Innovative Renewable Energy
Series Editor: Ali Sayigh

Ali Sayigh *Editor*

Green Buildings and Renewable Energy

Med Green Forum 2019 - Part of World Renewable Energy Congress and Network

Springer

Innovative Renewable Energy

Series editor

Ali Sayigh
World Renewable Energy Congress, Brighton, UK

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Ali Sayigh
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Introduction

This is the Mediterranean Green Buildings and Renewable Energy Fifth Forum. It is the third one in Florence, School of Architecture, Italy. The Forum is part of the World Renewable Energy Network (WREN), organized jointly with, two other institutes, the University of Florence (ABITA), and ETA—Florence Renewable Energy.

The Technical Committee consisted of:

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13. Prof. Antonella Violano—Italy

The forum received 71 abstracts representing 25 countries. The full papers received by the end of May are 50 papers covering the following 10 topics mentioned in the contents.

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About the Editor

Ali Sayigh, BSc, AWP, DIC, PhD is a UK citizen and graduated from London University and Imperial College in 1966. He is fellow of the Institute of Energy and the Institution of Engineering and Technology, chartered engineer, and chairman of Iraq Energy Institute, Fellow of the Royal Society of Art.

Prof. Sayigh taught in Iraq, Saudi Arabia, Kuwait, and England, from 1966 to 2004, specifically the University of Reading and the University of Hertfordshire. He was head of the Energy Department at Kuwait Institute for Scientific Research (KISR) and expert in renewable energy at AOPEC, Kuwait, from 1981 to 1985.

He started working in solar energy in September 1969. In 1972, together with some colleagues he established as an editor-in-chief *The Journal of Engineering Sciences* in Riyadh, Saudi Arabia, and in 1984 he established the *International Journal for Solar and Wind Technology*. The latter became *Journal of Renewable Energy* in 1990. He is editor of several international journals published in Morocco, Iran, Bangladesh, Nigeria, and India. He established the World Renewable Energy Congress/Network (WREC/WREN) in 1990. He is member of various societies related to climate change and renewable energy. He is chairman of Iraq Energy Institute since 2010.

He was consultant to many national and international organizations, among which are the British Council, ISESCO, UNESCO, UNDP, ESCWA, UNIDO, and UN. He organized conferences and seminars in 52 different countries; published more than 600 papers;

edited, written, and associated with more than 75 books; and supervised more than 80 MSc and 35 PhD students. He is editor-in-chief of *Renewable Energy Magazine* (published annually), since 2000. He is the founder of WREN—a Renewable Energy Journal published by Elsevier and was the editor-in-chief for 30 years from 1984 from 2014.

He is the editor-in-chief of *Comprehensive Renewable Energy*, coordinating contribution of 154 top scientists, engineers, and researchers in eight volumes published in 2012 by Elsevier, which won the 2013 PROSE award in the USA. He founded Med Green Buildings and Renewable Energy Forum in 2011. In 2016, he established the peer-reviewed international open-access journal *Renewable Energy and Environmental Sustainability* (REES), which is published in English online by EDP in Paris.

Winner of the Best Clean Energy Implementation Support NPO—UK, in 2018 WREN was rated globally as one of the best organizations in the UK promoting renewable energy. In November 2018, Prof. Sayigh was elected fellow of the Royal Society of Art (FRSA).

Part I
Mediterranean Future Cities Vision

Chapter 1
Refurbishment of Goris Old Bath Building as Tool for Historic Urban Environment Green Traditions Rehabilitation

Nune Petrosyan and Marina Bunatyan

First references about Goris old settlement go back to the thirteenth century. The old settlement was founded on the left bank of the Vararakn River, in a picturesque area surrounded with hills, rocks, caves, and ravines. For defensive purposes, dwellers used to build their homes—the Goris city, administrative center of the Marz (region) of Syunik—by carving the nearby cone-shaped rocks and in the caves. The neighborhoods were formed along the natural paths connecting the caves (Fig. 1.1).

Nowadays the city is located on the direction of the "North-South" transcontinental highway (currently under construction).

Also, Goris city is one of the rarely preserved historical cities still keeping its historical value via its urban identity: row construction, equally developed quarters of completely two-story houses of the authentic masonry construction, local basalt stone with edges softened by curved plaster decoration called "barqash," and two arched gates, one big for the cart and a small one for the people. Wooden hanging balconies decorate the road-facing side of the buildings and larger household ones on the rare-side internal yards—protected from the dominating winds. The city regular roadnet, equipped with irrigation channels along the roads, divides the city into equal quarters with approximately 100–120 m rectangular parts. All transversal road axes directed to the old cave rural settlement Kyores on the other bank of the river [1]. The central historical core of the city—almost completely consisting of historic buildings, immovable tangible cultural heritage—is involved in the historical heritage list adopted by the Government (Fig. 1.2).

The historic buildings' performance coupled with the regular roadnet has a significant cultural value in identifying the shape and sense of identity of the city. Due to the mentioned values, Goris city has the potential to be developed into a regional hub of culture and education, forming a sustainable economic region, and to ensure a high quality of life for the inhabitants. This considers also protection, revitalization,

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Fig. 1.1 Panoramic view of old (cave) and new (valley) Goris settlements

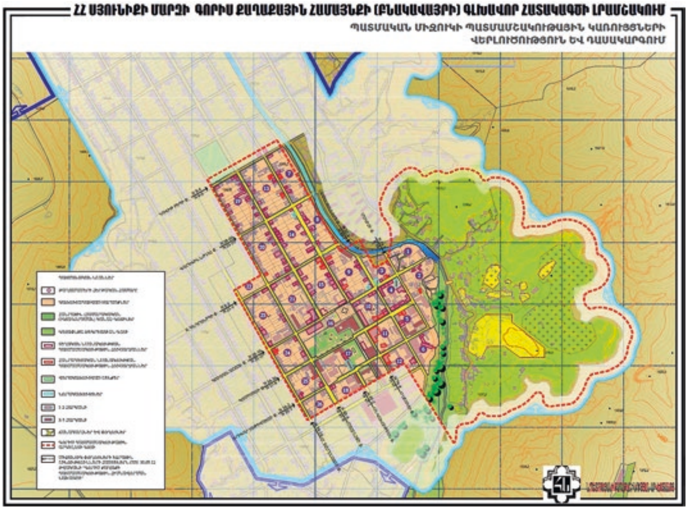

Fig. 1.2 Goris historic preservation (historical core)

rehabilitation, and refurbishment of the buildings of the historical core, thus keeping the urban identity. This considers evaluation of the buildings via their technical conditions, architectural value, and role in the city structure. A special role is given to the former bath building—a footprint and the only three-story preserved building of old Goris. Nowadays, the preservation via refurbishment of this historic building becomes urgent, as the level of damage caused by fire, which had taken away the roof of the building, is worsened by the precipitation and natural weathering of the materials, which finally can cause gradual and complete demolishment, thus partial loss of urban identity. The whole building itself is at risk. As a result the city can lose the only preserved of 2 three-story buildings and historical performance of the streetscape and silhouette of the city, thus the cultural value of the city as well. Old buildings of the city contain information about the history that happened before—in different times, different societies, and different cultures. So, preservation and rehabilitation play a cultural role and provide cultural continuity. The adaptive reuse of the old bath building is the ultimate form of recycling, which helps reduce construction waste from demolishing and save the energy that is usually spent on manufacturing and transporting building materials and tools (Fig. 1.3). The historical

Fig. 1.3 Old bath building current condition

core buildings make the heritage of Goris unique and recognizable in the world. The former bath house is situated in the middle of the street of Makich, mainly in the historically built district, registered in the monuments list. The building has suffered a major fire. Two main functions—bath and gymnasium—have been applied to the structure at different times, then in different levels of the building in the meantime. The architecture of the building differs greatly from the vast majority of the residential development of the center as by height, as well as by external decoration and material. The difference between the two-storied main buildings of the city's historical core is, firstly, the only three-story building in that segment, the difference in appearance is the combination of sandblast basalt and sandstone, using Goris's special arcade, original shapes of details—the three-centered circle arches of the windows and the special local design fences of the windows—also remained (Fig. 1.4). Currently, the structure is gradually declining with continuous weathering and rainfall, with a high degree of accidental breakdown. Thus, the issue of the resuscitation of the structure becomes urgent.

But the idea is not to keep the historic bath building as a museum, but rather to reuse to meet the nowadays needs of the population. To save a valuable part of the history of the city and to benefit local people, it is necessary to:

- Combine the state, co-financing, and private investments, even through stage-by-stage projects, to find solution for reuse of the structure (observing all possible options—guesthouse (retaining and reusing the separate rooms of the gymnasium, with formerly functioning decoration and furnishing, adapting to the given period and the given device), conference hall, IT technology center, craft training center, etc.). The solution to the problem solves one more important urban development problem in the immediate proximity of the main public center of the city within the framework of a historically active environment, in essence, the solution will increase the value and attractiveness of the entire neighborhood by activating the life of this segment and creating a better and safer environment thanks to the lighting and human flows, raising the value of real estate in this segment and ensuring security.

For the heritage identity protection, and in order to avoid the irreversible loss or decrease of the historical value via the intervention actions, during the sustainable refurbishment process of the historic building of public bath and gymnasium in Goris, a holistic approach to the building and its historic urban environment as united and integral system is needed. Below, one of the proposed options—IT technology center refurbishment—is presented (Fig. 1.5). The streetscape appearance, elevation, materials, details, and building technologies of the protected part are decided completely as the originals. Backyard parts, with damaged and demolished parts, are proposed to be rebuilt in a modern pattern, emphasizing the modern additions to the historic parts.

The tools of different sustainability certification apply a rating method to compare different options of the refurbished building to assess the improvements in energy efficiency and materials achievable through refurbishment. The optimal solution considers a junction between the environmental sustainability and the heritage

Fig. 1.4 Authentic details (fences, arch, fire place)

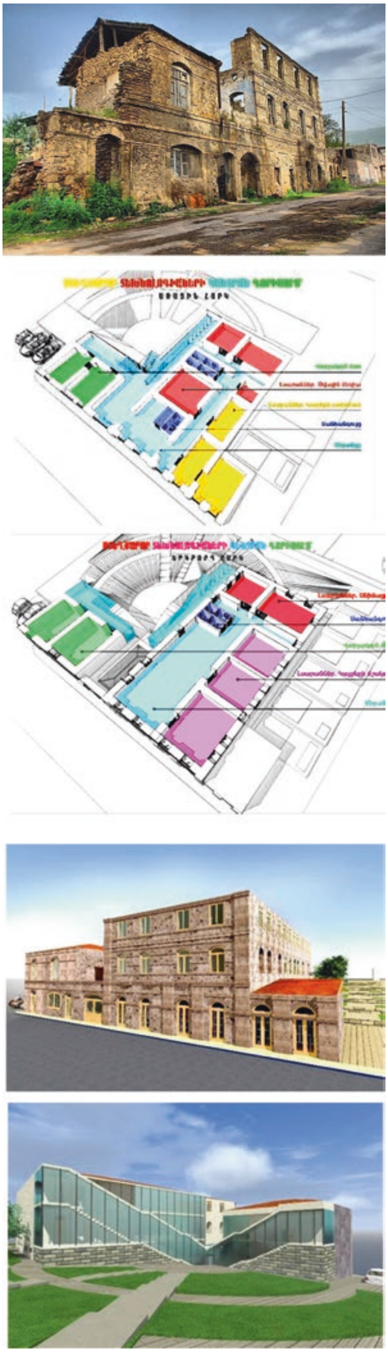

Fig. 1.5 IT center proposal

protection, as the historic bath building plays an important role in the preservation of Goris historical core identity and in the case of its refurbishment consideration of not only the aspects of savings through refurbishment but also a broader range of benefits from historic, artistic, cultural, and social values to the preservation of authenticity and use of materials compatible with the originals (Fig. 1.5). The outcome of the operation is both sustainable development and identity protection of historic urban development and also benefits for the citizens via working place formation and educational facility improvement.

In this case, some of the properties as of the buildings and also of the street and the built-up environment have been so defaced that they have altogether lost not only their character and beauty but also their significance. All the measures proposed are set to preserve the rich heritage of the historical core, particularly Makich Street architectural character, and to prevent further destruction and devaluation of these historic properties and rehabilitate the building and neighborhoods as green lively centers with tastefully preserved energy-efficient buildings and landscaping, promoting the development of creative technologies (refurbish the former bath and school building to green building of the IT center) [2, 3].

Conclusion

The properties identified of historical value include regulations that are established to protect and preserve the historic old bath building, such as:

1. Protecting and preserving architectural character and integrity of properties of the existing building and its environment that are considered of historical value.
2. Narrowing the Makich Street to slow down vehicular traffic and widening one-sided sidewalk to encourage pedestrian and bicycle traffic.
3. Introducing stone paving of street, with the restoration of the water channel, to further set the historic identity and atmosphere.
4. Beautification and landscaping by rich flora of local famous mulberry trees.
5. Proper green street lighting using urban design furnishing that fits the scale and historic character of the street.

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Chapter 2
Climate Adaptation Action: The Role of Clean Energy and Strategic Action Plans of South Mediterranean Cities

Mohsen Aboulnaga, Naguib Amin, and Bruno Rebelle

Introduction and Background

Sustainability and development are closely linked to overcome and counterbalance global climate change risks that are widely manifested in cities around the globe. These risks stand as major challenges toward development. Also, local governments face major challenges to adapt climate change risks and transform to more sustainable energy resources to achieve Sustainable Development Goals (SDGs) 2030. These challenges are highly populated cities, unprecedented urban sprawl and inefficient resource management, as well as high energy consumption and air pollution and water pollution due to less use of sustainable transportation and increase of environmental degradation.

Climate change (CC) worldwide has caused serious impacts in recent decades on both the natural and human systems. The manifestation of climate change impacts (direct or indirect) on the built environment has been witnessed in different sectors such as agricultural and food security, ecosystems, water, coastal zones, energy, forests, tourism, health and fishery [1].

According to Pedro B. Ortiz, it is predicted as part of the alternate plan B for climate change that, by the year 2100, the harm had already been done. Since the

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late twentieth and the early twenty-first centuries, mankind realized that the abuse of fossil fuel energy and gas emissions had caused climate change resulting in a world that overheated [2]. Also, fossil fuel emissions were stopped by 2035 in an attempt to adhere to the Paris 2015 Agreement, but nevertheless, the spin-off effect had already been triggered [3].

Published reports on July 12, 2018, stated that 200 hundred citizens were killed and thousands are striving for clean water due to torrential rainfall, devastating floods and landslides that hit many prefectures in Japan (Kyoto, Hiroshima, Kochi and Okayama) [4, 5] and in European cities in 2018 [6]. Energy, greenhouse gas (GHG) mitigation and climate change adaptation are high on the global agenda. The COP 22 (2016) resulted in a major political commitment and action on CC and SD [7], while Paris Agreement on climate change—COP 21—yielded a global long-term goal of keeping the increase in global average temperature to well below 2 °C above pre-industrial levels and limiting the increase to 1.5 °C, since this would significantly reduce risks and CC impacts [8]. This was supported by the outcomes and recommendations of COP 23 and COP 24 which were held in Bonn, Germany (November 2017), and in Warsaw, Poland (December 2018), respectively [9, 10].

Energy use worldwide was recorded in 2017 at 222 TWh with only 19% from renewables. Such energy use led to recorded CO_2 emissions from fuel combustion of 10.9 billion tons [11]. In most countries of the MENA region, the built environment, including buildings, is responsible for more than 50% of the total energy consumption [12]. In this endeavour, increasing the awareness and responsiveness of national authorities to the need for and benefits of a strong involvement of cities in local sustainability, notably in sustainable energy management, is an important step to achieve sustainable development and cleaner environment at the national level. In 2007, the Egyptian Government has established a National Committee on CC to develop strategies and policies that resulted in (a) the initial, 2nd and 3rd National Communication on CC reports of 1999, 2010 and 2014, EEAA and UNDP; (b) National Strategy for Adaptation to Climate Change and Disaster Risk Reduction 2011, UNDP; (c) National Air Quality Policy 2015, NAQP, UNEP; (d) Egypt's Indicators Development; and (e) Egypt's Vision and Sustainable Development Strategy 2030 [13–19].

Local governments (municipalities) can play a key role in achieving energy savings and climate adaptation actions. In this context, the EU initiated the regional project 'Cleaner Energy Saving Mediterranean Cities' (CES-MED) under the European Neighbourhood and Partnership Instrument (ENPI) in 2011 for supporting South Mediterranean countries, including Egypt [20, 21]. The EU is committed to reduce CO_2 emission by 20% by 2020 and more ambitious to reach at least 40% by 2040. The EU analysis of different scenarios shows that domestic emission reductions of 40% and 60% below 1990 levels would be the cost-effective pathway by 2030 and 2040 [21].

Scope and Objectives

This work highlights the results of an implemented European Union-funded project Cleaner Energy Saving Mediterranean Cities (CES-MED), contract no. ENPI 2012/309-311/EuropeAid/132630/C/SER/MULTI, which was covering eight countries in the South Mediterranean region (ENPI-South). The Cleaner Energy Saving Mediterranean Cities (CES-MED) project was conducted between 2015 and 2018 in Egypt and involves two governorates (Red Sea and Luxor), and the aim of the project is to support and strengthen the capacity and involvement of the local authorities to embrace and implement clean and sustainable energy policies with respect to national regulatory and legislative frameworks [21]. This project comprises four tasks: (1) understand the energy consumption in all sectors that utilize energy in the city, (2) map energy consumption over 1 year and CO_2 rate of emission, (3) develop the priority planned action to reduce energy use and CO_2 emission and (4) climate action. The scope of this work is to assess the sustainable energy performance of the two cities with the objective to develop a Sustainable Energy and Climate Action Plan (SECAP) including a baseline emission inventory (BEI) that is based on European Commission Joint Research Centre (EC-JRC) guidebook published in 2013 [22].

Methodology

In order to calculate the greenhouse gas (GHG) emissions, there are many recognized methods and tools developed by international institutions. Methods and tools for the GHG inventory vary based on many factors and locations. The inventory could be either measured or calculated. Most of the following reviewed methods and tools are estimates based on calculation and not measured. The Clinton Climate Initiative and ICLEI launched an emission tracker tool, known as the ‘Project 2 degree’ which encourages cities to calculate their GHG emissions of both municipal operations and the entire community in a uniform way and to enable cities to plan meaningful actions that save energy and money and make a profound impact in the fight against climate change [23]. ICLEI also created two tools: (a) International Local Government GHG Emission Analysis Protocol (ILGEAP)—intended to provide an easily implemented set of guidelines to assist local governments in quantifying the greenhouse gas emissions both from their internal operations and from the whole communities with their geopolitical boundaries [23]—and (b) HEAT tool [24]. In addition, the World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI) established the Greenhouse Gas Protocol–Corporate Accounting and Reporting Standard (GGP–CARS) with the purpose to mainly assist companies/organizations in preparing GHG emissions inventory through the use of standardized approaches and principles, to simplify and reduce the costs of compiling a GHG inventory [25]. It also provides business with information that can be used to build an effective strategy to manage and reduce GHG emissions. Nevertheless, the WBSCD and WRI also established another tool 'The GHG Protocol for Project Accounting' which is intended to provide a credible and transparent approach for quantifying and reporting GHG reductions from GHG projects to enhance the credibility of GHG project accounts by applying common accounting procedures and principles and providing a platform for harmonization among different project-based GHG initiatives and programmes [27].

Furthermore, several tools are available for different industry sectors. For instance, there is a tool for calculation of emissions from purchased electricity, heat or steam, a tool for allocation of emissions from a combined heat and power (CHP) plant and a tool for calculation of GHG emissions from transport or mobile sources [26].

More tools were developed by many institutions such as Bilan Carbone tool that was developed by Agence de l'Environnement de la Maîtrise de l'Energie (ADEME). This tool is also a method for companies and local authorities to calculate their GHG emissions. The Bilan Carbone encompasses a methodological book including an emission factor guide and Excel tools for territory and organization approaches with databases of 1500 emission factors, as well as a series of other Excel tools, e.g. help the user to generate data [27].

In the USA, California Climate Action Registry has established a method 'California Climate Action Registry Project Protocols', which aims to present the rules, policies and procedures for registering projects and creating offset credits with the Climate Action Reserve. It also describes the process used by the reserve to develop protocols for determining the eligibility of, and quantifying reductions from, carbon offset projects [28]. Also, this method depends on a tool called the CARROT tool [29].

In the UK, the Centre for Urban and Regional Ecology (CURE), School of Environment and Development, at University of Manchester has also developed a Greenhouse Gas Regional Inventory Protocol (GRIP), which is basically a stakeholder-orientated approach that focuses on mutual learning and depends on three main steps: (a) set up a regional greenhouse gas inventory; (b) develop 'energy scenarios'; and (c) use the scenario outputs to inform plans [30], and the tool can be found in [31]. The AEA Technology, report to Department for Environment, Food and Rural Affairs in the UK, has established a method called 'Local and Regional CO_2 Emissions Estimates for the UK (2005–2006)'. It is intended for estimating the local and regional CO_2 emissions. However, this method was done in 2005–2006 and provides a spatial disaggregation of the national CO_2 inventory on an end user basis in which emissions from the production and processing of fuels (including electricity) are reallocated to users of these fuels to reflect the total emissions relating to that fuel use [32]. However, this method has no tool developed, but it is a study providing spatial disaggregation of emissions in the UK, not meant to be a methodology for municipalities.

The Ecospeed in collaboration with Climate Alliance, European Energy Award, Swiss Cantons and Federal Office for Energy and Environment of Switzerland have developed 'ECORegion—Regional Energy—und Greenhouse Gas Balances' which offers local and regional authorities an easy and solid calculation method for energy consumption and CO_2 emissions. By providing the same methodology, the national data and calculation parameters with centralized data update each year in an Internet-based tool, a comparison of emission inventories of different cities is possible, and inconsistencies coming from the use of individual tools are erased [33]. This tool offers the preparation of a so-called start balance, where CO_2 emissions of the city are calculated only proportional to the number of inhabitants and to the number of employees in a total of 19 economic sectors (top-down approach). Based on this start balance, the 'end balance' can be calculated with individual data (bottom-up approach). In the case that no local data are available, the values calculated in the start balance remain included, offering complete data sets for the emissions in the different sectors which are more or less adapted to the local conditions [34–37]. The ECORegionsmart is a monitoring tool for energy end use and CO_2 emissions divided into three sectors: (a) household, (b) economic and (c) transportation. The ECORegionpro includes also industry, other non-energy sources and all greenhouse gases. ECORegionpremium is an advanced version of ECORegionpro including scenario-calculations and measures. ECORegioncommunity can be used to manage a portfolio of cities and municipalities which use ECORegion [38]. Nonetheless, this tool doesn't take other sectors into account, mainly public and tertiary buildings and renewable energy.

It is clear from the above review of methods and tools that there are only two tools that are concerned with calculating GHG emission inventory in cities and the rest are for either projects or companies and power plants. Thus, for the CES-MED project, the European Commission Joint Research Centre (EC-JRC) method was exploited to calculate the GHG emissions in the two cities. This tool was developed for the CES-MED project [39, 40].

Methodological Principles of the Inventory

The methodological principles of an inventory are the following:

- Emissions are assigned to energy consumers.
- Inventories must be addible: for example, if all localities of the governorate make their inventory, the sum of inventories equals the governorate inventory.
- A recent reference year: 2015, to describe a territory evolving rapidly.

Calculation Method

In this project, the baseline emission inventory (BEI) is a calculation, not a measure method. In order to get a complete consumption and emissions inventory, we used several statistical data from reliable sources (electricity distribution, building surface, energy bills for public buildings, etc.), on which calculation hypothesis was applied when necessary (energy costs, unitary consumption of buildings, etc.), to obtain energy use of all sectors and non-energetic emissions (waste, water, agriculture). Hence, this requires stakeholders' mobilization; data gathering, data processing and analyses were pursued. A full mapping of energy consumptions and GHG emissions to understand, describe and act efficiently was required (Fig. 2.1). Figure 2.2 also presents the method of the calculation. It is important to note that this method of simplified calculation approach is likely to be tainted by various uncertainties including (a) structural and activity data, (b) hypothesis and (c) emission factors. The level of uncertainty is illustrated in Fig. 2.3.

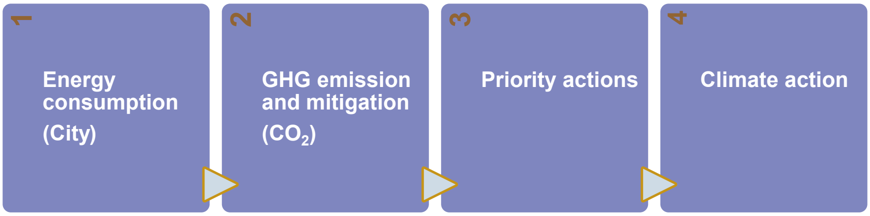

Fig. 2.1 The main process of the project

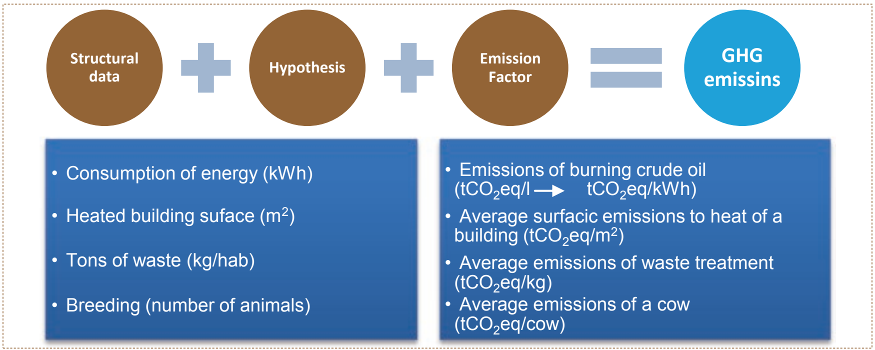

Fig. 2.2 Method of the calculation approach

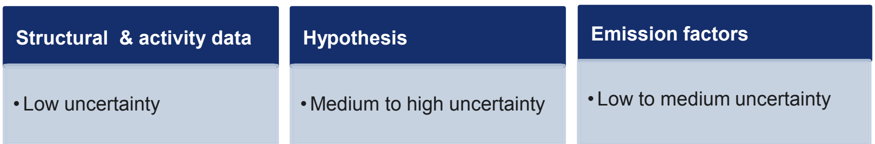

Fig. 2.3 Level of uncertainty

Considered Scope

Developing this BEI, we judged that it is necessary to include the following sectors but could not find sufficient hypothesis or structural data on stroke out subtopics. The baseline emission inventory (BEI) of two cities in Egypt was conducted (city of Hurghada, governorate of Red Sea, and the city of Luxor, governorate of Luxor) (Figs. 2.4 and 2.5).

The BEI, which is part of the preparation for the Sustainable Energy and Climate Action Plan (SECAP), is based on calculation not a measure. It includes the scope and methodological principles of the greenhouse gas (GHG) emissions of the city of Hurghada based on data collection from the Governorate of Red Sea and many other national and governmental entities. The BEI covers many sectors such as (a) residential buildings, (b) tertiary buildings and public lighting, (c) industry, (d) transport, (e) waste and water management, (f) agriculture (crops, animal production and fishing) and (g) tourism. To apprehend the results of the baseline emissions inventory (BEI), it was useful to understand the greenhouse gas (GHG) emissions' orders of magnitude in the world and in Egypt (Table 2.1). These average values are valid for the whole Egypt, including the city of Hurghada—Governorate of Red Sea. In the two cities studied by the BEI-SECAP team, the average GHG emissions per capita is aligned with the national ratio for the city of Luxor but significantly higher for the city of Hurghada (34% higher than the national average). This result for the city of Hurghada is due to the importance of the tourism sector. Knowing that the IPCC set a target of dividing by two the global human GHG emissions, currently

Fig. 2.4 The administrative area for the BEI, Luxor city—Governorate of Luxor, Egypt. (Source: https://satellites.pro/Luxor_map.Egypt)

Fig. 2.5 Impression of the city of Luxor, west bank and heritage sites

Table 2.1 Greenhouse gas emissions' orders of magnitude in the world and in Egypt

Item	Data
World human GHG emissions:	53 billion tCO_2eq/year
World human GHG emissions per capita	7.55 tCO_2eq/year
Egypt's GHG emissions in 2012	295 million tCO_2eq/year
Egypt's population in 2012	85,660,902
Egypt's GHG emissions per capita in 2012	3.44 tCO_2eq/year

Fig. 2.6 The administrative area for the BEI, city of Hurghada—Governorate of Red Sea, Egypt. (Source: https://satellites.pro/Hurghada_map.Egypt)

reaching an average of 7.55 tCO_2eq/capita/year, we observe that emissions of Egyptian citizens at 3.44 tCO_2eq/capita/year are already near the target (3.50 tCO_2eq/capita/year). However, Egyptians' GHG emissions tend to increase and could exceed this limit in the coming years due to the rapid development currently underway. Hence it is another reason why Egyptian cities need to develop strategic plans to reduce their energy consumption and GHG emissions.

Baseline Emission Inventory

The baseline emission inventory (BEI) was carried out for five centres within the administrative borders of the governorate, including the city of Luxor, Al-Bayadyah, Al-Toud, Al-Gornah and Al-Zeineyah; however, Armant and Esna were not covered (Figs. 2.4 and 2.5), whereas, the baseline emission inventories (BEI) for the city of Hurghada, Governorate of Red Sea, and the city of Luxor, Governorate of Luxor, Egypt, are presented in Figs. 2.6 and 2.7. Table 2.2 lists some date input of the two cities. The BEI is part of the preparation for the Sustainable Energy and Climate Action Plan (SECAP) and is based on calculations and assumption, not detailed measurements. The methodological principles of the GHG emissions are based on

Fig. 2.7 Impression of the city of Hurghada, Governorate of Red Sea

Table 2.2 Data input in the baseline emission inventory

Item	Value
Electricity emission factor (EF)	0.54
Year of data collection	2015
Cities' administrative area for BEI	416 km^2 (Luxor) and 111.3 km^2 (Hurghada)
Energy consumption	MWh final energy/year
CO_2 emission	ktCO_2 eq/year

data collection process and data crunching. The BEI covers consumption sectors such as (a) residential buildings, (b) tertiary buildings, (c) public lighting, (d) industry, (e) transport, (f) waste and water management, (g) agriculture (crops, animal production and fishing) and (h) tourism.

Compared to the Covenant of Mayors (CoM) recommendations for the SECAPs:

- Non-energetic and energetic GHG emissions for waste management and energetic GHG emissions for water and wastewater management (pumping, treatment, etc.) were taken into account as the two cities (Hurghada and Luxor) can plan actions on both of these topics.
- Non-energetic emissions of industrial activities (refrigerant leakage of buildings and vehicles) were not taken into account, as information on these topics wasn't sufficient. Note that these topics are not mandatory according to the CoM [41].

Additionally, it is important to understand what are the tertiary buildings. These are defined as all types of buildings that are neither residential, nor of industrial or agricultural uses, for example, stores, offices, banks, hospitals, logistical warehouse, sport and leisure facilities and other private service buildings.

Detailed Methodology for Each Sector

An Excel spreadsheet file was created to gather all data collected from the Governorate of Red Sea, specifically for the city of Hurghada (administrative borders) stating each source, year of reference and calculations made. This file allows data crunching to calculate GHG emissions from information related to energy consumption.

Common Data Sets

For the BEI calculations, statistics on both population and employment numbers were required to pursue this step. The population and employment statistics for both cities (Hurghada and Luxor) are gathered from the Central Agency for Public Mobilization and Statistics (CAPMAS) [42]. Table 2.3 lists the population for the two cities under study. One of the key reports used for producing this BEI is the Energy Balance Report 2013–2014 published by CAPMAS [42]. One of its tables describes the final consumption of petroleum products, natural gas and electricity for 2013–2014 per domain of activity (industry, transport, residential, agriculture and others). It will often be referred to the above table in the following sections, to ensure data coherence or to complete lack of data using national ratio per capita or more adapted units (land surface area). For the employment statistics, the employment figures are typical of Hurghada activities. Tourism is the main sector, with more than 33,000 jobs. So, to take into consideration this specificity, a specific part was created in the BEI. Table 2.4 lists the number of employed persons in 2015, whereas energy demands in Egypt per sector and energy (2015) is listed in Table 2.5.

Emission Factors of Energetic Consumption (IPCC, NREA)

The emission factors used for fossil fuels are those of the Covenant of Mayors guidelines (IPCC methodology). The emission factor for electricity is a local factor directly communicated by the Ministry of Electricity and Renewable Energy (MoERE) and the New and Renewable Energy Authority (NREA), and it includes wind and solar energy production (Fig. 2.8). In the city of Hurghada, there is one wind farm with a total power capacity of 5.2 MW and an annual production of 4628 MWh/year.

Climate Action

Climate action for internal guidance to the city of Luxor, Governorate of Luxor (Municipality), and city of Hurghada, Governorate of Red Sea, regarding the vulnerability of climate change, climate risk assessment and climate adaptation, was conducted. The proposed structure of this section has been developed based on extensive literature review. An introduction to climate change impacts, particularly in Mediterranean countries with emphasis on Egypt, mainly urban areas, costal zones, agriculture, water and ecosystems, health and tourism, was presented. It also highlights the national and regional strategy on climate change adaptation (CCA). A subsection dedicated to climate data feeding in estimations of the climate change impacts in the future, as well the evolution of the climate conditions in the area (temperature increase, rainfalls, etc.), was highlighted. The adaptation scoreboard

Table 2.3 Population of the city of Hurghada Red Sea and city of Luxor, Egypt (2015)

	2009	2010	2011	2012	2013	2014	2015
Egypt	80,442,443	82,040,994	83,787,634	85,660,902	87,613,909	89,579,670	**91,508,084**
Gov. of Red Sea	324,714	344,384	365,342	388,852	413,192	443,728	**472,203**
City of Hurghada[a]	**180,997**	**203,978**	**216,747**	**230,315**	**247,336**	**263,209**	**279,684**
Gov. of Luxor	N/A	1,031,014	1,099,304	1,073,284	1,088,445	1,119,000	**1,141,041**
City of Luxor[a]	**489,065**	**517,813**	**526,822**	**536,580**	**543,426**	**565,653**	**573,420**

[a]In 2015, the population of the city of Hurghada was 279,684 inhabitants, which is about 0.3% of Egypt's total population, whereas the population of the city of Luxor is 573,420 inhabitants, which corresponds to about 0.6% of Egypt's population, which is almost 50% of the Governorate of Luxor total population

Table 2.4 Number of employed persons in various sectors, Hurghada and Luxor (2015)

	Number of employed persons (Private, NGO, Gov.)			
	Manufacturing	Agro-food	Tourism	Total
Egypt (2012)	3,285,249[a]	7,991,148[a]	1,410,000[a]	29,596,846[b]
Egypt (2009)	3,104,720[a]	7,252,829[a]	1,620,000[a]	25,448,525[b]
City of Hurghada[c]	**313**[d]	**225**[d]	**33,238**[d]	**129,058**[d]
Luxor[c]	**7203**[d]	**3354**[d]	**22,856**[d]	**288,500**[d]

[a]Egypt country report for the 2014 ministerial conference on youth employment
[b]CAPMAS
[c]The data for the city of Hurghada represent the year 2015
[d]Hurghada Labour Force directorate

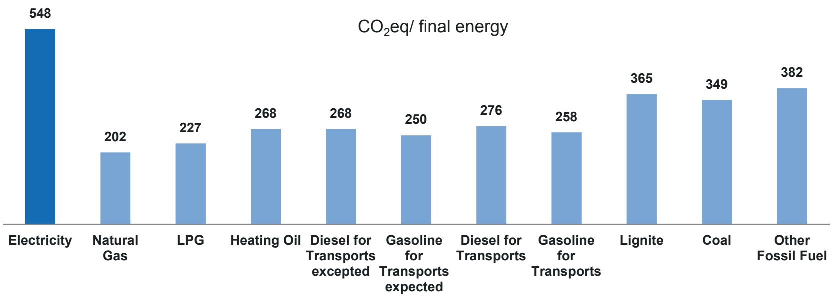

Fig. 2.8 Emission factors used in the BEI for fossil fuel and electricity. (*Source: Covenant of Mayors (COM) and MoERE—NREA*)

including a self-assessment from the Governorates of Luxor and Red Sea against the standard adaptation scoreboard in the SECAP template is also presented. Also, the assessment focused on the climate data and climate change projections with a climate overview in Luxor and in Hurghada highlighting the main climate trends and the climate change risks by sectors in both cities (Luxor and Hurghada) and the governorates' scores in the adaptation of cycle-specific steps. The risk analyses and vulnerability assessments that are based on the Future Cities Adaptation Compass tool were conducted and suggested templates for the risk assessment of the city of Luxor and city of Hurghada. Finally, the vulnerability analyses of both cities were carried out. The proposed adaptation actions in the city of Luxor and city of Hurghada, in terms of strategic actions, were highlighted and discussed.

Results and Discussions

Total Energy Consumption

Total energy consumption in the city of Luxor administrative boarder is estimated to be 4.937 GWh final energy/year (2015), equivalent to 8.61 MWh/person/year. This rate is considered to be high, due to the important impact of tourism. If tourism

Table 2.5 Energy demands in Egypt per sector and energy (2015)

Sector	Coal (ktons)	LPG (ktons)	Gasoline (ktons)	Jet fuel (ktons)	Kerosene (ktons)	Diesel (ktons)	Fuel oil	Other	Gas (Mm^3)	Electricity (MWh)
Industry	300	22			1.0	3110	2299		13,818	37,320
Transports			5927	628		3697	286		498	441
Residential		4135			3.3				1734	61,962
Agriculture					0.4	771				6310
Other						5123	86	1166	5503	37,552
Total	**300**	**4157**	**5927**	**628**	**4.7**	**12,701**	**2671**	**1166**	**21,553**	**143,585**

Final Energy Consumption/ Year City of Luxor	GWh/year
Residential building	1243
Tertiary building (inc. governorate buildings)	295
Public Lighting	6
Industry	518
Transport	2002
Water, Waste	27
Tourism	842
Agriculture*	4

* includes crops, animal production and fishing

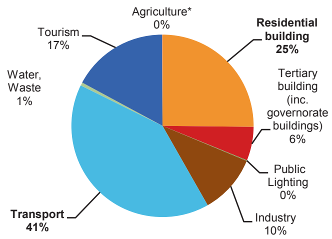

Fig. 2.9 Final energy/year (2015)—Luxor, Governorate of Luxor, Egypt

Final Energy Consumption/ Year City of Hurghada	GWh/year
Residential building	441
Tertiary building (inc. governorate buildings)	305
Public Lighting	11
Industry	16
Transport	1303
Water, Waste	10
Tourism	1196
Agriculture*	56

* includes crops, animal production and fishing

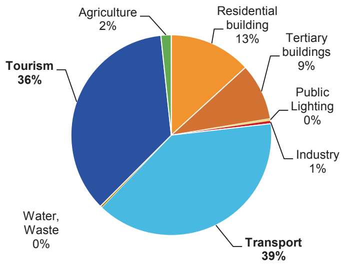

Fig. 2.10 Final energy/year (2015)—Hurghada, Governorate of Red Sea, Egypt

consumptions were not considered, energy consumption would go down to 7.14 MWh/person/year.

For the city of Hurghada, the total energy consumption is 3.338 GWh final energy/year in 2015, equivalent to 11.9 MWh/person/year. This rate is considered very high, due to the importance of the tourism sector. If tourism consumptions were not considered, energy consumption would go down to 7.65 MWh/person/year. Such energy consumption rate is still quite high; as in the case of the city of Hurghada, it was impossible to get a separate accounting of some transport sector consumptions linked to tourism activities. Figures 2.9 and 2.10 present the distribution of final energy consumption for each sector in each city.

Total GHG Emissions

Global GHG emissions of the city of Luxor are estimated to be 1797 ktCO_2eq/year in 2015 and correspond to 3.13 tCO_2eq/person/year (Fig. 2.11). This is an equivalent to 15.300 km drive by car. It is very comparable to the average emissions per capita in Egypt which is 3.44 tCO_2eq/person/year. For the city of Hurghada, global

GHG emission/ year City of Luxor	$kteCO_2/yr$
Residential building	501
Tertiary building (inc. governorate buildings)	17
Public Lighting	3
Industry	147
Transport	531
Water, Waste	14
Tourism	240
Agriculture*	204

* includes crops, animal production and fishing

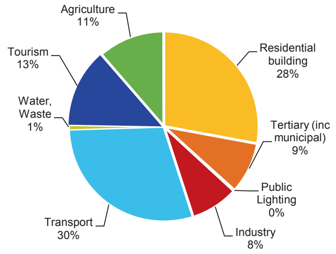

Fig. 2.11 Final GHG emission/year (2015)—Luxor, Governorate of Luxor, Egypt

GHG emissions/ year City of Hurghada	$kteCO_2/yr$
Residential building	215
Tertiary building (inc. governorate buildings)	158
Public Lighting	6
Industry	4
Transport	353
Water, Waste	23
Tourism	491
Agriculture*	88

* includes crops, animal production and fishing

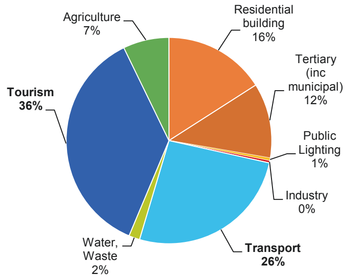

Fig. 2.12 Final GHG emission/year (2015)—Hurghada, Governorate of Red Sea, Egypt

GHG emissions are estimated to be 1338 $ktCO_2eq$/year in 2015 and correspond to 4.78 tCO_2eq/person/year (Fig. 2.12). This is an equivalent to 25,700 km drive by car. This GHG emission is significantly higher than the average emissions per person in Egypt (3.44 tCO_2eq/person/year), which is mainly due to the high weight of the tourism sector in the city. By excluding the specific emissions of the tourism sector, the emission rate falls at 3.0 tCO_2eq/person/year, which is lower than the Egyptian average, although this figure still contains some emissions from tourists' activities (goods transport and public transport) that couldn't be isolated from inhabitants' transports emissions.

Climate Actions

The Sustainable Energy and Climate Action Plan comprise seven priority actions including (1) transport, urban sustainable mobility master plan; (2) tourism, sustainable green boats; (3) tourism, green and sustainable hotels and resorts; (4) sustainable approach for governorate buildings; (5) sustainable approach for residential building; (6) solar energy development; and (7) green city awareness unit. However, focus will be on the highest three priorities. Results of the most important priority actions are presented. Results of the most important priority actions are presented. The action plans comprise three main folds: convert (retrofit) hotels and resorts, increase energy efficiency (improving natural venting and using LED lamps would reduce energy consumption by 75%), and use clean energy to mitigate GHG emission. (a) One option is to substitute fossil fuel with natural gas in combination with solar water heating systems (such as heat swimming pools); (b) convert engines' boats to run on natural gas instead of fuel and diesel and to cover on-board energy needs from solar PV on board; and (c) raise awareness among diving centres and diving boats or yacht operators to promote responsible tourism practices: optimization of boats occupancy, energy conservation, water and waste management and responsible approach of coral reef and marine environment. The cuts in energy use and GHG resulting from the actions (tourism and transport) in the priority sectors based on the actual use and emission (Table 2.6) are listed in Tables 2.7, 2.8, 2.9 and 2.10.

Priority Actions

Action results indicate that tourism and transport are the major sectors consuming the largest portion of energy in the city of Hurghada. Energy consumption in the tourism sector is 1626 GWh/year and GHG emissions 606 teCO_2/year and followed by energy consumption in the transport sector, which is 1303 GWh/year and GHG emissions is 639,649 teCO_2/year respectively (Table 2.6). Also, the greenhouse gases (GHG) emissions 'Business as usual' – BaU scenario 2015–2030 for the city of Luxor and city of Hurghada are illustrated in Fig. 2.13.

Business-as-Usual Scenario

Starting from present data, the BAU reference scenario projects the evolution of energy and emission levels forward to the target year (2030), under the hypothesis of continuing current trends in population, economy, technology and human behaviour, without the implementation of additional emission reduction actions. Thus, the Joint Research Centre (JRC) of the European Commission calculated the BAU coefficient for Egypt. For each year this coefficient represents the multiplication factor to reach the emission of the target year (2030). The BAU scenario of the city of Hurghada and city of Luxor forecasts an important rise of emission until 2020 (+34%) and then a stabilization until 2030 (−4%).

