of Pharmacia UpJohn Company LLC. located near an environmental protection area, USP administration could create new green areas and ecological trails in the region, considering interests and needs of companies and civil society organizations located near the campus.

Another way of recuperating surrounding areas could be initiatives related to monitoring program for groundwater use for non-potable purposes in the campus and surrounding areas such as plant irrigation, toilet washing, and firefighting. Geological and hydrogeological studies could be conducted to evaluate the aquifer dynamics and treatment methods for groundwater use for non-potable purposes.

The groundwater use restriction as institutional control was established by CETESB as a way to enable the land reuse with use restriction for any purpose. Nevertheless, as noted by Rebouças et al. (2006) and Puga et al. (2015) in scientific studies, the sustainable and integrated management of water resources in the country is fundamental to water availability for all, especially in times of water crisis. In the future, the legislation and methodology for management of contaminated areas in the state of São Paulo which consider the groundwater use restriction for land reuse, may be revised to meet the needs of future generations.

The university could then encourage the development of studies and alternatives for groundwater treatment so that cleanup targets are equal to or below drinking water quality standards in order to make groundwater potable for any use.

As an institution, USP must not only comply with legislation, but also develop pioneering improvements, actions and studies that could benefit and improve quality of life of university students and surrounding communities.

# 6 Conclusion

The process of elaborating a sustainable management plan for a contaminated area on USP capital campus resulted in the selection of USP Leste site as case study, selection of 48 sustainable practices that were classified regarding the objectives of USP Working Groups and identification of 7 sustainable actions adopted on case study. Based on these preliminary results, a sustainable management analysis was conducted in order to assess the practices already applied on the case study and the reasons for some have not been implemented yet.

The analysis enabled the identification of intervention measures that need to be improved and how some sustainable management practices could be applied on contaminated area to maximize potential benefits. For example, use renewable energy sources (wind and solar) to power methane ventilation system, in order to minimize costs of electricity consumption, reduce air pollutants emissions and improve quality of life on campus and local communities.

The following steps include the specification of sustainable practices that could be applied in the case study according to the needs and guidelines of USP, based on the survey of all practices implemented in selected successful cases of sustainable management of contaminated areas and some practices recommended by USEPA.

Expected to be completed in 2017, the research about elaboration of sustainable management plan approaches how sustainable principles could be included on the process of land contamination management, protecting human health and minimizing adverse environmental impacts. On a wider level, the plan could provide subsidies for the planning and development of other sustainable projects in other contaminated areas of USP, considering solutions that meet the needs of community, local and/or global economy and environment.

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# Greening University Campuses: Future Trends

**Walter Leal Filho**

**Abstract** This final chapter presents an overview of some well known campus greening initiatives, and outlines some future trends.

**Keywords** Sustainability · Campuses · Greening · Higher education

## 1 Introduction

For decades, universities have long been agents of sustainable development, but not always focused on sustainable development practices on their own campus. Sustainable development is often expressed in term of "greening" which means the implementation of different "green technologies" e.g. solar panels or waste management. Many universities have introduced "green" programmes and curricula, but aspects of teaching, research and sustainable curricula related to their own campus have not been fully addressed. A major work produced in 2015 documented and disseminated a variety of experiences in this field (Leal Filho et al. 2015). The many papers which are part of this book have also shown this is changing, and that more and more universities are engaging on campus greening.

As centres of learning, universities educate a variety of students, many of whom will become future world leaders, major employers, decision makers and teachers. Universities also play a crucial role in the implementation of the principles of sustainability, as they are major employers and consumers of goods and services. They are also very influential from an economic perspective, being vital to local or even regional economies.

As stated by Sonetti et al. (2016) "campus greening is often the first step universities take towards sustainability". But not always. In many cases and due to a

W. Leal Filho (✉)
Research and Transfer Centre "Sustainable Development and Climate Change Management", Hamburg University of Applied Sciences, Ulmenliet 20, 21033 Hamburg, Germany
e-mail: walter.leal2@haw-hamburg.de



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variety of reasons, universities engage less on campus greening, and more on research or teaching. The main reasons for this are twofold.

Firstly, campus greening can be a costly exercise. Apart from human resources, initiatives on campus greening often require substantial investments and improvements in infra-structure, which many universities prefer not to pursue.