Table 2.6 Energy consumption and GHG emission in tourism and transport

Sector	Energy consumption	% of the total	GHG emissions	% of total
Tourism	**1626 GWh/year**	43%	**606,000 teCO_2/year**	44%
Tourism	Electricity	Natural gas	Water	Sewage water
	653,939 MWh/year	18,000,000 m^3/year	4,986,505,000 m^3/year	2,238,145,000 m^3/year
Transport	**1303 GWh/year**	39%	**639,649 teCO_2/year**	33%
Transport	Municipal fleet	Tourists' transport	Tourist transport GHG	Total GHG emission
	1773 MWh/year	1,302,887 MWh/yr	115,531 teCO_2/year	755,180 teCO_2/year

Table 2.7 Planned action results—tourism, city of Hurghada

Energy in MWh/year	Situation in 2015		Cut expected in 2030		Situation in 2030	
GHG in tCO_2eq/year	Energy	GHG	Energy	GHG	GHG (BAU)	Cut/BAU
Tourism	**1,196,294**	**490,915**	**−439,958**	**−218,077**	**633,280**	**34%**
Awareness raising (hotels and resorts) (10%)	1,114,026		−111,402	−46,084		
Hotel and resort refurbishment[a]	1,002,624[a]		−300,787	−164,564		
Awareness raising and occupancy optimization in diving boats	50,489		−5049	−1340		
Diving boats refurbishment[b]	45,440		−22,720	−6089		
Efficiency and renewable energy in harbour			pm	pm		

[a]Overall energy consumption of hotels after 10% cut due to awareness raising efforts
[b]50% after all efforts made on efficiency due to awareness

Table 2.8 Planned actions results—transport, city of Hurghada

Energy in MWh/year	Situation in 2015		Cut expected in 2030		Situation in 2030	
GHG in tCO_2eq/year	Energy	GHG	Energy	GHG	GHG (BAU)	Cut/BAU
Transport	**1,302,890**	**352,230**	**−521,160**	**−140,891**	**454,377**	**−31%**
Charter for transport service improvement			−130,290	−35,223		
Sustainable urban mobility plan:						
– Promoting new engines			−130,290	−35,223		
– Active mobility development			−65,145	−17,611		
– Traffic optimization through urban planning			−130,290	−35,223		
– Public service and RTB			−65,145	−17,611		

Table 2.9 Planned action results—tourism, city of Luxor

Energy in MWh/year	Situation in 2015		Cut expected in 2030		Situation in 2030	
GHG in tCO_2eq/year	Energy	GHG	Energy	GHG	GHG (BAU)	Cut/BAU
Tourism	**841,846**	**239,669**	**−247,050**	**−130,271**	**309,173**	**42%**
Awareness raising (hotels)			−2719	−1495		
Awareness raising (transport)			−3200	−858		
Awareness raising and occupancy cruise boats			−219,000	−59,000		
Cruise fleet refurbishment				−59,000		
Land transportation replacement			−6400	−1716		
Hotel and resort refurbishment			−10,876	−5982		
Efficiency of lighting heritage sites			−4855	−2670		

Table 2.10 Planned actions results—transport, city of Luxor

Energy in MWh/year	Situation in 2015		Cut expected in 2030		Situation in 2030	
GHG in tCO_2eq/year	Energy	GHG	Energy	GHG	GHG (BAU)	Cut/ BAU
Transport	**2,002,401**	**530,813**	**−800,961**	**−212,325**	**685,000**	**−30%**
Charter for transport service improvement			−200,240	−53,081		
– Promoting new engines			−200,240	−53,081		
– Active mobility development			−100,120	−26,541		
– Traffic optimization through urban planning			−200,240	−53,081		
– Public service and RTB[a]			−100,120	−26,541		

[a]Rapid transit bus

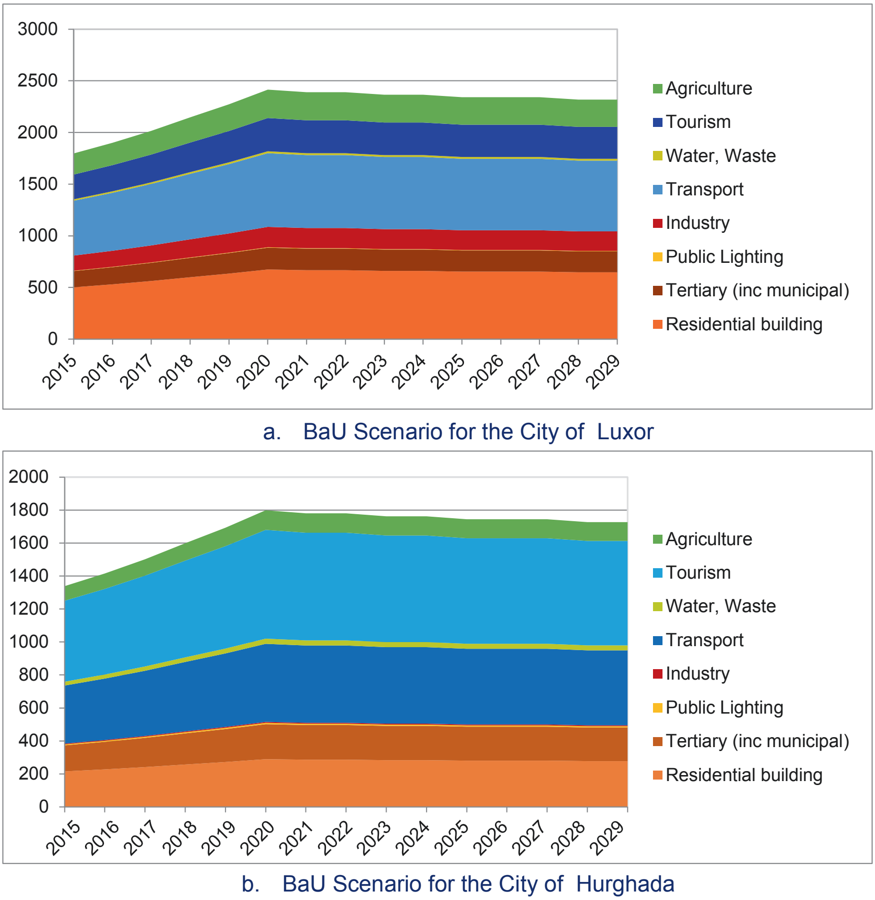

Fig. 2.13 GHG emission BAU scenarios 2015–2030—Luxor and Hurghada. (**a**) BAU scenario for the city of Luxor. (**b**) BAU scenario for the city of Hurghada

Table 2.11 Climate risk assessment of receptors, city of Hurghada and city of Luxor

Receptors	City of Hurghada		City of Luxor	
	Impact	Probability	Impact	Probability
R1—Public Health	1	2	2	2
R2—Transport	1	1	2	2
R3—Energy	1	1	1.5	1
R4—Water	1	2	1	2
R5—Social	1	1	2	2
R6—Buildings' stock and materials	2	2	1.5	2
R7—Tourists	2	2	2	3
R8—Agriculture	0	0	1.5	2
R9—Costal zones—ecosystems	2	3	2	2
R10—Green zones—forests	0	0	1	1

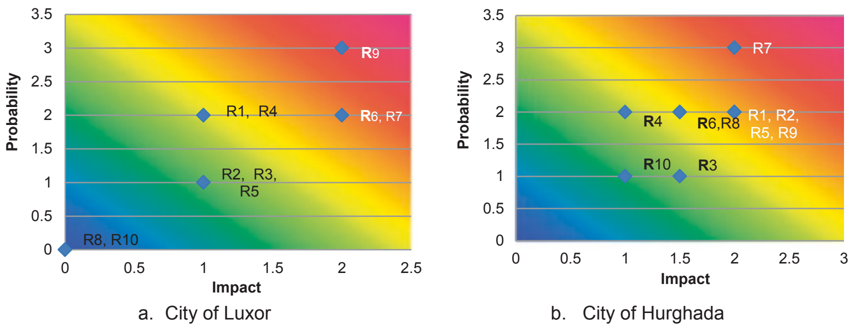

Fig. 2.14 Risk assessment based on climate data for both cities—Egypt. (**a**) City of Luxor and (**b**) city of Hurghada

Climate Risk: Vulnerability Analysis

Climate risk assessment based on climate data availability was carried out and presented. The vulnerability analyses of the city of Luxor and city of Hurghada were carried out by combining the results of Table 2.11 and the probability of scale 1 (high), 2 (medium) and 3 (low) for each receptor. Ten receptors (R_{1-10}) were used to determine the risk assessment: R1, public health; R2, transport; R3, energy; R4, water; R5, social; R6, buildings' stock and materials; R7, tourist; R8, agriculture; R9, costal zones–ecosystems; and R10, green zones–forests. Figure 2.14 shows the results of the assessment and the most vulnerable sectors.

Conclusion

Baseline emissions inventory (BEI) for both cities were conducted. Results indicate that tourism and transport sectors in Hurghada, Governorate of Red Sea, are the highest in terms of annual energy consumption and GHG emissions. Tourism and transport consumed total energy of 1626 and 1303 GWh/year and generated GHG emission 606,000 and 639,649 teCO_2/year, respectively. Also priority actions were developed in view of the BEI. Actions can be implemented to reduce these figures by 2030, if compared to 2015 figures. In tourism, energy consumption can be cut 37% (−439,958 MWh/year) and GHG emission by 44% (−218,077 teCO_2/year) as well as cut in emissions 34% from the BAU, whereas for transport, cut can be 40% (−521,160 MWh/year) and GHG emission 40% (−140,891 teCO_2/year) as well as cut in emissions 31% from the BAU scenarios. In terms of climate change risk assessment, coastal zones and tourists are most vulnerable to such impacts.

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Chapter 3
Smart and Sustainable Urbanism with Identity in Mediterranean Cities

Derya Oktay

Introduction

Although the concept of 'sustainability' in its modern sense emerged in the early 1970s in response to a dramatic growth in understanding that modern development practices were leading to worldwide environmental and social crises, during the 1970s and 1980s, the word 'sustainability' was connected with the quotation from the Brundtland Report 'development which meets present needs without compromising the ability of future generations to achieve their own needs and aspirations' [1]. However, with that definition hereafter, the notion of endurance and continuity was thought to be the domain of natural science that studied environmental measures to ensure that controlled growth meant that we use the earth in a way that endowed the same rights for future generations. Falling beyond the realm of natural science, the city, the community and their concerns were treated as separate entities, rather than being incorporated into the sustainability context. What is more, most of the literature viewed the city and urban living as detrimental to the natural environment and hence a challenge to sustainable development.

On the other hand, considering that the city is an organic and dynamic entity and may take many different forms and meanings at different time intervals, the 'time' factor needs to be taken into account as well. In line with these, sustainability can be regarded as a perspective or paradigm in which we consider the three dimensions of society, environment and economy together, extending the fourth dimension of 'time'.

Although there is an increase in frequency of use of the phrase 'smart city', the concept of a smart city itself is still emerging, and the work of defining and conceptualising it is in progress. The concept is used all over the world with different context and meanings, most of which are explained with the use of advanced

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technology. A range of conceptual variants generated by replacing the word smart with adjectives such as digital or intelligent are readily used and reused. Some are recognising the use of smart city as an urban labelling phenomenon, noting that the label smart city is a concept and is used in ways that are not always consistent. However, whatever term is used, one cannot say that the cities described as 'smart' are really smart. It should be accepted that a city is not the mere collection of buildings, and higher technology use alone in the buildings and environment does not ensure a perfect function, and people would ignore design that ignores them. So, what is needed is 'smart planning', not 'smart cities'. In an era in which serious environmental problems are threatening cities and their inhabitants, as cultural integrity is constantly under attack and many cities lack identifiable, socially inclusive and responsive environments, there is an urgent need for a radical shift towards a comprehensive strategy that would safeguard the environment and people along with the optimum use of technology, for which we use the phrase 'smart and sustainable urbanism'.

In line with these, this paper firstly provides a conceptual understanding of sustainable urbanism and a critical review of its philosophical and practical framework; secondly, it analyses the town of Taormina, a town with distinctive features in Sicily providing valuable clues for identifiable and ecologically and culturally sustainable development in the Mediterranean context. A mixed-method approach is used in the study accommodating literature survey, on-site analysis/observations and a user survey carried out by the author in order to understand the views and expectations of the local residents. The paper, finally, determines some key objectives for design/redesign strategies with a view to enhancing urban identity and sustainability based on the findings of the study.

Understanding Sustainable Urbanism

Sustainable urbanism grows out of three late twentieth-century reform movements that have transcended McHarg's antisocial environmentalism to highlight 'sustainable development', that is, a development which is non-damaging to the environment and which improves the long-term health of human and ecological systems [2]. The 'New Urbanism', 'Smart Growth' and 'Green Architecture' movements provide the philosophical and practical framework of sustainable urbanism. Each of these movements, however, has revealed certain insularity [3].

Within architecture and urban design, the movement known as the New Urbanism, which appeared in the early 1990s and has become a strong force for re-evaluating the physical layout of communities, cannot be considered efficient and urban, as its focus has been better-designed suburban development. New Urbanism cannot be considered new either, as it revives many ideas about the city and planning that was mainstream before the Modern Movement. Another criticism about New Urbanism is about the elitism within the movement [4]. The movement is open to criticism on a number of fronts indeed—in particular for being focused on better-designed suburban development, often for upper-income groups, rather than the creation of truly 'urban' places, and for not incorporating green building design and landscaping. Furthermore, it can be considered a new type of 'ideal vision' conceived, ordained and disseminated from above and not rooted in specific places or local cultures.

Just a few years later, in the mid-1990s, 'Smart Growth' evolved as an effort to recast the policy debate over sprawl in a way that more directly linked the environment, the economy and the daily life concerns in pursuit of a positive and sustainable urban growth as essential to the quality of the city and urban life [2, 5]. The movement focused especially on mechanisms to promote more compact, walkable and economically efficient urban development.

Compact cities are argued to offer opportunities to reduce fuel consumption for traveling, as homes, work and leisure facilities are closer together. They are also favoured by many in the field of urbanism because urban land can be reused, while rural land beyond the urban edge is protected. Economic benefits, due to high concentrations of people supporting local economics and easier access to services and facilities, are also suggested. Compact cities with higher densities may also mean that people are more likely to meet each other on the street than in low-density areas [6–9]. However, the case of the compact city cannot be said to be proven, and there are many counter-arguments on its 'negativity'. The overriding problem with the compact city is that it requires us to ignore the causes and effects of decentralisation and benefits it may bring.

On the other hand, anti-sprawl strategies, which have obvious consequences for green and open space, have frequently lead to deadlocks in planning, especially concerning green space. Research supports the intuitive belief of a beneficial relationship between contact with nature and quality of life. A city with high-quality and generous green spaces symbolises good planning and management, a healthy environment for humans, vegetation and wildlife populations and bestows pride on its citizenry and government. On that ground, it can be stated that if green space is deprived, a compact city may become the antithesis of a green city.

Overall, what is disregarded in all these approaches is that cities also have social-cultural aspects. As stated by Rees [10], 'Cities are the engines of economic growth, the centres of social discourse and the living repositories of human cultural achievement, but also nodes of pure consumption and entropic black holes of industrial society'. McKenzie [11] efficiently defines social sustainability as 'a life-enhancing condition with communities, and a process within communities that can achieve that condition'. In this understanding, social sustainability is a system of cultural relations in which the positive aspects of disparate cultures are valued and promoted and there is widespread participation of citizens not only politically but also socially in all areas of urban life environment.

To this point, we have to ask ourselves what specific measures need to be taken to create smartly planned sustainable urban environments. In this context, it is important to understand that the idea of sustainability is not new and the traditional cities are excellent examples to learn from regarding various dimensions of sustainable urbanism.

What Contributes to the Creation of Urban Identity?

Various elements contribute to the creation of urban identity as viewed from a holistic perspective. Based on a comprehensive review of the literature and the findings of the author's previous survey-based research [12, pp. 202–203; 13] and considering the results of observations (through an urban designer's eyes) of more than 50 cities in 27 countries, it can be claimed that the most powerful elements contributing to the identity of the city are natural environment, social-cultural environment, identifiable quarters, public spaces and, in some cases, landmarks.

Considering older and historic cities which have a strong identity, the most significant determinant of the urban identity is the local urban context that is formed by all elements of the physical and natural elements, in particular the urban environment created over generations. In this context, two important elements organise the city: the district and the public domain. However, the acknowledgement that the basic elements of the city are the district and the public domain, the street and the square, is in opposition to important trends in contemporary city planning. The dense district is today generally replaced by a scattered distribution of slablike buildings, which can hardly be recognised or imagined as an entity. Consequently, identity of the districts is lacking, and buildings are designed with little concern for their relationship to each other or for their effect on the quality of the city. Spaces left between them have become undefined, undesirable, useless and unliveable.

A major part of the urban experience is the experience of the public domain that could be differentiated into functional components, such as streets, parks, plazas and, in Lang's terms, quasi-public spaces that are either privately owned spaces open to the public or public spaces to which access is controlled [14]. In addition to providing for a variety of ways to get from one place to another, the public domain provides many spaces for a wide range of additional functions and activities.

On that ground, this paper will continue with a case study carried out in Taormina in Sicily, a town with distinctive characteristics in the Mediterranean, which teaches many lessons that can contribute to meeting contemporary and future planning and design needs, to test the ideas introduced above.

Case Study: Taormina (Sicily)

On-Site Analysis

Taormina is situated 240 m above sea level on the north-eastern coast of the island of Sicily. The town's geographical position and the magnificent landscape with its rich vegetation make Taormina a unique place and a favourable resort in the Mediterranean. The picturesque and orderly historic centre displays a large number of buildings and other remains from the town's Hellenistic, Roman and Medieval periods dating back to 396 BC. The town resembles a huge 'balcony' perched on the hillside with a dramatic view of Mount Etna. Presently, Taormina provides a large number of hotels, restaurants and a variety of entertainment facilities, where the majority of its residents (80%) earn their living from tourism. The history of Taormina has alternated between prosperity and decline under the rule of various civilisations including Greeks, Romans, Byzantines, Normans and Spaniards. The Greek theatre that dates from the third century BC is referred to as the 'Antique Theatre' and is the symbol and the major attraction of the town. It sits atop a hill surrounded by a dramatic landscape and overlooking Mount Etna (Figs. 3.1, 3.2 and 3.3).

The urban plan is of clear medieval origin, based on a number of thoroughfares, among which is the *Corso Umberto* (Umberto Street), the major street, along which there are several renowned meeting places, such as *Piazza IX Aprile* (9 April's Square).

Corso Umberto is a very well-defined semicircle in the urban texture of the old city and links *Porta Catania* (Catania Gate) in the south with *Porta Messina* (Messina Gate) in the north (Figs. 3.4 and 3.5). These two arched gates are in fact the gates to the heart of the historic town and provide a strong 'sense of place' marking 'inside' and 'outside' for the pedestrians. Much of *Corso Umberto* is typically medieval in appearance (Fig. 3.6). The street is narrow and paved with cobblestone, a locally appropriate material which does not reflect the heat in summer days but adds character. Buildings with a variety of styles line the street, and diverse

Fig. 3.1 The map of Taormina (Source: Bonechi, 1998)

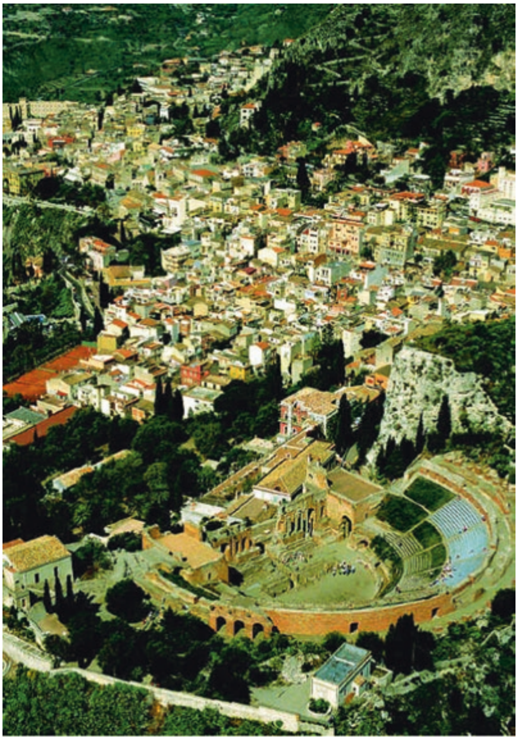

Fig. 3.2 The view to Taormina and the antique theatre (Source: Bonechi, 1998)

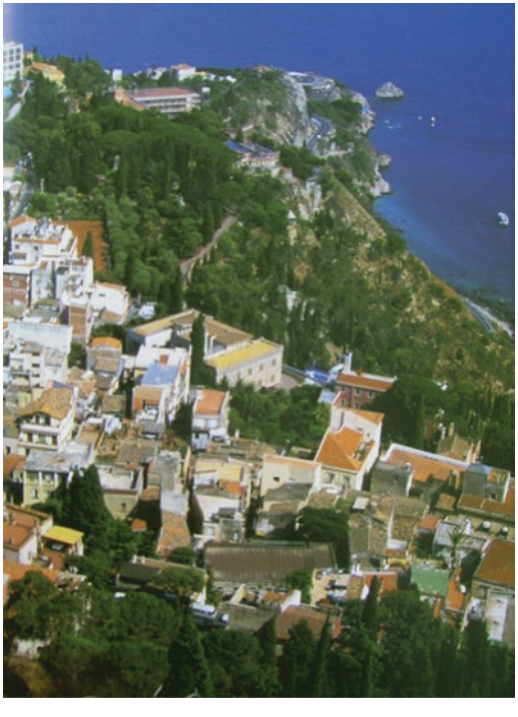

Fig. 3.3 The view from the town to the Ionian Sea (Author's Archive)

Fig. 3.4 Porta Messina (Source: Author's Archive)

Fig. 3.5 Porta Catania (Source: Author's Archive)

Fig. 3.6 Medieval houses on Corso Umberto (Source: Author's Archive)

functions, including the houses above the shops and restaurants, make it a place that is alive round the clock. The street is closed to vehicular traffic between the two gates and served by a loop of vehicular traffic on one side. It is fortunate that a new multi-storey car parking has been introduced outside Taormina allowing the visitors and tourists to leave their cars and walk to the city centre. Many lanes and alleys lead off it, many of which are spanned by arches and stepped (Figs. 3.7 and 3.8). These give picturesque glimpses of the surrounding hillsides with their luxuriant vegetation, gardens and villas and the maze of medieval alleys below against the background of the blue sea. Occasional small squares with bars and meeting places and a great variety of elegant shop windows make the walk along the street a very pleasant experience (Fig. 3.9).

Piazza IX Aprile (9 April's Square), the main square, opens out from the central street, *Corso Umberto*, breaking the continuity of the town's central axis. Surrounded and ennobled by buildings of considerable monumental and architectural interest, the square is a highly identifiable public space in the town. The piazza, shaded and embellished by plants, is not only the favourite destination of tourists and visitors, as the compulsory stop of the evening promenade along the main street, but also an outdoor 'living room' for the local residents as they get together in the afternoons and spend time watching the world go by. The clock tower dominates the lower side of the square and forms an entrance leading into the medieval town, separating the latter from classical and Hellenistic Taormina through an arch. Because of its strategic

Fig. 3.7 Typical stepped street in Taormina (Source: Author's Archive)

Fig. 3.8 Corso Umberto with Piazza IX Aprile on the left (Source: Author's Archive)

Fig. 3.9 Typical ornamented houses around Corso Umberto (Source: Author's Archive)

position, the piazza offers a panoramic view of the bay and of Mount Etna. Elegant open-air bars and meeting places invite one to take a rest (Figs. 3.9 and 3.10). The city offers many other plazas and many worthwhile historic buildings as well (Figs. 3.11 and 3.12). The medieval houses and palaces in the town, buildings of distinctive character, display a mixture of architectural styles.

It is fortunate that the newer parts of the city outside the gates are in harmony with the older core; the buildings were designed with sensitivity in topography each building having a view towards the sea and getting air like in the ancient Greek city Priene, the first planned city in urban history planned by Hippodamus [15]. The city's grid-planned streets divided the sloping hillside into blocks, which were further divided into lots for private housing. So, the characteristic slope of the hilly topography of Taormina is still perceived. The majority of those buildings are walk-up-type apartments, and in some cases, a green, semiprivate courtyard is provided between the building and the retaining wall by the street. Because of the steep topography, an apartment building could be situated between two parallel streets, and while the main entrance is from one street, car access could be given from the other street, with a car park located on the terrace of the building (Figs. 3.13, 3.14 and 3.15). The majority of the buildings was designed in respect to the local traditional architecture with appropriate interpretations. The architectural elements like roofs, arcades, terraces, balconies, narrow windows, pastel colours and ceramic ornamentations are the new interpretations of the local

Fig. 3.10 Life in Piazza IX Aprile (Source: Author's Archive)

Fig. 3.11 Variety of uses in and around Piazza IX Aprile (Source: Author's Archive)

architecture. Also, small public spaces or plazas are provided for local residents to communicate and socialise, while spending time outside (Fig. 3.16).

The castle of Castelmola is located in the Village of Castelmola near Taormina that was an outpost against foreign invasions. The castle, nestled atop a cliff

Fig. 3.12 A small square (piazza) on Corso Umberto (Source: Author's Archive)

Fig. 3.13 A quasi-square on Corso Umberto (Source: Author's Archive)

Fig. 3.14 The view towards the newer areas in Taormina (Source: Author's Archive)

Fig. 3.15 The view towards the newly developed areas in Taormina (Source: Author's Archive)

overlooking a beautiful landscape, is a point of attraction and reference point where one drives and looking over the unique context of Taormina provides an overall picture of the town that is good for the imageability, hence identity of the town. Located in the centre of the town, the municipal garden is a green area offering a panoramic view of the coast and of the volcano, with gardens mainly composed of tropical and local Mediterranean plants, all supporting the ecological sustainability.

Fig. 3.16 Gathering in a small urban space in central Taormina (Source: Author's Archive)

Fig. 3.17 The cable car connecting the town to the beaches (Source: Author's Archive)

The coast of the town, which could easily be reached by the cable car, is kept in its original character without creating an artificial, polished 'beach club' environment that could be found elsewhere. The sea has previously been exploited for fishing; however, today it is a fundamental tourism resource in Taormina (Figs. 3.17 and 3.18).

Fig. 3.18 The natural beaches in Taormina (Source: Author's Archive)

Results of the Analysis and the User Survey

In line with the analysis, on-site observations at various time intervals and the findings of the author's user survey with local people, visitors and tourists regarding their views and evaluations about the town and urban life, Taormina could be considered a sustainable city with identity owing to the following:

- Locally appropriate urban context, which was set out similar to Hippodamus's plan of Priene, allows most of the buildings to have a view towards the Ionian Sea and be naturally ventilated.
- Walkability owing to its compact urban form and human scale, enhanced by the regulations and introduction of a multi-storey car park outside the old city allowing the visitors and tourists to leave their cars and walk to the city centre.
- The use of cobblestone, locally appropriate material, as street pavement.
- Identifiable and frequented public urban spaces with unique qualities enabling local people to meet and socialise and visitors to pass the time.
- Mixed-used quality in central parts where houses, commercial and recreational uses and tourist facilities are mingled.
- Non-existence of separation between the local people and visitors/tourists, the possibility of perceiving the local lifestyle.
- Easy access to all parts of the town despite the level changes.
- Characteristic trees and local plants as the main components of the major public spaces.
- Rich architectural heritage and appropriately renovated and reused historic buildings.
- Economic viability of the town owing to its being a centre for cultural and recreational tourism including sea resources.

– Keeping the local Sicilian spirit without creating the image of a commercialised place.
– Satisfaction of the residents of the town with the fact that tourism prevails the urban life for 12 months of the year.

The characteristics of the town, which help create a strong identity, an important component of sustainable urbanism, can be defined as:

– Its geographical position surrounded by steep slopes, with buildings well integrated with the slope and the cliff in the background without creating artificial terraces
– Flexible-grid urban pattern applied on the steep topography
– Presence of a powerful symbol: the Greek/Antique Theatre
– Presence of a highly identifiable and well used major public space: *Piazza IX Aprile*
– Presence of a highly identifiable main street as 'a place to go': *Corso Umberto*
– Presence of great unity in the townscape; unity in diversity of forms, colours and functions
– Maintaining the authentic character, true to its identities, and keeping the local Sicilian spirit without giving way to Disneyland images, despite the prevailing tourist-oriented functions
– Opportunity of viewing the entire town from a higher level
– Rich greenery and landscape unifying buildings
– A hierarchical network of well-defined outdoor spaces
– Surprising effects: glimpses to the Ionian Sea walking through the streets
– Vitality in public spaces due to the range of mixed uses including residences
– Opportunity of having contact with local people in all areas including the main public spaces
– Similar age range of buildings
– Similar building materials and textures
– Narrow balconies with iron-worked railings and rich greenery
– Locally produced ceramic ornamentation and symbols on building walls
– Residents' direct contact with the street: sitting/socialising in their front balconies
– Transparency/visibility of functions seen as one walks through the spaces
– Similar pattern of ownership
– Common image of the town perceived by residents, visitors and tourists
– Mild climate
– Cheerful pace of life due to the flow of tourists in the streets and bars/cafes/restaurants

Conclusion

Considering the fact that a city is not the mere collection of buildings and higher technology use alone in the buildings and environment does not ensure a perfect function, what is needed is 'smart planning', not 'smart cities', as the latter is reduced to the technical perfection in the built environment. As we live in environments that have often been very damaged, in ecological, social and cultural terms, and lack qualities to perceive a place with identity, there is an urgent need for a radical shift towards a holistic approach to sustainable urbanism or smart and sustainable urbanism with identity. This calls for sensitivity to traditional urbanism and impact of global ideas, practices and technologies on local, social and cultural practices. In that sense, as determined above, the town of Taormina in Sicily possesses various characteristics that can inform modern planning and urban design.

Urban design of compact cities can obviously contribute to a more sustainable way of life, particularly in industrialised societies. However, since cities are all different in form and structure owing to a host of place-specific factors, it cannot be expected that they should all fit the same formula when it comes to the question of a sustainable urban form. The degree of compactness and/or defragmentation should therefore be context-sensitive, like in Taormina where the urban texture is nicely fit with the steep topography both in the older and newer areas of the town without damaging the natural line of the slope, an important element of the urban identity.

Public spaces should be paid great attention, not only in central districts but also, and most importantly, in the urban edge and newly developed settlements, where the space between is becoming more important as densities increase. The community should contain an ample supply of specialised open space in the form of squares, greens and parks whose frequent use is encouraged through placement and design. Public spaces should be designed to encourage the attention and presence of people at all hours of the day and night. Inspired by Taormina, new urban areas could be planned and designed around a hierarchy of spaces for different purposes, the idea of shopping strip could be revived in order to prevent the shopping malls to be the norm, and the street pattern could be organised in a way that each street has an identity through the continuity, design and functional layout of buildings. The streets should be designed first for people taking into account the functional and aesthetic needs of people rather than complying with cars only.

We must widen our definition of the sustainable neighbourhood to include social as well as environmental concerns. In the new settlements, there must be places that foster special rituals where all residents come together in common pursuit and observance as used to be done in the streets and courtyards. There should be places that support multiple public activities, recreation and settings arranged to encourage safe, and everyday, personal exchanges among people who might otherwise remain strangers. Further, it should be kept in mind that social sustainability is a system of social-cultural relations in which the positive aspects of disparate cultures are valued and promoted and there is widespread participation of citizens not only politically but also socially in all areas of urban life environment.

As observed in Taormina, which possesses an ideal integration with the natural environment and climate, sustainable urbanism seeks to connect people to nature and natural systems, even in dense urban environments. In this context, an attempt at integrating such features as edible landscapes of fruit trees into the city would be beneficial for dwellers in terms of lower heating and cooling bills, lower food costs and reduced risk of flooding and landslide damage. Trees with canopies can be used for their shadowing effect and for the definition of spaces both in streets and courtyards. As for architecture, briefly, what are important to sustainable buildings are conformity of the building to its environs and in particular to the climate, the use of local and regional materials and the flexibility to adapt to changing conditions over time. High-tech innovation and new sustainable technologies undoubtedly have an important role to play, but in an energy-depleted world, cities that can delink from their dependence on these are likely to be more resilient.

Naturally these ideas and principles will not achieve their objective without an appropriate application strategy. Urban planning and design are a shared responsibility, and putting aims into practice depends on evaluations within a far broader political-economic context. For this reason, a common vision shared by every strand of society needs to be determined, and for this to materialise in the long run, uncompromising efforts must be made that do not resort to low quality and cheap solutions.

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Chapter 4
Climate Action: Urban Farming as an Innovative Tool for Regenerating Cities to Be Sustainable—Case of the City of Conegliano, Italy

Mohsen M. Aboulnaga, Youssef M. AbouZied, and Sara S. Abouelsoud

Introduction

Cities are a major source of resource consumption and GHG emissions due to rapid population increase and urban activities [1]. According to the UN-Habitat, cities are responsible for 50–60% of the global CO_2 emissions and about 75% of the global primary energy with buildings and transport as major contributors [2]. The city of Conegliano, Italy, is experiencing climate change impacts, specifically sustainable urban development; thus, resilience of urban infrastructure is essential in adapting to global climate change risks. In 2003, after 10 years of the evolution of Zoppas-Zanussi to Electrolux group, production has been transferred out of the centre; since then this area was abandoned and turned into a "black hole" that left a huge site (165,000 m^2) with less economic, social and environmental values [3]. Many proposals for urban regeneration were taken into account, but none is manifested until now; hence, the city of Conegliano should be green and sustainable [3]. Urban agriculture plays an increasingly important role in global food security [4]. It provides a solution for growing needs of cities to expand without harming the ecological balance and produce clean food. Integrating urban farms into the city fabric has many economic, social and environmental benefits. It offers clean food, while improving air quality resulting from carbon emissions and air pollution mitigation. It also helps in creating solutions to wastewater and organic waste in megacities, contributes to creating jobs, supports the economic growth by increasing the GDP and acts as a "zero kilometre" self-sustained economy, healthy communities through providing organic food, in turn, green spot for the city [4].

Urban farming has been extensively exploited to harvest edible plants and vegetables in Europe, particularly in Milan (Stephen Borie), and in many parts of the world including Japan, China, South Korea, the USA and Europe [5–8].

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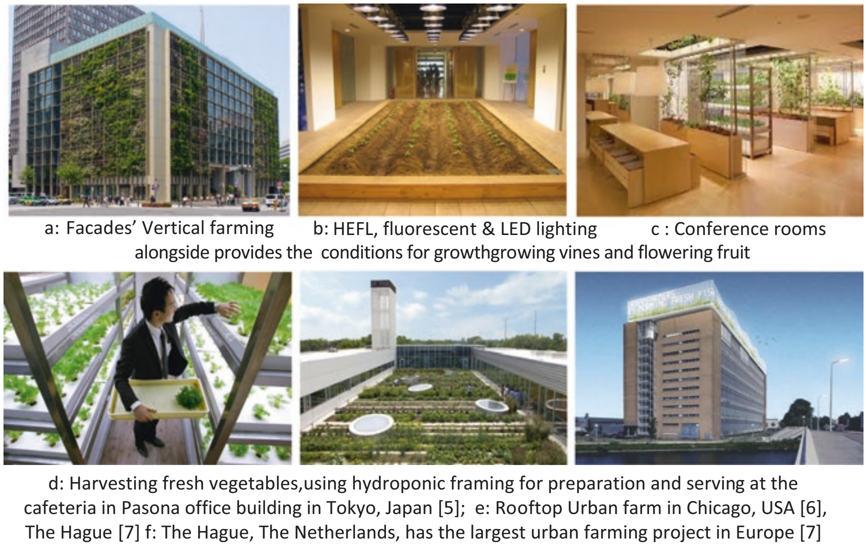


Fig. 4.1 Examples of urban farming in different cities (Asia [5], the USA [6] and Europe [7]). (Source:https://asiasociety.org/blog/asia/multimedia-downtown-tokyo-office-farm-takes-green-building-new-heights)

Figure 4.1 illustrates some of the examples in Europe and Asia. In Pasona building in Tokyo, a total of over 200 species of fruits, vegetables and rice live within Pasona, including lemons, broccoli, salad greens, berries, squash, eggplant and passion fruit [5].

Objectives

The aim of this work is to redevelop the abandoned site of Zoppas-Zanussi to Electrolux group of Conegliano and to improve livability in the city through innovation. The study focuses on the building and surrounding site by virtue of using urban farm incorporated on the building's walls and roof. It also addresses the project's economic sustainability, environmental sustainability and social sustainability to meet Sustainable Development Goals. Figure 4.2 shows the objective and sub-objectives of the study.

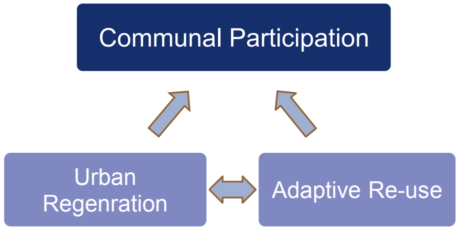


Fig. 4.2 Sub-objectives of the regenerative city

Fig. 4.3 The site and abundant building of Zanussi factory, city of Conegliano, Italy. (Image (**a**) source: www.Google.com/map/, Image (**b**) and (**c**) source: https://site.unibo.it/urban-farm/en/location-2019/conegliano-zanussi-area)

Issues and Challenges

The problems of the city are:

- Site and building are a brown field (Fig. 4.3b, c).
- Scarcity of public and green areas.
- Inefficiency in adaptive reuse policies of this abandoned site for more than 10 years.
- Site area is very large reaching more than 165,000 m^2.

Figure 4.3 shows the site and building before utilizing urban farming, sustainable, smart architectural solutions and technologies in the city of Conegliano, Italy. Urban farming is a challenging design issue for architects and urban designers alike as it tackles a new typology of buildings introduced to the city and its people (Fig. 4.4). Also, urban farming has a high maintenance cost of creating the built environment for plants. Urban farming consumes many resources, thus producing high CO_2 emissions.

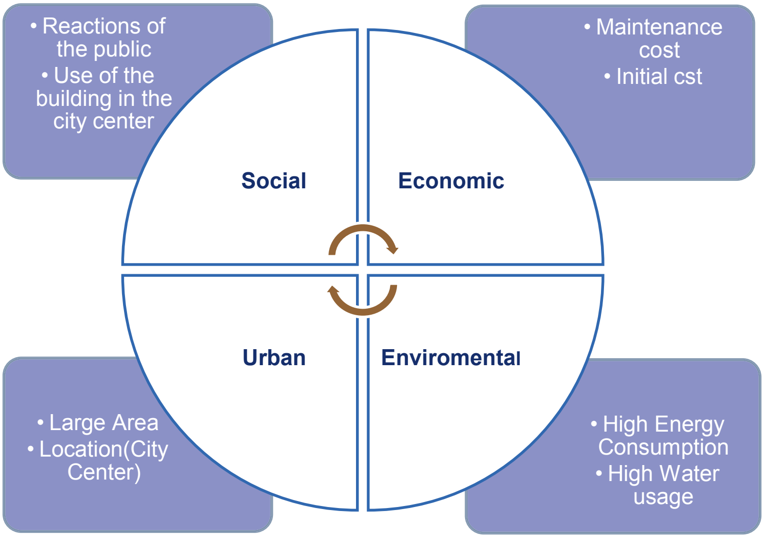


Fig. 4.4 Design challenges of urban farming

Methodology

The methodology of the study depends on inductive and applied approaches: the first includes a review of the site and assessment. The second applied innovation, solutions and technologies by analyzing the site and building's design approaches that were executed in the project exploiting urban farming and architectural solutions and systems.

The Site and Architectural Features

Site Assessment and Elements

The abundant Zanussi Factory is located in Conegliano, Province of Treviso, Italy. The site is considered a great asset due to its location near the city centre (Fig. 4.5), located in a viable area surrounded by many bus stations, Conegliano central train station and four main streets (Via Daniele Manin, Via C. Colombo, Via Cesare Battisti, Via Innocente Pittoni), which secures a high flow around this area and thus making it a possible hub for the city as shown Fig. 4.6. In addition, the community garden (Parco Mozart) is located on the northwestern part of the site, acting as an important constrain to the design through its attraction to users as well.

Fig. 4.5 Layout of the city of Conegliano, Italy

Fig. 4.6 Urban setting and transport network about the site, Conegliano, Italy

Architectural Features and Solutions

This project is considered to be a social and an economic HUB for the city of Conegliano, Italy. Therefore, it is designed to represent this innovative idea in the best possible way (Fig. 4.7). The building is oriented towards the NNW while the longer sides area towards ENE and WSW, which have high solar exposure compared to the other facades. To adapt to this problem, we added Boston ivy plants on a cable trellis system (Fig. 4.7) to help in reducing solar gains, produce oxygen and represent the urban farming growing inside the building on its outside along with double-glazed glass to minimize heat gains (Figs. 4.8 and 4.9).

The internal building is divided into many sections; this distribution of suggested uses inside the existing building's skeleton of the old factory without demolishing any part was thought of in order to minimize the waste in embodied energy. The spaces are distributed according to the convenience of the existing space to the spatial requirements of the new one as shown in Fig. 4.8. The site contains a large unbuilt area in the western part. In this project, it was intended to redesign such area to serve our project and, in turn, the city (Figs. 4.9 and 4.10). The outdoor areas include a main piazza, green areas and a kid's area to emphasize social interaction (Fig. 4.9). In addition, it was intended to create a buffer zone on the northern part of the site by using wind turbines to generate electricity, while creating a barrier from

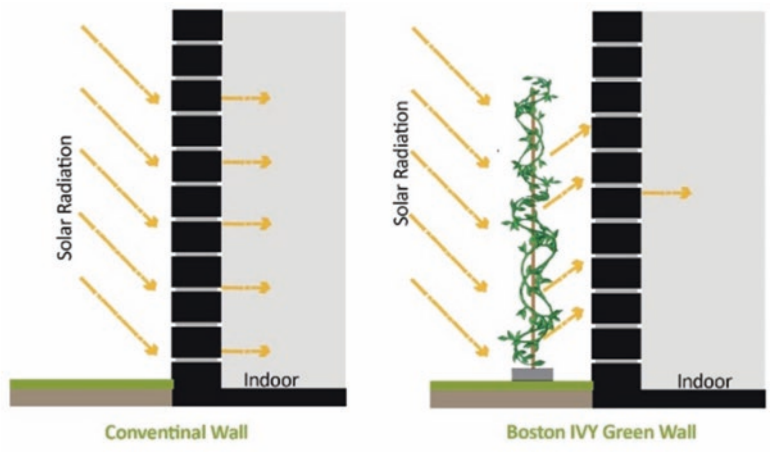
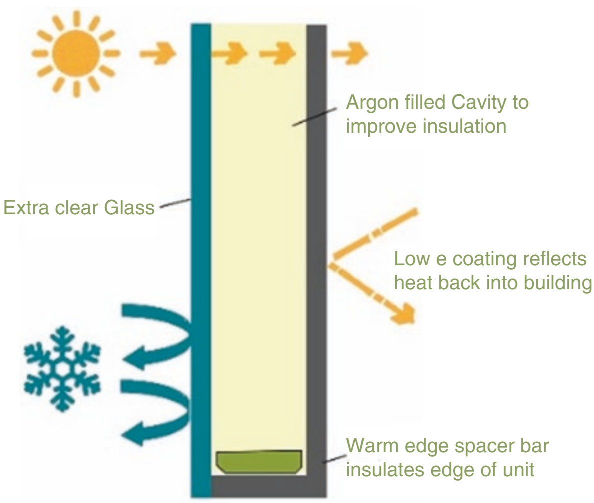


Fig. 4.7 Boston ivy façade. (Source: Credit Authors)

Fig. 4.8 Double-glazed glass. (Source: Credit Authors)



the train railway generated noise as well. In this project, it was realized the importance of having a self-sustained project that can operate for many years with least amount of energy, minimal waste and best possible production as shown in Figs. 4.10, 4.11 and 4.12. It has been decided to use an aquaponic system along with Boston ivy facades in order to minimize water and energy waste in our project (Fig. 4.13).

Two types of plants are exploited in the project; each is used for a specific reason (Fig. 4.14):

Fig. 4.9 Main façade view. (Source: Credit Authors)

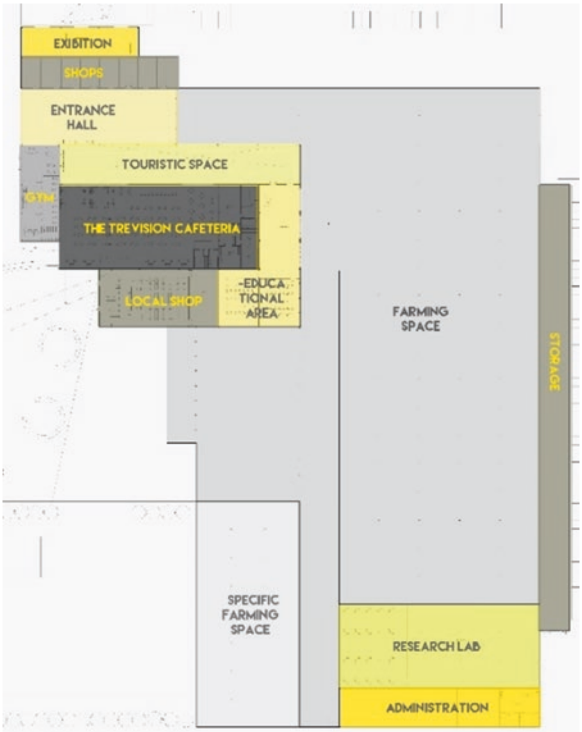


Fig. 4.10 Project zoning and uses. (Source: Credit Authors)

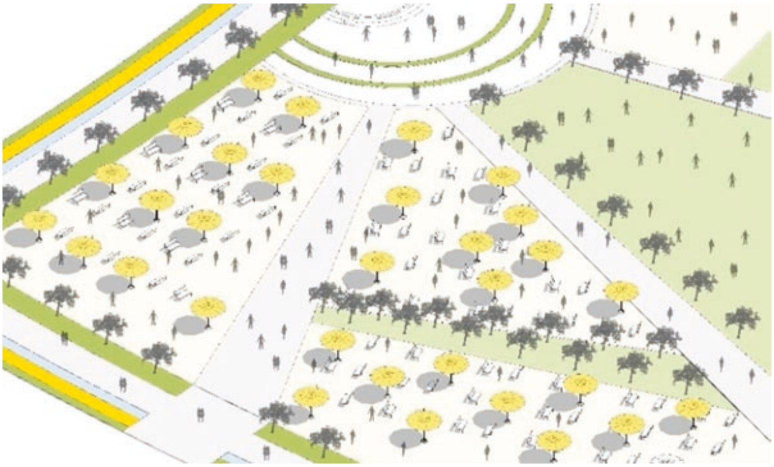


Fig. 4.11 Outdoor piazza. (Source: Credit Authors)

Fig. 4.12 Current project vs. traditional farms

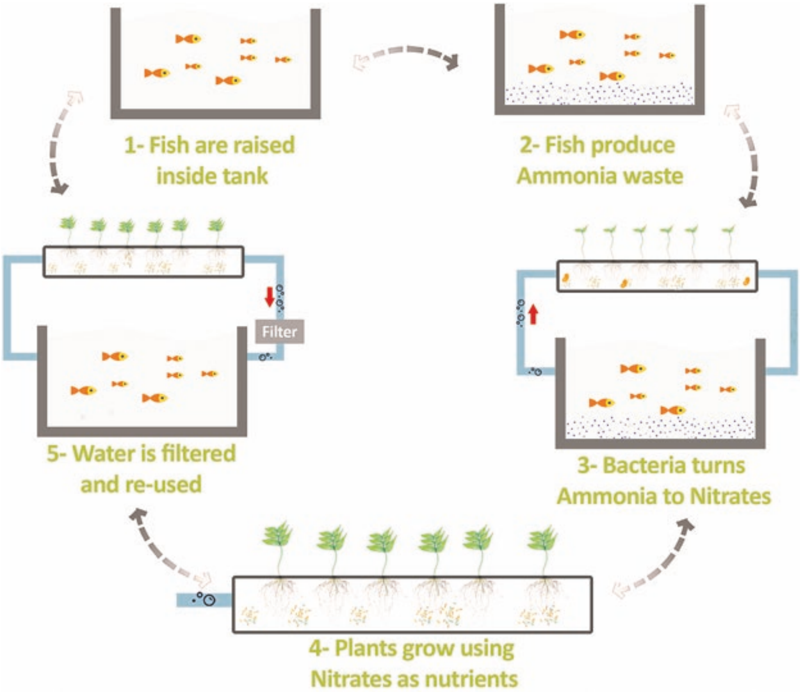


Fig. 4.13 Aquaponic system

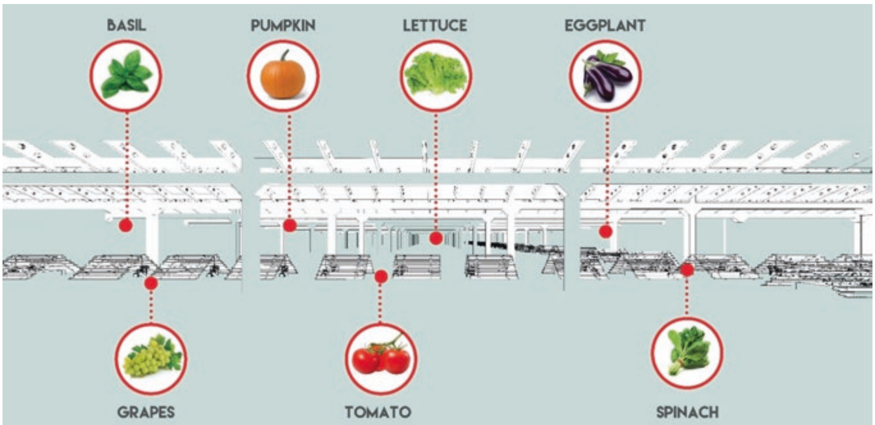


Fig. 4.14 Cultivated vegetables and herbs

Fig. 4.15 SWOT analysis of the project development in Conegliano, Italy

(a) *Glera grapes (Vitis vinifera "Glera")*: This type of grapes is the one used to manufacture the well-known *Prosecco wine*. We intended to provide grapes for the wine industry found in Conegliano and its suburbs to help grow the industry, while providing adequate income for the project.
(b) *Tomato*, *basil*, *eggplant*, *lettuce*, *spinach and pumpkin*: These products can be cultivated easily in an aquaponic system, while also being part of the daily diet of this region. These plants are found in many of the signature dishes of Conegliano.

These plants are found in the daily diet of Italians and can be cultivated in the weather conditions of the area [9].

- *SWOT analysis*

  A SWOT analysis on strength, weakness, opportunities and threats was conducted on the different points found in the project. Figure 4.15 depicts the findings of the assessment.

The Project and Sustainable Development

The main challenge for this site was its huge scale, but at the same time, it was its biggest asset. Since we decided that we wanted to create a new Green Hub, we had to make it as sustainable as we could. Given the size of such project, it was a challenge to address all three pillars of sustainability and balance between them. The following SDGs: SDG 7, affordable and clean energy; SDG 8, decent work and economic growth; SDG 11, sustainable cities and communities; SDG 12, responsible consumption and production; and SDG 13, climate action (Figs. 4.18 and 4.19), were addressed.

Economic Sustainability

The economical aspect is considered one of the important aspects of sustainability as the cost of the project can determine the feasibility of the project. In this project we decided to distribute the sources of income found in the project in order to help supply the farm with enough money to cover its expenses, while keeping the produce in a considerably low price for the people to buy easily (social aspect). In addition, some services that are found in the project are provided for a considerably low or discounted fee to help serve the community with the least possible charge on the people. The main sources of income in the project are the money earned from the grapes sold to the wine industry and products sold in the local store, the cafeteria and the rented shops.

The variety of income sources helps maintain the project's viability. We wanted to create a project that can be self-sustainable whether economically or environmentally.

Social Sustainability and Innovation

The social aspect in the project was a key element that was addressed in the design process itself. The main factor of success in this project lies on the communal participation as we are aiming to create a new vibrant city in the heart for Conegliano. We wanted to create a project that the people felt that they belong to and are part of. The Green Hub contains many spaces that encourage social interaction: the outdoor piazza, kid's area, gym area and the cafeteria.

All these spaces are designed for the people to come and visit the site on a regular basis to feel that this area became a part of the city fabric once again; thus, this sense of belonging will ensure the livability and viability of this project for years to come.

Environment Sustainability

Last, the environmental pillar was tackled in the project too. We tried to reach a near-zero energy and waste building through a design of dependent systems that work with each other to minimize the waste of materials or energy. This was designed on many levels: (a) the aquaponic system that helps minimize the water waste and recycles the fish and plant waste as mentioned before; (b) the wind turbines found on the northern part of the site help to generate onsite energy that helps reduce the energy waste and thus minimize the costs; (c) the energy efficient LED lighting, for the facades; and (d) the Boston ivy that requires minimal maintenance and adapts to the cold weather of Conegliano mixed with double-glazed glass to minimize the heat loss in winter and heat gains in summer.

To mitigate GHG emissions mainly CO_2, attempts were made to reduce the project's carbon footprint and keep the site eco-friendly as much as possible. Another important decision was taken into consideration to keep the current structure, while retrofitting it to ensure environmental sustainability by reducing the waste, hence the embodied energy.

Business Model and Feasibility

- **Business Description:**
  - The Green Hub® is an upcoming project located in Conegliano, Italy. An urban farm project provides this city with organic produce along with a social hub for the people to enjoy. The products are mainly targeting the local community along with the wine industry.
  - The wine industry is one of the largest in this city, and their Prosecco wine is well known both inside and outside Italy.
- **Products and Services:**
  - Conegliano is already known for the wine industry found in the area and the presence of the Conegliano School of Wine reflects the importance of such industry. The difference between our project and the other vineyards is that our grapes are organic and produced in monthly cycles to keep constant supply to the wineries as it is cultivated in an induced environment. Also we cover the social aspect for the city as we intend to create a central area for the people to visit and enjoy themselves.
  - This area can be used by anyone as a public space that contains various entertainment elements for different age groups.
  - The users have different choices upon arriving to the site:

    Using the public area (piazza) to enjoy some relaxing or family time
    Visiting the Treviso cafeteria that serves local dishes made with fresh products from the farm
    Using the public gym area
    Shopping at the local store that sells organic products from the farm
    Having an educational tour to see the urban farm from inside and learn more about the process

  - All these options provide an experience that cannot be found in a traditional vineyard and thus making it having an advantage than any ordinary farm.
  - We aim to create a project that the people will like and enjoy spending time with as they feel a sense of belongingness and thus helping to keep this project running for a long time.
- **The Market:**

  The wine industry has been in this area for centuries and the Conegliano School of Wine was founded in 1876 due to the importance of this profession [10]. The ex-Zanussi area has been abandoned since 2003, and many of the city officials have debated over this area, and several purposes of urban requalification have been taken into account, whose the best idea is to use the area for an urban agriculture project promoted by Bologna University International Challenge, UrbanFarm 2019.

- **Competitive Factors:**

  The following items and factors are listed to assess in the SOWT analysis against the factors as shown in Table 4.1.

From the above, we might conclude that we are a few steps behind the other competitors; however we are providing healthier produce, better quality and on site social services to contribute more to the community and the city.

Startup Expense Capitalization

The initial cost for the startup will be for renovating the site and buying the required equipment and systems for each space according to its design. An investor along with governmental grants and sponsorships that could help the project to start shall cover the costs.

Table 4.1 List of competitive factors and indicative results for the SWOT

Items factor	Our project	Strength	Weakness	Competition	Importance
Products	Grapes, vegetables and leisure services	Variety of products and services	Risk of being distracted with different aspects	Provide only grapes	Critical
Price	Above average pricing	Price/quality ratio is very good	Higher pricing than usual for the buyers	Lower pricing but also lower quality	Critical
Quality	Organic produce with highest quality control	Highest quality in the market for excellent wine		Non-organic	Critical
Supply	Monthly supply due to induced environment	All-year supply for the buyers		Seasonal supply	Very important
Expertise	Medium experience	Contains scientists and professionals who provide training at the beginning	Team working is just starting	Very high experience	Very important
Location	In the city centre	City centre is in the middle distance between all wineries	Long distance for supply and delivery	Located near the wineries	Important

Twelve-Month Profit and Loss Projection

- In the first year, it is planned to provide no less than 20 wineries with the needed supply of grapes. During that time, the marketing team should assess the actual market share and the users' feedback on our products and services.
- **Four-Year Profit and Loss Projection:**

  By that time, we intend for the project to cover most of the wineries in the area with long-term contracts as more stability is achieved. In addition, our products will be improved with time after receiving the feedback. We intend on covering at least 40–60% of the project initial cost by that time.

Results

The project provides benefit to the city of Conegliano in Italy whether economically, socially and environmentally. In terms of economic viability, the project would provide many jobs on year by year calculations as shown in Fig. 4.16. The anticipated new jobs due to the project are 240 after 10 years. This indicates how the project is economically viable and achieving the social sustainability. It increased from 28 jobs in phase 2 (42 jobs) by 50% from year 1 (28 jobs), whereas it would increase in phase 3 (70 jobs) after 3 years by 67% and then would increase in phase 4 (100 jobs) by 43%, in total, an increase after 10 by 257% from staring the project and operation (Fig. 4.16).

The reduction of CO_2 emissions due to the use of urban farming compared to conventional buildings without urban farming in cities is illustrated in Fig. 4.17. The CO_2 emission is mitigated by 79%, if the site and building to be designed as a business as usual (BaU) way [11–13]. This indicates the environmental viability of the project in contributing to the city of Conegliano's footprint.

Urban farms could have a huge impact on the urban fabric introduced to the city, but if applied properly with consideration of urban and social factors. It could act as a catalyst for its surrounding as well as strong asset in adaptive reuse of abandoned buildings. Urban farms provide food security, job opportunities and green lungs in the heart of the cities if designed correctly. This project won the public voting award for the UrbanFarm 2019 competition along with the Conegliano municipality bonus for the innovative ideas provided to create a successful marriage between urbanism and agriculture in cities [14]. It also achieved the third ranking project. The project's sustainable solutions are depicted in Figs. 4.18, 4.19, 4.20 and 4.21.

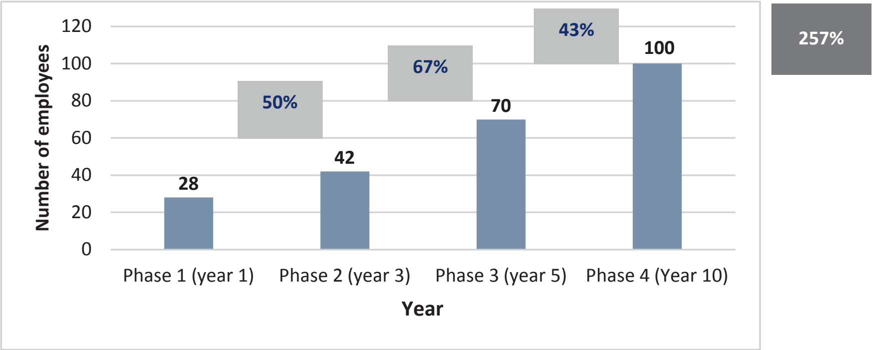


Fig. 4.16 Jobs generated year by year due to urban farming in 10 years

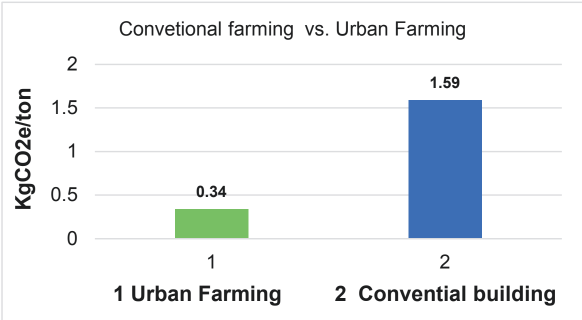


Fig. 4.17 CO_2 emission mitigation by urban farming compared to conventional buildings

Fig. 4.18 Impression of the site and building solutions after improvement, Conegliano

Fig. 4.19 Site layout after development, Conegliano, Italy

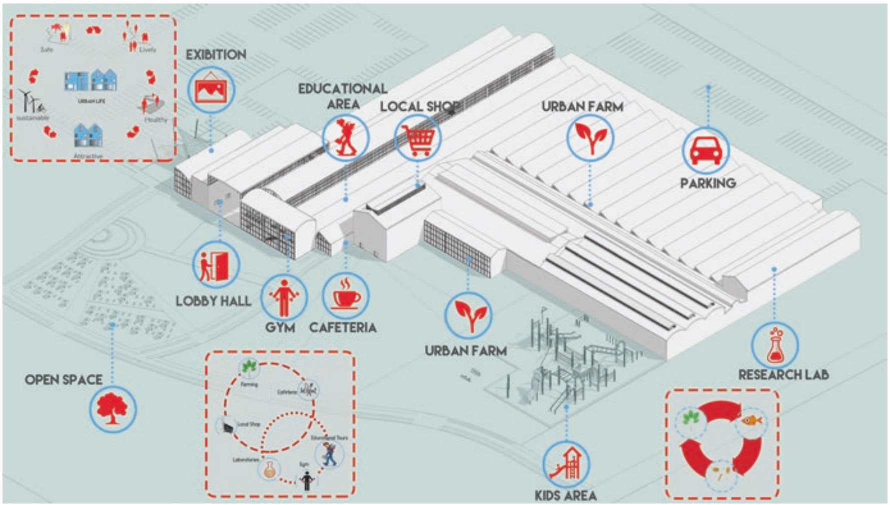


Fig. 4.20 Project's outcomes, Conegliano, Italy

Fig. 4.21 Project's enhancement to achieve SDGs. The project linked to Sustainable Development Goals 7, 8, 11, 12 and 13

Conclusion

The Green Hub® is a project that aims to integrate the urban farm with its surrounding urban context to create a living heart for the city of Conegliano. This project covers all three pillars of sustainability: environmental, social and economic aspects, to achieve a self-sustained project. For us communal participation was a key factor in the design, so we were keen to create various social spaces beside the urban farm to attract more people to the area. We believe this project helps to create a livable, healthy and sustainable urban environment in the city of Conegliano and to be an exemplary model for others. The project development contributes in achieving Sustainable Development Goals (SGDs) 7, 8, 11, 12 and 13.

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Chapter 5
Future Cities for Climate Action: Automated Code Compliance Checking in Reference to Energy Efficiency Building Regulations

Asmaa S. Eid, Mohsen M. Aboulnaga, and Ayman H. Mahmoud

Introduction

Cities in the Mediterranean region are facing many challenges such as high energy use and climate change risks. Energy accounts for two-thirds of global emissions [1]. According to the IEA, the built environment including buildings in most countries of the MENA region is responsible for more than 50% of the total energy consumption [2]. Egypt is experiencing high electrical energy demands, especially in buildings due to high population increase. Energy use in residential and commercial buildings accounts for 62% of the 2015 total electricity produced in Egypt [3]. The IPCC indicated that despite the fact that greenhouse gases' emission in Egypt is almost 1% of the world's emissions, it is one of the nations that will be heavily affected by the impact of climate change phenomena [4]. Climate change (CC) severe events have been manifested in many areas in Egypt during the past 5 years in the form of heat waves and storms that led to floods in Cairo, Red Sea region and Alexandria. Figure 5.1 illustrates some of the severe events of climate change impacts which are manifested in the MENA region and in Egypt.

Making cities green can assist in mitigating CO_2 emissions, adapting to CC and achieving resilience. Moreover, the transition to a low-carbon energy sector is vital to reduce CC risks. According to IRENA annual report 2017, renewable energy, coupled with energy efficiency gains, can provide 90% of the CO_2 emission reductions needed by 2050 [5]. Therefore, developing sustainable cities including buildings, based on Energy Efficiency Code Compliance Checking (EECCC) for a better future, is imperative to ensure such challenges are lessened amid the manifestation of global climate change and at low cost.

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Fig. 5.1 Climate change impacts manifested in the MENA region and in Egypt. (**a**) Flood in Ras Ghareb, Egypt, 2016. (Image source: *Westwards* 2016). (**b**) Severe storm in Amman, Jordan. (Image source: *Arab News*, Oct. 25, 2018). (**c**) Severe flood in Doha, Qatar. (Image source: *Gulf Times*, Oct. 22, 2018). (**d**) Severe storm in Kuwait city, Kuwait. (Image source: *Kuwait times*, Nov. 13, 2018)

There is an immediate need for applying the automated checking for energy efficiency building codes in developing countries to enhance energy efficiency and mitigate GHG emissions. The Energy Efficiency Code Compliance Checking (EECCC) is one of the most vital issues in making buildings low carbon, energy efficient and meet green standards, especially amid the urgent actions needed to offset climate change risks and attain sustainable development goals. The EECCC process depends on a series of complicated procedures based on multiple advanced calculations. Most of these procedures are performed manually on 2D drawings in many countries, which may increase the possibility of ambiguity, inconsistency in assessments and time and money waste; besides each modification needs to be done by the assigned specialized responsible consultant that accordingly delays the construction process. With the aid of BIM, previous successful measures and attempts have been developed to automate the rule-based code compliance checking process in order to facilitate the application of national or international building codes and overcome such obstacles and inconsistencies.

Egypt Sustainable Development Strategy: Energy

In 2016, the government launched Egypt's Vision and Sustainable Development Strategy—SDS 2030. Energy is 1 of the 12 main pillars of the SDS 2030 which is based on 3 main dimensions: economic, social and environmental as shown in

Fig. 5.2 [6, 7]. Since energy is one of the main SDS, we believe ensuring automation of CCC would significantly decrease energy in buildings of which is about 80% are existing buildings [8]. Within the strategy, the pillar of energy focused on six strategic objectives [9]. It is clear from Fig. 5.3 that the building sector contributes to the government strategic objectives 4, 5 and 6. Prior to SDS 2030, the government introduced the Egyptian code for improving energy efficiency in buildings (ECIEEB) which was supported by many decrees [10, 11] as shown in Fig. 5.4. Many initiatives based on Egypt's SDS 2030 have been implemented to enhance energy efficiency in administrative buildings at the level of community, including (a) energy efficiency campaigns for raising awareness on the importance of energy efficiency and how it is achieved in buildings, especially residential buildings [12, 13], and (b) energy efficiency internationally funded projects, for instance, the UNDP-GEF

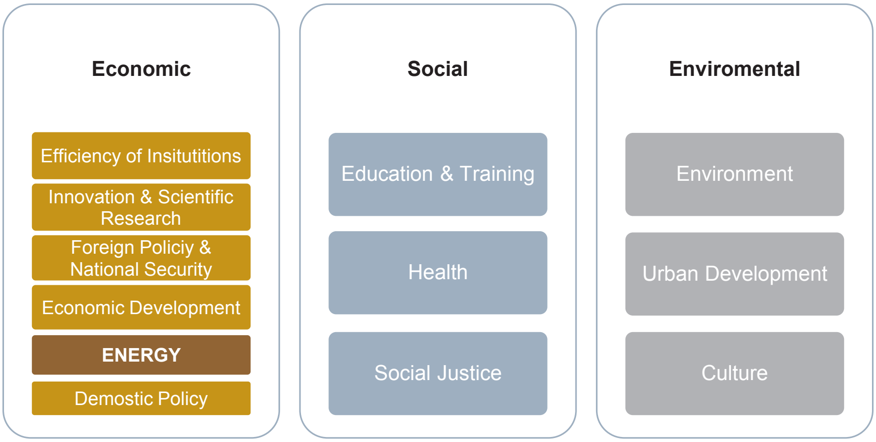

Fig. 5.2 Main pillars of Egypt's SDS 2030. (Credit: After Egypt's SDS 2030. Source: www.sdsegypt2030.com)

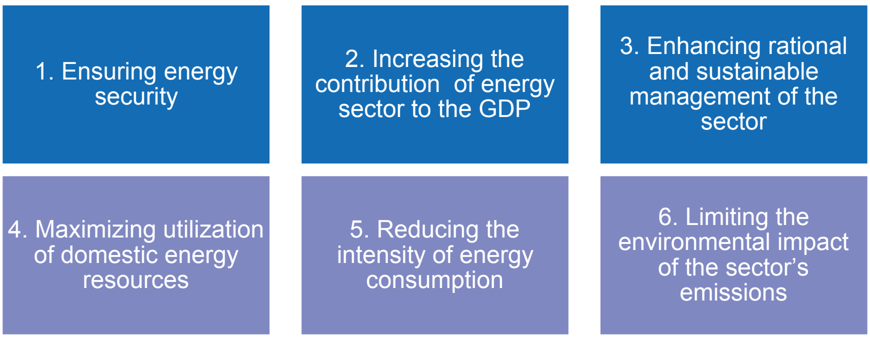

Fig. 5.3 SDS 2030 energy pillar objectives in linkage to building energy sector. (Credit: After Egypt's SDS 2030. Source: www.sdsegypt2030.com)

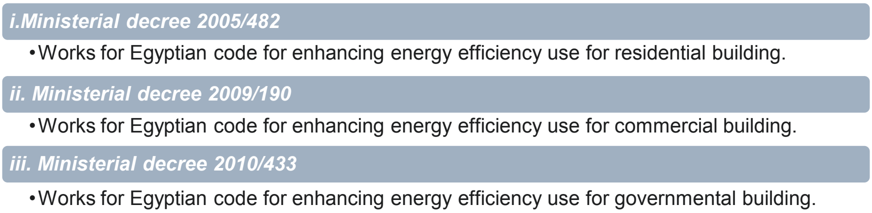

Fig. 5.4 Government decrees related to energy efficiency building codes

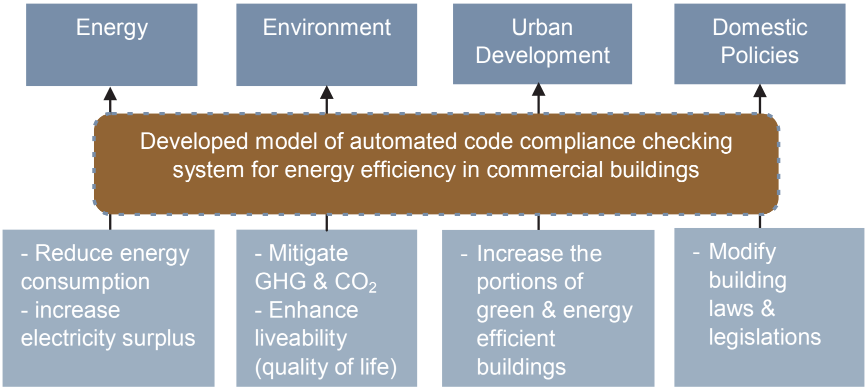

Fig. 5.5 Automated CCC impact on achieving pillars of Egypt's SDS 2030. (Credit: author)

Energy Efficiency Improvement Project which is implemented by the Ministry of Electricity and Renewable Energy [14, 15].

In order to contribute towards achieving the strategic objectives for SDS 2030, within the context of building regulations, BIM environment and construction market, it is vital to develop a reliable system that can assure building design compliance with the Egyptian code for enhancing energy use in buildings. This would ensure a colossal amount of energy consumption since automated CCC will be applied on buildings in future extensions that would be energy efficient. It can be said that application of the automated CCC system would have positive impact in achieving four pillars of Egypt's SDS 2030 in parallel. These pillars are energy, environment, urban development and domestic policies. These impacts are illustrated in Fig. 5.5 [16].

Research Goal

This research work intends to investigate the potential for digitization of the Egyptian building regulations concerning energy efficiency in commercial buildings and develop a method to construct a specific data model schema that enables automated compliance checking using visual language programming. This would support professionals while conducting construction projects to ensure that their project complies with the requirements of ECIEEB. Meanwhile it would support building authorities in facilitating the process of CCC and building licensing.

Automated Code Compliance Checking: Outlook

In recent years, various relevant references spanning across 40 years have been identified with the aim to develop a method for CCC automation. Some of the primary studies and their influences have been classified in a timeline conducted by Dimyadi and Amor [17]. Ismail et al. classified the previous trials according to the used techniques in the development of the code compliance checking process [18]. Choi and Kim had also classified the previous research cases according to the focus of the research for each author. These classifications are presented in order to figure out an overview of the research history [19]. Dimyadi and Amor divided the history of CCC into two eras: pre-2000 and post-2000. The pre-2000 era is mostly about the early applications developed based on the advanced 3D graphical computer-aided design (CAD) system that will not be discussed in this part as the research is focusing on the BIM-based CCC measures [17].

As for the post-2000, since the emergence of the Industry Foundation Classes (IFC) that is known by most professionals simply as a data model developed by the BuildingSMART Alliance [20] (earlier called IAI) to facilitate interoperability in the building industry [21], several important tools have been developed and utilized and also are being used today [17]. In Helsinki, Finland, Solibri Model Checker (SMC) was developed as quality assurance solution for BIM validation, compliance control, design review, analysis and code checking. SMC has a set of built-in rules with limited user customization [22]. SMC is considered one of the most reliable CCC software that is largely used by different governments worldwide. The CORENET e-plan checker was developed by the Singaporean government in 2002. It was developed to be CORENET e-Submission System (e-SS). It is a G2B (government to business) Internet-based system that enables industry professionals to submit project-related electronic plans and documents to regulatory authorities for approval within a secured environment [23]. The CORENET e-PlanCheck commissioned an independent platform, FORNAX, to sit on top of the already existing EDM ModelChecker. FORNAX is an object library written in C++ developed by novaCITYNETS Pte. Ltd., which is an e-government solution provider in Singapore [24]. Each object contains all the relevant attributes for the Singapore codes as well as the rules that apply to that object [25]. In 2006, the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia announced Design Check, a new system that incorporated Express Data Manager (EDM) suite that was developed by Jotne EPM Technology in Norway as an object database with tools to manage complex product data models [26], as the core rule bases and compliance checking engine for the Building Code of Australia (BCA) [27]. The system allows for checking designs at different stages—sketch design, detailed design and documentation.

It enables the checking of building models against individual clauses within a building code or, alternatively, checking individual object types or group of objects rather than the entire building model [27]. SMARTcodes project to automate BIM-based code compliance was initiated also in 2006—perhaps inspired by CORENET's e-PlanCheck—by the International Code Council (ICC) in collaboration with BuildingSMART Alliance, the organization behind IFC and other model interoperability efforts that mainly depend upon the availability of information in appropriate digital formats and rule conformance verification systems [28].

In the United States, the US Department of Energy (DoE) has developed two systems in 2010: REScheck for residential compliance and COMcheck for commercial compliance, in order to allow anyone to check a building design against the applicable energy standards like the ASHRAE Standards 90.1 (Energy Standard for Buildings Except Low-Rise Residential Buildings). Both of these compliance checking applications have all the standard criteria hard-coded into the tools [29]. Also in Scottsdale, Arizona, Avolve software has developed an electronic plan review called ProjectDOX enabling online permit applications and plan review via electronic service. Avolve also designed Online Application Submission (OAS) as a simple and friendly web application that makes it easy to submit, permit and plan review applications directly via a jurisdiction's web site [30]. Another recent initiative to automate code checking is the AutoCodes Project by the organization Fiatech (which stands for "Fully Integrated and Automated Technologies for Construction"). Fiatech is a global consortium of capital project industry stakeholders that was launched in 2000, and as its name suggests, it is focused on developing advanced technologies for buildings, infrastructure and other AEC industry segments such as process plants, oil and gas, etc. [31]. It launched the AutoCodes Project in 2011 with the objective of using technology to enable a digital review process, including automated code checking of BIM models, making the building regulatory process faster, more uniform and ultimately more competitive. Its vision is to be able to reduce the review time "from 60 days to 60 seconds" [31].

It can be concluded that the CORENET is the most successful project of automated CCC assisting the government in licensing different types of buildings in the country as it is an integrated web-based and submission system attached by a characterized platform with its own library for used objects and standardized BIM maturity level, while Solibri, SMARTcodes, Fiatech AutoCodes and Avolve software tend to be commercial versions of CCC systems that mainly intend to make profit. On the other hand, other measures have been conducted by individual researchers based on BIM technologies. In 2005, Nguyen performed a CCC system integrated with 3D CAD for checking International Building Code (IBC) with special focus on fire walls, structural members and egress doors [32]. Tan et al. developed another CCC system for checking building envelope in the light of Canadian building regulations with focus on exterior walls [33]. Balaban also performed CCC system for checking fire codes concerning the Turkish building regulations within his doctoral dissertation in 2012 [34]. Additional measures for CCC were conducted in 2015 and 2016 and Luo and Gong also developed a BIM-based CCC system for checking deep foundation construction plans in reference to Chinese building regulations [35]. Malsane studied automation of CCC for fire safety for existing UK building regulations [36]. Hongling et al. developed safety rule-based automated identification in construction based on Chinese regulations [37], while Takin et al. has the same interest concerning safety planning in buildings but within Malaysia's regulations [38]. Nour developed a BIM-based electronic code checking for buildings using bounding volumes to test Egyptian legislative rules for residential buildings in new settlements [24]. Getuli (2017) studied CCC for construction health and safety within Italy. And finally, the latest study in the topic was performed by Choi and Kim who developed rule-based building code checking system for BIM-based quality improvements based on Solibri Model Checker (SMC) Application Programming Interface (API) [19]. All the previously mentioned systems have one common thing that all are hard-coded with reference to an independent standard representation.

Visual Programming Language

Many studies have been conducted on visual code checking language (VCCL) or the visual programming language (VPL). Preidel and Borrmann introduced a visual code checking language (VCCL) for code translation and showed the possibility of translating building codes with visual programming language. They applied their approach on the German fire safety code. They assured that VCCL becomes a powerful toolkit for the preparation of building model data and the subsequent checking processes [39, 40]. Zhou et al. also presented a visual programming language (VPL)-based code translation approach for automated compliance checking of overall thermal transfer value (OTTV) for verification of their approach [41].

This research work proposes the use of VPL for CCC, where clear accessible digital translation of building regulations can be created. Amann et al. have defined VPL as "a formal language with visual syntax and semantics. It describes a system of signs and rules on the syntactic and semantic level with the help of visual elements, which are more readily understandable for non-professional programmers. Visual programming languages are often referred to as flow-based, since they represent complex structures as a flow of information" [42]. The VPL user interface mainly consists of campus, nodes and wires. The campus works as a placement work space. Nodes are individual components, which represent method, function or data object. These nodes are stored in a built-in digital library. Customized nodes, which do not exist in the built-in library, can also be created with assistance of other programming languages such as Python and C Sharp. Wires are responsible for arranging and connecting nodes in the workspace [43]. The most common VPL platforms are Dynamo, which is an add-in in Revit developed by Autodesk, and Grasshopper 3D, which is a plug-in in Rhinoceros developed by Robert McNeel and associates. In the AEC industry, the VPL is used whether to generate geometry, to automate repetitive tasks or to check compliance with specific rules. Based on the above review, automated code compliance checking concept has been applied on various building codes, whether using hard-coded language programming or visual language programming. However, limited measures have worked on the energy efficiency code. Therefore, this work intended to focus on the Egyptian energy efficiency building code for commercial buildings to develop an automated tool for checking its compliance with the assistance of BIM to mitigate energy consumption and CO_2 emissions.

Analysis of Energy Efficiency Regulations for the Building Envelope

Egypt is divided into eight different climate regions including (a) northern coast region, (b) Delta and Cairo region, (c) northern upper Egypt region, (d) southern upper Egypt region, (e) eastern coast region, (f) high hills region, (g) desert region and (h) southern Egypt region [10]. Each region has its own climate characteristics that affect the design of the building. In this research, it is intended to work on the part concerning the design of building envelope. It is also intended to focus on air-conditioned buildings in the Delta and Cairo region. The code regulates the design of the building envelope in terms of façade orientation, window to wall ratio (WWR), wall resistance (*R*), solar heat gain coefficient (SHGC) and shaded glass ratio (SGR). Table 5.1 lists the assigned values of *R*, SHGC and SGR in relation to façade orientation and WWR.

Methodology and Application

In order to an develop automated tool that can check compliance with the assigned regulation of building envelope design, the required parameters need to be added into the BIM model as a first step. For instance, in Revit, these new parameters can be added as shared parameters as indicated in Appendix 1. In many cases, the values of such parameters may need to be entered manually by the design team based on the material characteristics in order to ease the process of extracting data [11]. The second step is to convert the assigned requirements of the building envelope design of the energy efficiency code as indicated in Table 5.1 into logic sentences in order to be converted into a visual code.

The process of developing the visual code is divided into two parts; the first part is related to calculating the WWR of each façade and the second part is related to checking the *R*, SHGC and SGR values in relation to the orientation and WWR of the façade. The visual code is developed by Dynamo as it is one the most commonly used interfaces of visual language programming for architects and designers. Figure 5.6 shows a part of the developed visual code for checking WWR in relation

Table 5.1 Required values of *R*, SHGC and SGR in relation to façade orientation and WWR

Orientation	Walls with openings														
	R-value					SHGC					SGR				
	10% < WWR < 20%	20% < WWR < 30%	30% < WWR < 40%	40% < WWR < 50%	50% < WWR	10% < WWR < 20%	20% < WWR < 30%	30% < WWR < 40%	40% < WWR < 50%	50% < WWR	10% < WWR < 20%	20% < WWR < 30%	30% < WWR < 40%	40% < WWR < 50%	50% < WWR
North	N. R.	N. R.	N. R.	0.2	0.6	N. R.	N. R.	N. R.	N. R.	N. R.	N. R.	N. R.	N. R.	N. R.	N. R.
North-east/north-west	N. R.	N. R.	0.2	0.2	0.2	N. R.	N. R.	0.6	0.4	0.2	N. R.	N. R.	25%	50%	80%
East/west	N. R.	N. R.	0.2	0.4	0.4	0.7	0.4	0.3	0.3	0.2	10%	50%	60%	65%	80%
South-east/south-west	N. R.	N. R.	0.2	0.4	0.7	0.7	0.4	0.3	0.3	0.2	20%	55%	65%	70%	80%
South	N. R.	N. R.	0.2	0.2	0.4	N. R.	0.8	0.6	0.4	0.3	N. R.	10%	30%	50%	60%

N.R. means Not Required

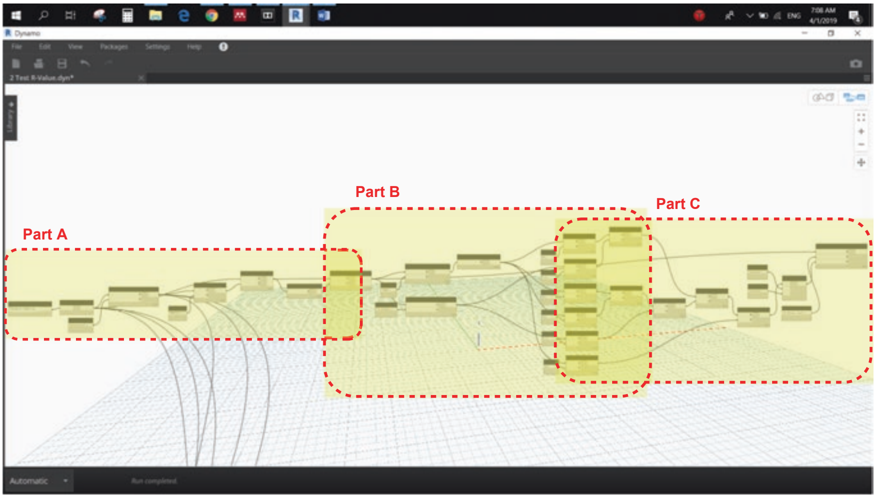

Fig. 5.6 Developed visual code for checking WWR in relation to *R*-value of the north façade

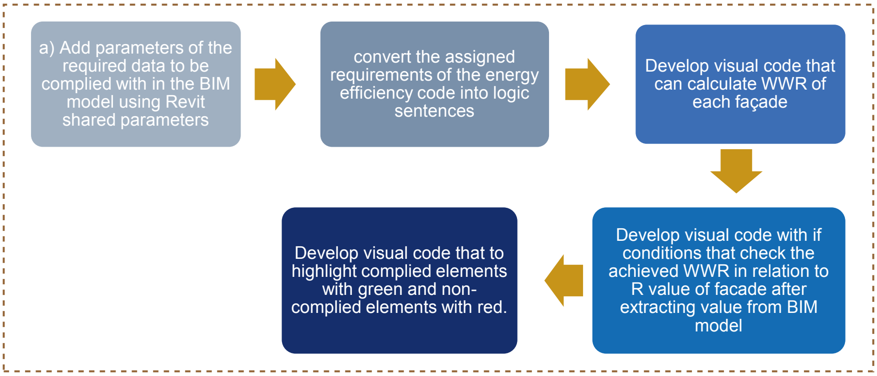

Fig. 5.7 Adopted method to develop VPL checking code

to *R*-value of the north façade. Closer zoom in around the parts of the code are shown in Appendix 2 which is presenting the developed visual code for checking WWR in relation to *R*-value of the north façade. Part A, B and C present the developed visual code for checking WWR in relation to *R*-value of the north façade. The complete developed visual code for checking WWR in relation to *R*-value for all building façades is also presented in Appendix 3 where the complete developed visual code for checking WWR in relation to *R*-value for all building façades is highlighted. The adopted method to develop VPL code using BIM environment is presented in Fig. 5.7.

Results and Discussions

A new expression of the building envelope regulation code has been developed with the assistance of VPL. Initially, this visual code filters all buildings' elements of the corresponding BIM model. Relations have been developed to define corresponding relationships among walls, openings and their material properties. Also relational value among WWR, *R*-value, SHGC and SGR have been assigned and connected with relational operators. Checking compliance with the building envelope has been tested with if-then conditional nodes. The final checking results are presented visually via appearing text message with the building element ID to show whether it is compliant or not, besides highlighting the complied building element with green colour and non-compliant building element with red colour as shown in Appendix 4. Further methods of results' representations are intended to be examined in order to integrate virtual reality visualization into the project.

The VPL shows a promising potential of developing automated tool for checking code compliance (CCC) with no need for strong programming background or hard-coded environments. It also gives the design team the ability to assure quality of their design during the design phase. The developed tool can also be integrated into a wide range of BIM platforms.

One advantage of the developed code is that it is flexible enough to be edited, modified and restructured to create a new checking tool for new criteria. Nevertheless, the result visualization needs more developing efforts to be more indicative and appealing for users. It adds also to the possibility of integrating the visualized results, not only into the BIM model but also into the project's architectural sheets and documents.

Conclusions

This study has worked on introducing VPL-based automated code compliance checking (ACCC) for the design of buildings' skin in reference to the Egyptian code (a hot climatic zone) for enhancing energy efficiency in commercial buildings. A tool has been developed with the assistance of Dynamo that includes key checking requirements regarding the buildings' envelope. It can be used for checking compliance of the building elements with the assigned requirements of the energy efficiency code and also visualizing checking results. It also facilitates the process of confirming accuracy of compliance with the energy efficiency code. Simultaneously, it can be exploited by architects and designers to check the compliance of their newly designed projects at an early stage. For further research, testing the developed tool on multiple case studies could be carried out to ensure reliability and also integrating VR technology for better visualization of the checking results.

Appendix 1

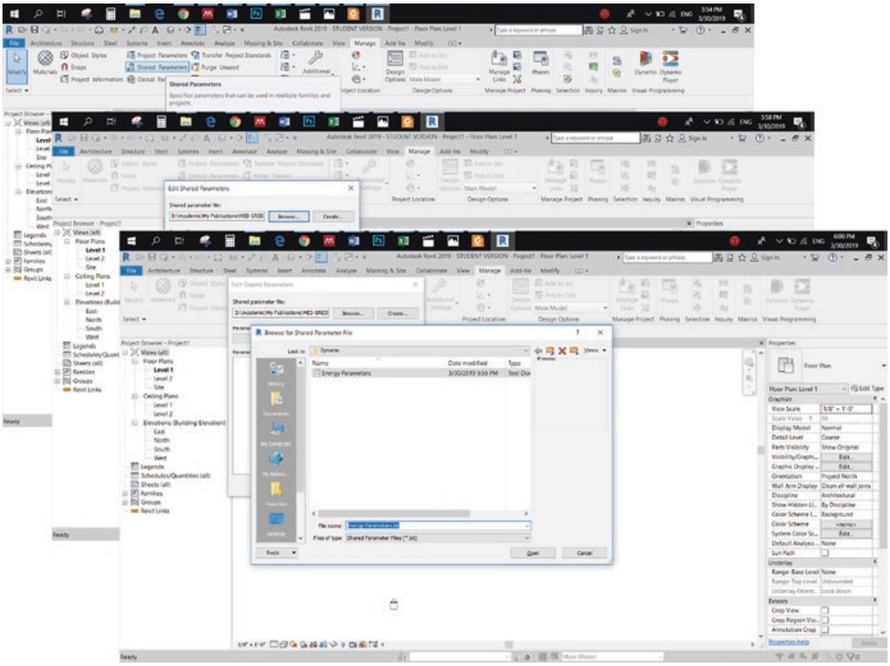

Fig. 5.8 Creating shared parameters in the BIM model

Appendix 2

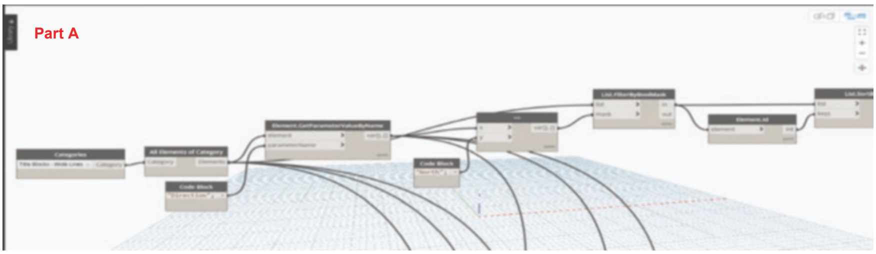

Fig. 5.9 Part A—Developed visual code for checking WWR in relation to *R*-value of the north façade

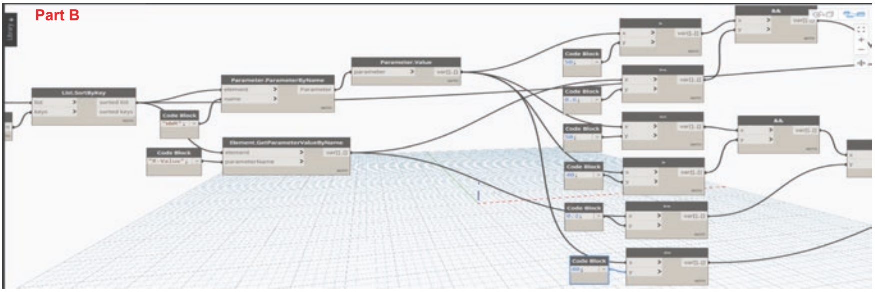

Fig. 5.10 Part B—Developed visual code for checking WWR in relation to *R*-value of the north façade

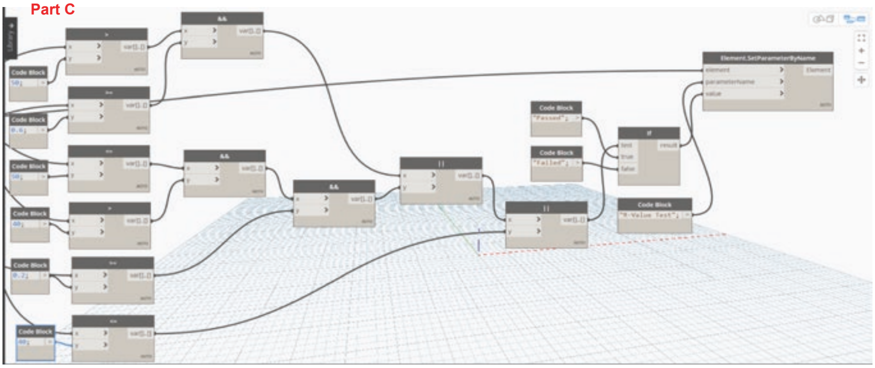

Fig. 5.11 Part C—Developed visual code for checking WWR in relation to *R*-value of the north façade

Appendix 3

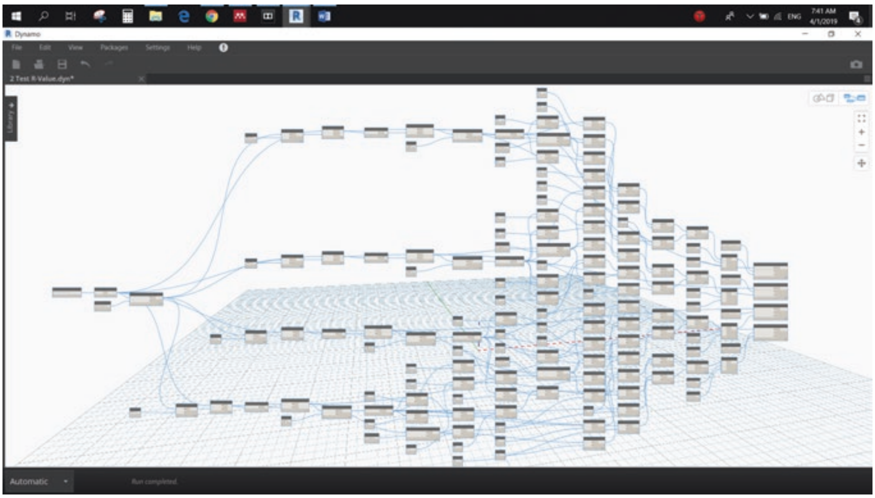

Fig. 5.12 Screenshot of the complete developed visual code for checking WWR in relation to *R*-value for all building façades

Appendix 4

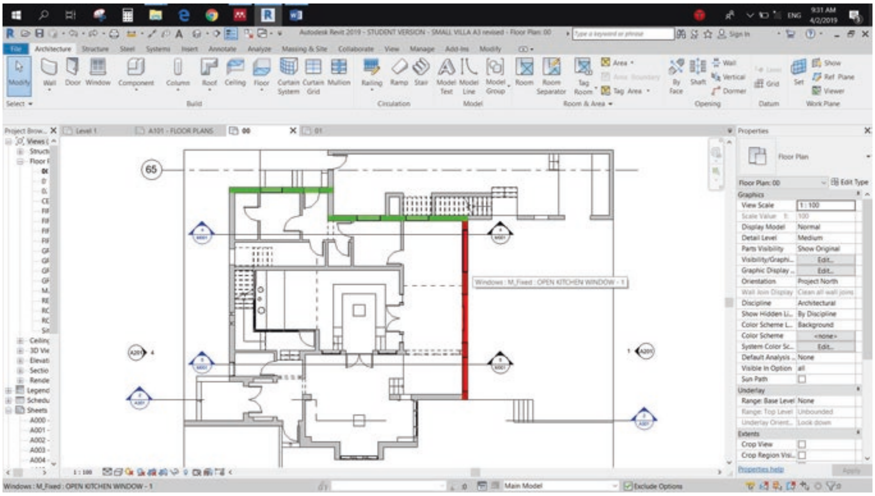

Fig. 5.13 Result representation for compliant and non-compliant building elements

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Chapter 6
Urban Spaces for Playing in Thermal Comfort Conditions: A Case Study

V. Dessi and R. Eltonouby

Introduction

The paper reports an ongoing research experience between the DAStU of the Politecnico di Milano and the association Animum Ludendo Coles (later called Ludendo), which in turn has an agreement with the Alma Mater Studiorum University of Bologna, Department of Education Sciences. This collaboration among the three bodies allowed highlighting the issue of free play in public spaces as a valuable opportunity for psychomotor development from different points of view. Ludendo involves children in the participatory planning in order to propose to recover traditional games that can be translated into the creation of urban space paving that replicate a game, for example, the hopscotch or the track of marbles.