Secondly, in order to yield the expected benefits, campus greening programmes need to be undertaken as part of a major, institutional approach towards environmental conservation and resources efficiency. Ideally, a university will already have a well accepted mission statement and commitment to sustainability, so that the efforts seen in respect of energy conservation, waste prevention and management, water use and transport on campus are perceived as parts of a major institutional strategy. This is admittedly, not the case in all universities.

Despite the above, there is a variety of examples of initiatives aimed at supporting campus greening. One example of the support being offered, is the Greening Universities Toolkit V2.0, a guidance document published by the Environmental Education and Training Unit (EETU) at the UN Environment Programme. This approach combines the concept of sustainability with the facilities management practices at universities. Elsewhere, a comparative study of the efficacy of interventions to foster a more sustainable use of electricity on US campuses performed by Wisecup et al. (2017) showed that progresses can also be seen as far as energy use is concerned.

On this paper, a small set of university operations and activities used in order to "green" a campus will be sketched out. It will start with the "Greening Universities Toolkit V2.0". Then, it will describe some of the activities undertaken by the Rice University and by Sheffield University, which provide a good example of how to realize campus greening. It is hoped this final paper may encourage university authorities to implement "their own transformative strategies for establishing green, resource efficient and low carbon campuses" (UNEP 2014, p. 11)

## 2 Greening Universities Toolkit V2.0

The "Greening Universities Toolkit V2.0" has been developed in the framework of the Environmental Education and Training Unit (EETU) by the United Nations Environment Programme (UNEP) in collaboration with the Cooperative Research Centre for Low Carbon Living, Australia. The toolkit is the result of numerous collaborations of "green universities" experts and researchers as well as of numerous case study contributions by many universities from around the globe.

According to UNEP, the aim is to support Universities to develop and implement their own transformative strategies for establishing green, resource-efficient and low carbon campuses.

The Toolkit intends to provide universities with not only guidelines for green campus implementation, but also presents best practice strategies undertaken from universities around the world. The emphasis is on practical guidance, showing by case studies what works and how. To effectively support the transformative process in Universities the toolkit is structured into the following main chapters: Universities and sustainability: definitions, issues, risks and challenges (I), strategies for initiating transformation (II), Indicators (III), Strategies and Technologies (IV), Policy, governance and administration (V), Resources for change (VI), Greening your university brochure (VI) and Global Exemplars (VIII). Basically the focus is on the sustainable planning, design, development and management of the university campus.

After having decided to transform the university campus into a green sustainable campus one of the first basic steps is to create a sustainability management programme, that is "the engine room for change" (UNEP 2014, p. 29). The assumption is that it is not possible to realise all possible targets at once, so each university has to focus on own targets and to follow its own prioritized strategies. Possible strategies range from the practical day-to-day management such of reducing power consumption, of the physical plant to "green" curriculum development and "green" procurement policies at universities. Generally each management plan can address the following objectives and targets:

- Energy, Carbon and Climate Change
- Water
- Waste
- Biodiversity and ecosystem services
- Planning, Design & Development
- Procurement
- Green Office
- Green Lab
- Green IT
- Transport
- Learning, Teaching and Research
- Community Engagement.

The Toolkit has been in implementation for some years now. And the results achieved are encouraging.

In the following parts of this chapter, three different best practice case studies will be presented: one from Rice University in the United States, one from University of Sheffield, United Kingdom, and one project performed at the Asia Institute of Technology in Thailand.

## 3 Rice University (RU)

Rice University in Houston (Texas, USA) is very well-experienced in implementation sustainability strategies. In order to become more sustainable in the use of their resources the University permeated the following operations in the aspects green building, food, transportation, waste management, greener grounds and recycling:

Buildings: In 2006 RU set the goal that all new buildings should be certified as green buildings in accordance to the guidelines of the construction program by the United States Green Building Council (USGBC). These resource efficient buildings save energy and water resources, reduce waste and are more cost effective.

Food: Food takes a big part in waste reduction. RU manages to create the least food waste possible, it uses 30% of local farmer products and allows, that farmers markets are held on the campus grounds every week. The university also only sells fair trade coffee. With the help of a special ID card, which is used in every canteen or dining hall at the university campus, the RU can collect data for calculating just the right amount of food and produces so as little waste as possible.

Cleaning: All cleaning products are ordered centrally through a special department. The RU specifically uses a green seal approved product as the general purpose cleaner. It consists of hydrogen peroxide, citrus oil and a biodegradable surfactant. They also use microfiber cloths, which last considerably longer and are more absorbent than traditional rags.