The premise is that children, as an important and effective part of the cities, should experience the city as much as possible by playing outside, but opportunities to do this are falling. It has been reported that children now have less time and opportunity to play than children of previous generations [1]. Children and young people should be able to play freely in their local neighborhoods. Providing play opportunities is as much about creating general public space that offers play opportunities as it is about designing and developing designated play spaces [2]. Without a good range of play opportunities, children may lose the chance to develop their physical and social skills, emotional intelligence, independence, self-esteem, and self-confidence [3].

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Thermal Comfort and Children

Outdoor thermal comfort is an essential parameter to assess the value of an outdoor recreational space based on intended use and health benefits (e.g., activity types) [4] to improve urban well-being using urban microclimatic design [5, 6]. Nevertheless, recent thermal comfort models (e.g., PET, UTCI) have been developed considering adult's body models in terms of dimension and physiology (the "average man" has 1.8 m^2 of body surface area and resting heat production of 90 W or 50 W/m^2). There is little-to-no certainty that the models can be applied to children [7].

However, it should be remembered that in the physiological response to the microclimatic conditions of a place, there are substantial differences between adults and children; for instance, literature has asserted that children are more vulnerable than adults to extreme heat [8] and that they have inferior thermoregulation during extreme heat to that of adults and thus experience differing thermal comfort and responses [9].

This means that the differences may result in variations from thermal comfort models tested and created for adults (e.g., Physiological Equivalent Temperature by Hoppe; Universal Thermal Climate Index (UTCI)), with many assuming the "average man" (1.8 m^2 body surface area, resting heat production of 90 W or 50 Wm^{-2}) [7].

Some studies [4] have attempted to link the sensation of comfort to the energy and metabolic flows of children performing outside activities with results yet partial and still to be compared with the literature on the subject [10] but that are starting to represent points of reflection and valid tools to make an assessment of comfort adequate to the physiology and metabolic activity of children.

It is also important to point out that the results of the research and experiments confirm that the heat load experienced by any individual is related to local weather but also to the design of the built environment that partially has an impact on the microclimate and can thus be altered through design interventions [7].

For this reason, the public space project cannot ignore the consideration of the type of users and activities that can be carried out. Enhanced focus on bioclimatic design is necessary for creating playground spaces that are more conducive to active play, where children can thrive within safe thermal conditions for longer periods of time. In turn, heat stress potential can be substantially lessened, and children will gain increased benefits from exercise even during the warm season [7].

The Methodology

In order for an urban space to be considered livable and viable, it must have a range of characteristics not only linked to the physical configuration but linked to the ability to attract people and ensure that they can remain in that space for a prolonged time, both seasonally and daily; this means that if people enter a square to buy ice cream, elements that encourage them to stay in this space must be offered. Other shops with shop windows that can be observed while walking, games for children, areas to sit in the cool in the summer and in the sun in winter, or simply the desire to observe other people present who carry out activities are just some indications. Many aspects cannot be solved by the redevelopment project of a square, but sometimes it is enough to trigger a process for this to develop satisfactorily. For this reason, the pre-project phase, the analysis of material and immaterial flows, neighboring schools, materials, vegetation, and accessibility, is particularly important and offers indications for the project phase. Particularly when planning to design an inviting and welcoming space especially for children, it is important to know the characteristics of the different ages of children who have very different needs depending on their age.

Particularly, in the age between 0 and 3 years, they usually play alone and tend toward experimentation with touch, sight, and sound. Playing in sand, clay, water, swings, and slides (the last two with the help of an adult) is appropriate for this stage. In the age between 3 and 6 years, with the onset of social awareness, children usually play in groups; they play with abstract elements, tables, and benches, as well as with swings, slides, and movable equipment. In the age between 6 and 8 years, children gravitate toward activities which involve movement and action. Children in this age group enjoy testing their dexterity with elements such as climbing nets and other complex structures that call upon different motor responses. In the age between 8 and 10 years, and upward, children opt for grouping together. Structured games with objective rules played in groups or teams tend to predominate at this age [11].

The first phase of the proposed methodology involves an analysis from different points of view, in particular:

- The relationship with the surrounding area:
  - An analysis of the physical configuration starting from a deep observation of the morphology (dimensional ratio H/D1, H/D2)
  - Accessibility, i.e., if the space is reached by public transport and a cycle path
  - An analysis of the present functions and activities
- The space strictly intended for people, adults and children, with analyses concerning:
  - The observation of behaviors, i.e., what type of activity they carry out and which paths they prefer
  - What kind of users spend time in located activities
  - How much time is spent, on average, in the square
  - What equipment there is in the space, benches, tables, games, fountains, and garbage cans
  - What kind of vegetation there is and what and how many trees and bushes; if there are green walls and what type of permeable horizontal surfaces there are
  - How pervious surfaces there are, and what materials are used

- Microclimatic analysis:
  - Is it possible to identify the microclimatic conditions of urban space (with microclimatic measurements or simulations)?
  - What comes out from the shadow analysis (at different times of the year and day)?
  - Is it possible to create maps that represent thermal comfort conditions?

The Assessment of Users' Needs

If the project has to take into particular consideration the use by children, it is first of all necessary to listen to their voice, to understand how they experience the public space, what they like, what they don't like, and how they would like it to be. These needs must then be translated into requirements that the space must have, in terms, for instance, of surfaces and equipment. The needs can be gathered through interviews and questionnaires.

General Guidelines

Once the area has been identified from many points of view, we can begin to introduce the design phase that also concerns the redefinition of surfaces and elements that configure urban space. In particular the elements to be taken into consideration are:

Vertical surfaces: Vertical surface that surrounds the playground has a great influence on the characteristic of the playground and how the users perceive or access it access; they are necessary to define the limits of the urban space and, sometimes, when free of windows and according to the texture, can be considered as surfaces useful to play (with ball) or to climb.

Horizontal surface: The first conditioning factor in any future playground is the configuration of the ground surface where it is going to be placed. If the occasion of being able to work on natural terrain arises, we can greatly enhance and simplify the design of the playground if we respect the existing topography. Since children respond more enthusiastically to irregular forms than to uniform, rectilinear shapes, the possibilities of a natural area in and of itself for providing ample play opportunities are considerable indeed [11].

Paving: It is one of the most important elements in the urban space. Depending on the necessities and characteristics of the location, various types of surface treatments are used in playgrounds. Thus, a footpath requires a paving material different from that used in the swings and slide area, where there is a consistently higher risk of falls. In general, all paving in a playground should be stable, firm, able to pad falls, with a texture that is not too rough, and a nonslip surface in both wet and dry conditions. Any joints or discontinuities in the paving should be treated to not obstruct movement in a wheelchair or on crutches. Different combinations of textures and colors in paving in order to achieve a specific effect, whether for informative or purely aesthetic reasons, can be highly inspiring for kids. This can be done where we wish to provide information, mark a change in direction or a transition from one play area to another, to distinguish areas for rest and relaxation, and so forth. Additionally, changes in texture can be detected by blind children, and even particularly bright colors can be perceived by visually impaired persons [11].

Vegetation: It is a highly valuable element in the design of any space intended for use by children, whether for its environmental or aesthetic aspects or simply for fun. Plants, in particular trees and pergolas, improve air quality and serve as a protective barrier against solar radiation. Additionally, dense plant species mitigate wind and reduce bothering noises. Plants are a natural habitat for birds and other small animals, making it a prime consideration to conserve and protect any existing vegetated area there may be on the site. It is especially important to conserve and incorporate any existing trees into the project, unless they present a danger to the health of the children. Mature trees offer an appealing, solid aspect which saplings and recently planted trees have not yet acquired. Furthermore, their placement might lay the groundwork for the layout of a design [11].

Areas for resting: A space, no matter how small, where a child can sit quietly and relax or gather strength to continue playing, is an invaluable addition to any playground. Such zones must comply with the corresponding accessibility criteria. A rest zone might be composed simply of a set of benches or other seating elements that are protected from the wind and rain. An open area equivalent to a circle of 1.5 meters in diameter should be set alongside the benches in order to allow wheelchair users to maneuver without difficulty [11].

Area for play: The area for the game is necessary when the presence of children is expected. If we expect the presence of a particular age group, we can identify a particular game; otherwise it is possible to organize areas with equipment or flooring designs integrated with the design of the whole urban space.

Shading elements: There are many benefits of integrating shade into various parts of the play environment. The shadow they cast can let children play longer without overheating, keep equipment cool to the touch, and help to increase the life of your play equipment. For example, if we plant deciduous plant species, sunlight will penetrate the canopy in the wintertime, while plenty of shade will be ensured for the summer months. Shade could be provided by trees and pergolas and by artificial elements like projecting roof and shields.

The games: Games in public spaces vary a lot from place to place, with requirements that meet local regulations. Here we try to encourage and enhance the game of the local tradition with 3D objects or inserts in the pavement that reproduce local street games. The collaboration with Ludendo in this sense is a robust support both in the identification of the games and in the eventual realization.

Application on a Case Study

This approach was implemented in Piazza Artigianato, a square in Milan, and a focus on the environmental approach is reported in the paper. The square is about 1460 m^2, located in Forlanini district of Milan, Italy. It is part of the Zone 4 administrative division, located southeast of the city center.

The square is in a rectangular shape (62 × 28 m) and stretches along the N–S axis, and the buildings are on the east and west sides; this means that the shadows during the day have a symmetrical behavior between morning and afternoon and that the central hours of the day are always sunny. Therefore, in the spring and summer season, the shade in the central hours of the day is only guaranteed by the presence of large trees, mainly located in the south part of the pedestrian area.

The square is well shaded in both spring and summer, thanks to the presence of two different types of trees, but with a lack of the green areas. The square can be accessible by different types of transportations, using Milano Forlanini station (S5, S6 or S9 trains) which is located 9-min walking distance from the square or using bus stops (73 or 45 bus lines) which are located closest to the square. In 5-min walking distance to the west locates a primary school (Istituto comprensivo De Andreis), along with another primary school (Via Meleri), which locates 11 min away from the square (Fig. 6.1).

Fig. 6.1 A view (on the left) from the north side of the square and (on the right) the plan

Function Analysis

Piazza Artigianato is characterized by 2 four-story buildings along the east and west sides, which on the ground floor are occupied by commercial shops, with shop windows on the street, as shown in Fig. 6.2 that shows the location of the different commercial activities. It must be pointed out that some of these shops work on attracting users to the piazza as well, in addition to that, 5 out of 20 of the shops are abandoned.

Materials

The pedestrian area is surrounded by an asphalted sidewalk, while the inside of the square is characterized by a dark pavement in cobblestones. The pervious surfaces are limited to the areas around the trees, and they are very scarce. It means that these warm materials contribute to increased surface temperature and discomfort conditions.

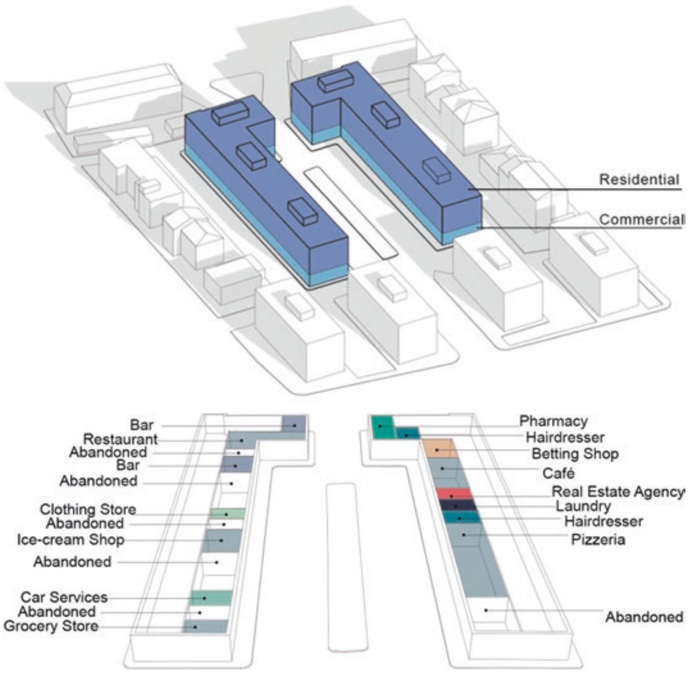

Fig. 6.2 Configuration of buildings and commercial activities in Piazza Artigianato

Vegetation

The piazza has two different types of trees, five of *Celtis australis* and four of *Acer campestre*. Their presence guarantees to have more acceptable environmental conditions, even in the hottest moments of summer days, where there is always someone who stops to consume a quick lunch, alone or with company. However, it should be pointed out that all the shadow produced by the vegetation is casted by the *Celtis australis*, since the *Acer* are still young and with a small crown. It is also important to point out that there is no presence of planted areas except for limited places found only around trees.

Microclimatic Analysis

The sun path simulation shown in Fig. 6.3 is developed by Rhinoceros® and Grasshopper® software. That shows, along with what is mentioned in the previous analysis part, that in winter the square is for most of the day in the shade, while it is sunny for a few hours in the central hours of the day, when the sun reaches its

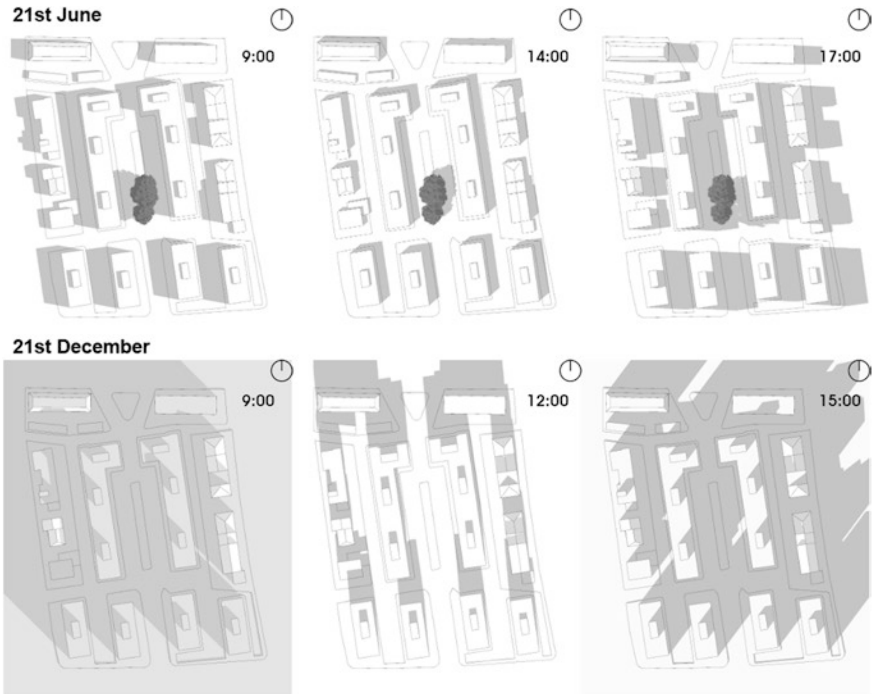

Fig. 6.3 Shadow maps of Piazza Artigianato in June and December in different hours of the day

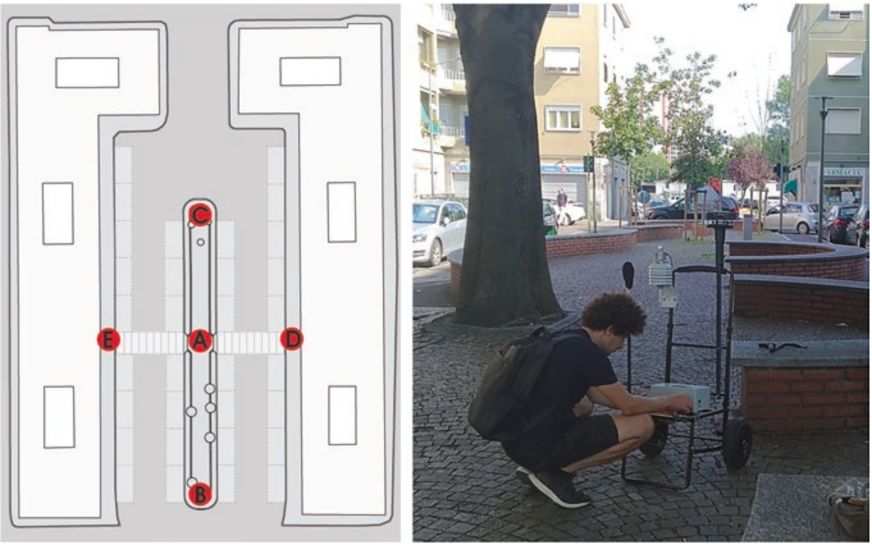

Fig. 6.4 Field survey in Piazza Artigianato: measured points and trolley with the movable microclimatic station

maximum height, to the south. In summer it is sunnier even in the morning and afternoon, alternately, while the central part is completely shaded only by late afternoon (Fig. 6.3).

The microclimatic analysis was completed with the assessment of the variables necessary for the calculation of the UTCI comfort indicator in different points of the square, as shown in Fig. 6.4. The graphic representation of the comfort conditions was done with a very effective mapping of the whole area at a particular time of day and with graphs that report the conditions of only one point at a time but for the whole span of a day.

The thermal simulation is developed by OTC model® software. Piazza Artigianato is almost aligned along the north-south axis with the south edge open and able to receive a lot of solar radiation throughout the year.

In winter, while the deciduous vegetation loses all the leaves, this aspect is appreciating. If we observe from Fig. 6.5, at 12 o'clock on 21st of December, the solar radiation is almost present throughout the space. However, especially because of the values of solar radiation and low air temperature, the values associated with the thermal comfort conditions are low. UTCI, the comfort indicator that provides for a value of between 9 and 26 °C to perceive acceptable conditions, reaches a maximum value of 8 °C for that day, during the hottest moments of the day.

In spring, in the middle of the day, the values of thermal comfort are acceptable, at least when it is evaluated with solar radiation (UTCI between 15 and 22 °C in the central hours of the day). In the shade of trees or buildings, the comfort conditions are not satisfactory.

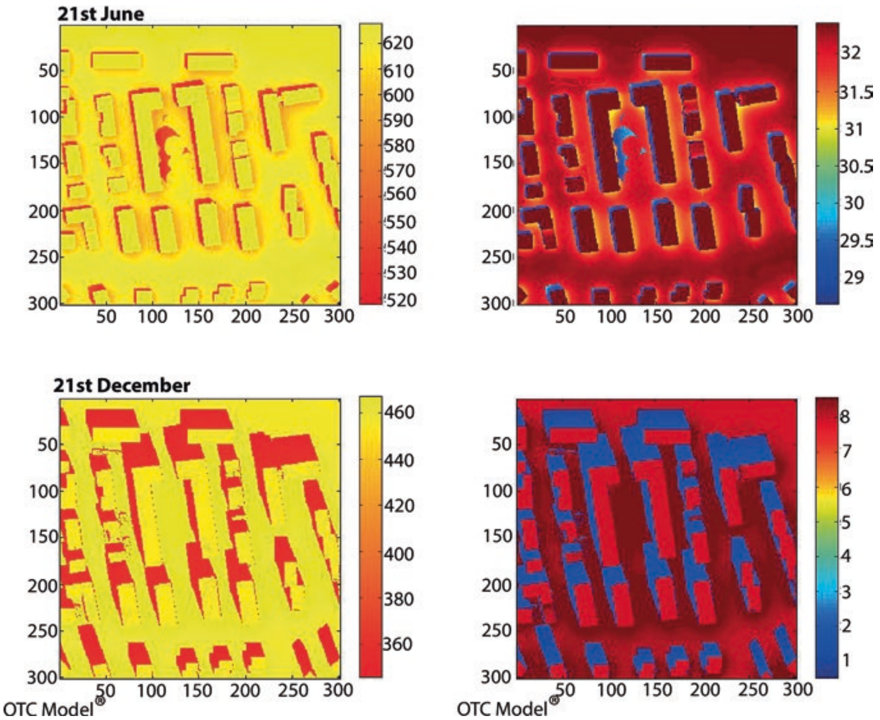

Fig. 6.5 Solar radiation maps (on the left) and UTCI (comfort) (on the right) in June and December of Piazza Artigianato

In summer, temperatures and high solar and thermal radiation values determine very variable comfort conditions, depending on whether you are in the sun or in the shade. In the central hours of the day, the shadow on the ground brought by the buildings is very limited; the most important shade is undoubtedly the one produced by trees, which in summer reach the maximum development of the crown. In the sun, the comfort conditions are unsatisfactory (UTCI can exceed 32 °C, when the acceptable values reach a maximum of 26 °C). In the shade, the microclimatic conditions are decidedly more acceptable (Fig. 6.6).

Preliminary Results

The work related to environmental performance and the observation of the elements that configure the urban space represent a rich and refined cognitive framework to be able to undertake a project that generally satisfies the thermal comfort conditions

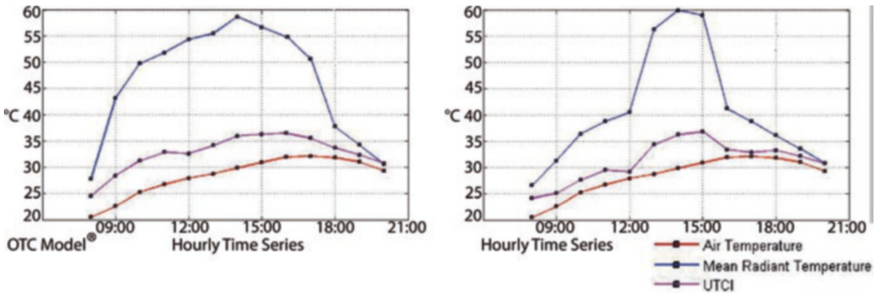

Fig. 6.6 Thermal comfort conditions during a day of a sunny area (on the left) and another shaded one until midday (on the right). The difference is evident in terms of mean radiant temperature and UTCI

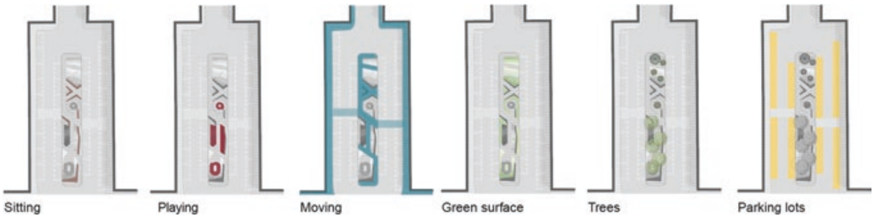

Fig. 6.7 Proposal for sitting, playing, and moving areas. Localization of new and confirmation of existing elements of green surfaces, trees, and parking lots

and the usability of an urban space. However, the goal is to identify specific strategies and therefore specific requirements to respond, in a more decisive manner, to the satisfaction of a range of users that is often not taken into consideration.

For this reason, it is advisable, before defining the project, to take into account the real needs of the users, that is, the children who live in the area and who attend the nearby school, both as regards the use of space and the perception of environmental variables and therefore of comfort. It is also interesting, when working with the children at the table, to test a sort of draft of the project that is defined and perfected with their suggestions. In this regard, strategies have been identified that concern the improvement of the activities present and not always in evidence, including parking, movement, and play activities (Fig. 6.7).

New plants have also been proposed, both new trees and bushes, and horizontal green surfaces, new and different possibilities for sitting and moving, and new flooring materials (Fig. 6.8).

Furthermore, a game has been identified, the snail, inserted as a design of the pavement that can be recognized or known by children. It will therefore be interesting to evaluate their reactions in this regard, given that this is an element that will give the square a new identity.

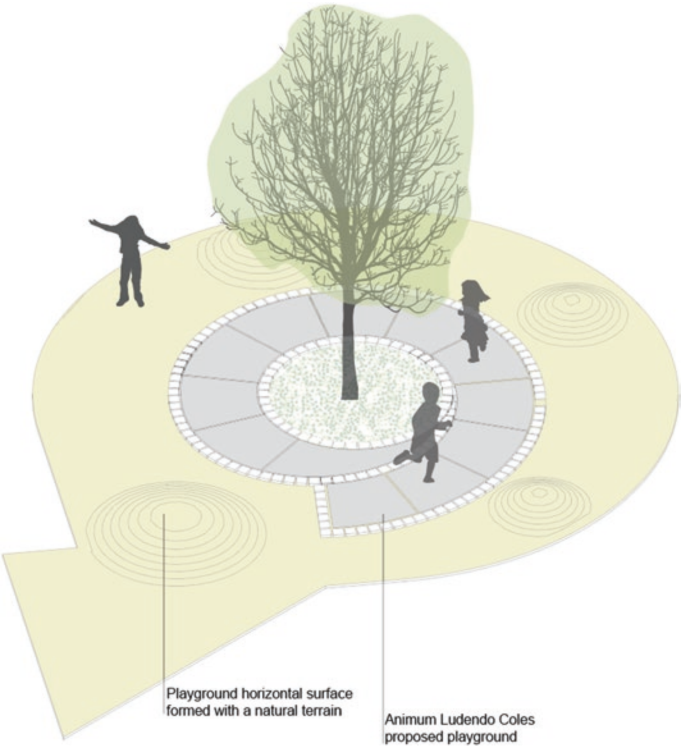

Fig. 6.8 Traditional game proposed and realizable by Ludendo

Conclusion

There is a difference between a public space that contains children's play equipment and an urban space, which considers children as privileged users and therefore designed for them. There is also a difference because the energy flows from the environment to the person are perceived and processed by the body in a different way, depending on whether it is an adult or a child. Therefore, when designing a livable and vibrant public space, the microclimatic conditions, which can partly define the way in which space is used, must therefore be taken into great consideration, and therefore it is necessary to be clear about the type of user that can use the space and delineate solutions that guarantee acceptable comfort conditions for the various possible activities and different users.

The work presented is a research work that intersects three skills and that includes the indications coming from the analysis of the answers to the questionnaires, in the case study, given to children and adults in the area who live near the square (phase not yet completed).

The guidelines, aimed at urban regeneration of parts of the city, are useful when declaring an interest in dedicating urban spaces to children and traditional games with the idea that the game represents a vehicle not only for the psychomotor growth but also for the enhancement of local traditions. The guidelines that accompanied the analysis and the pre-project phase are applicable to each space, while the project must take into account the responses of that specific community, as well as the resources in terms of materials, vegetation, water, but also of the memory represented by street games. The real conclusions of this work, still partial, will be evaluated in terms of thermal comfort, as was done in the analysis phase, because comfort is an indicator of the project in the environmental design approach. The proposal must take into account the indications derived from the results of the evaluations carried out in the analysis of the existing space, but it is also necessary to take into consideration that the thermal comfort of the child, which generally performs activities with a high metabolic level, is different from that of adults and more restrictive, therefore even more difficult to achieve.

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Part II
Resilience and Adopting to Change

Chapter 7
The Diurnal and Nocturnal Aspects of Urban Heat Island During the four Seasons—Case of Casablanca

L. El Ghazouani, M. Mansour, A. Lachir, M. Faouzi Smiej, and N. Laaroussi

Introduction

The urban extension produces important and radical consequences for the human being, his environment, and precisely the urban climate. Among these consequences is the urban heat island (UHI), a situation where the cities' or metropolitan areas' ambient temperature is dramatically altered and becomes warmer than the surrounding rural areas [1].

If we plot an isotherm map of such a situation, the city will appear as an "island" in the background of rural temperature [2]. The UHI operates when the differences in energy and stability between urban and rural areas produce differences in the warming and cooling rates in those areas. This causes the distinctive diurnal air temperature pattern that generates the UHI, and these differences control the intensities of the UHI [3].

The UHI affects the urban quality of life through its impacts on human health, ecosystem function, local weather, and climate. There is a direct relationship between peak UHI intensity and heat-related illness and fatalities [4]. This demonstrates the importance and relevance of UHI-related studies.

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In this way studies and researches follow one another to assess the UHI causes. They show that the geometry of the city, its topography, and its thermal properties are the most important factors that induce an UHI [5–7]. The emission of anthropogenic heat and pollution affects the UHI intensity, but its impact is weaker, and it depends on the season [6, 8].

In terms of methodology, different approaches have been used to compare temperature datasets from rural and urban stations. To carry out such analysis, we considered the following criteria:

1. Rural stations must be in close proximity to the city and have similar climatic features [9].
2. Taking temperatures at several points in the city [10].
3. Studying the temporal series of temperature of stations that are engulfed by the city as it grows [11].
4. Studying the phenomenon via satellite observations [12].

Having regard to recent studies about the increase in city temperatures and the effects of environmental issues, such as global warming on health, we conduct our study on the UHI phenomenon, which is a central topic in urban climate research.

Describing the Study Area

The city support of our study is Casablanca, a Mediterranean emerging economic capital.

Over the years this city and its region become a driving force for development, an innovation center, and an exchange hub.

The city of Casablanca is located on the Atlantic coast in the west center of Morocco; its latitude and longitude coordinates are 33.589886 north and 7.603869 west, respectively (Fig. 7.1). The area of the region of Grand Casablanca is 1117 km^2 [13].

The region of Grand Casablanca concentrates nearly 19% of the national urban population. Its population is increasing, as shown in Table 7.1. The rate of urbanization is close to 92% in 2008 compared with 57% nationally [12].

The spatial distribution of the population is unequal. The districts found in the heart of the city (Casa Anfa and Al Fida Mers Sultan) are the most densely populated and concentrate around 22.2% of the total population although they occupy only about 4% of the total area of the region [12].

Historically, this city built by the Zenets of Berber origin. The name Anfa refers to the port where ships used to obtain grain from neighbouring agricultural plains.

In the fifteenth century, Anfa was destroyed by the Portuguese and forgotten for almost three centuries. In the eighteenth century, Sultan Moulay Mohammad Ben Abdellah built another port where trade with Europe and America make it a privileged cramp of the Atlantic Ocean. The sultan named the city “the white house” in Spanish “Casablanca.”

Fig. 7.1 Location of Casablanca

Table 7.1 Development of Casablanca population, from 1960 to 2030

Year	1960 (CR)	1971 (CR)	1982 (CR)	1994 (CR)	2004 (CR)	2008 (ER)	2014 (CR)	2030 (PR)
Population of Casablanca region (millions)	1.0	1.7	2.5	2.9	3.6	3.7	4.2	5.1

Source: Statistical Yearbook of Morocco 2009
CR census results, *ER* evaluation results, *PR* projection results

Since the twentieth century, the city knows an important influence on the urban and infrastructural side [12].

The climate of the Grand Casablanca region is oceanic: mild and rainy in winter and humid and temperate in summer with the absence of frost in winter and high humidity during the year. As for rainfall, it varies from 1 year to the next [12].

Data

The only data source for this research is satellite images from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard Aqua and Terra satellites. We chose to use the images from the Aqua satellite because of the good temporal resolution as well as the much more convenient time of passage for this study. Indeed, the Aqua satellite passes over Morocco around 1 pm and 1 am, unlike the satellite Terra which passes around 10 am and 10 pm. The study of UHI suits more to the hours of passage of Aqua. However, large spatial resolution (1-kilometer pixel) is not a problem as the study area is not a city but a region.

The day images were obtained by the services of the Royal Center for Remote Sensing (Rabat, Morocco), and the night images were obtained from NASA Land Processes Distributed Active Archive Center (LP DAAC) collections available on US Geological Survey (USGS) EarthExplorer website.

Image processing was done on ArcGIS software which generated a series of maps useful for illustration and interpretation.

Methodology

- On the spatial scale, the study area was delineated by 20 km on both sides of the Grand Casablanca region, namely, the northeast and southwest. Thus the study area covers 345,623 Ha and has a 95 km Atlantic seafront (Fig. 7.2).
- On the time scale, we created four landmarks spread over the year. These landmarks correspond to the equinoxes and solstices: the day number 21 of the months of March, September, June, and December. This choice is relevant because it allows excluding the effect of the hot or cold climate. The study covers one decade, from 2008 to 2018, in order to exclude the effect of a cold year or a hot year and also consider the consequences of global warming.

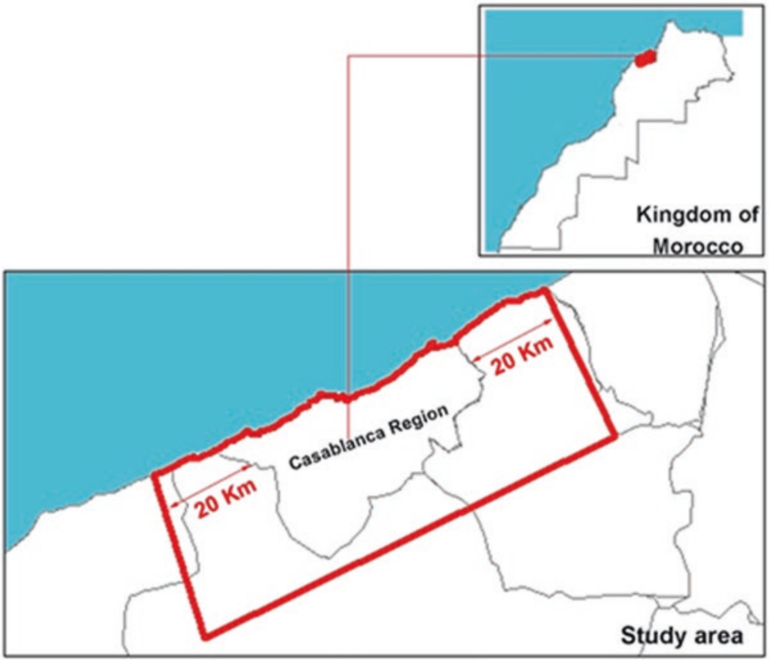

Fig. 7.2 Location of the study area

Table 7.2 Study dates for day images

Day images	Spring equinox March 21 Julian date: 80	Summer solstice June 21 Julian date: 172	Autumn equinox September 21 Julian date: 264	Winter solstice December 21 Julian date: 355
The day of experimentation	March 25	June 27	September 28	December 25

Table 7.3 Study dates for night images

Night images	Spring equinox March, 21 Julian date: 80	Summer solstice June, 21 Julian date: 172	Autumn equinox September, 21 Julian date: 264	Winter solstice December, 21 Julian date: 355
Image acquisition period	March 21 to March 28	June 17 to June 24	September 21 to September 28	December 18 to December 25

A small methodological arbitration was imposed against the constraints of day images. Faced with cloud masks, missing data, no coverage of the area, or unavailability of the image, the authors had to go to the next day (s) to find the information sought. Table 7.2 shows the dates of experimentation.

For the night land surface temperature (LST), the images were extracted from MODIS product MYD11A2 V6. This product provides in each 1-kilometer pixel an average value of clear sky LSTs during an 8-day period. Selected images are given in Table 7.3.

Results and Discussion

Reading Results by Day Versus Night

The visual analysis shows that the UHI is clearly marked at night, unlike the day when it is less intense.

The north of the study area always present a heat island when compared to its surrounding environment. This island corresponds geographically to dense urban area with the highest fraction of artificial surfaces in the study area: the city of Casablanca. This observation is maintained over the four seasons as shown in Fig. 7.3.

The maximum land surface temperature (LST) at night can reach 21 °C in against 3 ° C as a minimum.

This nocturnal aspect was seen in other cities and explained by the urban geometry and radiative exchange [14], enhanced cooling by evapotranspiration in the built environment [15], and/or landscaping and soil moisture availability [16, 17].

This conclusion has also been underlined by other authors [18, 19].

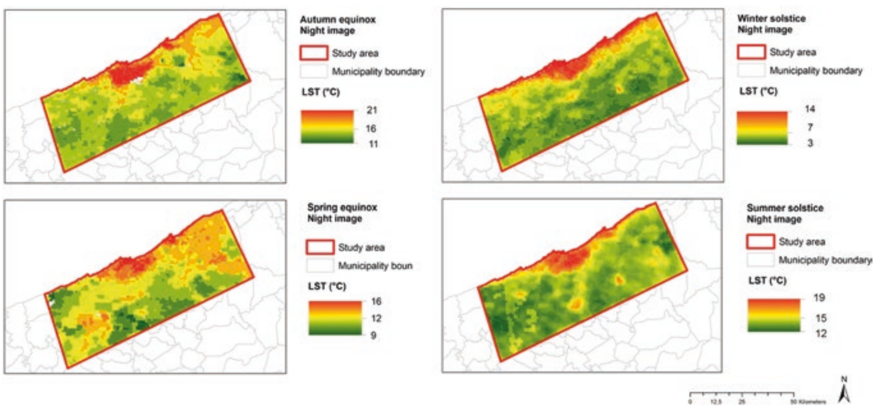

Fig. 7.3 Night images during the four seasons

Reading Results by Seasons

Beyond the temporality day/night, we propose in the following an analysis of UHI variation across different seasons. Indeed, in autumn, the UHI is less marked in the day; the difference between the city and its periphery is not revealing, unlike at night when an island of heat appears in the most urbanized and most artificial part of the city.

In spring, the UHI is clearly marked both day and night with maximum temperatures of 32 ° C in the day (1 pm) and 16 ° C at night (1 am) as shown in Fig. 7.4.

In summer, due to the rising temperatures of this hot season, a large area of "hot" areas appears on the map. The difference center-periphery is less marked as the season is hot. At night the materials will continue to reflect the energy received during the day until the last hours of the night. In winter, contrary to the assumption of the predominance of the UHI over the seasons, the city appears colder than its periphery as shown in Fig. 7.5. Indeed because of its coastal facade, the sea breeze and the orientation of the city are favorable to the flow of wind in the city which allows ventilating and measuring less the effect of the UHI. At night the observation is the same. The UHI is still apparent with a clear differentiation between the urbanized city and its rural area.

Conclusion

This work allowed crossing the phenomenon of UHI according to two temporalities: day/night, and that of the four seasons in order to skirt the subject in its annual rate evolution. We can retain from this study:

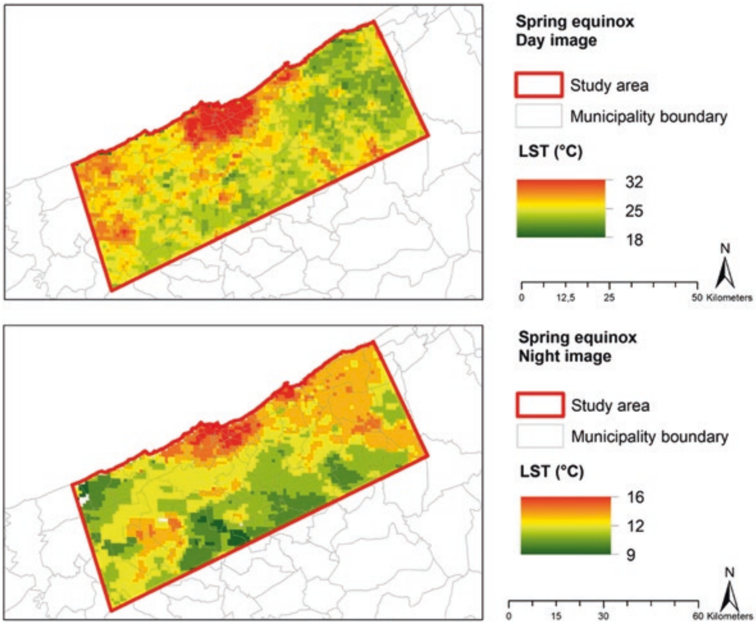

Fig. 7.4 Day and night images for a spring equinox

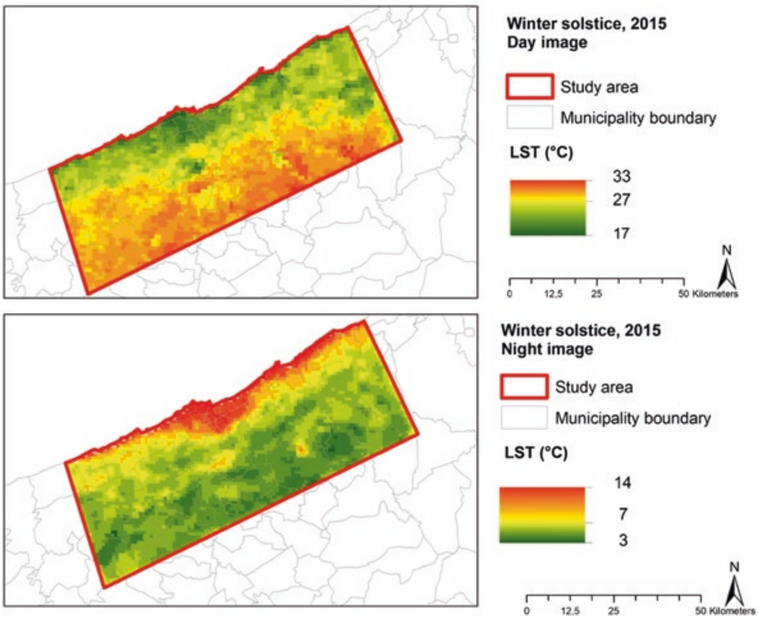

Fig. 7.5 Day and night images in a winter solstice

– In the day, the UHI is less important over the seasons unlike the night when it is a clearly visible phenomenon, marked and measured over the four seasons.
– The UHI is a phenomenon that doesn't depend on the seasons or more generally climate, so it is a phenomenon highly dependent on urbanization, forms, and materials of a city.

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Chapter 8
Green Healthcare System: Main Features in Supporting Sustainability of Healthcare System—A Review

Jazla Fadda

Introduction

Green healthcare system is likely to be most compelling because of its potential to protect and promote health, both directly and indirectly. “Health system” and “healthcare system” have slight difference, the former addressing the solutions needed to focus on the ultimate outcome of interest, i.e., the population’s health and each individual’s health, and the latter addressing the formal system of care designed primarily to treat illness. A successful health system has three dimensions: outcomes—means attaining the highest level of healthcare, which is effective, safe, timely, patient-centered, and efficient; equity—meaning that treatment is applied without discrimination or disparities to all individuals and families, regardless of age, group identity, or place; and fairness, the system is fair to the health professionals, institutions, and businesses supporting and delivering care. According to IOM, there are were six objectives of the twenty-first century healthcare system: safe by avoiding injuries to patients, effective by avoiding underuse and overuse, patient-centered by ensuring that patient values guide all clinical decisions, timely by reducing waits, efficient by avoiding waste of equipment, supplies, ideas, and energy, equitable by providing care that does not vary in quality because of personal characteristics such as gender, ethnicity, geographic location, and socioeconomic status. A sustainable health system also has three key attributes: affordability, acceptability, and adaptability by responding to new diseases, changing demographics, scientific discoveries, and dynamic technologies. According to the Office of the Federal Environmental Executive, “green or sustainable building is the practice of designing, constructing, operating, maintaining, and removing buildings in ways that conserve natural resources and reduce pollution”). It identifies opportunities to

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enhance environmental performance in the following domains: site selection, water conservation, low-emitting materials, alternative transportation, daylighting, reduced waste generation, local and organic food use, and green cleaning materials.

The Review Procedures

Objectives

The main objective of the review is providing an overview of variety of evidences related to the main features of green healthcare in supporting sustainability of healthcare system; the main sub-objectives of this paper are:

(a) To review the main components and characteristics of successful and sustainable healthcare system
(b) To review the main pillars of green healthcare
(c) To provide an evidence of the role of green healthcare as a driven force impacting the sustainability of healthcare system

A literature review was used to generate a conceptual framework of the direct and indirect effects of climate change, and how it can impact health directly and indirectly depending on some vulnerability factors. The review was held to answer the following questions:

- What are the main components of successful healthcare system?
- What are the main components of the sustainable healthcare system?
- What are the main pillars of green healthcare?
- What is the role of green healthcare in the sustainability of healthcare system?

A search has been conducted to generate variety of sources, using computerized resources (Medline, Scopus, and pro-quest); different key words were used to synthesize the inputs, such as healthcare system, sustainability in healthcare system, green healthcare, and green hospitals.

About 50 search results were generated from the previous search engine; the relevant studies were reviewed to match this paper questions to find the association between green healthcare system components and the sustainable healthcare system.

Inclusion and Exclusion Criteria

The paper reviews the studies and journal articles that address the green healthcare system and sustainability.

This paper excludes the economic and financial part correlated with green healthcare system.

Key Findings

Healthcare System and Sustainability

"Health system" is different from "healthcare system" because the former refers to the *solutions that need to focus on the ultimate outcome of interests, i.e., the population's health and each individual's health, and not only on the formal system of care designed primarily to treat illness.*

A successful health system has three attributes: first is "*Outcomes*" outlined by healthy people, meaning attaining the highest level of health possible; second is "*superior care,*" meaning care that is effective, safe, timely, patient-centered, and efficient; third is "*Equity*" means fairness, refers to applying treatment without discrimination or disparities to all individuals and families, regardless of age, group identity, or place, and that the system is fair to the health professionals, institutions, and businesses supporting and delivering care [1].

Six quality aims for the twenty-first century healthcare system was addressed by IOM

- Safe by avoiding injuries to patients from the care that is intended to help them.
- Effective by providing services based on scientific knowledge to all who could benefit and refraining from providing services to those not likely to benefit (avoiding underuse and overuse, respectively).
- Patient-centered by providing care that is respectful of and responsive to individual patient preferences, needs, and values and ensuring that patient values guide all clinical decisions.
- Timely by reducing waits and sometimes harmful delays for both those who receive and those who give care.
- Efficient by avoiding waste, including waste of equipment, supplies, ideas, and energy.
- Equitable by providing care that does not vary in quality because of personal characteristics such as gender, ethnicity, geographic location, and socioeconomic status [1].

Healthcare System and Sustainability

Sustainability in healthcare means a complex system of interacting approaches to the restoration, management, and optimization of human health that have an ecological base, that are environmentally, economically, and socially viable indefinitely, that work harmoniously both with the human body and the non-human environment, and which does not result in conflict [2].

A sustainable health system has three key attributes:

- Affordability, for patients and families, employers, and the government (recognizing that employers and the government ultimately rely on individuals as consumers, employees, and taxpayers for their resources)
- Acceptability to key constituents, including patients and health professionals
- Adaptability, because health and healthcare needs are not static (i.e., a health system must respond adaptively to new diseases, changing demographics, scientific discoveries, and dynamic technologies in order to remain viable) [3].

Green Healthcare System

Green healthcare means the *incorporation of environmentally friendly practices into* ***healthcare*** *delivery—appeals to health professionals and institutions for many reasons. It offers the potential to safeguard the environment, an increasingly compelling challenge* [1].

Green healthcare has great potential to protect and promote health, both directly and indirectly. *These health benefits may operate on at least three scales: local, community, and global. On the local scale, within the walls of a hospital, research facility, or clinic, green construction and operation can protect patients, workers, and visitors. For example, choosing safe cleaning agents or limiting the use of pesticides can reduce the potential for toxicity among those exposed* [4].

On the community scale, reducing the ecological footprint of a hospital reduces environmental hazards and protects natural resources, such as pedestrian infrastructure, reducing packaging, biodegradable cutlery to reduce the volume of waste sent to landfills. On the global scale, green practices reduce environmental degradation, such as purchasing food or supplies from local sources to reduce greenhouse gas emissions that contribute to climate change [1]**.**

"*Green or sustainable building is the practice of designing, constructing, operating, maintaining, and removing buildings in ways that conserve natural resources and reduce pollution* [5]. This definition is applicable to healthcare facilities design, construction, and operation stages.

The Green Guide for Healthcare (2006) identifies opportunities to enhance environmental performance in the following domains: site selection, water conservation, energy efficiency, recycled and renewable materials, low-emitting materials, alternative transportation, daylighting (the use of natural light in a space to reduce electric lighting and energy costs), reduced waste generation, local and organic food use, and green cleaning materials [6].

The concept of healthcare facility design for public and environmental well-being has different characteristics, which are aspirational, economical, prudent, long-term, and contextual.

Green healthcare facilities aim not only to avoid harm, but also to enhance well-being and to restore the environment. Green healthcare facilities provide value and save money. Moreover, Green healthcare reduces future risks, such as those related to energy price shocks, building-related health problems, and building obsolescence.

On the other hand, long-term means that the benefits of green buildings emerge over years, or even over the entire life span of a building.

Finally, contextual means that green buildings yield benefits not only within their own walls, but also in the context of the community or even the national or global arena.

Green healthcare principles can be implemented at physicians' offices, clinics, medical centers, and community hospitals [1].

There are also ethical reasons for pursuing green healthcare. Biomedical ethics are usually based on four principles:

- Autonomy
- Beneficence
- Nonmaleficence
- Justice [7, 8]

- The provision of green healthcare is consistent with beneficence because it provides benefits to patients and staff as well as to the community and future generations. Nonmaleficence means avoiding harmful results from certain conventional practices [9].

The Principles of the Ethical Practice of Public Health begin with a statement that, prima facie supports green healthcare: "Public health should address principally the fundamental causes of disease and requirements for health, aiming to prevent adverse health outcomes; this is why green healthcare reflects both biomedical and public health ethics" [10].

Green health facilities should address the following key environmental factors: ventilation, aesthetic pleasantness of the building, sunlight, noise reduction and positive sound stimulation, connection to nature, socially supportive spaces where patients can be with family, and increased behavioral control. This will reduce the pain, emotional anxiety, and other physiological indicators of stress.

Low air circulation can concentrate pollutants to two to five times higher than in outdoor air. If the ventilation system is not efficient, the pollutants will stay there longer, thus affecting health, such as VOC, Microbial VOC, such as mold and mildew, Semi VOC from fire retardants and pesticides, inorganic gases, such as ozone, carbon monoxide, and nitrogen dioxide, and particulate matter from burning fuels in cars and burning combustion products. The health impacts might be headache, nausea, nasal and chest congestion, wheezing, eye problems, sore throat, hoarseness, fatigue, chills and fever, muscle pain, and neurological symptoms, such as difficulty remembering or concentrating, dizziness, and dry skin. It contributes to lost productivity and dissatisfaction with the work environment.

Green Healthcare System Main Components

The review outlined the main components of *Green Healthcare System*.

Leadership

Leadership is essential at all levels towards safety and sustainability key organizational priorities, through education, goal setting, accountability, and incorporating these priorities in all external relations and communications. Develop and commit to a system-wide green and healthy hospital policy. This can be attained by horizontal integration within the hospital, research and innovation, operating plans, continuous education, community engagement, stakeholder's collaboration and networking, and incorporating sustainability into accreditation standards. A task force consists of representatives of various departments and provisional within the organization to help guide and implement efforts. Dedicate staff resources at the executive/directorate and facility levels to address environmental health issues organization—or system-wide. Invest in research to remove barriers to further innovation. Assure that strategic and operating plans and budgets reflect the commitment to a green and healthy hospital. Provide opportunities for educating staff and community on environmental factors that contribute to the burden of disease, as well as the relationship between public environmental health and disease prevention [11–13].

Substitute Harmful Chemicals with Safer Alternatives

The healthcare sector is a major consumer of chemicals including those well documented to cause serious impacts on health and the environment. Thus, a sector whose mission is to protect human health is contributing to the burden of disease. By addressing chemical exposure in health settings, the health sector can not only protect patient and worker health, but also actively demonstrate the safe management of chemicals thereby leading by example. Through chemicals and materials policy and protocols to protect patient, worker, and community health and the environment [14–16].

Reduce, Treat, and Safely Dispose of Healthcare Wastes

Hospitals generate millions of tons of waste each year, the combined toxic and infectious properties of medical waste represent an underestimated environmental and public health threat. Burning of medical waste generates a number of hazardous gases and compounds; moreover, disposal of solid waste produces greenhouse gas emissions. Properly managed, healthcare waste should not cause any adverse impacts on human health or the environment, through reducing, treating, and safely disposing of healthcare waste, and reducing the volume and toxicity of waste produced by the health sector. A variety of non-burn technologies can be used to disinfect, neutralize, or contain the wastes for landfill disposal [17–19].

Implement Energy Efficiency and Clean, Renewable Energy Generation

Solar and wind can both significantly reduce greenhouse gas emissions and protect public health from the myriad impacts of climate change, including increased heat-related illnesses, the expansion of vector borne diseases, and increased droughts and water scarcity in some regions and storms and flooding in others. Moving away from fossil fuels also brings with it the health and economic co-benefit of reductions in hospital admissions and treatments for chronic illnesses such as asthma, lung and heart disease caused by the pollution created from the extraction, refining and combustion of coal, oil, and gas. Effective strategies such as implementing energy conservation and efficiency programs that will reduce energy consumption by a minimum of 10% in a single year and conducting regular energy audits and use the results to inform awareness, besides integrating occupant education and awareness programs to reduce energy consumption related to occupancy [20].

Energy conservation and efficiency program can reduce energy consumption by a minimum of 10% in a single year, energy savings of 2%, resulting in a 10% reduction in each 5-year period. Moreover, it should be investigating sources of onsite, clean, renewable energy and include its generation in all new building plans [21].

Reduce Hospital Water Consumption and Supply Potable Water

Lack of water and sanitation infrastructure is a major problem that directly impacts hospitals and healthcare systems through overburdening them with more disease in the population. Health facilities can conserve water resources by closely metering water use, installing water-efficient fixtures and technologies, growing drought-resistant landscape, and making sure that leaks are quickly repaired, switch from film-based radiological imaging equipment, which uses large quantities of water, to digital imaging, which uses no water and no polluting radiological chemicals, besides regular analysis of water quality and implementing on-site wastewater treatment technologies, and develop joint projects with the community to improve and protect water supplies, water quality, water delivery and wastewater systems for the entire population [18, 22].

Improve Transportation Strategies for Patients and Staff

The health sector is a transportation-intensive industry that requires lots of ambulance hospital vehicles, delivery vehicles, and staff and patient travel, which leads to air pollution impacts. Shifting to hybrid technologies, all-electric vehicles, and compressed natural gas and encouraging hospital staff and patients to use bicycles can reduce emissions. Improve transportation strategies for patients and staff. This requires developing transportation and service delivery strategies that reduce hospitals' climate footprint and their contribution to local pollution. Transportation choices have a huge impact on the communities within which hospitals are situated [23, 24].

Food

A growing number of healthcare facilities in developed and developing countries that purchase and serve food to patients and workers are reducing their environmental footprint and improving patient and worker health by making changes in hospital service menus and practices. Moreover, promoting local, sustainable production, by producing their own food onsite, and supporting nutritious, localized sustainable food systems to reduce their own immediate footprint while supporting food access and nutrition reduce hospitals' environmental footprint while fostering healthy eating habits in patients and staff. Purchase and serve sustainably grown, healthy food and support access to locally and sustainably sourced food in the community [25, 26].

Pharmaceutical Pollution and Safer Pharma

More than 600 pharmaceuticals and their metabolites have been found in the environment worldwide; this impact on the environment has implications for human health including antimicrobial resistance. Levels of pharmaceuticals in the environment are likely to rise in years to come, as the global demand for pharmaceuticals grows. In countries and hospitals where there are an abundance of pharmaceuticals, health systems can play an essential role in reducing pharmaceuticals pollution by reducing over-prescription practices, besides reducing pharmaceutical waste by decreasing the amount of drugs prescribed, and minimizing inappropriate pharmaceutical waste disposal, promoting manufacturer take-back, and ending the dumping of pharmaceuticals as part of disaster relief. Moreover, the impact of pharmaceutical industry on the environment has implications for human health including antimicrobial resistance [20].

Green Building

The health sector has the potential, through its market power, to influence the construction industry to develop safer, more resilient, greener, and healthier building products and systems. The significant environmental and health impacts associated with hospital buildings have led to the creation and adoption of a wide variety of "green building" tools and resources related to healthcare. This can be attained through: minimizing the combined footprint of building, parking, roads, and walks, using high reflectance roofing and paving, or "green roof" systems, using materials that are replenishable and support human and ecosystem health in all phases of their life cycle, reducing transportation energy. Moreover, employing passive systems increased resilience and redundancy, such as using narrow floor plates for daylighting and natural ventilation avoiding materials such as lead and cadmium-containing paint and coatings, PVC, CPVC as well as asbestos with safer alternatives. Moreover, focusing on natural ventilation or mechanical systems to enhance air quality and lighting and acoustical settings reduces stress and supports health and productivity [20, 27].

Purchasing

The health sector spends huge amounts of money on purchasing goods. Healthcare purchasing results in a significant environmental impact and can also have significant human rights impacts. Creating and implementing green and ethical purchasing policies can play a central role in implementing many of the goals of the Green and Healthy Hospitals Agenda. This could be attained through buying safer and more sustainable products and materials, besides sourcing sustainably produced supply chain materials from socially and environmentally responsible vendors. By this HCS can positively impact the supply chain, compelling manufacturers to provide safer, more environmentally sustainable products, produced under healthy working conditions and in accordance with international labor standards [17, 20, 28].

Drivers of Leading Organizations

According to Leonard Berry's book who discovered "The soul of service" there are nine drivers of sustainable business success.

- Strategic focus
- Executional excellence

- Control of destiny
- Trust-based relationships
- Investment in employee success
- Acting small
- Brand cultivation
- Generosity
- Value-driven leadership

This will confirm that *it's all about well-structured services*, or the process, we can't approach better outcomes without well-designed process capturing all the aspects of green healthcare system. The environmentally friendly practices into *healthcare* delivery is of high importance for the professionals and institutions to safeguard the environment and sustain improvements.

Conclusion

This paper addresses green healthcare system by highlighting on the main pillars of the successful and sustainable healthcare system and incorporating all friendly practices appeals to health professionals and institutions, to safeguard the environment, an increasingly compelling challenge.

Green healthcare system is not merely go green concept, it's going beyond by incorporating all the aspects of healthcare system, such as leadership, substituting harmful chemicals with safer alternatives, safe disposal of wastes, energy efficiency, renewable energy generation, transportation strategies, food, green building, safer pharma, and purchasing.

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12. South Africa | Hospital Staff Empowerment and Cost Savings, Victoria Hospital.
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Chapter 9
Urban Grapevine: Visions of Regenerative Multifamily Housing in Washington DC

Michael Binder, Marcie Meditch, Lael Taylor, and Jenny Wienckowski

Introduction to the Living Building Challenge

The Living Building Challenge (LBC) [1] was created by Cascadia Green Building Council in 2006 and has been administered by the International Living Future Institute (ILFI) since 2011. The goal of the LBC is to create a fundamental systemic transformation of the building industry and its products, making them truly sustainable and even regenerative (repairing the damage inflicted by unsustainable practices in the past). In 2015, ILFI released the Living Community Challenge (LCC) [2], extending the principles of the LBC to entire communities. Recently, the Living Product Challenge (LPC) [3] was introduced to transform manufacturing of consumer goods as well.

In order to achieve *full certification* under the LBC (version 3.0), a project must meet 20 requirements, or *Imperatives*, organized into 7 categories, or *Petals*, as summarized in Chart 9.1. A detailed description of every LBC Petal and Imperative is beyond the scope of this document but can be found on the ILFI website (see ref. [1]). It is also possible for a project to achieve *Petal Certification* by meeting the Imperatives for three of the seven Petals; at least one of them has to be energy, water, or materials. *Net Zero Energy Certification* is also an option. More details regarding these partial certifications can be found in reference [1].

The LBC recognizes that context is essential and each Imperative and Petal makes allowances for development density and climate. Certain Imperatives are

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Chart 9.1 Living Building Challenge categories (Petals) and requirements (Imperatives)

Petal	Imperatives
Place	1. *Limits to Growth*—protecting undeveloped land and natural habitats
	2. *Urban Agriculture*—building resilience by growing food on-site
	3. *Habitat Exchange*—protecting habitats on a global scale
	4. *Human-Powered Living*—conserving energy, reducing pollution, and promoting fitness
Water	5. *Net-Positive Water*—harvesting and recycling all water needs on-site
Energy	6. *Net-Positive Energy*—generating more clean, renewable energy than is used on-site
Health and Happiness	7. *Civilized Environment*—access to daylight and clean fresh air
	8. *Healthy Interior Environment*—promoting indoor air quality
	9. *Biophilic Environment*—access to nature
Materials	10. *Red List*—eliminating toxic materials
	11. *Embodied Carbon Footprint*—carbon offsets for energy used in construction
	12. *Responsible Industry*—promoting transparency in material contents
	13. *Living Economy Sourcing*—using locally sourced materials and expertise
	14. *Net-Positive Waste*—recycling materials (source and waste streams)
Equity	15. *Human Scale and Humane Places*—places for people, not cars
	16. *Universal Access to Nature and Place*—maintaining public access to waterways and natural features
	17. *Equitable Investment*—ensuring that sustainability is not just for the wealthy
	18. *JUST Organizations*—building social equity, community engagement, and worker welfare within our companies
Beauty	19. *Beauty + Spirit*—beauty is essential to sustainability
	20. *Inspiration + Education*—using buildings for public outreach and education (tours, programs, publications, websites, etc.)

best satisfied at the neighborhood or community scale rather than in each building; this is handled through the concept of *scale jumping*.

The LBC is also aspirational and recognizes that certain Imperatives like rainwater harvesting for potable uses and graywater recycling are illegal in many parts of the world (particularly in the United States). The ILFI has established temporary *exceptions* for cases like this. In order to qualify for an exception, a project must demonstrate that they have made a good faith effort to implement the Imperative and to document the reasons why the exception is needed. In the case of regulatory barriers, the project team must petition the appropriate authority and be rejected. In this way, the design and development communities serve as agents of change to better align regulations with sustainability goals.

Another important distinction between the LBC and other rating systems like LEED is that LBC certification is based on actual performance, not simulated or calculated behavior. A project must therefore have a full year of operational history and data that prove its compliance with the Imperatives before it can become certified.

Introduction to the Urban Grapevine Project

In 2015, Washington DC's Living Building Challenge Collaborative sponsored a competition in partnership with the DC Department of Energy and Environment (DOEE) and the DC Housing and Community Development (DHCD) authority. The goal was to envision a small community of 10–15 affordable single-family homes in DC's Deanwood neighborhood, capable of meeting all 20 Imperatives of the Living Building Challenge. Over 25 design teams competed in that competition, and many exciting concepts were represented in their submissions. The winning entry in this competition was the *Urban Grapevine* project, which is described in more detail below.

Project Site

The Deanwood neighborhood is located in the easternmost corner of Washington DC. It was first settled by African Americans after the Civil War, developing into a vibrant community founded on a strong spirit of self-reliance. Marvin Gaye, the popular American R&B composer and performer, grew up in the Deanwood area; his hit song "I Heard It Through the Grapevine" helped inspire the project name—Urban Grapevine. The Marvin Gaye Nature Trail passes close by the project site (Fig. 9.1). The grapevine is a fitting metaphor—a living organism rooted in place, deriving all their resources from the site, producing shelter and nourishment.

In recent decades, Deanwood has suffered from problems all too common in many American cities: a vicious cycle of poverty, crime, unemployment, and educational

Fig. 9.1 Project site location and existing condition

underperformance. Although there are many well-kept residences and community resources in this neighborhood, there are also abandoned and vacant properties like the project site. This area of the city is often referred to as a “food desert” because of the scarcity of stores selling wholesome and nutritious foods (fresh fruit and vegetables, protein, low-fat and low-sugar foods). The site had been previously developed and therefore satisfies the *Limits to Growth* Imperative. Bicycle racks on-site and proximity to public transit, including buses and the Capitol Heights Metrorail Station, help the project satisfy the *Human-Powered Living* Imperative. Most of the parking spaces on-site will have electric car-charging stations as well.

Project Goals

In order to restore the community’s sense of self-reliance and opportunity, the goal of the competition and the focus of the Urban Grapevine project are to develop not just affordable housing but *affordable living*. Designers, developers, investors, and government must look beyond making housing cheaper to build and recognize the long-term need for communities that are more affordable to live in. Sustainable affordability, in turn, requires infrastructure that is efficient and resilient and a population that is healthy, happy, educated, secure, and confident.

The centralized industrial infrastructures for power, water, waste, food production, and health care developed in the twentieth century have made urban dwellers increasingly dependent on systems they can neither see, understand, nor control. As these systems begin to break down (as recent headlines from cities like Flint, Michigan, clearly indicate), economically challenged residents are often disproportionately affected. The decentralized infrastructures of the twenty-first century will, the authors believe, reintegrate people with the systems they rely on in their daily lives.

The philosophies and methods embodied in the Living Building and Living Community Challenges represent a visionary and viable set of tools for creating neighborhoods that are environmentally and economically sustainable, socially equitable, healthy, and beautiful.

Community Design

The LBC’s first Petal is *place* and the Urban Grapevine’s first challenge was to create a community where residents feel safe and connected to each other. The ten single-family homes are designed around two small courtyards that provide space for children to play and neighbors to socialize together (Figs. 9.2 and 9.3). A third, centrally located courtyard provides space for planters where residents can grow fruits and vegetables for themselves and to trade with others. This garden space also meets LBC’s Imperative for urban agriculture (Fig. 9.4).

Fig. 9.2 Urban Grapevine site plan

Fig. 9.3 Computer rendering of semiprivate courtyard

The centerpiece of the community is a greenhouse that not only houses the rainwater cistern, water filtration, and energy storage systems but also provides a community kitchen and potting tables for starting seeds each year. This facility is intended as a resource for the surrounding neighborhoods as well, a place where residents can learn about good nutrition and urban farming. Indeed, the entire site is intended to function as an integrated ecosystem according to the principles of *permaculture* [4].

Permaculture was developed by Bill Mollison as a design tool for individuals and communities looking to create a self-sufficient lifestyle combining elements of agriculture and ecology in a modified working landscape. Based on site-specific observation and analysis, Urban Grapevine developed a landscape plan that features

Fig. 9.4 Computer rendering of central courtyard and greenhouse

fruit and nut trees throughout the site. These woody plants are underplanted with perennial vegetables and edible wild plants such as rhubarb and sunchoke and bio-accumulators such as false indigo and white clover. Even the flowers have a job in this landscape, as they provide seasonal nectar and pollen for beneficial insects and are integral to the stormwater management process. These design features help Urban Grapevine satisfy the LBC Imperatives for *Biophilic Environment*, *Civilized Environment*, *Human Scale and Humane Places*, *Universal Access to Nature*, *Beauty + Spirit*, and *Inspiration + Education*. They provide opportunities for residents to build self-reliance, empowerment, and physical and spiritual health. Urban agriculture has received a great deal of attention and support from area residents in recent years, and this project is intended to inspire a network of community gardens throughout the DC area.

Energy

Energy independence and security are critical issues throughout the world today. The United States is still heavily dependent on fossil fuels like coal, oil, and natural gas. Energy prices have been kept relatively low by government subsidies and through the use of environmentally questionable extraction practices like fracking. Even so, low-income families are having difficulty in keeping up with energy bills,

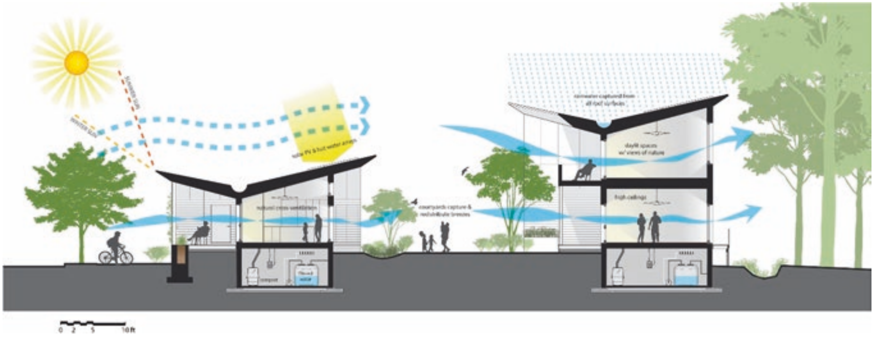


Fig. 9.5 Typical site section showing arrangement for passive solar control and natural ventilation

and the US energy infrastructure experiences seasonal capacity shortfalls, especially in areas with hot and humid summers like Washington DC.

High-performance, energy-efficient construction can no longer be considered a luxury. Architects, engineers, and developers throughout the United States are seeking ways to make affordable housing that is tight, well-insulated, efficiently heated, cooled, and ventilated. The Urban Grapevine houses employ broad roof overhangs and planted screening walls for seasonal control of solar gain (Fig. 9.5). Operable windows and courtyards are positioned to take maximum advantage of prevailing breezes in the summer (Fig. 9.5).

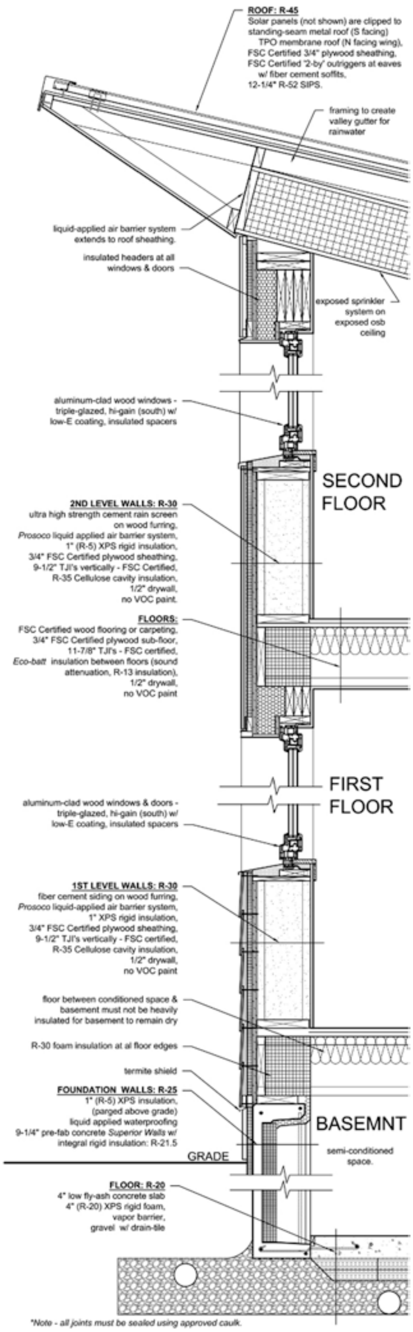
Using BEopt [5], a program developed by the US National Renewable Energy Laboratory (NREL), the Urban Grapevine team experimented with different envelope systems, levels of insulation, energy-efficient lighting, equipment, and appliances. The goal was to find an optimum balance of energy efficiency, environmentally sustainable materials, and affordability. Ultimately, the multidisciplinary team of architects and engineers agreed on the wall section shown in Fig. 9.6. Combined with passive solar design and ample natural daylighting, an ENERGY STAR [6] appliance package, LED and CFL lighting, a SEER-22 mini-split heat pump system, and an energy recovery ventilator (ERV), the final predicted energy budget for each house was 57% less than the *Building America 2010*[1] benchmark design (see Fig. 9.7).

Water and Waste

Although many private and governmental programs have been created to reduce energy use and carbon footprint, many designers have concluded that access to clean water will represent a much more critical and challenging issue in the next century.

[1] *Building America is a program created by the US Department of Energy to define a set of standard building practices. The 2010 benchmark assumes construction that conforms to the International Energy Conservation Code (IECC) 2009.*

Fig. 9.6 Cross section of typical wall, roof, and floor construction



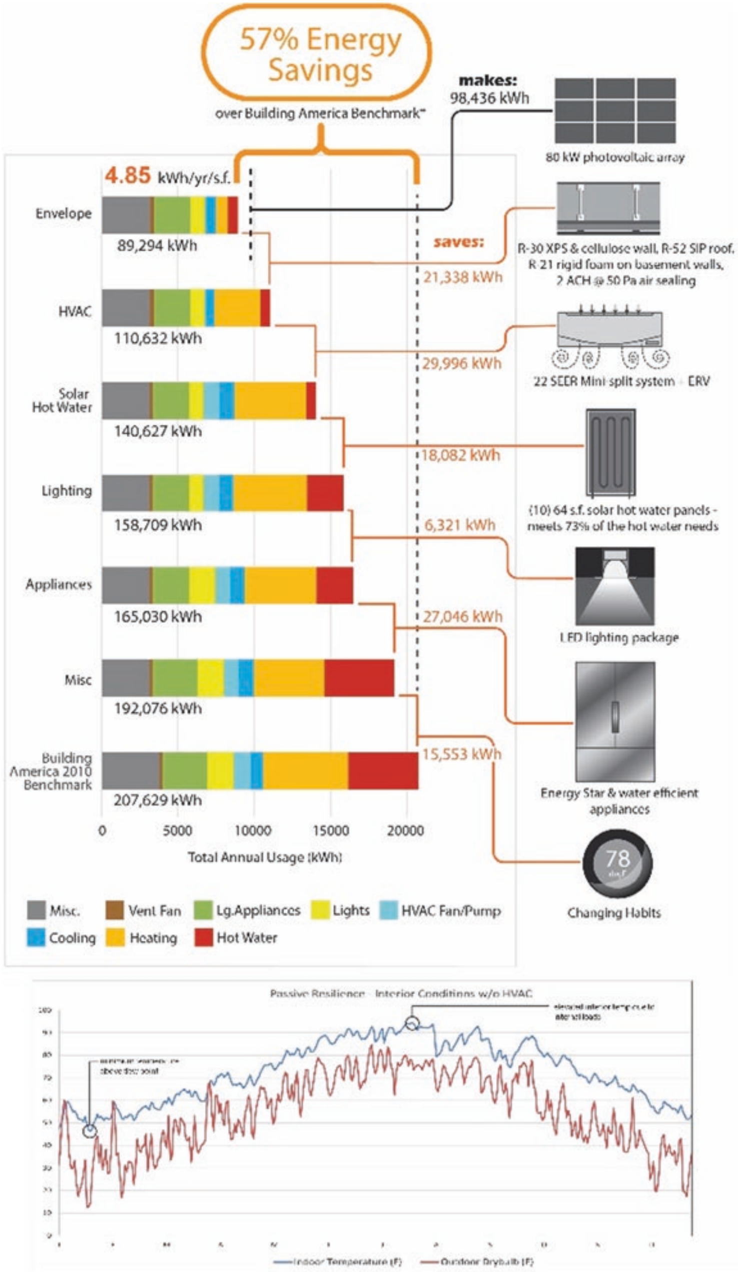


Fig. 9.7 Energy breakout by use compared to Building America 2010 benchmark design

Excessive water use (including industrial applications) and emerging climate change have already led to droughts in many parts of the world. The *Net-Positive Water* Imperative of the Living Building and Living Community Challenges mandates use of rainwater falling on the site as the only source of fresh water (except where scale jumping makes more sense). Water cannot be drawn from underground aquifers and surface waters (rivers, lakes, etc.) unless the water is cleaned to comparable quality standards and returned to those sources. Graywater and blackwater must be filtered and sanitized (preferably without chemicals) and can be recycled into the buildings, used for irrigation, or allowed to infiltrate the land on-site.

Achieving net-positive water balance was one of the greatest challenges in the competition. Urban Grapevine is literally designed around water (Figs. 9.8 and 9.9).

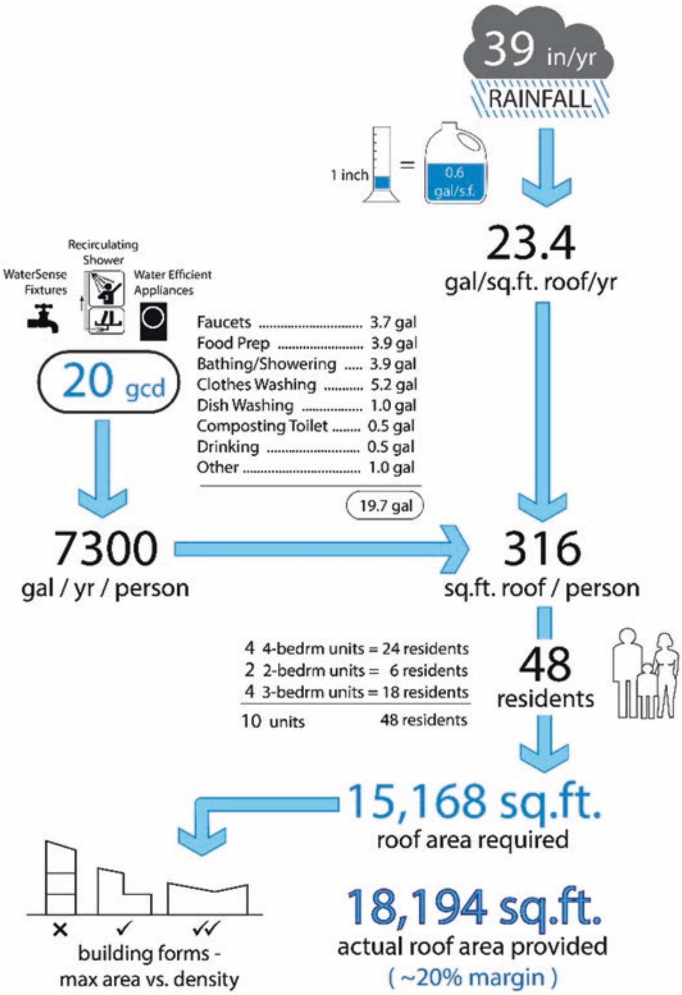


Fig. 9.8 Water collection and use calculations

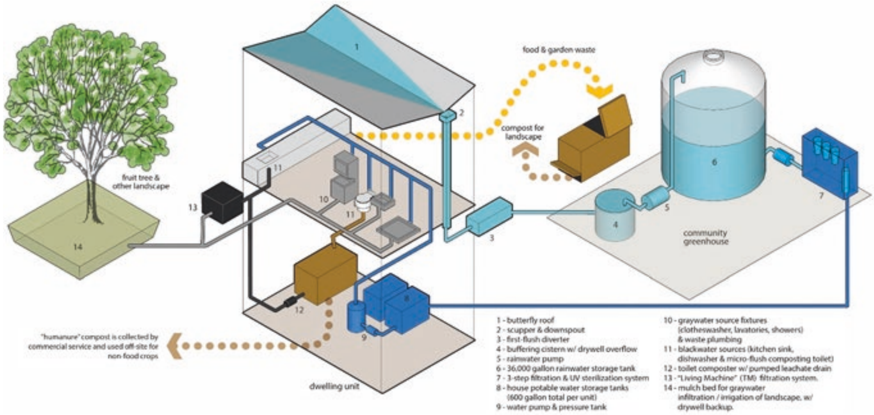


Fig. 9.9 Community-level water supply and waste infrastructure diagram

By using low-flow water fixtures, micro-flush composting toilets, and innovations like recirculating showers, it is possible to reduce per capita daily water use to 76 L (20 gallons US) without causing deprivation for residents. Washington DC annual rainfall is approximately 100 cm (39 in.). Allowing for first flush diversion, evaporation, and other minor losses, the amount of roof area required to support each resident is approximately 29.4 m^2 (316 $ft.^2$). After experimenting with a wide range of housing densities and floor plans, the design team arrived at a design with 10 duplex and triplex single-family units, a mixture of 2, 3, and 4 bedroom dwellings. The design will accommodate up to 48 residents, requiring a total of 1394 m^2 (15,000 $ft.^2$) of roof area. The actual design has a roof area of 1673 m^2 (18,000 $ft.^2$), providing approximately 20% extra capacity.

Many of the other competition entries proposed higher densities, including townhomes, but the calculations above suggest that there is a maximum density to any project if filtered and sterilized rainwater is the only source of potable water available. Higher densities might be possible if graywater can be recycled for potable uses, for example. A similar strategy would be required in regions that get less water.

Rainwater harvesting also drove the selected roof form for the project—a butterfly roof collects all water from the surface to a single location. As shown in Fig. 9.9, the water is pre-filtered before being conducted to the centrally located 136,000 L (36,000 gal US) community cistern, whose architectural prominence serves to remind residents that they are all connected to nature and to each other by water. The cistern's capacity was selected to carry the community through dry seasons and the occasional prolonged drought. At approximately 1-week intervals, water from the cistern is filtered (via reusable canister filters) and sterilized using ultraviolet light and is transferred to smaller tanks in the basement of each house. This makes the water supply resilient to power outages and periods without solar power (heavy snow storms that may hit Washington DC).

Graywater from showers, lavatory sinks, and clothes washers are minimally filtered, and they are conducted to the root zones of the many fruit trees planted around the site.

Blackwater from kitchen sink, dishwasher, and composting toilet (small among of liquid) are cleaned by small Living Machines™ [7] located in planters adjacent to each house. These systems use plants and soil microbes to break down and consume waste, producing graywater as an effluent which can then be used for tree irrigation as well.

William McDonough [8, 9], a visionary leader in sustainable design, advocates for the elimination of the very concept of waste (see also the *Net-Positive Waste* Imperative discussed in reference [1]). Food waste from kitchens is composted for use as fertilizer in the community gardens, while compost from the toilets is collected and transported off-site for use on non-food crops (or receives additional processing to eliminate the threat of pathogens before being used to grow food).

Additional LBC Imperatives

In addition to the LBC Imperatives related to the design and operation of the project as described above, there are others that are largely about materials, sourcing, and accounting. All materials selected for the Urban Grapevine project are *Red List Free* (where possible) or *Red List Compliant*. Red List materials are those known to have a negative impact on human or ecosystem health. Manufacturers typically will not disclose the chemical makeup of their products unless forced to do so by law. Under its Declare program [10], the ILFI has compiled a database of products shown to be Red List Free and Compliant. Each project certified under the LBC must add at least one product to this database.

The amount of research and documentation required to meet the *Living Economy Sourcing* and *Embodied Carbon Footprint* Imperatives was considered beyond the scope of the competition design. Tools such as Building Information Modeling and carbon footprint calculators would facilitate the documentation of these factors in a more mature and detailed design.

Several other requirements such as the *Habitat Exchange*, *JUST Organizations*, and *Equitable Investment* Imperatives can be fulfilled through donations to third-party organizations and were not considered design issues that must be addressed in the design.

Conclusions

This paper has attempted to summarize the goals and methodologies of the Living Building Challenge and their implementation in the Urban Grapevine project. The intent of the authors has been to demonstrate how regenerative design principles can be used to create communities that are more affordable, resilient, and healthier to live in. The goals of the competition and its winning entry are not only to improve the health of the ecosystem but to empower underserved urban residents in building a more self-reliant and prosperous lifestyle for themselves.

Many challenges lay ahead in developing projects like Urban Grapevine. Current practices in government funding, private investment, lending, and valuation tend to focus on first costs of construction only, rather than looking at the entire life cycle of manufacturing, operation, and disassembly. Hidden costs to society and ecosystem services are typically disregarded. This must change before large-scale adoption of Living Building is considered affordable. Regulatory restrictions are also a factor when considering features like renewable energy, decentralized urban water supply, and composting of waste. Demonstration projects like Urban Grapevine, if built, would serve to help reshape public perception of such systems and their attendant risks.

The strong interest that the DC Department of Energy and Environment and the DC Housing and Community Development authority have shown in advancing projects like Urban Grapevine is extremely encouraging. These organizations have the resources and political influence to effect real change in the way our society funds, regulates, and constructs sustainable projects in the future.

Acknowledgments The authors wish to acknowledge the contributions of Thomas Serra—the project's engineering consultant—and John Murphey—architectural design consultant. Their insight and work were essential to the success of the Urban Grapevine project.

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Chapter 10
Towards Resilient Cities: Improving Unplanned Urban Areas—Strategic Environmental Assessment and Upgrading Guidelines in Developing Countries

Mai M. Barakat, Mohsen M. Aboulnaga, and Mona F. Badran

Introduction

The world is currently witnessing an increase in urban population due to the need for better jobs, income, and better life. Currently, 50% of the world's population is residing in cities and the United Nation indicated that by 2050, 70% of the world's population will be in urban areas [1]. Such huge increase will cause tremendous pressure on cities' infrastructure, which in most cases are not resilient such as transport, and resources consumption (energy, water, and building materials), which in turn would generate more waste, and greenhouse gas (GHG) emissions, mainly CO_2 emissions, and cause air and water pollution. Cities worldwide are not only facing these challenges but also experiencing a threat by climate change impacts that affect the survival of humans. In megacities worldwide, the situation will be even more complex, especially in developing countries (Lagos and Cairo). Through the homogenous challenges faced by megacities worldwide such as climate change, high carbon emissions, and rapid consumption of resources (energy, water, and materials) as well as the increase of informal areas, especially in developing countries, upgrading and improving urban areas to provide sustainable living environments is of prime importance.

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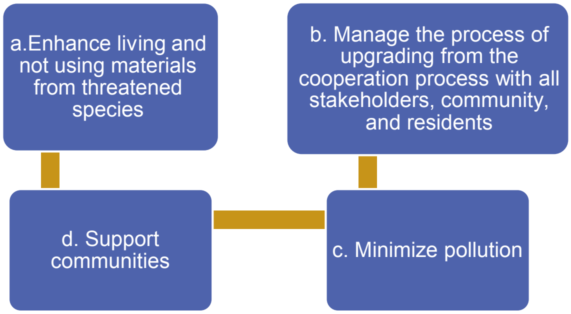

Fig. 10.1 Sub-objectives of the research

A recent study indicated that one in every four people will be living in slums by 2030 [2]. Understanding the critical decision that should be taken to integrate architecture and other engineering disciplines is essential to ensure successful cooperative plan that merges all building systems to consume less energy and emit low carbon.

Nonetheless, thoughts have been generated when we look around how people can think about saving energy or climate change disasters or a resilient low-energy structure when he cannot even have a secure outstanding shelter to live in and protect his own family. That is why upgrading of slums is the main concern to save a family that will consequently lead to a secure, equal, and prosperous society [3, 4].

Objectives

The aim of this paper is to provide a solution towards upgrading informal areas, enhance its living conditions, and assess unplanned urban areas through strategic environmental assessment (SEA). It focuses on sustainability indicators that enhance residents' living that support the upgrading process of their slums and making it resilient. Figure 10.1 shows the sub-objectives for the study [5].

Issues and Challenges Concerning Slums' Upgrading

Upgrading slum areas has many challenges, as some coherence should be achieved in the society and finding feasible solutions on a full scale for most of the slum area, taking into consideration the diversity within the slums and its dwellers. Due to the fact that unplanned informal areas are not similar or homogenous places, slum dwellers can be potential for living a better life in an urban area or criminal elements making use of the informality in the slums. In Egypt, until 2015, the upgrading projects of informal areas did not achieve the set targets due to the fact that many people in the community trusted that they will not qualify for an upgrading program as they are not considered a priority. Figure 10.2 summarizes these challenges [6].

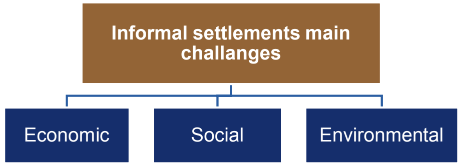

Fig. 10.2 Informal areas' main challenges

a. General view of the informal area b. Site after demolishing the slums c. A 3-D layout of the model

Fig. 10.3 Maspero informal area in the heart of Cairo, Egypt. (Image source: (**a**) https://www3.shorouknews.com/news/view.aspx?cdate=21072015&id=83f86506-49a9-4094-958d-0b9e246a9c5b. (**b**) https://www.al-monitor.com/pulse/originals/2018/07/egypt-maspero-july26th-heritage-destroying-modernisation.html. (**c**) https://issuu.com/maddplatform/docs/maspero_parallel_participatory_proj)

Methodology

The methodology depends on qualitative and quantitative approaches. The first includes a study on the international informal areas' upgrading and its different procedures, whereas the quantitative part is applied on the local informal area in downtown Cairo—Maspero Triangle. The study analyzed different informal areas around the world concerning sustainability and strategic environmental assessment (SEA). A full review of sustainable indicators concerning cities and informal areas has been assessed to detect individuals' needs according to their lifestyle and economic and social level [7].

Study Area, Data, and Period

Maspero area is located in the neighborhood west of Cairo; it has been named after a French Egyptologist, Gaston Maspero, who had served as director of the Egyptian Museum in 1914. It is accessible from Downtown via Corniche El Nile, from New Cairo via 6th of October Bridge, from Cairo University via 15th of May Bridge and from October via El-Mehwar and 15th of May Bridge. Figure 10.3 shows the site of Maspero Triangle where the research study was conducted. The study was conducted in 2017 before demolishing of Maspero by more than 4 months. Interviews and data were collected from an average of 15 families who lived inside the area [8].

Indicators for Measuring the Sustainability of Slums

The five indicators used in defining slum households to estimate the incidence of slums are access to improved water, access to improved sanitation, structural quality or durability of housing, sufficient living space (not overcrowded), and security of tenure as illustrated in Table 10.1 [9].

Strategic Environmental Assessment (SEA)

The strategic environmental assessment (SEA) tool was used in the assessment of the two models of global organizations: GIZ and Norman Foster. These projects were compared based on a well-planned sustainable development goals checklist.

In addition, a detailed assessment was also conducted to evaluate the local case study based on economic statistics and other sustainable development (SD) dimensions—livability, viability, and equitability. These dimensions are listed in Appendix 2 [10, 11].

Assessment of GIZ and Norman Foster's Strategy

The following assessment is conducted to measure sustainability indicators of projects Norman Foster and GIZ (Fig. 10.4). Norman Foster project was selected in the study because of his environmental and sustainable concepts in the project besides that it won the first prize of Maspero Triangle competition. On the other hand, GIZ was selected due to its approach towards energy efficiency goals and its strategies in upgrading four other informal settlements (Ezbet el-nasr, Gezert el-dahb, Markz el-abhas, and Ein shams) and these are excellent comparative cases to indicate which one would provide better model in upgrading informal settlements. The sustainable community indicators checklist consists of the 14 questions [12] and are listed in Appendix 1. However, GIZ has many missing indicators.