Grounds: The campus grounds are actually a designated arboretum. The objective is to maintain the current green areas. Also campus grounds concept proposes the use of porous paving and the use of green roofs, keeping buildings cooler and conserving energy.

Recycling: Recycling bins can be found extensively across the whole campus and in every dorm or office. Here they also recycle special items like, electronics, lab equipment, clothing, batteries and printer cartridges.

Transportation: A special effort is made that the least use of personal vehicles is done. RU is adjacent to a metro line and several bus lines are within walking distance of the campus, but more important is that the undergraduate students have a free metro card during the academic year. Besides public transportation there is an existing carpool program. For inter campus traveling, RU has a personal shuttle Bus (for free) that connects inter-campus departments. In addition several bike tracks that connect the campus, and bike lockers, showers and even a bike repair station can be found on the campus.

## 4 University of Sheffield

The University of Sheffield sets a good example by planting semi-mature new trees and retaining the already existing trees for improving the biodiversity of the campus and encouraging wildlife as a whole. Currently, the campus itself has limited green areas and few trees. Now, according to their Masterplan, they want to make the campus as green as possible. Where doable the university will plant large scale trees mainly along the walking and cycling line. As an additive overall objective the university seeks to create a strong identity for the University Quarter and contributing to Sheffield's reputation as England's greenest city.

## 5 Thailand

At the Asia Institute of Technology in Thailand, efforts on the 3R (reduce, reuse and recycle) waste management initiatives on the campus community were performed.

The environmental attitudes and opinions of the residents were investigated, and their behavioral responses to waste management initiatives were analysed by Tangwanichagapong et al. (2017). The authors identified the fact that 3R waste management initiatives had positive effects on people's attitudes about resources, waste management and consciousness of the need to avoid waste, but these initiatives did not affect recycling and waste management behavior. A voluntary approach-only cannot bring about behavioral change. Incentive measures showed a greater positive effect on waste reduction to landfills. Nevertheless, the demonstration projects helped to increase the overall campus recycling from 10 to 12%.

## 6 Some Lessons Learned

The examples outlined throughout this book as a whole, and on this chapter in particular, allow us to draw some basic lessons, which may be useful to any university interested to pursue campus greening. These are:

1. Context
   Universities need to consider their context, i.e. campus university or decentralized buildings—or a combination of both—in order to design the sort of campus greening strategy which best meet their needs. Whereas there are universities whose campuses are spread over many acres of land, some are in city centres, do not have large land areas they need to attend to, and need to focus—as a priority—in their buildings.
2. Thematic priorities
   Whereas large universities and rich universities in industralised countries may be able to afford "all campus" efforts, many others may not. Therefore, in a developing country context, where resources are limited, universities should focus on sets of priorities, and should not try to do everything at the same time. The focus may be-depending on the local context—on sustainable landscaping, waste prevention/management practices, transportation, energy or water conservation on the campus. A focus on a few areas with concentrated efforts, may prove more effective than a wide spread and thin distribution of resources.
3. Fostering interest among staff
   It is a reality that the numbers of academic and support staff actively engaged on campus greening are rather low, compared to their total. There is thus a perceived need to tackle their lack interest and to foster their willingness to participate in initiatives towards achieving sustainability on campus.

4. Engaging students
   No campus greening initiative may fully succeed, without the active involvement of students, as one the most important stakeholders of any university. Their active participation should be encouraged, and their ideas and suggestions should be welcome in any campus greening project.

Finally, a final lesson to be learned is the fact that campus greening initiatives should be perceived—and treated—as long term efforts. Results should not be expected in periods of months, but will sometimes take years to be achieved.

## 7 Conclusions

The task of developing a green campus is an extremely important one, not only to reduce their impact on environment and on the climate, but also to provide an inspiring and welcoming environment in which everyone likes to study and work. Management programmes on university campuses such as the ones presented in this chapter can have long-term effects on the institutions themselves and on society as a whole. With the words of Ball State University:

> Our society needs ideas and actions that enhance the environmental health and integrity of the places where we live and work. Educational institutions are complex human communities that pose unique opportunities to explore, understand, and respond to the interrelationship of environmental issues. College and university campuses can be a vital link bridging current community needs and understandings with future visions. (Ball State University 2017)

The most successful initiatives in order to "green a campus" are those who are embedded in a "whole institution universal network", that means partnerships between students, faculty, and staff, including through courses and independent study projects, as well as through environmental organisations.

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