Figure 10.5a represents the applied indicators in the projects of the GIZ community and the missing ones. It also shows that GIZ is still missing nearly 50% of the leading sustainability indicators; 8 out of 15 indicators that will directly affect the quality of its projects, the selected indicators indicate projects over local and specific scale, zero waste management, heritage and waste management are broad-scale indicators that will affect society also zero-waste management is not covered, as it only exists in huge scale projects and needs high technology integrated with extra cost. The climate and context indictor is missing due to extra cost and neglecting of urban planning strategies [13]. Nonetheless, the applied indicators in the comparative models of the two projects of Norman Foster (Maspero Triangle) and the missing ones are illustrated in Fig. 10.5b. It shows that Norman Foster succeeded in achieving all the indicators, 14 out of 15 (93.33%) indicators, except applying local food as the project concentrates mainly on urban needs [14, 15].

Table 10.1 Indicators to measure sustainability of slums

Indicator	Definition	Features of acceptable conditions
Access to improved water	A household is considered to have access to improved drinking water if it has at least 20 L/person/day for family use, at an affordable price of less than 10% of the total income	• Piped connection to house or plot • Public standpipe serving no more than five households • Protected spring water • Rainwater collection
Access to improved sanitation	A household is considered to have access to improved sanitation if an extra disposal system, in the form of either a private toilet or public toilet shared with a reasonable number of people, is available to the household	• Direct connection to public sewer • Direct connection to septic tank • Pour flush latrine • Ventilated improved pit latrine (with slab)
Structural quality/ durability of housing	A house is considered durable if it is built in a nonhazardous location and has a permeant structure adequate enough to protect its occupants from extremes of climatic conditions such as rain, heat, cold, and humidity	• Permanent building materials are used for walls, roof, and floor • Compliance with building codes • Dwelling is not a dilapidated state • Dwelling is not located near toxic waste • Dwelling is not located on flood plain • Dwelling is not located on a dangerous right of way (railway, highway, power line, etc.)
Sufficient living space (not overcrowded)	A dwelling unit is considered to provide sufficient living area for household members if there are fewer than three persons per habitable room	• Not more than two persons per room • The alternative is to set a minimum standard for floor area per person (e.g., 5 m^2)
Security of tenure	Security of tenure is the right of all individuals and groups to effective protection by state against arbitrary unlawful evictions	• Evidence of documentation that can be used as proof of secure tenure status, as indicated by: • Households with formal title deeds to both land and residence • Households with enforceable agreements or any document as a proof of land arrangements

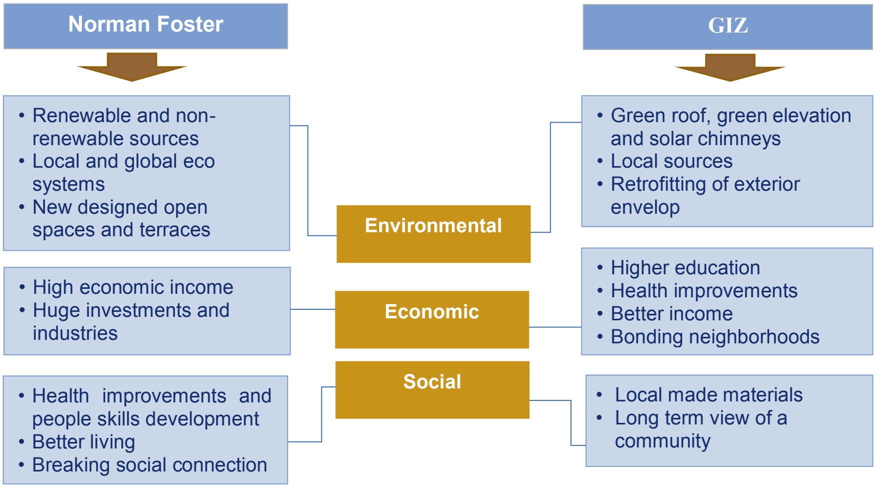

Fig. 10.4 Sustainability indicators for GIZ community and Norman Foster + Partners Firm

Results of the Assessment

The assessment results are outlined as follows:

- GIZ services are built on a wealth of regional and technical competence, tired and tested management expertise.
- Believe that combining social responsibility, ecological balance, political participation, and economic capability only will allow current and future generations to lead a secure and independent lives.
- Advocate respects for human rights, equal opportunities, and integrity.
- Support the rule of law and civic participation and committed to ensuring fair negotiation processes, both within and outside the company.
- Promote an oriented market, ecologically, socially, and economically, and observe the principles of corporate responsibility in our work [16, 17].

The Norman Foster's model depends on sustainable development's strategies at all levels and awareness of climate change impact, and most of the project's wide scale is based on sustainable, full, and productive economic growth and economic viability. To assess these two projects and bring about a well-integrated approach and coherence with the surroundings, yet use sustainable materials that support their designs, it is vital to understand these two projects. In addition, having extensive international experience and contacts in emerging economies and developing countries, it is the high ability in creating strong connections in its programmers between its activities and results in partner countries (GIZ Agenda 2030 is a partner in achieving SDGs).

On the other hand, Norman Foster project assessment showed that it was leading that of GIZ in 11 global goals—ensure healthy lives, ensure inclusive and equitable

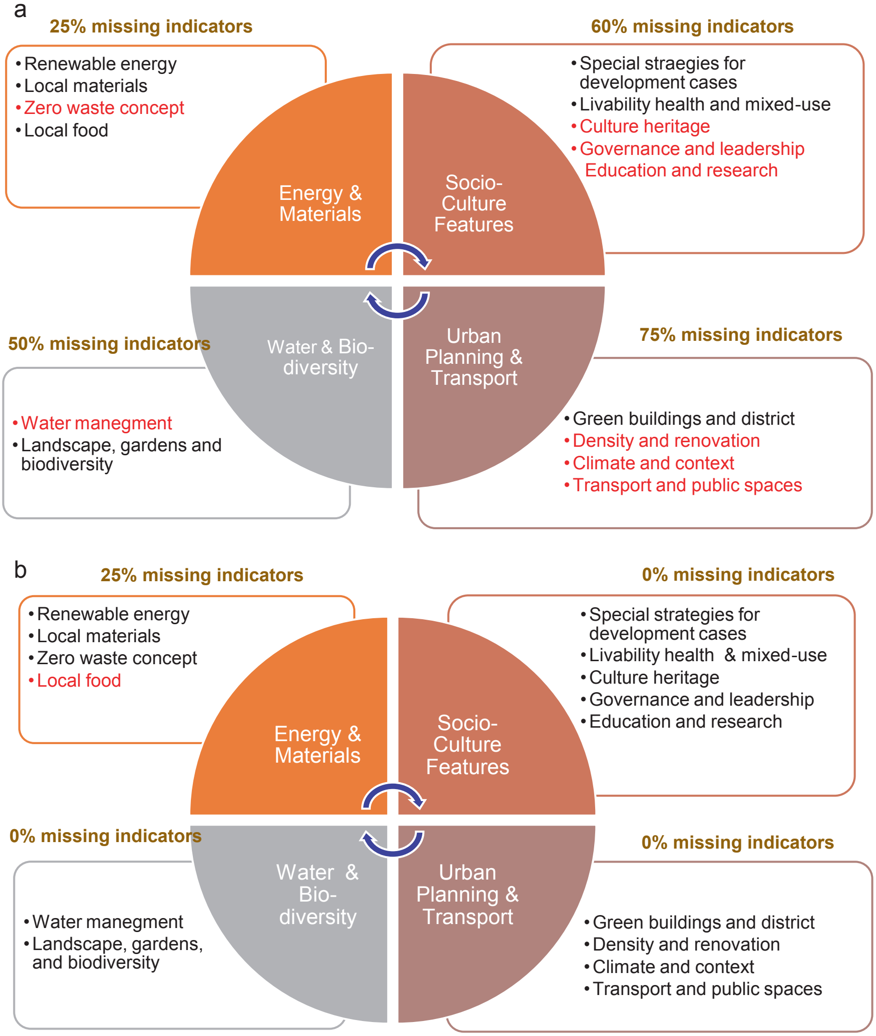

Fig. 10.5 Sustainability indicators for Norman Foster and GIZ modeled projects—Cairo, Egypt. (**a**) Sustainability indicators for GIZ community. (**b**) Sustainability indicators for Norman Foster. Text in red refers to non-existing indicators in the Project ▬. Text in black refers to existing indicators ▬

quality, ensure availability and sustainability, ensure access to affordable, build resilience infrastructure, reduce inequality, make cities inclusive, provide sustainability consumption, take urgent action to combat CC, conserve and sustainability, protect, restore and promote, promote peaceful and strengthen the means of implementation (Fig. 10.5). Detailed results are shown in Table 10.2 [18, 19].

Table 10.2 Sustainability goals checklist of the two modeled projects

Sustainability goals	Available for GIZ	Available for Norman Foster
End poverty in all its forms	NA	✓
End hunger, achieve food security, and improve nutrition and promote sustainability agricultural	✓	NA
Ensure healthy lives and promote well-being for all ages	✓	✓
Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	NA	✓
Achieve gender equality and empower all women and girls	✓	✓
Ensure availability and sustainability of water and sanitation for all	NA	✓
Ensure access to affordable, reliable, sustainable, and modern energy for all	✓	✓
Promote sustainable economic growth, full and productive employment, and decent work for all	✓	✓
Build resilience infrastructure, promote inclusive and sustainable industrialization, and foster innovation	NA	✓
Reduce inequality within and among countries	NA	✓
Make cities and human settlements inclusive, safe, resilience, and sustainable	✓	✓
Ensure sustainable consumption and production patterns	✓	✓
Take urgent action to combat climate change and its impacts	NA	✓
Conserve and sustainably use the oceans, seas, and marine resources for sustainable development	NA	✓
Protect, restore, and promote sustainable use of ecosystems, sustainably manage forests, combat desertification, and reverse land degradation and halt biodiversity loss	NA	NA
Promote peaceful and inclusive societies for sustainable development, provide justice and build effective, accountable and inclusive institutions at all levels	NA	✓
Strengthen the means of implementation	✓	✓

✓ Exist (applied), *NA* not applied

Comparative Assessment of Different Consultants' Proposals for Maspero Triangle, Cairo

Assessment of the sustainable development indicators was developed over a studied and calculated data of each sustainable indicator regarding the three proposals that have been presented for upgrading Maspero Triangle as listed in Appendix 2 [19].

The challenges facing upgrading of selected area are illustrated in Fig. 10.6. Nonetheless, another main challenge the exchange of properties that will allow private investors to develop the Nile waterfront—with the exception of a New Museum, at the same time, allow the public sector to secure property of the popular neighborhood, to upgrade this area using the revenues of the sales of the land along the waterfront, and the taxation on real estate profits.

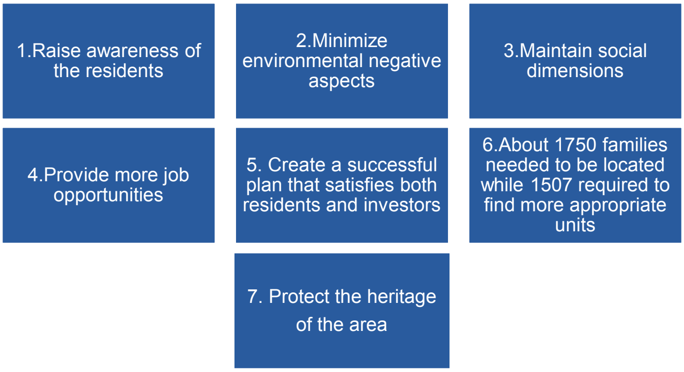

Fig. 10.6 The challenges facing upgrading of selected area—Maspero Triangle, Cairo, Egypt

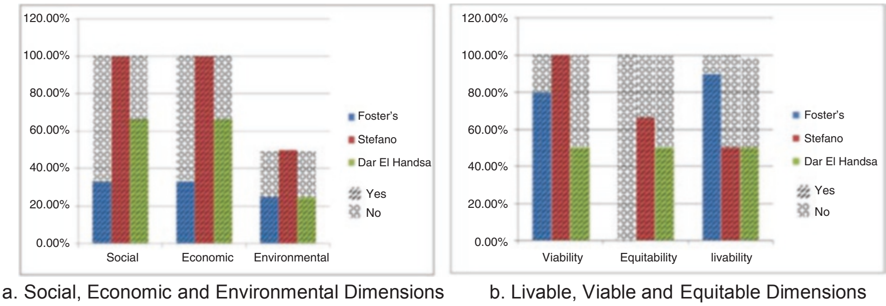

Fig. 10.7 Results of the projects' sustainability dimensions assessment. (**a**) Social, economic, and environmental dimensions. (**b**) Livable, viable, and equitable dimensions

Results and Discussions

The notion of economic inclusion of the residential core, such as exhibited through initial intentions in various proposals, may be enough for the competition scope, but it fails in responding to real resident's conditions. What will happen to the current shops and workshops? Are they considered? Will they be allowed to reopen? Moreover, how will this affect both Maspero and beyond?

Finally, there is a challenge that was not successfully confronted. Historically, the edges of the triangle were developed independently from the core; they were always built more lavishly with a different political or social statement looking outwards and leaving the poorer houses isolated behind. We can look at the edges still pointing outwards while the core is renovated but even isolated in the center of the area. Figure 10.7 illustrates the result of applying this assessment over the three proposals [20].

What Would an Organization like GIZ Recommend for Maspero?

In this section, it was imperative to indicate what should an entity such as GIZ recommend for the project based on the pervious assessment. These recommendations are listed as follows:

- Communicating between residents and investors to find suitable solutions for the relocation according to their needs
- Allowing residents to participate in the upgrading plans by being the workers themselves, consequently most of them will find job opportunities in the same area, however
- Making a survey for residents to find a suitable scenario that makes all parties satisfied with the planning strategies
- Keeping an update log with residents—Foster's missed time planning that makes residents insufficient of the project and cannot decide their situation whether to leave temporary or leave forever
- GIZ makes always walking an option in which there is a road for the pedestrian, but Foster missed this point
- Achieving satisfaction through GIZ, as it tends to make residents plan their food to gain some extra salary in addition to organic food that is afforded all the time for them, Foster's plant roofs only for decorations or insulation [21]
- Facing the risk of disasters that could be presented in the form of crimes in our case
- Linking adaptation policies with climate change in policy design and plans (Table 10.3)

Table 10.3 The six dimensions for sustainable informal areas (slums)

Social	Economic	Environmental
– Culture should be identified within the community – Residents should participate in the planning and execution phase – Equity should be achieved within residents concerning job opportunities and facilities urban distribution	– Increase job opportunities – Raise household individual income – All sectors of residents shall participate in decision making – Deal with slums residents as an economic opportunity	– Provide a plan to protect natural systems – Manage a team that is aware of environmental planning – Deduce the protection system for plants and animals – Create a clear system for protecting residents from air and noise pollution
Viability	**Equitability**	**Livability**
– The project should be socially and environmentally sustainable – The project should be financially viable to investors – Should be affordable to entity – Should provide value for money – Should be economically viable	– Decrease crime rate – Develop education level – Raise the employment rate	– Allow walkability to be a viable option – Provide roads for bicyclists – Plan a safe passage for pedestrians – Provide enough nearby employment opportunities

Guidelines for Upgrading Slums Within Sustainable Development Indicators and Principles

(a) Strengthening capacity building, revising policies and regulatory frameworks, and legal/technical constraints to effectively upgrade at scale; yet to overcome institutional bottlenecks and encourage local commitment, including political understanding, strengthening learning and training.
(b) Preparing National/City Upgrading Programs by helping committed countries design upgrading programs to scale.
(c) Supporting regional, global knowledge, and learning that capture and share the varied approaches and local practices to get the job done better with the full involvement of the affected communities; organizing networks of practice; fielding specialists to help countries and cities move to scale.
(d) Investing in slums with appropriate, necessary infrastructure and municipal services identified, implemented, and operated with the community.
(e) Strengthening partner capacity to pay attention to resources and robust tools to assist governments and communities perform efficiently and effectively and create better jobs in informal urban areas.
(f) Using resources effectively—save a proportion amount of resources, including money and land during material sourcing, construction—use or disposal; save water amounts, energy, or materials due to short life, poor design, inefficiency, or less than ideal construction and manufacturing procedures.
(g) Buildings are supposed to be more manageable, affordable, and maintainable in use, and minimize pollution.
(h) Creating minimum dependence on polluting products and materials, management practices, energy, power, and forms of transport, and create healthy environments.
(i) Managing the process of projects is a vital and overarching aspect in delivering sustainable projects, both in the first instance and also in ensuring their performance over time [22, 23].

Conclusions

Two modeled projects (Norman Foster + Partners and GIZ) were assessed using the SEA tool and sustainability goals. The study concluded that deduced critical guidelines are necessary in upgrading unplanned areas. These guidelines include developing services, housing design, and transportation, to expand the potential employment pool in the area. Creating urban social spaces also allow for the integration of cultural, educational, social, and environmental aspects; yet encouraging projects such as "Eradication of Illiteracy" provided by voluntary institutions to empower women and youth.

The results of assessment show that partnership between local organizations and global ones is needed in order to assess residents' needs, skills, and culture so that we can apply maximum number of sustainable goals within the terms of the project. The other assessment was done to assess if a local case study in downtown Cairo can be applied to enhance other slums in other developing countries since it addressed the social, economic, and environmental aspects with reference to sustainable indicators goals, yet applying the terms of this assessment will result in enhancing slums' residents' quality of life, promote economic and social development, and creative skills. It must be stated that if unplanned informal area to be demolished such waste should be included in the circular economy where recycling and reuse can be made by utilizing the waste materials from demolishing.

Appendix 1

1. Does the indicator address the carrying capacity of a community's built capital—the human-made materials (buildings, parks, playgrounds, infrastructure, and information) that are needed for quality of life and the community's ability to maintain and enhance those materials with existing resources?
2. Does the indicator address the carrying capacity of the natural resources—renewable and nonrenewable, local and nonlocal—that the community relies on?
3. Does the indicator address the carrying capacity of the ecosystem services upon which the community relies, whether local, global, or from distant sources?
4. Does the indicator address the carrying capacity of esthetic qualities—the beauty and life-affirming qualities of nature—that are important to the community?
5. Does the indicator address the carrying capacity of the community's human capital—the skills, abilities, health, and education of people in the community?
6. Does the indicator address the carrying capacity of a community's social capital—the connections between people in a community: the relationships of friends, families, neighborhoods, social groups, businesses, governments, and their ability to cooperate, work together, and interact in positive, meaningful ways?
7. Does the indicator provide a long-term view of the community?
8. Does the indicator address the issue of economic, social, or biological diversity in the community?
9. Does the question address the issue of equity or fairness—either between current community residents (intragenerational equity) or between current and future residents (intergenerational equity)?
10. Is the indicator understandable and useable by its intended audience?
11. Does the indicator measure a link between economy and environment?
12. Does the indicator measure a link between environment and society?
13. Does the indicator measure a link between society and economy?
14. Are the projects of the upgrading slums address resilience?

Appendix 2

SD dimensions	Indicator	Foster's proposal	Stefano's proposal	Dar El Handsa proposal
Social	Is culture identity well defined?	No	Yes	Yes
Social	Have the residents participated in the plan?	No	Yes	No
Social	Is the equity between residents achieved?	Yes	Yes	Yes
Points achieved in percentage		33.3%	100%	66.6%
Economic	Do job opportunities increase?	Yes	Yes	Yes
Economic	Is there participation for all sectors?	No	Yes	Yes
Economic	Did household individual income increase?	No	Yes	No
Points achieved in percentage		33.3%	100%	66.6%
Environmental	Is there a plan to protect natural systems?	No	No	No
Environmental	Is the team aware with environmental planning?	Yes	Yes	Yes
Environmental	Is the planning aware with the protection of plants and animals?	No	No	No
Environmental	Is there a way for citizens' participation?	No	Yes	No
Points achieved in percentage		25%	50%	25%
Viability	Is the project socially and environmentally sustainable?	Only 50%	Yes	Only 50%
Viability	Is it financially viable to investors?	Yes	Yes	Yes
Viability	Is it affordable to the entity?	Yes	Yes	Yes
Viability	Does it provide value for money to the entity?	Yes	Yes	Yes
Viability	Is it economically viable?	50%	Yes	Yes
Points achieved in percentage		80%	100%	90%
Equitable	Did crime rate decrease?	No	Yes	No
Equitable	Has education level developed?	No	No	Yes
Equitable	Did they succeed to decrease unemployment rate?	No	Yes	Yes
Points achieved in percentage		0%	66.6%	66.6%
Livability	Is walking a viable option?	Yes	Yes	Yes
Livability	Is there a road for bicyclists?	No	No	No
Livability	Is it safe for pedestrians and bicyclists?	No	No	No
Livability	Are there enough nearby employment opportunities?	Yes	Yes	Yes
Points achieved in percentage		50%	50%	50%

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Part III
Mediterranean Green Architecture

Chapter 11
Paving the Way Towards Zero Energy Hospitals in the Mediterranean Region

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Introduction

Voracious energy consumption patterns in buildings are being recorded in many European countries. These are attributed to low energy performance of buildings, linked to aging building stocks and very low rates of renovation [1, 2]. Hospitals and clinics are considered among the most complex building systems, as they host several energy intensive functions (HVAC under strict comfort conditions, high hot water demand, life support equipment, etc.). Most importantly, such buildings must have an assured, constant supply of energy to meet with the demands of large numbers of patients.

A recent study published by the World Bank Group estimates that the health sector generates 5% of global CO_2 emissions (2.6 billion metric tons) annually [3], whereas across the European Union (EU), approximately 15,000 hospitals have a high demand for heating and electricity [4]. More specifically healthcare facilities in Cyprus are responsible for over 8% of the total energy consumption in the tertiary sector, while being the third most energy intensive use after restaurants and shopping malls [5].

Therefore, the energy performance of Hospitals needs to be comprehensively studied and further investigated, in order to develop a nearly zero energy definition for healthcare facilities across the EU. Improving their energy performance will have a crucial impact in meeting the EU long-term goal (2050), which is to achieve a reduction of the CO_2 emissions of 85% with respect to the 1990 levels.

In Cyprus, Health Services in the public sector are provided by 6 general hospitals, 3 specialized centers, 2 small rural hospitals, and 39 health centers, as

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well as many subcenters for provision of primary healthcare services. In 2016, the private sector included a total of 74 hospitals, polyclinics, and diagnostic centers, all profit organizations. In 2016, the total number of hospital beds was 2918. Of these, 1562 were operating in the public sector (1379 in general hospitals, 51 in rural hospitals, and 132 in the Hospital for Mental Health) and 1356 in the private sector [6]. Whereas various public hospitals were studied regarding their energy performance [7, 8], there is no comprehensive study for the private healthcare sector. In this paper, the energy profile of five private hospitals/clinics, all in the Nicosia District, will be presented, and their energy performance will be discussed. The questionnaires used for the energy assessment of the buildings were developed under the ZenH Balkan Project, which is funded by the European Union.

Methodology

Five clinics were selected based on their location and size. The clinics were chosen to be within the Nicosia District, in order to share similar—inland—climatic conditions, having at least 1000 m^2 of conditioned space and a minimum number of ten beds. The sample corresponds to a 22% of the private clinics in the Capital District.

The energy audit of the clinics was conducted in accordance to the European Standards: EN 16247-1:2012 [9] and EN 16247-2:2014 [10]. The team of accredited energy auditors, which performed the audits, was supervised by the Cyprus Institute's (CyI) project research team. The CyI team provided the Energy Audit team with the contact details of the representative of the five clinics and the questionnaire template to be used for the energy assessment of the buildings.

The hospital representatives provided the following information to the Energy Audit team:

- Architectural drawings: Plans, sections, and elevations.
- Electromechanical drawings: Information on the lighting system, HVAC system, and the hot water production of the building.
- Energy consumption information: Electricity, fuel, and water bills for the past 3 years.

The Energy Auditors conducted at least two visits at each of the buildings. The visits included discussions with hospital representatives regarding the energy management of the building and inspection of the buildings' services (e.g., boilers, chillers, lighting). The outcome of the audits will be summarized under the following sections:

- General information
- Envelope elements' thermal properties
- Energy sources and systems
- Energy consumption

Energy Performance

General Information

Three of the clinics were constructed between the late 1970s and late 1980s, whereas the remaining two in the 2000s. The oldest clinic (see Table 11.1, Clinic 5) has undergone renovation in 2007, whereas clinics 2 and 3 are expected to undergo major renovations within the next 5 years, as mentioned by their representatives.

The examined clinics have four to six air-conditioned floors (see Table 11.2), and range from small to large size in terms of beds, with the national average being 18 beds per private clinic [11] and average beds' occupancy of 78% (see Table 11.3).

Thermal Description of the Envelope

All clinics have a reinforced concrete frame (columns, beams, and slabs). The wall panels are either of brick or of aerated concrete block. The roof is thermally insulated in all clinics, except clinic 4, whereas the walls are insulated only in clinics 1 and 5.

Table 11.1 Construction and renovation

	Construction year	Renovation year
Clinic 1	2006	–
Clinic 2	1987	–
Clinic 3	1982 and 1987 (extension)	–
Clinic 4	2009	–
Clinic 5	1977	2007

Table 11.2 Conditioned area per floor (m^2)

	Basement	Ground floor	First floor	Second floor	Third floor	Fourth floor	Total conditioned area
Clinic 1	938	1288	1274	1274	1274		6048
Clinic 2	1002	1120	1190	–	–	–	3312
Clinic 3	430	473	469	451	390	390	2603
Clinic 4	238	340	340	340	–	–	1258
Clinic 5	–	409	328	301	22	–	1060
Average	–	–	–	–	–	–	2856

Table 11.3 Clinics' beds and occupancy

	Beds	Patients' rooms area (m^2)	Occupancy (%)
Clinic 1	65	1255	90
Clinic 2	42	540	80
Clinic 3	36	900	70
Clinic 4	11	270	80
Clinic 5	14	340	70

Table 11.4 U-value for the various building envelope components (W/m^{2}K)

	Walls	Column/beam	Roof	Openings
Clinic 1	0.48	3.09	0.86	4.1
Clinic 2	1.03	2.94	0.53	4.1
Clinic 3	1.39	3.33	4.13	4.1
Clinic 4	1.39	2.94	0.53	4.1
Clinic 5	0.41	2.94	0.53	4.1
Directive 366/2014	0.40	0.40	0.40	2.25
Directive 359/2015	0.72	0.72	0.63	3.23

The beams and columns are not thermally insulated in any of the clinics. The openings in all clinics are double glazed with aluminum frame. The thermal transmittance (U-value) of the various envelope elements (i.e., walls, column/beams, roof, and windows) of the clinics was calculated using the tool (U-valueCmcalculator.xls) developed by MCIT [12]. Actual information on the construction of the building (e.g., thickness of wall and material) were used for the calculation of each component's U-value. The results are given in Table 11.4.

The clinic with the best thermal performance of its envelope is clinic 5, which was renovated in 2007, followed by clinics 1 and 2. None of the clinics complies with the requirements of Directive 366/2014 [13] for nZEB or the Directive 359/2015 [14] for category B buildings.

Energy Sources and Systems

Energy Sources per Energy Need

The main energy source used in all the clinics is electricity, followed by diesel oil, which serves for heat production. Most clinics utilize also solar thermal energy for their hot water (HW), while clinic 4 has additionally onsite production of solar PV energy (Table 11.5).

Type and Number of Energy Systems

To meet the heat demand (for heating and HW), each clinic has two boilers, with the exception of clinic 4, which only uses one (see Table 11.6). The main hot water production systems (boilers) are supported in four out of five clinics with thermal energy from solar collectors (Table 11.7). The clinic with the highest installed capacity of heating production systems overall is clinic 1, whereas clinic 2 has the highest installed capacity of solar collectors.

Most of the clinics use a combination of centralized system and ductless (split unit) system for their cooling needs, with the exception of clinic 1, which is fully supported

Table 11.5 Energy sources per energy need

	Cooling	Heating	HW	Lighting and equipment	Laundry
Clinic 1	Electricity	Diesel oil	Diesel oil + solar thermal	Electricity	Outsourced
Clinic 3	Electricity	Diesel oil	Diesel oil + solar thermal	Electricity	Electricity
Clinic 3	Electricity	Electricity	Diesel oil	Electricity	Electricity
Clinic 4	Electricity + solar PV	Diesel oil + solar PV	Diesel oil + solar thermal	Electricity + solar PV	Electricity + solar PV
Clinic 5	Electricity	Electricity + diesel oil	Diesel oil + solar thermal	Electricity	Electricity

Table 11.6 Energy systems (heat production)

	Central heating system + HW	Number	kW	Installation date
Clinic 1	Boilers	2	650	2017
Clinic 2	Boilers	2	320	2004
Clinic 3	Boilers (only for HW)	2	40	2001
Clinic 4	Boilers	1	139	2008
Clinic 5	Boilers	2	72/103.5	2011

Table 11.7 Supporting systems (HW production)

	Hot water (supporting system)	Number	kWp (approx.)
Clinic 1	Flat-plate collectors	16	21.4
Clinic 2	Flat-plate collectors	30	40.2
Clinic 3	–	–	–
Clinic 4	Flat-plate collectors	6	8.0
Clinic 5	Vacuum tube collectors	6	18.1

by a centralized system (see Table 11.8). From the remaining four clinics, three of them use the central air-conditioning systems as their main cool providing system, whereas in clinic 3, the main system is ductless split unit, which is also used for heating. In clinic 4, there are 75 PVs installed on the roof, which are connected to the electricity grid and amount to 24 kW of installed capacity.

With regards to the installed capacity of the systems and their installation date, it can be deduced from the acquired data that, clinic 1 has the highest installed capacity and overall the oldest air-conditioning systems, dating back to 2004. The newest systems can be found in clinic 5, installed from 2011 to 2018. The indoor

Table 11.8 Energy systems (HVAC)

	Central air-conditioning system(s) + ductless systems	Number	kW	Installation date
Clinic 1	Chillers	2	761	2004
	DX units	2	8.32	–
	VRVs	1	33.5	2004
	AHU	14	121 (average)	2004
Clinic 2	Chillers	1	322	2011
	AHU	3	22/32/40	2004
	HRU	1	6	–
	Split unit	5	7.1	2003
Clinic 3	Chillers	1	79	2018
	AHU	2	–	2007
	Split unit	25	3.5/5.1	2007/2012
Clinic 4	PAC	1	26	2008
	AHU	1	–	–
	VRV	5	24/30/35(2)/48	2008
	HRU	2	16	2008
	Split unit	2	3.6	2008
Clinic 5	Chillers	2	65/120.09	2018
	AHU	2	–	2012
	HRU	1	15	2011
	Split unit	1	5.3	2011

Table 11.9 Indoor thermal conditions—patients' rooms

	Temperature (°C)	Relative humidity (%)
Clinic 1	23.5	50
Clinic 2	22.8–23.9	43.1
Clinic 3	22	41–50
Clinic 4	22	–
Clinic 5	22.5	42.9

thermal conditions in all five clinics are similar, with the mean temperature in patient rooms kept between 22 and 23.9 °C, and the relative humidity between 41 and 50% (see Table 11.9).

Lighting Fixtures/Lamps

With the exception of clinic 1, all the clinics have LED lighting (a mixture of both downlights and spotlights) installed throughout their buildings (see Table 11.10).

Table 11.10 Information on lighting fixtures/lamps

	Number of lights	Percentage of LED	Average kW per fixture
Clinic 1	2764	27	28
Clinic 2	970	100	20
Clinic 3	682	100	17
Clinic 4	396	100	19
Clinic 5	332	100	22

Table 11.11 Comparative evaluation

Envelope elements thermal performance	Energy systems aging (cooling)	Energy systems aging (heating)	Lighting systems	Energy systems aging (HW)
Lowest overall U-value → highest	Most recently installed → older	Most recently installed → older	Highest LED% → lowest LED%	Most recently installed → older
Clinic 5	Clinic 5	Clinic 1	Clinics 2/3/4/5	Clinic 1
Clinic 1	Clinic 3	Clinic 3		Clinic 5
Clinic 2	Clinic 4	Clinic 5		Clinic 4
Clinic 4	Clinic 2	Clinic 4		Clinic 2
Clinic 3	Clinic 1	Clinic 2	Clinic 1	Clinic 3

Comparative Evaluation of Clinics' Envelope and HVAC

The energy performance of the clinics was evaluated comparatively with each other (Table 11.11) in five categories, with one clinic (clinic 5) ranking overall higher than the others. Considering equal patients' rooms' occupancy, use of space, and indoor thermal conditions, this clinic is expected to have the lowest energy consumption per m^2.

Energy Consumption

The total final and primary energy consumption per m^2 was calculated (in Table 11.12) based on the energy consumption bills (for electricity and diesel oil) for 2017 provided by the clinics and an estimation of the energy production from the solar collectors.

From the results it can be observed that clinic 3 has the lowest energy consumption per m^2 and clinic 1 the highest, both with regard to final and primary energy consumption. The discrepancy between the expected energy performance and the actual energy consumption persists even after normalizing the energy consumption for occupancy rate.

The average final energy consumption, after normalization, is 363.2 kWh/m^2, which is very close to the average national final energy consumption for healthcare

Table 11.12 Energy consumption

	Area conditioned (m^2)	Final energy consumption (kWh/m^2)	Primary energy consumption (kWh/m^2)	Final energy consumption per occupancy ($kWh/m^2/occ$)
Clinic 1	6048	599.1	1356	611.8
Clinic 2	3312	392.2	767	405.4
Clinic 3	2173[a]	153.5	336	175.3
Clinic 4	1258	209.5	452	218.9
Clinic 5	1060	365.7	494	404.6
Average	–	344.0	681	363.2

[a]The basement of clinic 3 was not included in the conditioned spaces for the purposes of the energy consumption analysis, since the available data from its electric meter, provided from the hospital, were insufficient

institutions in Cyprus [5]. Nonetheless, the disparity between the energy consumption from the different clinics, varying from 175 kWh/m^2 (clinic 3) to 612 kWh/m^2 (clinic 1), prompts the need for further investigation.

Conclusions

Short energy audits were conducted for five private clinics, all located in Nicosia, during January and February of 2019. All the clinics are made of concrete frame with brick or concrete block infills. Overall the clinics' envelope elements do not meet the thermal performance requirements of the energy efficiency Directives 366/2014 and 359/2015. Their HVAC systems are on average 10 years old and four out of five use solar thermal collectors as a supplementary energy system for hot water supply, whereas there is additional onsite RES production from PVs in one of the clinics.

From the comparative evaluation of the clinics, conclusions were drawn based on the thermal properties of their envelope elements and the installation dates of their HVAC systems as to which clinics are expected to outperform the others and have the lowest energy consumption, considering equal occupancy, function, and indoor thermal conditions.

From the actual energy consumption, after normalizing with occupancy, it is observed that clinics present a different energy profile than anticipated. The inconsistency could be partly explained by the operating schedule of the HVAC systems. That is because increased energy consumption is possibly linked to both different operating schedules and settings of the HVAC system based on specific functions in the clinics (operation rooms, laboratories, examination rooms, and patients' rooms) and the consumption from specialized equipment used in each clinic.

The type of the HVAC systems and in particular if they are centralized or not is also of importance. The clinics with centralized HVAC systems, functioning for 12 or 24 h daily, will eventually have higher consumption than clinics which use split units, for cooling and heating, since the latter operate through local control and can potentially run for less than 24 h per day, according to thermal needs of the space.

Further studies on the energy consumption of healthcare centers, both private and public, are necessary in order to extract more accurate conclusions and develop a more accurate profile of the energy performance of the buildings in the sector.

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Chapter 12
Vernacular Elements as Indicators for Sustainable Interior Environment: Housing in Jordan

Dana K. Amro and Suheir M. S. Ammar

Introduction

Traditionally, in Arab world, the courtyard housing presents geographically, climatically, and culturally house unlike other regions of the world. Courtyards are known to serve many functions in hot arid regions by creating an open sheltered zone, helping to adopt natural cooling approaches, protecting areas from wind-blown dust or sand, and easing the effects of solar overexposure [1].

As in the study area, Jordan is a hot arid region; the new Jordanian buildings' standards were developed from ideas of foreign consultants from the UK [2]. Results of the new buildings' standards did not take into account the environmental challenges. Therefore, the adoption of the British model without considering different cultural and environmental conditions has contributed to the failure of the planning process in Jordan, as one of the reasons is of the disappeared courtyards from the new houses [3]. Presently, in modern houses, as Jaber [4] described, there are indoor environmental problems with Jordanian residential buildings with regard to the indoor air quality; this causes an increase in energy consumption and air pollution, which affect the quality of life for residents [3].

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This study examines the vernacular architecture elements such as the courtyard, Mashrabiyyah,[1] and fountain as indicators of sustainability within the contemporary residential buildings in Jordan affecting the residents' quality of life. This study importance is about focusing on contemporary courtyard houses, which, firstly, they considered a recent emphasis in Amman. Secondly, there is a lack of awareness about the importance of the courtyard and the quality of the indoor environment in residential buildings.

Vernacular Architecture Elements

Vernacular houses are advanced structures with their open-air interior courtyards that perform significantly as modifiers for climates in hot arid areas. Al Tawayha and Braganca [5] concluded that some of the vernacular Palestinian strategies and elements have good potential to be used in the design of new buildings and urban areas in Palestine to satisfy resident's needs and expectations to achieve a more sustainable built environment.

Courtyards, the main vernacular element, provide outdoor space for activities while keeping the residents' privacy and protect them from the wind and sun. They also serve as an air-well into which the cool night air can sink. The plain, thick-walled street facade of the house consists of few or no windows designed to withstand severe elements like hot winds and sandstorms. Roofs are usually flat and their height between 3 and 5 m [6–8]. The courtyard is a nice place for sitting for the family and its' relatives and enhance the relationship among people and the quality of residents' life. It gives them a nice cool place in summer to sit inside.

The second vernacular element is the Mashrabiyyah that has five functions and its design may fulfill some or all of these functions: increasing the humidity of the indoor air, controlling the passage of light, reducing the temperature of the indoor air, controlling the airflow, and ensuring residents' privacy (see Fig. 12.1). The third vernacular architectural elements exist in the courtyard is the water fountain. According to Attia [7], the focal fountain is located at the center of the courtyard, which helps to create a cold air reservoir, at the same time, humidifying the dry air in the microclimate around it.

The two main sustainability indicators, energy consumption and indoor environmental quality, will be extracted through the two aspects: natural ventilation and indoor comfort level.

[1] Mashrabiyyah: its name originally derived from the Arabic word "drink water" and referred to "a drinking water place." This was a cantilevered space covered with a lattice opening, where water jars were placed to be cooled by the evaporation effect as air moved through the opening. The Mashrabiyyah is a wooden lattice screen. It is composed of small wooden circular balusters, arranged at specific regular intervals, in a decorative and intricate geometric pattern [8].

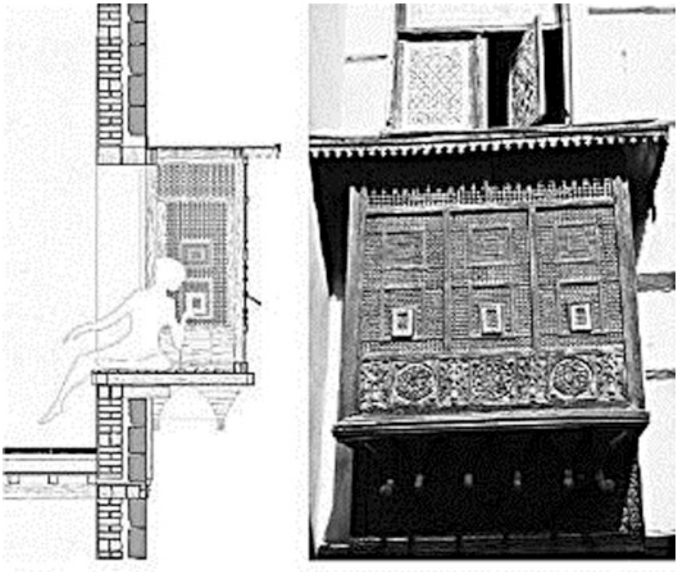

Fig. 12.1 Mashrabiyyah from inside and outside. (Source: [3], p. 108)

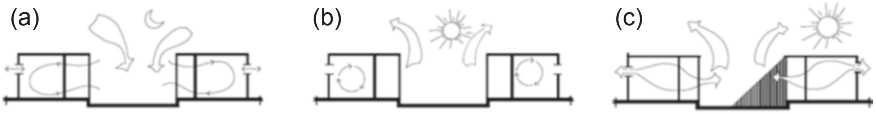

Fig. 12.2 Air circulation between the courtyard and adjoining rooms at night (**a**), midday (**b**) and afternoon (**c**). (Source: adapted from [3], p. 108)

Natural Ventilation

Courtyards are considered the heart of a dwelling, environmentally; the residents utilize the courtyard to serve as a collector of natural ventilation with cool air at night and a source of shade in the daytime [9]. Malik and Mujahid [10] stated that courtyard is placed in the center of the house in arid climates, to get shading and allow airflow. An open u-shaped pleasant place to sit inside called Iwan is to the north of the courtyard. Al-Mulla Hwaish [11] stated that the interior courtyard is a place suitable for working and relaxing inside. It provides a comfortable area during the hot season through opening and closing of doors which are employed to influence the courtyard's microclimate [9]. Moreover, the effect of this general concept on achieving comfortable conditions varies with climate changes, such as hot summers and relatively cold winters in hot dry and moderate climates, and through the day and night, as shown in Fig. 12.2 [12].

Fig. 12.3 The courtyard in a vernacular house "a plan and a photo." (Source: [13])

In addition, the air flow coming through the Mashrabiya can only affect the internal spaces if it circulates through them effectively. Tahtaboush is another cool place to sit inside. It is a space that lies between a shaded courtyard from north and a sunny garden from the south. This causes a nice air movement (see Fig. 12.3).

Indoor Thermal Comfort Level

The thermal comfort is affected by several potential factors such as natural ventilation, building orientation, and shading. Courtyards are developed and take into account those factors. Muhaisen [12] reported that courtyard thermal performance is mainly affected by the solar radiation penetration on the internal envelope. This may be dependent on the geometrical parameters of the courtyard and the sun's position. It has been argued that the thermal strategies to achieve well-being are different among different climatic regions. However, all of them can be guaranteed full access to internal spaces when desirable avoiding times of discomfort. Shading aids in escaping heat gain, which is the first rule of the indoor thermal comfort during summer. A lack of shade can cause building surfaces to absorb heat in their filling, raising the surface temperature above the ambient air which adds to the cooling loads. This is especially due to air temperature and humidity [8]. Vegetation inside the courtyard absorbs dust and dirt present in the atmosphere as well as reduce the amount of glare. The use of vegetation and water compensate for the lack of provided shade [7].

In addition, the water from courtyard fountain cools as it evaporates; the fountain can not only reflect architecture and multiply the decorative themes it can also serve as a means of emphasizing the visual axes and create a microclimate [6].

Research Methodology

Methodologically, the research design considered a qualitative method. Case studies are the main tools for this study, whereas field observations, documentary data, and visualizing materials are the qualitative tools for collecting data [14], which are used to attain the objective of the study.

A survey strategy was used to explore contemporary courtyard houses in Amman, the capital of Jordan; random selection was made to choose one house as a case study to be analyzed. The criteria for selecting the house has contained the vernacular architectural elements: courtyard, Mashrabiyyah, and fountain.

Vernacular Elements as Indicators for Sustainable Interior Environment in Contemporary Residential Housing

Baumer [15] mentioned that since the 1960s, people have become more aware of global environmental problems. Society must have also become mindful of the strong relationship between modern industrialized societies and the environment in which people need to survive [16]. Designers need to support high standards of design and appreciate the overall quality of design to develop a connection between contemporary architects and their challenges in their attempts to revive vernacular architectural heritage as a sustainable element [17].

Since Jordan—case study area—is a poor country with limited resources in terms of water and energy, the construction processes should be dependent on urban designs. These take into account the economic considerations and limited resources. The importance of producing design tactics as well as integrating them among residential standards ensures that sustainable development is essential [3]. Jordanian's Ministry of Public Works and Housing has adopted renewed ideas into what attracts attention to the capabilities of establishing new buildings conducive of the revitalization of cultural heritage (courtyard and Mashrabiyyah) within sustainable development. This can be accomplished without negatively influencing the preserved character of the area [18].

Case Study Analysis

Field observation analyses have shown that the selected house, which is designed by architect Ayman Zuaiter, is located in western Amman within Abdoun neighborhood. The concept of this house type is a contemporary courtyard house using vernacular elements. The courtyard is in the middle of the house, and the daytime vital spaces in the house such as the living room, dining room, kitchen, and staircase overlook the courtyard. The courtyard design begins as an oblong shape with walls

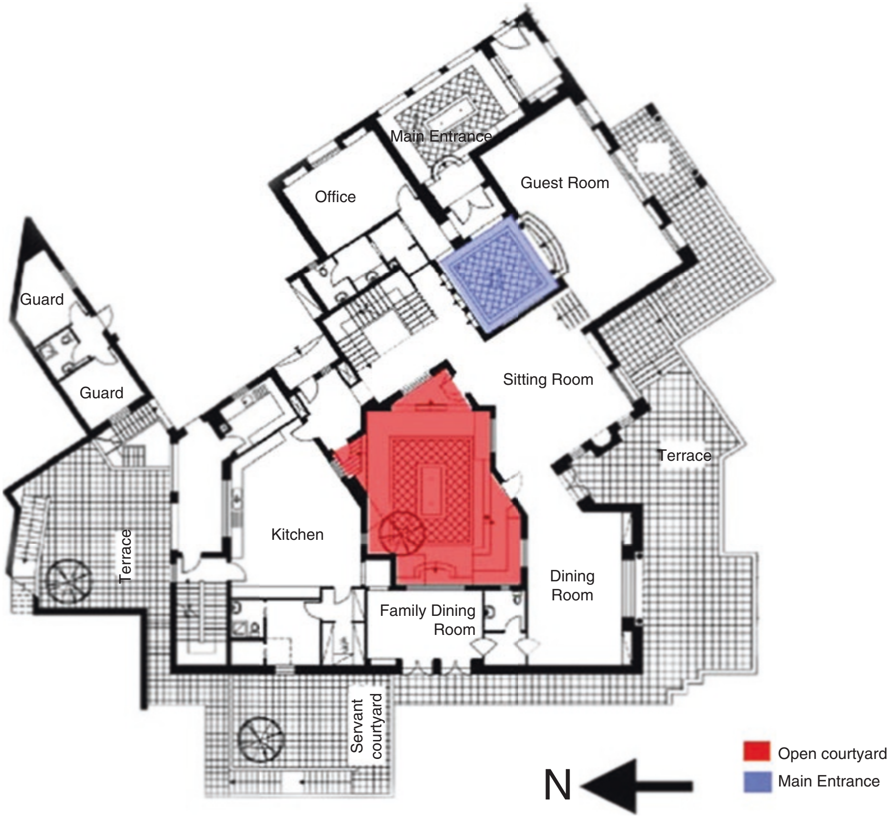

Fig. 12.4 The house plan (centered courtyard)

intermingled and broken in non-conforming and contemporary shapes to fit with the directions of walls of some spaces of the house that differ in direction from the two main perpendicular axes of the house (see Fig. 12.4). Trees, a wooden pergola, also provide shade in the sitting area in the courtyard. Living internal spaces formed in relation with them are shown in Fig. 12.5. The height of the courtyard is two stories, and higher than its width. The orientation of courtyard is important as it has a transverse axis leaning towards the north and south providing shade throughout most of the day. The courtyard measures 9.1 m long and 6.30 m wide (see Fig. 12.6).

The Mashrabiyyah appears in many different styles, in shape of box and flat screen, covering the windows. All Mashrabiyyahs existing on the second floor are to control the passage of light, control the airflow, reduce the temperature of air, increase the humidity, and ensuring one's privacy.

The contemporary design style does not have the water jar, but still reduce the direct sun glare and control the light, which is considered a solar control. Moreover, fountain is an oblong floor style tiled with blue oriental ornamentations (faience) and has two-nozzle sprinkler (see Fig. 12.7). The material used in flooring is stone as a natural local material.

Fig. 12.5 Shading in the courtyard

The natural ventilation and the indoor thermal comfort level analyzed according to the field observations are as follows.

Natural Ventilation

As the wind comes from the west, most the natural ventilation from the courtyard to the indoor spaces comes through the doors and windows in the ground floor. The cross ventilation is excellent with a natural breeze and cool air. On the first floor, the natural cross-ventilation comes through most of the windows and the Mashrabiyyahs as well as felt along the balcony. The ventilation is excellent for the inner rooms exposed to cool air in the summer.

Indoor Thermal Comfort Level

Indoor thermal comfort is achieved when the thermal air of the courtyard house is evaluated as follows:

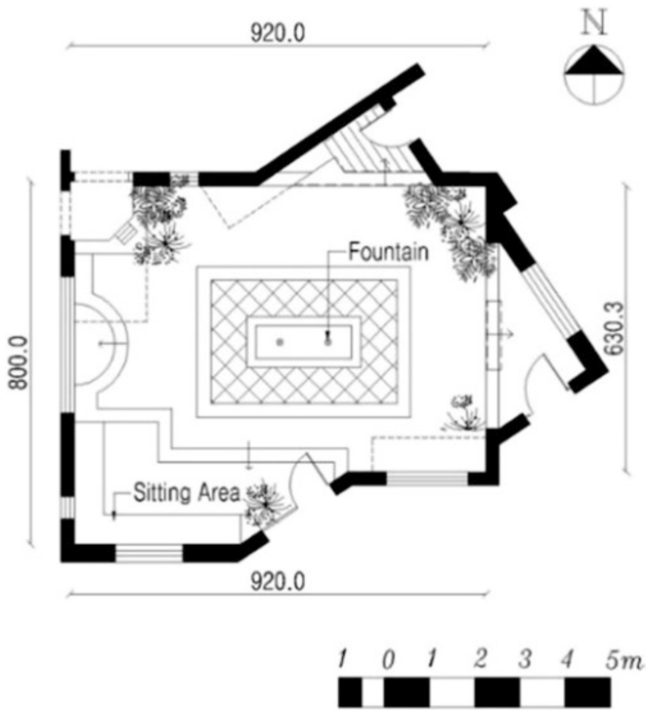

Fig. 12.6 The courtyard dimensions

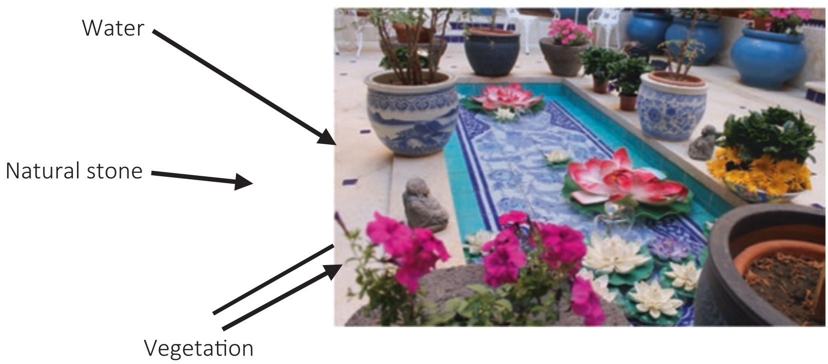

Fig. 12.7 The fountain

- *Cross-ventilation:* As mentioned previously for the windows of the house from the external façade and the courtyard. These two sides help the west wind movement for cross-ventilation as a good distribution for ventilation.
- *Temperature, humidity, and air velocity:* The temperature in the inner spaces decreases further due to the cross-ventilation and shading in the courtyard. Water

fountains tend to increase humidity in the courtyard and the surrounding areas. Trees and vegetation increase the humidity and provide shading.

- *Dust and glare:* Greenery inside the courtyard can absorb dust and dirt in the atmosphere and reduce the amount of glare.
- *Building orientation and shading:* Natural ventilation and natural lighting are needed for the sitting area. The courtyard axis towards the north provides shade most of the day for the build-in seats in the courtyard, and its location among the house's space will keep shading area at any time during the day.

Indications show that indoor thermal comfort levels are high throughout the presence of the courtyard. Mashrabiyyahs, fountains, and vegetation are the composite elements of such cooling systems.

Evaluation and Conclusion

The awareness of the importance of the vernacular elements and the courtyard is raising, due to their environmental performance, which increases the applicability of using it. This will bring new opportunities for using this old heritage passive cooling system in today's building, especially in houses which represent most of the world buildings. The contemporary courtyards are used as cool air reservoirs with the intention of improving the microclimate. The vernacular elements with the vegetation integrate in the courtyard as a way of passive cooling and preserving energy. Additionally, the courtyard model showed a higher performance in terms of daylight factors for winter and summer days. Table 12.1 shows the general observation on indicators or assessment of sustainability related to the residential buildings.

Table 12.1 General observations notes on the indicators of sustainability

Indicators of sustainability	Some observations on the contemporary courtyard house architecture
Energy efficiency	Less energy consumption due to: (i) The excellent cross natural ventilation (ii) Natural lighting throughout the courtyard and Mashrabiyyah (iii) Water fountains cooling and moisturizing the surrounded air
Indoor environmental quality Air quality, lighting, visual and acoustic comfort	(i) Windows are usually incidental and act merely as screens that allow excellent ventilation with other openings, i.e., external windows and inner windows and doors on the courtyard (ii) Sun shading through courtyard orientation, plants, and trees (iii) Water fountains cool and humidify the surrounded air (iv) Courtyards are often semi-enclosed to permit natural ventilation with visual and acoustic comfort
Natural local materials and resources	Using natural local materials such as natural stone and woods
Social sustainability	Courtyard existence support social relationship among the residents of the house and their relatives while enjoying cool air and nice planting and fountain

This study has proven that vernacular architectural elements from the vernacular house do play important roles not only in disseminating the symbolic meanings of its art, design, and construction, but also for its importance in representing their sustainability. Research has also shown that the vernacular elements in residential buildings give rise to the potential of saving vast amounts of energy when it is used in warmer climates. There is little doubt that leading architects of contemporary architecture have realized that buildings with courtyards would have attracted the attention of a much wider public, and this valued architectural means would have found a new dimension in the twenty-first century architecture.

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Chapter 13
Green Sustainable Regional Development and Digital Era

Narcisa Roxana Moşteanu

Introduction

Economic development is the process by which a nation improves the economic, political, and social well-being of its people. Economic development has a direct relationship with the infrastructure, population, health, education, business environment, and economic policy provided by each state, as well as its degree of intervention in the economy. Economic development is a political intervention effort to improve people's economic and social well-being. Economic growth refers to the increase of production levels, but economic development is a link to increase production accompanied by improved social and political well-being of citizens and businesses of a country. Therefore, economic development includes both growth and welfare values. Economic growth leads to increased labor productivity, positive competition, and higher-quality goods and services. Increased competition leads to the necessity of spending on education, research, development, and the appropriation and implementation of new technologies in all aspects of a country's economic and social life.

Every country wants to be wealthy, to have a sustainable economy and a healthy environment. The creation of wealth is also influenced by global climate change. To our disappointment, scientists inform us that greenhouse gas emissions continue to increase despite the global community's efforts to reduce them. Climate change is a serious threat to economic development (by worsening food shortages or political instability). Unfortunately, at present, in the globalized and interconnected world, there is an aggressive challenge to achieve economic growth, taking less into account the environmental degradation, which in turn represents a serious threat to the global community. From this point of view, the research is paying particular attention to regional development projects focused on green infrastructure, and

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priority is given to financing projects related to renewable energy infrastructure, carbon capture and storage facilities, modernization of water and canal systems, and public transport systems.

In the context of increasing demand for water, energy, and food, the need for more efficient use of resources is recognized, while pursuing the development of environmentally friendly products and goods. The transition to the green economy and smart city, which promotes new technologies while maintaining a healthy environment, requires policy tools to reduce pressures on water-energy supply. In this respect, special funds have been created to finance regional development projects that promote social and technological innovation, enhancing resource efficiency and environmental conservation. At the same time, the emphasis is also placed on education and awareness of the need to increase energy and water efficiency across the economy, as well as reducing food losses.

The human factor is one of the most important resources in economic development. Between economic growth and development is a two-way relationship. On the one hand, economic growth leads to human development, families and individuals using increased savings income to spend more on improving welfare, education, health, leisure time, and even developing individual entrepreneurship. On the other hand, human development with increased income leads to the bigger consumption, which in turn leads to the increase of production, the state budget revenue, and to the overall economic growth (reducing the social public expenditures in the same time).

The global approach to economic development policy has grown in the same time with the development of the international trade, the liberalization of human and financial capital movement, the rise of foreign investments, and the harmonization of tax legislation, in certain regions of the world, the implementation of digital finance through artificial intelligence. In the twentieth century, the biggest technological and social event at the same time was the emergence of the Internet. The most important technological events and with important social consequences were the discovery of the transistor, the integrated circuit, and the electronic computer. The Internet has become a social phenomenon, with the increasing number of users taking part in its current structure. Once installed in the fabric of society, the Internet has created and produced new consequences for society. The most important of these is the process of globalization. Therefore, the globalization is a phenomenon specific to the information society [1].

Global Economic Development—*Green* Sustainable Approach

Economic globalization involves four aspects that indicate types of flows across borders, namely: the flow of goods and services (free trade), flow of people (migration), flow of capital, and flow of technology. A consequence of economic globalization is the improvement of relations between the developers of those industries in different parts of the world, but also the erosion of national sovereignty over the economic sphere. The International Monetary Fund defines globalization as being the increase in *the economic interdependence of countries around the world by aggregate the volume and variety of cross-border transactions of goods and services, the more freely and faster the international capital flow, but also the broader dissemination of technology* [2]. The World Bank defines globalization as *the freedom and ability of individuals and firms to initiate voluntary economic transactions with residents of other countries* [3].

Globalization, according to specialists' opinion, is a phenomenon eminently economic, involving a growing economic interaction of states or integration of national economic systems, by increasing international trade, capital flows, and investment [4]. Globalization implies an intensive cooperation between countries and movements of production factors. These have led to the creation of many governmental agreements or inclusion in regional and international economic organizations.

Expansion of international trade and foreign investment has led to the transformation of product life into *displaced*. At present, the extraction, production, consumption, recycling, and/or final disposal of a product often takes place at great distances between them and/or in completely different countries. This has allowed companies to take advantage of cost savings by outsourcing to countries where the necessary production factors are good and cheaper (labor, energy, land, etc.). This process has shifted the potential impact on the environment associated with each stage of the life cycle of a product, changing the environmental burden among regions of the world [5].

The green economy aims at improving human well-being and social equity, significantly reducing environmental risks and ecological cuts. In its simplest form, a green economy aims at low carbon, resource efficient, and socially inclusive. In this type of economy, revenue and employment growth is due both to public and private investments, which reduce carbon emissions, increase resource efficiency, and prevent the loss of biodiversity and ecosystem services.

Artificial intelligence is the newest approach for economic developments. However, the concept is not so new. The history of *artificial intelligence* started around 100 years ago, in 1920, when Czech writer Karel Čapek published a science fiction piece called Rossumovi Universal Robots, which introduced the word *robot,* a humanoid *machine* that works for people [6]. In 1950, Alan Turing (mathematician, computer scientist, logician, and cryptanalyst) asked himself if *machines can think?* [7], and from this question the *artificial intelligence* started its journey. Nowadays machines are *intelligent*.

For the environment, the technology of the previous years has been a daunting enemy for most ecologists for many reasons: the manufacturing industry is creating a huge amount of hazardous waste, machine technology has increased the development projects that have led to the disappearance of many plants, birds, and animals, and our excessive energy consumption is one of the main causes of greenhouse gas emissions. Artificial intelligence comes to develop technologies that can help prevent and repair the damage done previously. Improving technology brings a serious stance in protecting the environment by straightening human errors.

Research Methodology

The present work paper is an exploratory research, based on investigative techniques. It is a fundamental and qualitative research, which aims to identify and encourage managing new financial methods through artificial intelligence and digital systems to achieve an efficient *green* sustainable regional development. Author of the paper wants to promote innovative techniques for financial *green* and *sustainable* regional development, using artificial intelligence, blending facilities, and smart cities approach and to underline the increased number of projects financed especially to create a healthy *green economy*.

Healthy Sustainable Financial Regional Developments

Globalization, Financial and Political Turmoil Effect on Regional Economic Developments

Globalization, Internet, and finance digitalization have connected countries, businesses, and people and have made it possible to change knowledge and experience and improve the operational systems in many areas of activity. However, the globalization has brought a positive outlook on business interconnection at transnational levels, too; the free movement of individuals and capital has often exposed national economies to dysfunctions. These type of distortions (migration of individuals and capital) impact the labor market (case of the transition from a centralized economy to an open market one; or, BREXIT), or the spread of turbulence and economic instability from one country to another (the 2007–2009 financial crisis).

Economists were among the first to attempt to quantify the different components of globalization in an attempt to assess its impact on economic growth [8, 9]. Indeed, globalization measures commonly used were exclusively economic (for example, imports and total exports or direct foreign investment, expressed as a share of gross domestic product). However, globalization is not just an economic process and, even if it is, economic globalization is more than a simple flow of goods and capital [10].

Globalization has changed economic realities. First, the competences of multinational companies are becoming increasingly mobile and knowledge intensive. Multinational companies thus give more attention to the availability and quality of the created assets of alternative locations. Second, among developing countries there are now considerable differences between the catching-up countries (e.g., newly industrialized countries) and falling behind, less developed countries. These developments have helped change the opportunity sets of both multinational companies and host countries. National strategies based on foreign direct investment are used all over the world, which increase the competition for the right kinds of investment [11]. Suggesting from this point of view is the definition given by George Soros—*Globalization is the development of global financial markets, the growth of transnational corporations and their increasing domination over national economies* [12].

Globalization and the opening of international markets have led to rapid population growth in some areas, the urbanization of some and the depopulation of others, increased poverty and inequality, and climate change, which can lead (in some places already led) to the lack of resources and social challenges. In response, many multilateral organizations have called for the development of an ecological economy that improves human well-being and social equity and reduces environmental degradation.

Growth, upgrading, and progression of production factors involve the use of different types of capital, including human, technological, and natural, to produce goods and services that has brought many benefits, including a higher standard of living and improved human well-being. At the same time, economic growth has been, over time, leading to environmental degradation.

Financial crisis drives direct to qualitative development and redefine the optics of regional and international development policy. In the evolution of society, crises can be defined as situations characterized by pronounced instability, accompanied by volatility and increasing uncertainty, economic, political, ideological, military contradictions, etc. The economic crisis is a phase of the economic cycle in which a relative surplus of commodities is formed in relation to the limited purchasing power of the population, which leads to declining production, bankruptcies, unemployment, etc. The emergence of economic crises also marks the beginning of qualitative changes in the economy for a new phase of economic activity. These changes are related to financial and banking sector, as well as economic and social life.

Economic and financial globalization can have as an effect the spread of economic crisis or instability of a financial system, very quickly from one country to another, and from one region to another. To avoid this phenomenon, regional or inter-institutional collaboration on bank financial legislation is needed.

A possible solution to avoid economic, social, and financial turbulences is *green* economy approach. A key component of *green* economy is that economic development regards natural capital as a key economic advantage and a source of public utility. The overall goal of the transition to a green economy is to enable economic growth and investment, along with enhancing the quality of the environment and social inclusion.

The green economy approach is a shift from the short-term understanding of environmental considerations as a cost factor that hampers economic growth and reduces competitiveness. *Green economy* may be a way to achieve a sustainable development. These considerations are considered fundamental to the long-term sustainability of economic growth. Overall, the green economy is the one that results in improved human welfare and social equity, significantly reducing the environmental risks and ecological degradation [13, 14].

Artificial Intelligence and FinTech—New Approach in Reducing Regional Economic Disparities

Artificial intelligence offers the ability to amplify and transcend the current capacity of capital and labor to develop economic growth. The global economy is confronted by a steady decline in business profitability across multiple industries, and this threatens to erode future investment, innovation, and shareholder value. *A new factor of production—artificial intelligence*—is under development, which can help increase profitability and economic growth and reduce regional disparities. Artificial intelligence comprises several technologies that can be combined in different ways to feel, understand, act, and learn. AI has the potential to increase the rate of return by an average of 38% by 2035 by changing the nature of work and creating a new relationship between people and machines, in which people are firmly in control and technology increasingly adapts to our wants and needs. The impact of AI technologies on business is projected to *increase labor productivity* by up to 40%—and enable people to make more efficient use of their time [15].

The digital revolution is changing the way of living, working, and communicating. The transformation that takes place within the telecommunications industry has a great impact on the surrounding world with the emergence and continued improvement of digital technologies [16]. Artificial intelligence is one of them. It is a recent technological breakthrough, which, combined with industrial technology, helps overcoming many human errors, exceeding human performance in different areas. IT programs are becoming more accurate, detecting and scaling objects better than human performance. Speech recognition systems can now identify the language of telephone calls and voice recordings with levels of accuracy that match human abilities. Translating from one language into another is now done in real time, using a simple application on the phone. Glasses can be connected directly to Google map or other search programs. All of these are already part of our lives. *Artificial intelligence* solutions have the potential to transform such diverse and critical areas as education, research, healthcare, finance, accounting, auditing, transport, and energy. It is not a single technology but a family of technologies. In addition, *artificial intelligence* solutions can help sustainable, rapid, and viable regional development. The regional economic disparities that exist in different areas of the world can be diminished considerably. Therefore, *artificial intelligence* can help to implement successfully regional development policy objectives [17], regardless of the geographical area, the spoken language, or the sectors of predominant activity.

Digital systems are becoming more and more used and representing a much faster, cheaper, and safer way when it comes to financial transactions. Access to modern telecommunications systems is a priority in all countries around the world, as in their evolution, financial and banking systems implement, use, and encourage online services for domestic and international financial transfers. Digitization and digital transformation have become the most commonly used words in the last decade, but especially in recent years. There is an excess of definitions of this term, used to describe the offline-to-online migration of commercial operations and businesses, including those found in many published research works. Contemporaneous economists defined digitalization as *the realignment of, or new investment in, advanced technology and business models to more effectively engage digital customers at every touchpoint in the customer experience lifecycle* [18].

Financial technology—*FinTech* refers to an emerging financial services sector that is becoming increasingly indispensable to financial institutions and has a steady impact on how technology supports or allows banking and financial services. Fintech, Financial Technology targets construction systems that model, value, and process financial products, such as shares, bonds, money, and contracts. Contemporary economists define Fintech as *a new financial industry that applies technology to improve financial activities* [19]. Currently, financial technologies are used by all types of business, from start-up to large corporations, in all economic sectors. FinTech has revolutionized the entire financial services industry by using innovative and advanced technologies such as blockchain, cryptocurrencies, artificial intelligence, and robo-advisors. These innovative financial technologies come to realign and reboost the efficiency and quality of financial services by cutting the human errors and time processing.

Financing Objectives of Regional Developments—Accent on *Green* and *Artificial Intelligence* Projects

The economic development of each country requires financial funds. Each state is trying to cover public expenditures from its own financial resources, but many times the economic and social needs outweigh internal financial resources. In an attempt to achieve harmonious economic development between different geographical regions, economic unions and financial organizations that are involved in concluding regional development, there have been created objectives, implemented by using financial aids. External aid may be nonrefundable in whole or in part, or reimbursable. External financial aid is provided through regional economic and social development programs in accordance with the objectives of the regional development policy of the respective organization or union.

Local Funds for Regional Development

The budget of each country provides resources for the financing of economic development, by sector and public activity. Each year, funds are earmarked for investment and economic development. In most of the countries there are public institutions dedicated for regional development implementation (in some countries there are ministries dedicated to regional development, such as Romania—the Ministry of Regional Development, in France—Minister de Reconstruction et

Urban Development, in Italy—the Minister of Regional Affairs, in other states, the development regional level is implemented by the Ministry of Economy or the Ministry of Finance). The national development plan of each country is designed to support the state by allocating funds from the state budget in addition to external financing sources for the implementation of local infrastructure development and improvement of projects. The nature and amount of the financial funds allocated depends on the regional economic and social needs of each country. Most funds aim at improving infrastructures, implementing new information and industrial technologies, education, health, and research [1].

Regional Financing Through European Regional Funds

Economic globalization entails rethinking the process of economic development and strength. Along with the globalization process, the economic development approach has been redesigned to ensure fairness and balance across the country.

Therefore, economic development policies aim a crossing, internally (Fig. 13.1), as well as externally (through the continuation of the cooperation with the international economic environment, with the regional economic policies promoted cross-border, or with the taxation policies promoted by the neighbors, or at regional level). Adherence to these organizations, the signing of treaties or economic agreements, and the receipt of aid or financial assistance from international bodies have a significant impact on the domestic legislation of each country. Thus, internal legislation must be adapted according to the international regulations to which the State is a signatory [1] (Fig. 13.2).

Currently, all European countries members of European Union benefit from European Structural and Investments Funds: European Regional Development Fund, European Social Fund, Cohesion Fund, European Agricultural Fund of Rural

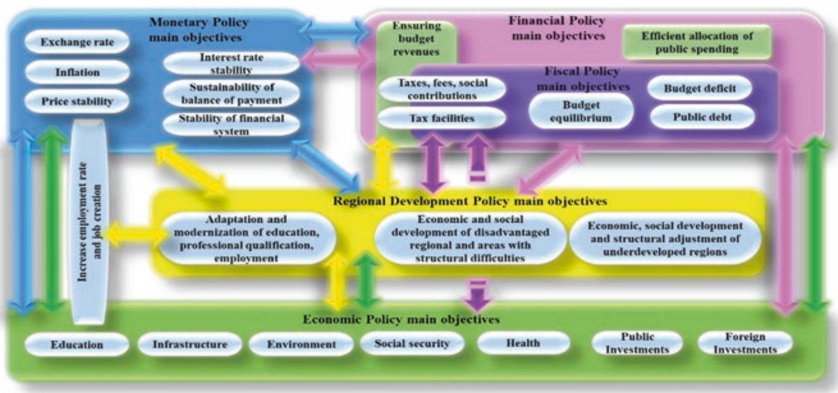

Fig. 13.1 The interdependence of economic policies. (Source: [1])

Fig. 13.2 The influence of international policies and agreements on internal legislation and policy. (Source: [1])

Development, European Maritime and Fisheries Fund, and European Union Solidarity Fund. All European countries contribute for these structural funds, with a percentage from their gross domestic product. All resources are collected to the budget of European Union, and from there, distributed back, according to their eligibility with objectives of regional development policy [1].

In order to receive external (European) non-reimbursable funding, Member States must draw up strategic plans with their investment priorities covering the five areas (employment, research and development, climate, energy, education, social inclusion, and poverty reduction). These are called Partnership Agreements. Details of the objectives they intend to achieve with the available resources are given in national and/or regional Operational Programs, and Rural Development Programs. These are designed to meet the socioeconomic and environmental challenges in the country or region in question. Member States must concentrate the Funds where they are most needed and will have an impact, and may use all the possible funding themes and models provided under the Regulations [1], giving a special attention to *green sustainable development*.

National authorities appointed by each Member State for managing regional development objectives are responsible for managing the actual programs. National, regional, and local authorities together are drawing up and applying selection procedures and eligibility criteria (including the minimum or maximum size of the project, the financing plan, and time frame). Applications for funding should be submitted to the national or regional authority managing the relevant program (see Fig. 13.3). Before applying for a grant, potential beneficiaries should check the investment priorities, eligibility criteria, and application procedure of the programs in their region and country [18]. After the project approval, the applicant is running the project, and after each staged achieved, and controlled, it will ask for repayment from the non-reimbursable budget approved [1].

According to European Commission [20], the *European Regional Development Fund* (ERDF) focuses its investments on several key priority areas: innovation and research, the digital agenda, support for small- and medium-sized enterprises (SMEs), and, the *low-carbon economy*. The ERDF resources allocated to these priorities will depend on the category of region: in more developed regions, at least 80% of funds must focus on at least two of these priorities; in transition regions, this focus is for 60% of the funds; and this is 50% in less developed regions. Furthermore, some ERDF resources must be channeled *specifically toward low-carbon economy projects*: more developed regions: 20%, transition regions: 15%, and less developed regions: 12% [20]. Giving the information from European Commission, the *European Social Fund* emphasizes human development, paying particular attention

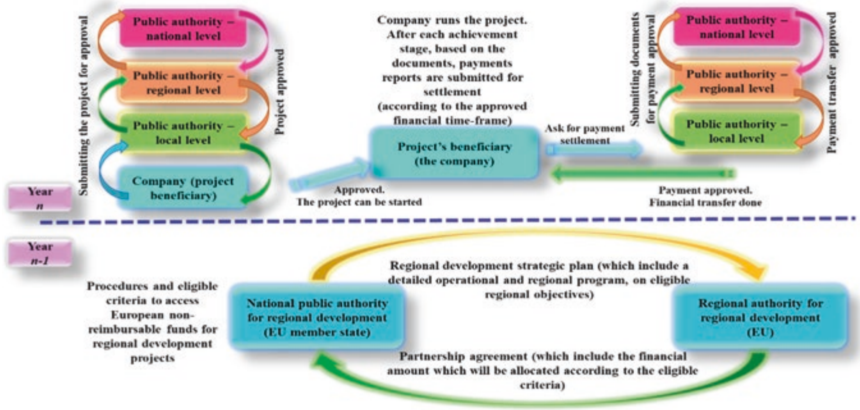

Fig. 13.3 General process for financing of regional development projects from European funds. (Source: [1])

to improving employment and education opportunities across the European Union. It also aims to improve the situation of the most vulnerable people at *risk of poverty*. This fund allocates resource on four main objectives: promoting employment and supporting labor mobility, promoting social inclusion and combating poverty, investing in education, skills and lifelong learning, and enhancing institutional capacity and an efficient public administration. In addition, 20% of this fund aid will be committed to activities improving social inclusion and combating poverty [20]. *European Union Solidarity Fund* was created to respond to major natural disasters and to express European solidarity to the regions affected by disasters in Europe. The fund was created as a response to the *severe floods* in Central Europe. It was used for 80 catastrophic events, including floods, forest fires, earthquakes, storms, and drought. So far, 24 different European countries have been supported [20].

Sustainable growth is one of the key tenets of the Europe 2020 strategy—developing a European economy that is greener, more resource efficient, and more competitive. Europe's regions and the EU's Structural and Investment Funds are now the driving force in making this a reality [21].

The global demand for environmental technologies, ecofriendly products and services, and sustainable design ideas is increasing dramatically. The worldwide market, currently estimated at EUR 1.15 trillion a year, could almost double, with the average estimate for 2020 being put at around EUR 2 trillion a year. The European Union has been making great strides to benefit from this. It recognizes the need to reinforce synergies between smart and sustainable growth to deal with the climate change, environmental and energy challenges, as well as growing resource scarcity. Continuing with our current consumption and production patterns is not an option. The EU needs to transform itself into an innovation-driven green economy and regional policy as an investment vehicle is now a key factor in making this happen [21].

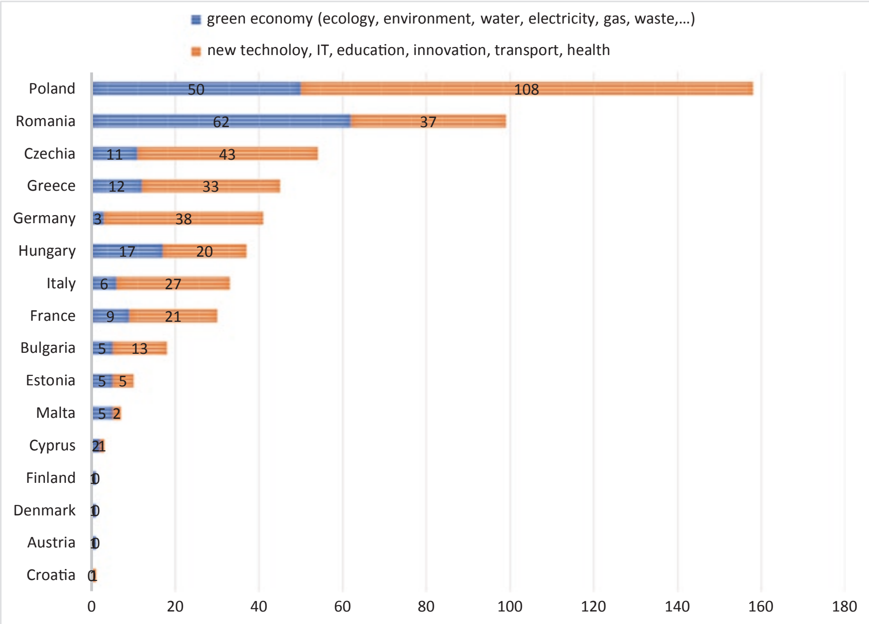

Fig. 13.4 Major projects financed in Europe, during 2014–2020. Green economy distinguished approach. (Based on data from source [22])

Since 2014, during the implementation of the objectives of the regional development policy, until now, in Europe, on number of 16 countries analyzed, there was more than 540 major projects financed from European Structural Funds, out of which 190 are dedicated for green economy (Fig. 13.4). The research revealed that the main projects related to *green* economy are coming from developing countries (e.g., Poland 158 major projects, out of which 50 are dedicated for healthy environment; similar case is Romania, with almost 100 major project, out of which 62 are dedicated to green economy).

Apart from European structural funds for regional development presented above, there is another European fund—Horizon 2020—dedicated for research and innovation. This European Fund supports the development of all projects related to: excellent science, industrial leadership, and societal challenges. Eligible projects have to focus on one from these objectives: frontier research, collaborative research to open new fields of innovation, training and career development, and access to the world-class facilities [23]. The funding process is similar to the one presented in Fig. 13.3. This fund is relatively new (starting with 2014) and foreseen, attracting and retaining research talent and supporting the development of the best research infrastructures, and promotes leadership infrastructure.

Financing Start-Ups, Innovation, and Entrepreneurship

In the member states of the European Union, the ministries of the economy or those dedicated to the business environment and entrepreneurship in partnership with the European Commission provide financing through *certain programs to encourage and stimulate the establishment and development of start-ups and small and medium enterprises* (SMEs). There is a minimum aid scheme, established through the program implementation procedure. Financial funds for this program are provided from the respective country's budget in collaboration with European funds. The main objective of the minimum aid scheme is to improve their economic performance, with priority in less-developed economic areas where the density of SMEs is reduced compared to the European average, labor market, the inclusion of disadvantaged people, the unemployed and graduates on the labor market. An essential condition is that the newly established company applying for such a program must have its headquarters in that country where they are applying. One company can apply for this program only once. The maximum location for each beneficiary is 45,000 euros. The process of financing is similar with the one presented in Fig. 13.3, only intermediate regional structures are eliminated. The company applies directly to the designated Ministry.

In European countries, *SMEs and women-owned start-ups* are eligible for loans from banks, following a loan agreement signed with the European Investment Bank (e.g., Romania). The European Investment Bank is borrowing from European Funds to support SMEs and start-ups. Priority has been given to women entrepreneurs. This transaction has support from the European Investment Fund, through its financial pillar of the Investment Plan for Europe also called the *Juncker Plan*. In order to have access to these loans, enterprises must be owned by more than 50% by one or more women, or 26–50% owned by one or more women, and the position of director general, administrative director, or finance director to be owned by a woman. The bank account is opened immediately (the same day) without requesting salary certificates or other property documents. The Investment Plan for Europe (Juncker Plan) is one of the EU's investment incentive measures in Europe that aims to increase employment and stimulate economic growth.

The European Fund for Strategic Investment. The European Fund for Strategic Investment is one of the three pillars of the *Investment Plan for Europe* and aims to overcome current market failures by addressing market gaps and mobilizing private investment. It helps to finance strategic investments in key areas such as infrastructure, research and innovation, education, renewable energy and energy efficiency, as well as risk finance for SMEs. European Investment Bank manages the fund. The European Investment Bank manages the European Fund for Strategic Investment. The projects supported by this fund are subject to the normal bank project cycle and governance. The fund supports both individual projects and investment platforms. Entrepreneurships, start-ups, utilities providers, public sector, banks, and investments funds can apply. The *European Investment Advisory Hub* is the *Europe's gateway* to investment support. It shares good practices, lessons learnt, and real-life case studies on project finance and project management.

Intelligent Regional Developments—Results and Discussions

We live in a constantly moving world, where artificial intelligence and the principles of smart business and finance are all debated, implemented, and monitored. Globalization and digitization are processes that gain their part in regional development funding mechanisms. Moreover, regional development objectives aim at implementing new information technologies in all regions of the world, including in disadvantaged areas. Thus, an international economic and social connection is required.

Smart city is the twenty-first century model of regional development. The Smart City concept integrates information and communications technology and various physical devices connected to the network to optimize the efficiency of city operations and services and connect with citizens. This includes data collected from citizens, devices, and assets that are processed and analyzed to monitor and manage traffic and transport systems, power plants, water supply networks, waste management, law enforcement, information systems, schools, libraries, hospitals, and public services.

Smart city technology allows city officials to interact directly with both community infrastructure and the city and monitor what is happening in the city and how the city is evolving. It may contribute for a unitary development of the region, but also for the growth of foreign investments and jobs, which leads to the increase of the general well-being of the society. Telecommunications service providers are an essential part of the ecosystem that will bring smart cities to life and their trusted status and underlying capabilities make them ideal partners for cities [24]. Currently, according to the specialists, there are 50 smart cities around the world. The top, based on geographical area is New York (USA), Tokyo (Asia), Melbourne (Oceania), Dubai (Middle East), and Buenos Aires (Latin America). International development organizations (multilateral development banks, development finance institutions, and bilateral donors) provide the main source of financial funds for smart cities. They can offer developing economies financial and advising support and risk mitigation through low-interest loans, equity investments, credit guarantees, and technical assistance.

Regional development through smart cities or efficiency principles, as well as recent approaches to change across all sectors of activity, requires detailed project analyses, problem identification and resolution, and decision-making skills. In particular, assess the impact of political, economic, and sociocultural, with accent on ecological and other influences on the entire community and the business environment.

In this context, a strategic analysis is used to diagnose the key issues that need to be address in the development of large development projects. One of these analyses is: PEST(ELI)—**P**olitical, **E**conomic, **S**ocial, **T**echnological, **E**nvironmental, **L**egal and **I**ndustry. PEST(ELI) analysis is a model used for large-scale projects. The analysis provides a four-way perspective on a particular policy, proposal, or business plan (Fig. 13.5).

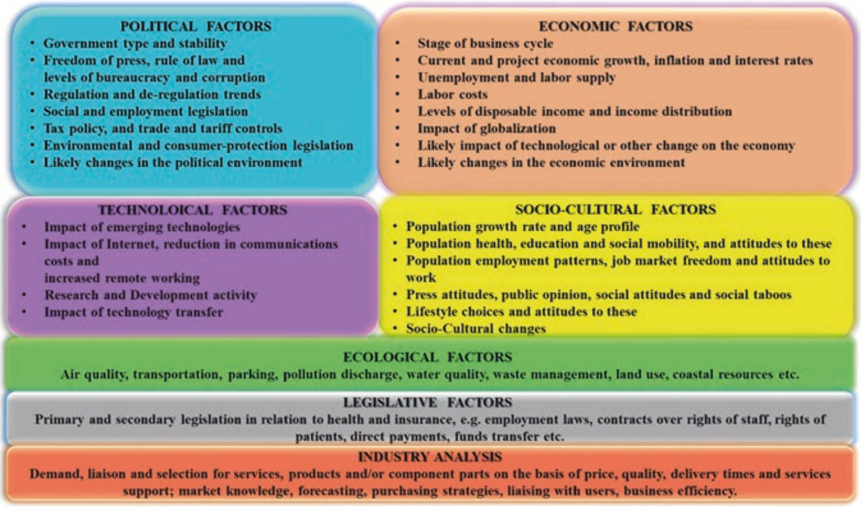

Fig. 13.5 PEST (ELI) analyze model. (Source: [1])

Blending facilities—the innovative financial instrument—an EU example. Investment needs in European countries are substantial. Government and donor funds are far from sufficient to cover these needs. Countries need to attract additional public and private finance to drive economic growth as a basis for poverty reduction. The European Agenda for Change emphasizes the support of inclusive growth and job creation as a key priority of EU external cooperation. In this context, *blending* is recognized as an important vehicle for leveraging additional resources and increasing the impact of EU aid [25].

Blending facilities is an instrument for achieving EUs' objectives external policy, complementary to other aid modalities and pursuing the relevant regional, national, and overarching policy priorities. The principle of the mechanism is to combine EU grants with loans or equity from public and private financiers. Grants can be used in a strategic way to attract additional financing for important investments in European Union countries by reducing exposure to risk. On a case-by-case basis, the EU grant contribution can take different forms to support investment projects: investment grant and interest rate subsidy (reducing the initial investment and overall project cost for the partner country), technical assistance (ensuring the quality, efficiency and sustainability of the project), risk capital (attracting additional financing), and guarantees (unlocking financing for development by reducing risk) [26]. The European Union implemented economic agreements with other economic unions around the world (see Fig. 13.6).

All the inter-regional agreements foreseen to implement *blending operations* through regionally or thematically focused financial instruments that support projects contribute to the fulfillment of European Union and partner country strategic (other region partner) development goals. Currently, European Union has seven *EU blending facilities*: Investment Facility for the Pacific (IFP), Asian Investment

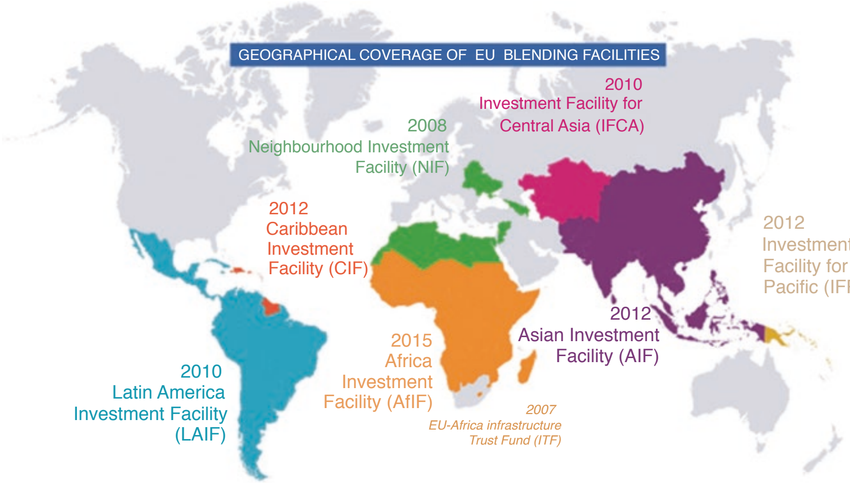

Fig. 13.6 Blending facilities between EU and other region of the world. (Source: [26])

Facility (AIF), Investment Facility for Central Asia (IFCA), Neighborhood Facility (NIF), Caribbean Investment Facility (CIF), and Latin America Investment Facility (LAIF). Through blending facilities, European Union cooperates with developing countries at different stages of development, including countries that have completed bilateral development assistance to cover the specific needs during their transition period between low-income and middle-income countries.

Conclusion

Intelligent specialization is now a policy concept for setting priorities where a region can benefit from a concentration in a specific economic, scientific, and technical field. Regional economic development is becoming more focused on knowledge and innovation, and therefore stimulates structural change by applying the principles of innovation and inter-regional cooperation.

Globalization opened the door for cooperation. *Green economy*, *smart city*, and *blending facilities* approaches can be a way for a modern and quick regional development. *Smart city* offers a possibility to develop a region from economic and social perspective. It offers international integration, visibility, economic recognition, and high competitiveness. *Green economy* may be a way to achieve a sustainable development. These considerations are considered to be fundamental to the long-term sustainability of economic growth. Overall, the green economy is the one that results in improved human welfare and social equity, significantly reducing environmental risks and ecological degradation [13, 14].

Building a Green Economy is not about throwing out the old system and starting from scratch, it is about making choices according to the full cost—not just the financial cost—of any and all activities [26]. And European Union, through their structural funds program, gives more attention to this.

The research concludes that regional development can be achieved also through artificial intelligence and digital finance systems implementation. Artificial intelligence combine financial information with tech capabilities, accelerate digital transformation of finance and accounting, and may create a more safety business and economic environment, reducing human error. We are living in a digital and intelligent era, where machines take over repetitive, time-consuming, and redundant tasks, giving finance professionals more time to approach higher level and more lucrative analysis and research. Digital solutions and new technologies offer great potential to overcome massive development challenges and can contribute in achieving the goal of universal access to financial services. The main benefits generated by these innovative tools include reducing the risk of error (especially human error), low risk of fraud, system automation, big data analysis, huge cost savings (by increasing the efficiency and decreasing in errors), increased reliability in financial reports, and reduced workflow.

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Chapter 14
The Role of the Architectural Survey in the Sustainable Refurbishment of the Historical Building Heritage

Paola Puma

Introduction

Cultural Heritage and Historical Building in the Sustainability Paradigm

"The protection and enhancement of cultural heritage contribute to preserving the memory of the national community and its territory and to promote the development of culture" [1]: the Code of cultural heritage and landscape, entered into in Italy since 2004, brings together in the concept of cultural heritage the artifacts and landscape assets relating to different scale of the habitat. Buildings of historical monumental interest to villas, parks, and gardens that have artistic or historical interest to public squares, streets, roads, and other urban open spaces of artistic or historical interest are all intended in a vision of common presence of each artifact to form without distinction of continuity the unique value so strongly settled in the personal and collective identity of the country constituing a truly distinctive element in social, civic, and economic terms.

Alongside the many other notions of constitutive assumption, cultural heritage is also defined by the characteristic of being in continuous change and change, following the transformations of the social environment of which it is simultaneously memory and development trigger. The different presence, function, and its same role depend in fact dynamically on the social, cultural, and technological context of reference and on the environment constituted by a community, the territory, and its institutions.

Among the peculiar characteristics of the Italian cultural heritage and the building one in particular, its historicity on a large scale certainly constitutes the most

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macroscopic character. On the one hand, it identifies and conditions about the approaches and methods of work, but on the other hand, it has constituted precisely the precondition of its longevity, through the flexibility to accept the transformations that the historical building heritage presents, sometimes even more than the modern architectural buildings [2, 3]. Thus, the possibility to get new skin at every stage of life substantiates the dynamism and flexibility of the historical Italian building heritage and gives an added value in terms of sustainability of the transformation interventions: is the historic building a resilient building?

The Identity Potential of Historic Buildings as a Driver of Sustainability

This continuous and changing interaction between artifact and environment therefore simultaneously makes the cultural heritage an object, a cultural, identity, and economic resource but also a marker for understanding the society that is called to preserve it, protect it, and enhance it in all its potential [4].

And if the notion of sustainability includes the enhancement of the potential of the environmental resources of urban and architectural contexts, this potential is defined by all those characteristics of material and immaterial value settled in the cities and in the historical buildings by the genius loci, and then the architectural survey can also take the function of a tool for revealing this potential, according to an innovative disciplinary meaning that inserts traditional instrumental attitudes on the inevitable paradigm of interpretation and transformation of contemporary urban reality defined by sustainability.

The Role of the Architectural Survey in the Sustainable Refurbishment of the Historical Building Heritage

The survey of architecture and environment is a technical discipline which due to the digital revolution of the last two decades has brought back into its own field many instrumental innovations that have fastly taken place consequently changing its scientific statute in a increasingly complex and constantly evolving framework [5].

In fact, the survey assumes variable configurations depending on the type of object investigated, the context conditions (human resources, technology and time available), and above all the purpose of the survey; if aimed at the documentation for the knowledge of the building, the documentation for the restoration of the building, the documentation for the construction of a new building.

Another non-secondary element that influences the operational framework project is also the size of the context in question and whether it consists of a single architectural building or an urban-scale complex (a square, a street, a block) or even from an urban quadrant or a settlement. For the reasons mentioned, the survey's outputs are articulated both in a linguistic sense—drawings, static or dynamic 3D models, videos, interactive mappings—and in a thematic sense—representation of dimensions, materials, functions, degradation characteristics, of the structural setup, and so on—in a very variable and wide spectrum of representations and views only partly codified and to be redefined each time on a case-by-case basis [6]. Considering the architectural survey as the first knowledge's phase of the building process, an important update is required today by looking at every transformation of the existing architecture in the logic of sustainable intervention, a logic in which the traditional instrumental and methodological variables of the architectural survey must be further supplemented by a series of representations capable of accounting not only for the physical characteristics of the building but also for its attitudes to resilience and its immaterial dimensions of economic and social value.

The study of the systems characterizing Italian historical settlements carried out through the disciplinary tools peculiar to Drawing and Survey has a long tradition and is based on well-established investigation methodologies and extensive literature. The continuous technologies improvement allows today to update the survey and representation methods attempting a discretization more pertinent to the multidimensionality of the complex systems analyzed (Fig. 14.1).

A deep understanding of urban realities, in fact, could pass only today for a more integrated representation that is able to give back both the material data (in its visible characteristics of size, shape, materials) and the immaterial one of its genius loci (in the features that define in such a peculiar way the character of an urban environment: from the function of a place to the chronological dimension that connotes the rhythm of life in the day or in the seasons, to the social typology of its inhabitants), both indestructible factors of identity formation of a city.

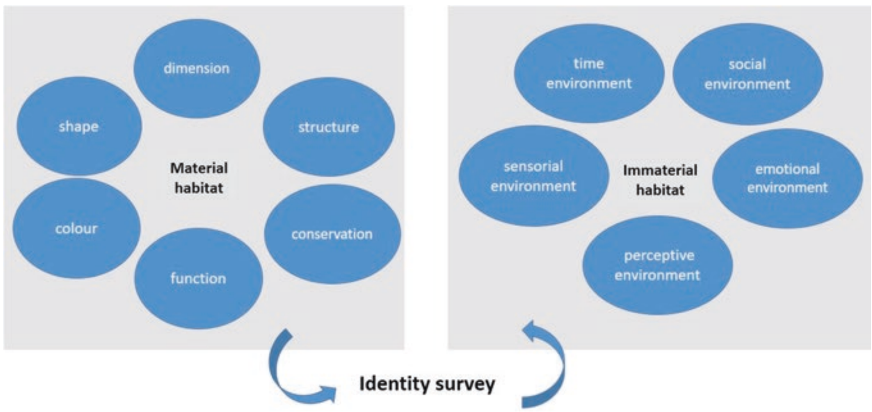

Fig. 14.1 The Identity survey model

The formulation of the workflow is therefore structured as follows:

(a) Acquisition of information elements on the architectural and environmental heritage
(b) Definition of the numeric, graphic and textual dedicated repertoires
(c) Production of documentary repertoires with multi-scalar contents: basic, when related to the description of natural and artificial buildings, and critics, when related to the thematic elaboration of basic information

To these standard representations we propose to add the interactive maps for the description of the identity features of the place: soundmap, chronomaps, and olfactory maps [8].

Results and Conclusions

The methodological and instrumental workflow described above focuses on the objective of verifying on the field the theoretical model of "identity survey" that, while substantially based on the 3D model and the use of canonical two-dimensional drawings of architecture, is not limited to visual suggestion but tends to the comprehension and involvement of the user in the dimensions of the townscape that make it an environment: the synchronic and diachronic physical impact with the place, the particular social interactions that take place there, etc.

Based on these premises, a campaign of "identity survey" has been designed and started on a sample case located in the historic center of Florence, Piazza San Pierino (Fig. 14.2).

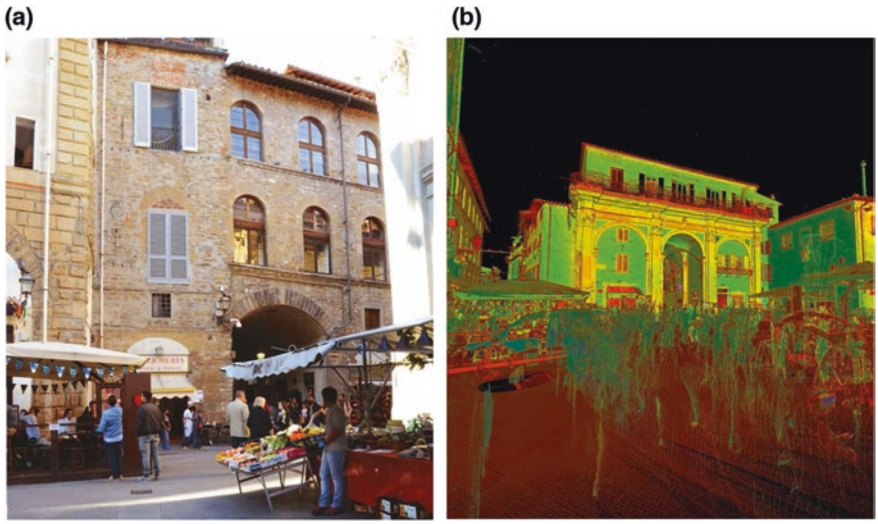

Fig. 14.2 (**a**, **b**) The S. Pierino square in picture and Laser scanner view

Fig. 14.3 Example from the interactive platform

The data acquisition phase was critically oriented towards a synthesis prepared for reading on several levels through the graphic and visual representation of the square describing together images and imaginary: together with the dimensions of the building, also those of memory and values that over time have stratified themselves to form the visual identity that all mentally associate to the historic center of Florence (Fig. 14.3).

The nodal and more innovative phase will be constituted by the interactive representation, interpreted as the convergence between survey data and 3D dynamic representations to allow the production of models destined to become dynamic data in real-time to realize "identity maps" to be used via smart devices [9].

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Chapter 15
People and Place: Identity Survey and Responsible Design for Architectural Resilient Regeneration Process

Paola Puma and Antonella Trombadore

The Challenge of Immaterial Resilience

A single-minded view of urban development has failed cities, both socially and environmentally. In social terms, this has created fragmented societies that are characterized by increased polarization. New developments have been created at the expense of social exclusion and gentrification, increasing spatial segregation and forcing the formation of deprived neighborhoods, which are often disconnected and hampered by issues of accessibility to basic services. The sustainable development approach has generally oriented toward the choices of architectural design as well as the dynamics of urban transformation, mainly focusing on technological solutions, technics, and materials. Following recent disaster experiences in European countries (earthquakes, floods, and fires), public and scientific debate has focused on the need to enrich the meaning of resilience. If we analyze the problems of the vulnerable contexts, characterized by the large architectural heritage, the environmental fragility, and the strong anthropic pressure or depopulation (i.e., as paradoxically, simultaneously suffered by some cities in the UNESCO heritage list) [1], as well as the material capacity of the cities and buildings to react to the disasters, it has emerged the same priority to implement the meaning of resilience in a new holistic approach oriented to include also the immaterial issue.

To promote the balanced life of the cities, ensure both environmental and social sustainability of built environments, and implement the regeneration of small towns and buildings, enhanced immaterial resilience can become a new driver of the holistic approach, not only for the rehabilitation after disasters but also to avoid immaterial damages. In this framework, we need to stimulate the international scientific debate to analyze and implement a new integrated approach based on the main matter of immaterial resilience, fostering the communities' capacity to take care and

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Fig. 15.1 Two examples of vulnerable contexts: town and city with different identity and resilience

regenerate their habitat from an architectural point of view, as well as their ability to remain *vital* with the aptitude to preserve the socioeconomic context and cultural identity, especially in the townscape symbolic components.

When talking about a holistic approach to the management of urban systems from the resilience point of view, so far it has been considered exclusively for the aspects of resistance to adverse events and attacks—natural or anthropogenic—which only cause material damages. Other types of attacks, however, cause other damage, more difficult to identify and deal with, especially in vulnerable contexts. We refer here to a series of processes that entail risks for urban livability (to name a few, population imbalances, from mass tourism to the abandonment of smaller centers, the loss of multidimensionality of historical settlements, the impoverishment of the functional mix to that of the social mix) because, even if immaterial, they induce transformations in the physical structure of the most fragile urban and architectural organisms, i.e., many small and/or historical towns; inner, distress, or neglect areas; urban situations contributing to the cultural heritage in the field of technical industrial sites; etc. [2] (Fig. 15.1)

Resilience and Sustainability: From Static to Shared Dynamic Vision

For a long time, resilience has been defined as the capacity of a social-ecological system to absorb or withstand perturbations and other stresses, such that the system remains within the same regime, essentially maintaining its structure and functions. Resilience describes the degree to which the system is capable of self-organizing, learning, and adapting. Many recent thematic events have addressed urban resilience in European cities, working in and with cities (Open European Day, Bonn 2018/4/25, by the European Environment Agency (EEA) and Local Governments for Sustainability, ICLEI; European Forum for Disaster Risk Reduction, Rome, 2018/11/21, by UNISDR, EFDRR; IFoU, Reframing Urban Resilience Implementation: Aligning Sustainability and Resilience, Barcelona, scheduled

2018/12/10, by UN-Habitat and Urban Resilience Research Network-UIC) [3]. More contributions focus on questions related to the implementation of adaptation measures than in the past; otherwise the need for exchanging knowledge among cities and creating new forms of collaboration across different policy levels and with stakeholders is tagged as a crucial issue.

Most of the literature refers simultaneously to resilience and sustainable development: both concepts are linked but not identical, and one cannot replace the other. Sometimes, sustainable urban planning reflects a static view of the future and aspires to a stable (fixed) future. While it is often expressed in utopian terms, sustainability is based upon a single slow-moving disaster scenario where humanity runs out of critical physical resources or overshoots the ecological carrying capacity. Resilience represents a more dynamic view of the future where risk, uncertainty, and surprises are the norms and where the increasing complexity, size, and interdependencies of the built environment produce an increasing diversity, frequency, and severity of disaster scenarios.

The existing framework and guidelines that currently direct ongoing efforts at both the European and the international level on the topics of resilience and sustainability [among we cite only the main ones, the 2030 Agenda for Sustainable Development-SDG 11th ("Make cities and human settlements inclusive, safe, resilient and sustainable"); the Convention for the Safeguarding of the Intangible Cultural Heritage, UNESCO, 2003 [4]; intangible cultural heritage and sustainable development, UNESCO, 2015; European Union Global Strategy (EUGS); A Strategic Approach to Resilience in the EU's External Action (Joint Communication to the European Parliament and the Council, Chapter: Resilience, Climate Change and Environmental Degradation), High Representative of the Union for Foreign Affairs and Security Policy, 2017; the New European Consensus on Development, 2017, which links resilience to the EU development agenda], overall, these shows the EU strategies and related actions in this arena are sector-centric and heterogeneous, prioritize natural disaster management, and are solely based on four drivers: leadership and strategies, health and well-being, economy and society, and infrastructures and ecosystems.

Day by day the effects of climate change are visible at urban and building scale, as well as the loss of environmental quality and the reduction of natural resources. A resilience-focused development plan must play into a new urban/building metabolism. When we plan and manage cities as organisms with their own metabolisms, they are not separate entities but, rather, highly interconnected. With a strong network that includes professionals from different disciplines and countries, the network will tackle the most relevant research challenges related to urban resilience conceptualization and implementation (e.g., global warming, resource scarcity, and the well-being of urban inhabitants). Researchers, practitioners, multilateral agencies, and civil and city-to-city learning networks will collectively shape the debates on how to critically understand and integrate different urban resilience implementation approaches and, thereby, will generate more holistic and inclusive urban resilience approaches [5].

Immaterial Resilience and Identity Survey: The Key Role of Architectural Representation

What are the key principles that, at an international level, are the theoretical prerequisites for interaction between immaterial resilience and resilient design?

Which methodological approaches are necessary for its successful development?

The network aims to overcome the state of the art implementing a new approach that links the material and immaterial aspects of resilience. The first one [material] refers to the infrastructures that involve the physical surroundings and landscape that serve a given purpose (e.g., transportation, power supply, water supply, management, and treatment). The second kind, the immaterial resilience, refers to the networks and interactions among individuals and groups, as well as their native habitat within and outside the community. Consensus about which precautionary measures can be seen as appropriate (and which not) is indispensable for the formation of immaterial resilience and should at the same time be understood as the result of collective construction work.

Since the architecture strongly conditions the interactions between people and their places (both within and outside of their community), thus affecting the development of future resilience, the social organization and the knowledge of the population (that suppose the previous education, the education through life, the interaction with the ruling statutes, the authority, the neighborhood police, and the interaction with other kinds of cooperation), help to shape an important dimension of resilience. The classical notion of resilience is based on four principal drivers. Here we propose adding immaterial value (e.g., cultural identity, genius loci, and memory of places) [6] to reinforce and support these established drivers, thereby producing a richer model.

The new model duplicates the existing one for the classic characteristics of material resilience also for the immaterial one. Immaterial resilient contexts could be defined using the same seven qualities of the resilient cities, adapting the model as follows:

- To withstand: robust and redundant, meaning well reacting as we saw the historical architecture and urban structures react to the continuous changes over the centuries
- To respond: resourceful and flexible, using the historical-built heritage as an example of layers of building creative knowledge; reflective, using the experience to inform future decisions
- To adapt faster to shocks and stresses: inclusive and integrated, taking in account the potentiality to share the people's experiences and their "place ownership" to create a community bringing together various stakeholder interests.

The intangible assets of architecture and urban heritage can contribute to environmental sustainability, as major sources of innovation and development. These include traditional buildings and settlements, historical city centers, and all of the elements in the human environment with notable historical, urban, architectural, social, and aesthetic value [7].

The challenge is how to incorporate the multidimensional values of traditional settlements in a typical and general development plan.

It incorporates physiognomic, morphological, demographic, cultural, urban, and architectural elements that are specific to traditional settlements in such a way that creates sustainable places. Communities and groups innovate in the face of change constantly.

Intangible architectural heritage is a strategic resource to enable the transformative development at the regional and global level. New materials can be adapted to respond to old needs, for example, when certain raw materials become scarce or unavailable. Old skills can provide solutions to new challenges, such as how the time-tested systems of cultural transmission have been adapted to information and communications technologies.

The network will tackle issues related to urban resilience theory development, frameworks, indicators, and metrics, while also navigating these practices through their shortcomings and future challenges. There is a lack of framework and guidelines assessing resilience building strategies to direct practitioners when evaluating how each proposed solution drives a city's patterns toward robustness or transformation, lock-ins or transitions. The network will greatly contribute to addressing this gap by challenging the mainstreaming practices in urban design and management that connect the constructed environment to nature and urban spaces. Information based on national and regional data will be brought together and processed by an interdisciplinary group of professionals. Furthermore, these networking bridges of existing knowledge will create added value at the European level.

The impact will be very high if the People&Place network will achieve the aim to articulate urban immaterial resilience in a *measurable*, *evidence-based*, and *accessible* way that can inform urban planning, practice, and investment patterns which better enable urban communities to valorize and preserve build environment (Fig. 15.2).

People & Place Concept: The Four Drivers

People & Place—as international research platform and network—aims to stimulate interdisciplinary debate on the theme of immaterial resilience, according to an extensive and broader meaning of the consolidated discipline, including the declinations linked to the environmental, social, and cultural sustainability of the transformations of the city: the built environment and vulnerable architectural and cultural heritage. The People&Place network will help to bridge science and society, while supporting a consistent operationalization of the 11th SDG, adding the symbolic dimension of the immaterial risk to the commonly shared hazards list (UNISDR's terminology) when addressing urban vulnerability toward incremental adaptations or transitions in new societal patterns of development.

Fig. 15.2 Graphic representation of City Resilience Index—The Rockefeller Foundation | Arup 2014 [5]

It is interesting to analyze the size and the sense of immaterial resilience related to four different drivers:

1. **Immaterial Resilience # Identity of the context:** describe the identity of the context by introducing the immaterial themes, by bringing out the People&Place relationship, and by pushing the identification of community-based level of resilience.
2. **Immaterial Resilience # Built environmental resources:** define new paradigms of narrative design with territorial patterns capable of describing the environmental system constructed both as a physical habitat and as an "emotional territory"; here we create the link between material and immaterial aspects that constitute the unique/unitary/constitutive characters of a context.

Fig. 15.3 Diagram with the relations of immaterial resilience with four main topics, as research's drivers

3. **Immaterial Resilience # Dynamic design:** investigate different methodologies related to the integrated design process.
4. **Immaterial Resilience # Resilient responsive design:** outline project modalities based on four scalar heavy approaches that can be combined with each other (self-reliant approach; autopoietic dynamics involving gray actions; error-friendly, evolutionary approaches involving green actions; dynamic, responsive approaches based on dynamic imbalance, which provides soft actions closely linked to the involvement of the population) [8] (Fig. 15.3).

People in Their Places

By observing the city, you get to know humans themselves, thereby establishing the unbreakable bond of a person to his/her place (Platone, "Politia," *The Republic*). This vision sees the city's functionality strictly connected to human needs by the ekistic elements, which compose human settlements: nature, man, society, shells, and networks. These five elements, which are embedded in the concept of *entopia*, as "feeling into the place" (C. Doxiadis 1974) [9], bring back the issue of the relationship and interdependence of a person to his/her place, where the human is an integral part of a settlement and inseparably connected to it, imprinted in his place—topos.

The sense of familiarity that binds the inhabitants of a place together and with the context develops over time and gathers all of the social dimensions of the life of a community and its culture. Every day in the city and in the architecture takes place a cultural layering of knowledge, traditions, and rules that constitute it in a continuous, unique, and irreplaceable way: a way to transmit and reflect the cultural notions, associations, and values about how a society thinks about time itself, which encompasses particular morphological and cultural characteristics that highlight the physiognomy of a place. In this relationship, architectural heritage has a role that is not only a testimonial of identity, multiplicity, and cultural wealth but also an element of social cohesion to be protected, as stated by the Sustainable Development Goals (SDG 11.4), the Sendai Framework, and the UNESCO chart [1], because it can contribute to making cities and human settlements inclusive, safe, resilient, and sustainable and it is also a key resource for building disaster resilience.

The Place: Human Built Environment

The places we consider has to be intended as the built environment, including ancient towns, old settlements, cultural landscapes, monuments, traditional buildings, and settlements. In general we include in the built environment all the artifacts having notable historical, urban, architectural, social, and aesthetic characteristics and significance: all places that fuse intangible assets, ideas, practices, and values that create a group's cultural identity (identity, "the perceived uniqueness of a place," "the sense of place") [10]. Considering human settlements as entopias, each context has a particular physiognomy that is connected to its unique entity, as it is expressed through the tangible and intangible landscapes and the perceptual image created by the senses of vision, hearing, touch, smell, and taste.

Furthermore, the Granada Convention made an important distinction in regard to the expression "architectural heritage" that shall be considered to comprise three permanent properties: monuments, groups of buildings, and sites. "Sites are considered to be the combined works of man and nature, being areas which are partially built upon and sufficiently distinctive and homogeneous to be topographically definable and are of conspicuous historical, archaeological, artistic, scientific, social, or technical interest." Therefore, for the first time, protection of architectural heritage overcomes the boundaries of buildings and incorporates intangible elements that, together with the shells (buildings), comprise the concept of site-topos and, by extension, the concept of entopia.

The Identity of the City as Immaterial Value

Immaterial values are intended as the intangible traces of the evolution of human society and settlements over time and were shaped through a diachronic connection of the past, present, and future. Each of these changes constitutes a time layer represented by a material reality in the physical structure of the city. In other words, the image is not only a physical or visual element but also a mental analysis of all components of the city, which reflects the way we use and access our cities. Understanding these layers and their relationship to each other is a crucial factor in understanding the city and sensing its identity. Problems start when something goes wrong in this temporal, spatial structure of the city and a distorted situation becomes prevailing, which causes loss of the city properties and adversely affects its identity and could lead to losing it. Considering that a true understanding of a city passes through a more holistic representation of its genius loci, the "identity survey" [7] methodology will overcome traditional representations that are based on graphical and visual language only. Applications of sensory output of smart devices can serve as a key to access a deeper level of knowledge for a given place pursued as well as the traditional architectural survey even with the multisensory reproduction of the environment. The study of material and immaterial systems that characterize the historical settlements needs to attempt a discretization more pertinent to the multidimensionality of their elements that define their character in such a peculiar and specific manner.

Immaterial Resilience for Responsive Design

The cultural capitals (as nonrenewable resources) represent an exception, and the critical problem's focus of this proposal is aimed at the public and scientific debate, with a focus on the need to enrich the meaning of resilience beyond the material capacity of the cities and buildings to react to disasters. Recently it has emerged the same priority to implement the meaning of resilience including a holistic approach to immaterial issues, knitting together people-centered and place-based approaches into integrated vision that share a common cultural thread. To promote the balanced life of the cities, ensure both environmental and social sustainability of built contexts, implement the regeneration of small towns and buildings, and enhance immaterial resilience are the main drivers for adopting holistic approaches [11].

The growing presence of the term "resilience"—not only in research but also in planning, governance, and politics—shows emerging challenges to all stakeholders. The sustainability debate and the growing awareness in risk research (i.e., referring to architectural historical and cultural heritage) have helped to focus attention on vulnerabilities and the need to create resilience across the scales of urban stocks, buildings, and local townscape and to provide a resilience framework to operationalize resilience by introducing additional tools and concepts from multiple disciplines and fields of application, implementing the new attitude of *augmented cities* [12].

The debate regarding the interaction between SDG 11th "make cities inclusive, safe, resilient, and sustainable" and resilience for mitigating and adapting to the impact of changes and the effects by reducing the key risks that these impacts pose to the built environment has only just been prepared, and some key questions remain open, but the potential contribution of urban design in architecture seems key. In order to move forward in the right direction, we need, first, to carry out a critical review of the main implications involved in our vision and the relative process-based innovations that are useful when examining the importance of the key principles that underpin the issues of "designing resilience" and, second, to examine the potential actions of future processes in urban design (Fig. 15.4).

As described by Prof. Tucci [8], a synergy is required among the three approaches/main categories [gray-green-soft] proposed by UN-Habitat to improve the resilience, mitigation, and adaptation of the built environment, with a particular emphasis on the dynamic-responsive approach. Several approaches, developed at the international level, drive environmentally friendly building design processes (for both new and existing buildings). These are generally oriented to ecological and green architecture integrating sustainable materials but lacking interactions with eco-conscious urban lifestyles. The term "responsive architecture" was introduced

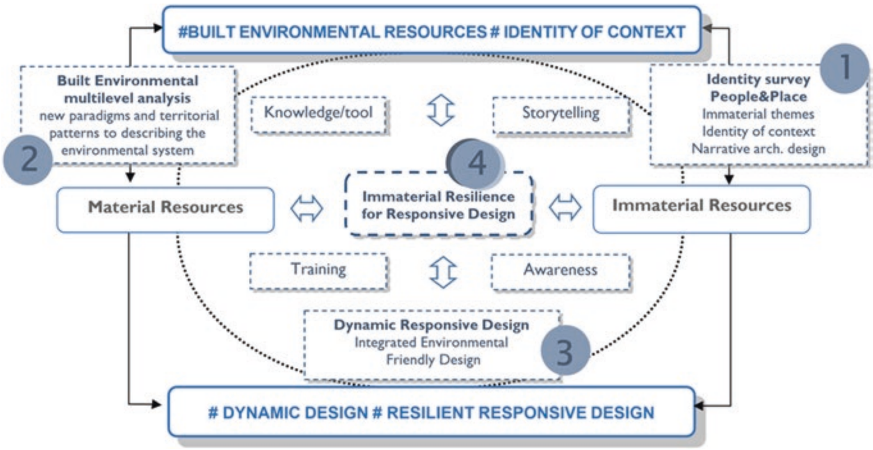

Fig. 15.4 Flowchart of the main topics and multidisciplinary activities related to immaterial resilience

by Nicholas Negroponte [13] who first conceived of it during the late 1960s. A dynamic adaptive approach for resilient responsive design is essential to a healthy and thriving community. Recent research has demonstrated that optimization of a building's dynamic behavior is directly associated with improvement to a city's resilience capacity; however, many cities have stark contrasts in design and maintenance conditions across their neighborhoods. Some areas are thriving, benefitting from easy access to beautiful, well-maintained public assets, meanwhile, others are under-resourced and overburdened by physical disorders. This may also mean engaging diverse groups in the design and decision-making processes. Dynamic adaptive design encourages the introduction of immaterial aspects into the design process and the involvement of all relevant parties, to elevate inclusivity as they envision the future of their community.

The Critical Mass of the Network

The structure of the network has a worldwide dimension and has the critical mass, expertise, and experience necessary to address the project's challenges. The People&Place Action involves a total number of 49 proposers: 84% of these higher education and associated organizations (e.g., universities, research centers); 10% private nonprofit NGOs; 4% business enterprises, companies, and consultings; and 2% government/organizations, from 12 European countries, 5 NNC institutions, and 5 international partners. The network has been conceived involving each proposer looking at its expertise and planning its positioning to efficiently cover the interdisciplinary activities. In order to strengthen the excellence of the network and its capacity to grow in both quality and quantity, the number of proposers is expected to increase

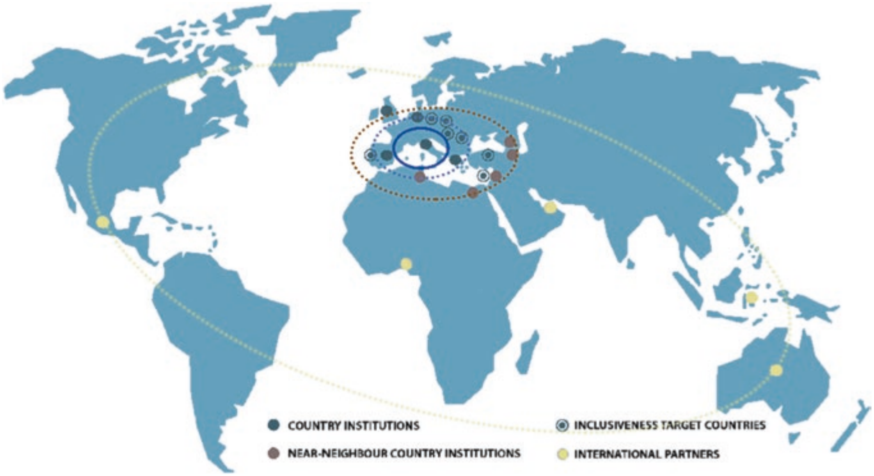

Fig. 15.5 Worldwide distribution of network

over the course of the action. The distribution was planned to achieve maximal diversification in terms of age, academic experience, scientific specialization, and—above all—geographical area, to reflect a variety of cultural and environmental characteristics and vulnerabilities, the mix of nationality, as well as from many disciplines, since the participation will strengthen the dialogue, transfer of knowledge and integration into the international scientific and professional communities.

The network will greatly benefit from the knowledge-sharing and expertise developed by five NNC institution participants and the academic and consulting partners from Asia Minor (three countries) to North Africa (two countries). Their inclusion was deemed to be valuable for many reasons: to share experiences and case studies related to urban transformations resulting from rapid social, economic, and political events, to serve as green and sustainable solution consultants, to analyze the added value of the intangible elements such as the regional and global impact of economic issues, to propose holistic strategies in the field of environmental design that go beyond the trend of green cities, and to contribute to the international seminars by testing the knowledge transfer and local capacity building (Fig. 15.5).

The well-balanced geographical distribution of the countries participating in the network will enable an exchange of knowledge.

Additionally, the network will benefit from the knowledge shared by the five international partners on their region-specific experiences. For example, from Oceania on their local indigenous communities (i.e., environmental psychology), from Asia on their joint international cooperation projects for post-tsunami urban/building actions, from the Middle East on their environmental resource management, from Central America on their networking experiences and efforts toward fostering the development of intangible resources, and from Central Africa on the strong anthropic pressure in their urban/suburban areas and its impact on their culture and resources.

The network's participants will bridge gaps between sectors to accelerate the exploration of the frontier of sustainability; develop new multilevel, interdisciplinary approaches to resilient responsive design; and create realistic, feasible concepts.

The network believes both profitable knowledge and effective governance are needed to create the strong foundations of a sustainable society. To accelerate this goal, the activity is oriented to help develop awareness by sharing knowledge in seminars, publications, workshops, conferences, and training schools.

In order to move from idea to implementation, the network encourages the development of strategies that combine science, creativity, and social entrepreneurship.

The participants will be organized in four multidisciplinary teams, as working groups (WGs) involving the stakeholders from start to finish, and, thereby, identify the concepts with the maximum positive impact and potential for success. For the successful realization of its specific objectives, the People&Place network is articulated into four WGs, where the dimension of immaterial resilience is modulated by the issues of built environmental resources:

- *Identity Of The Context—Identity Survey*, lead by Paola Puma, Unifi, Italy
- *Built Environmental Multilevel Analysis* lead by Helena Coch, UPC, Spain
- *Dynamic Responsive Design—Integrated Environmental Friendly Strategies* lead by Despina Serghides, Environment and Water Research Center of the Cyprus Institute
- *Immaterial Resilience For Responsive Design* [cross-disciplinary group] lead by Alessandra Battisti, Università La Sapienza, Italy

The cross-disciplinary WG will valorize the different methodologies and tools related to the integrated design process [for new construction and recovery interventions], combining different approaches and stressing the involvement of communities (social survey), supporting the identification of integrated solutions for immaterial risk: loss of identity of the places, imbalance [too much/too less presence of people], livability, and evolved ecosystem in the new Anthropocene.

Results and Conclusions

At international level the network will share, homogenize, and implement the knowledge about resilient responsive design, overcoming the current definitions of integrated design [related to the context]; energy-conscious design [focusing on the energy control, sustainable rehabilitation, and reuse strategies]; inclusive design [democratic and participatory processes and inclusivity]; adaptable quality design [flexible enough to adjust itself to changing individual and societal requirements with minimal intervention, focusing on relationship between the creation of quality urban environments and our quality of life]; and responsible design [also directly relates to the EU's 2020 objectives of smart, sustainable, and inclusive growth]. All the actors involved in the urban design process need to acknowledge own responsibility in creating better environments at different scales. This sets the scene for interventions at the neighborhood and district scales, helping in the formation of community ties that could lead to more active citizen involvement.

Note The paper is written jointly by Paola Puma and Antonella Trombadore.

Referring to the individual chapters, they have been written as follows:

P. Puma—A. Trombadore: 1. | 4. | 5. | 6. |
P. Puma: 3 | 4.1 | 4.3 |
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Part IV
Historic Buildings and Refurbishment

Chapter 16
Energy Retrofit Cost-Optimal Design Solutions in Social Housing: The Case of Three Tower Buildings of the 1980s

Michele Morganti, Valerio Vigoni, Edoardo Currà, and Alessandro Rogora

Introduction

This work aims at characterizing energy retrofit design solutions in social housing by means of cost-optimal analysis. The objective is to compare usual and deep building renovation scenarios with a design method useful to take into account relevant non-energy-related factor concerning architecture and social aspects, i.e. flat adaptations to users' needs, renovation of common spaces for cohousing activities, quality of building elements and life-cycle extension. All these factors improve the living quality of inhabitants and give additional economic value to the social housing districts. This objective is developed in the Italian regulation framework on energy efficiency and building renovation, taking into account EU cost-optimal methodology and Italian public incentives.

In Europe, the existing building stock consists of a large number of buildings, mostly dated back to past centuries. Several statistics estimate that about 65% of this stock has been built without any energy conservation measures [1]. As a result, the residential building stock across EU have extremely low energy performances and require urgent retrofit actions in order to meet the common target of greenhouse

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gas reduction within the next few decades [2, 3]. In fact, to this date, three-quarters of the buildings standing today are expected to remain in use [1, 4]. Therefore, energy renovation is a priority within EU policies and actions, in order to achieve a sustainable built environment and human well-being [5].

Italy, as other Mediterranean countries, is facing a challenging crisis of the real estate and construction market. This crisis affects especially the real estate public companies which manage a large amount of the above-mentioned building stock. Moreover, recent policies on the energy efficiency of buildings are not as effective as we expected: the great part of tax incentives is given to retrofits merely based on technologies existing in the market, without any balanced design approach that may lead to the optimal solution [6, 7].

For these reasons, methods to identify the most cost-effective retrofit measures for particular projects are still a major technical challenge, and cost-optimal solution in social housing is of primary importance: real estate companies may have the need of support in the selection process of the cost-optimal energy retrofit design solution [8, 9].

In this framework, we present three tower building of the 1980s, located in a social housing district of Rome (Italy), as case study. This kind of districts represents—in Italy, as well as in other European countries—most of the urban expansions built during the second half of the twentieth century, thanks to public investments. In recent years, public social housing has been widely investigated by researchers, architects and practitioners because it represents one of the most relevant parts of the existing stock where urban renovation with a holistic approach can take place, aiming at promoting multiple benefits for the inhabitants (social, economic, environmental, safety, health, aesthetics, etc.) [10–12]. On one side, these districts were designed according to innovative architectural design concepts and theories. On the other side, public housing districts were built to meet the fast-growing housing demand. For this reason, the construction process focuses on minimizing costs and time, producing low-quality urban environment. Nowadays, this housing stock suffers for users' discomfort, unhealthy conditions, typological obsolescence and structural and technological deficiency. The combination of the above-mentioned features makes even more important the study of the social housing stock because it allows for a holistic approach in district renovations that could support policymakers in the decision process.

Our study attempts at including non-energy and economic factor in this process. We aim at determining the optimal design solution and at establishing to what extent deep renovation is competitive with respect to the usual renovation. This work forms part of an ongoing project that evaluates seismic and energy renovation of social housing district with a holistic design approach, using the Heritage BIM process.

Case Study

In the first half of the 1970s, the Italian Law n. 865/71, on the basis of Law n. 167/62, introduces the "Piani di Edilizia Economica e Popolare" (PEEP), an urban planning tool which selects and defines public areas for new social housing districts.

As mentioned above, the main purpose of the PEEP was to meet the sharp increase of social housing demand, introducing low-cost flat in the market, thanks to an agreement. In this agreement, the public administration grants the building leases to a private contractor. The PEEP has been the most widely used planning tool over the last three decades, to the point that it characterizes numerous suburbs of the major cities. Moreover, nowadays the PEEP districts account for a large part of the urban footprint (from 9% to 15%) [11].

In the city of Rome, the PEEP has been developed in three stages [13]. The first stage took place between the 1970s and the first half of the 1980s, divided into 48 urban areas for a total of 379,547 rooms. The second stage has been approved in 1978 by the municipality of Rome, providing for 186,486 additional rooms in 41 new areas. Finally, in order to meet the growth of housing demand between 1987 and 1997, the "PEEP completing measure" has been approved, providing 144,000 rooms in 28 areas. Nowadays, about 71,000 social housing flats are managed both by the territorial agency for social housing of Latium, namely, ATER (48,000 units), both by the municipality of Rome (23,000 units). These buildings officially accommodate 198,352 inhabitants, which correspond to about the 14% of the inhabitants of the city of Rome [13].

The three tower buildings selected as case studies are located in the Vigne Nuove district (Fig. 16.1). The district was planned since the 1972 and completed in 1982. The towers, built in the last stage of the district development, were designed by architects Chiarini, Aymonino, Mazzacurati and Prantera [14]. The plan should have included five 15-storey tower blocks, built at the beginning of the 1980s, a service building and an urban park. The latter two were never completed. The buildings are a typical example of the industrialized building system widely used in Italy for social housing districts during the 1970s and the 1980s, composed by cast-in-place reinforced concrete walls and slabs and precast reinforced concrete panels for the façades. Each tower building accommodates 268 inhabitants in 82 flats. Eight different flat types contain from two to six inhabitants. Each floor has from four to six flats and two common spaces (Fig. 16.2). The biggest flat types (gross surface, SUL > 85 m^2) are the most common (44% of the total flats), followed by smaller types (SUL < 65 m^2—41%) and by medium-sized types (SUL 65 > m^2 > 85—15%).

Fig. 16.1 Vigne Nuove housing district: plan (left) and aerial view with the three tower buildings object of study

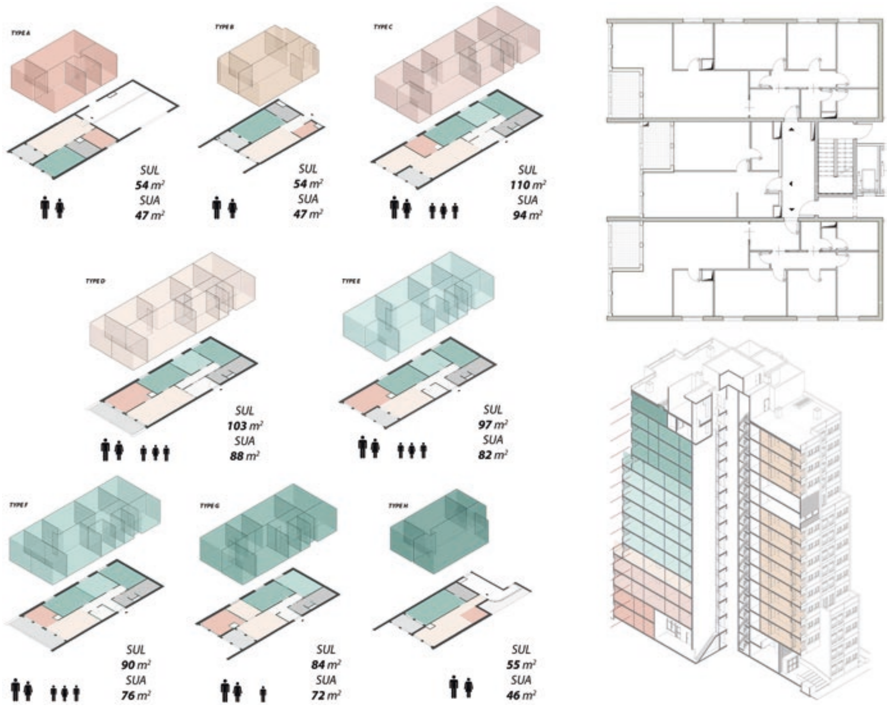


Fig. 16.2 Actual situation: flat types, typical floor plan and axonometric section with flat types

Today the building requires major maintenance works: the building elements and the structure finally reached the end of their life cycle. This is the occasion for proposing an integrated approach to the building renovation that goes beyond usual retrofit actions merely based on the application of technologies existing in the market, without any balanced design approach, leading to the optimal solution. In fact, about 10 years ago, the towers underwent this kind of retrofit action: longitudinal reinforced concrete walls of the façades north-east and south-west where covered with thermal insulation (4 cm of thickness). However, it results in a one-off action that has very limited effect on the thermal performance of the building and leaves unanswered several problems concerning the characteristics of the envelope (thermal bridges, water infiltrations, materials degradation, structural performance reduction).

As a result, the economic investment is revealed all too often ineffective in terms of cost. Moreover, the south-east and north-west façades, based on precast concrete panels represent a crucial problem for the building's energy performance, due to the continuity between façade system and interior floors, generating linear thermal bridges, largely diffused on the whole building. In addition, the lack of a waterproofing layer on roofs and the worn-out sealing joints of precast panels cause several water infiltrations (Fig. 16.3).

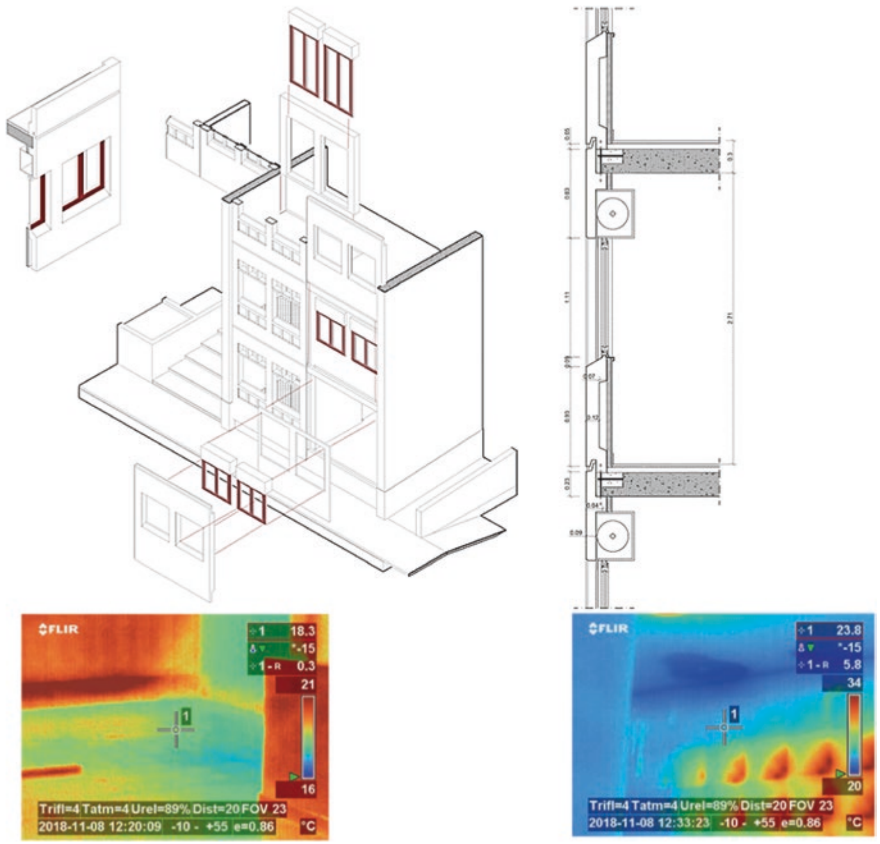


Fig. 16.3 Actual situation: axonometric section and vertical section of the precast concrete panel façade (top); on-site thermography of water infiltrations (below)

Method

The aim of this work is characterizing energy retrofit design solutions in social housing by means of cost-optimal analysis. The method has been conceived in order to develop an integrated design approach, useful to control and assess architectural, seismic, energy and economic aspects in one single platform. For this reason, the building has been modelled with Revit software, applying the well-known H-BIM method (Fig. 16.4). The seismic analysis lies outside the scope of this study, but it is worth to underline that the building renovation design scenarios include structural renovation solutions, as well as the method permits to assess this aspect.

Possible retrofit actions have been proposed and considered in a balanced combination both in the usual building renovation scenario and in the deep renovation scenario. Three different conditions were compared: *actual situation* (the reference case), *scenario A* that includes usual renovation solutions and *scenario B*, which

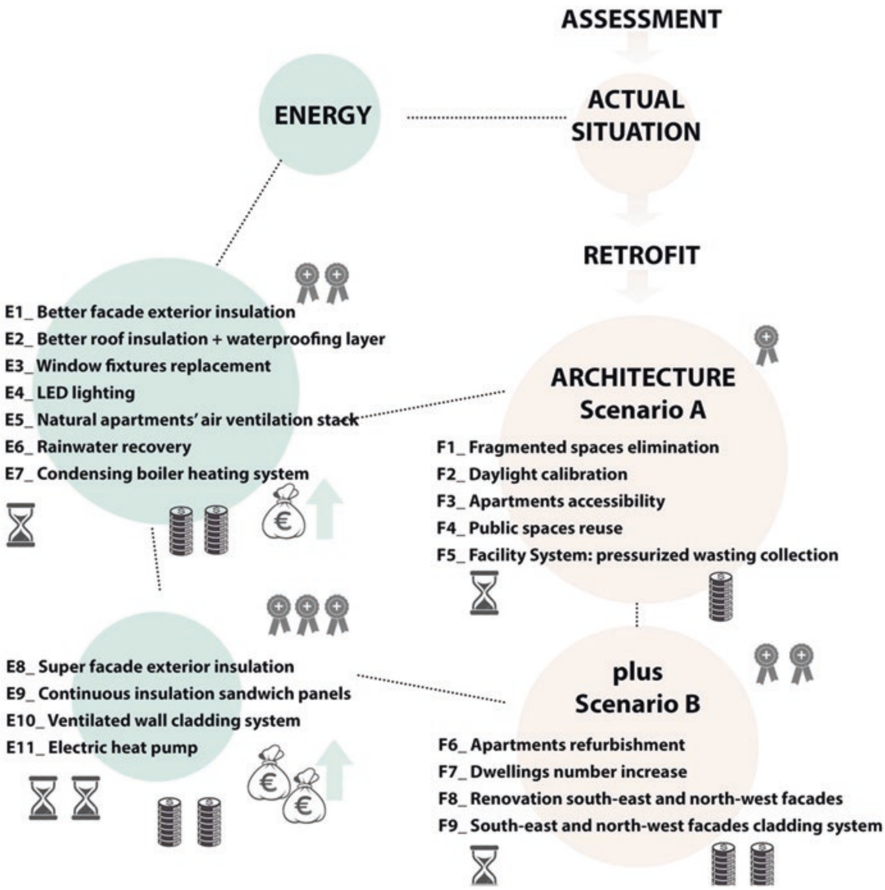


Fig. 16.4 Design solutions diagrams and energy retrofit actions

includes advanced renovation solutions (Figs. 16.5, 16.6, and 16.7). More in detail, scenario A deals with more usual design solutions for retrofit with the aim to comply with minimum requirements of Italian energy efficiency regulation. In this scenario, the following solutions have been applied: new thermal insulation of the envelope—replacement of the existing thermal insulation layer with new expanded polyurethane panels (7 cm) and an interior intervention adding to the existing insulation (5 cm) polyurethane panels (7 cm) on the precast façades; replacement of the heating system with a high-efficiency condensing boiler; high-performing window; and LED lights.

Scenario B, based on deep renovation solutions, is characterized by thermal superinsulation of the envelope; naturally ventilated façade for south-east and north-west reinforced concrete walls; insulation sandwich wall in replacement of the existing precast panels; high-performing window (as in the scenario A); and LED lights (as in the scenario A). These solutions provide the higher thermal

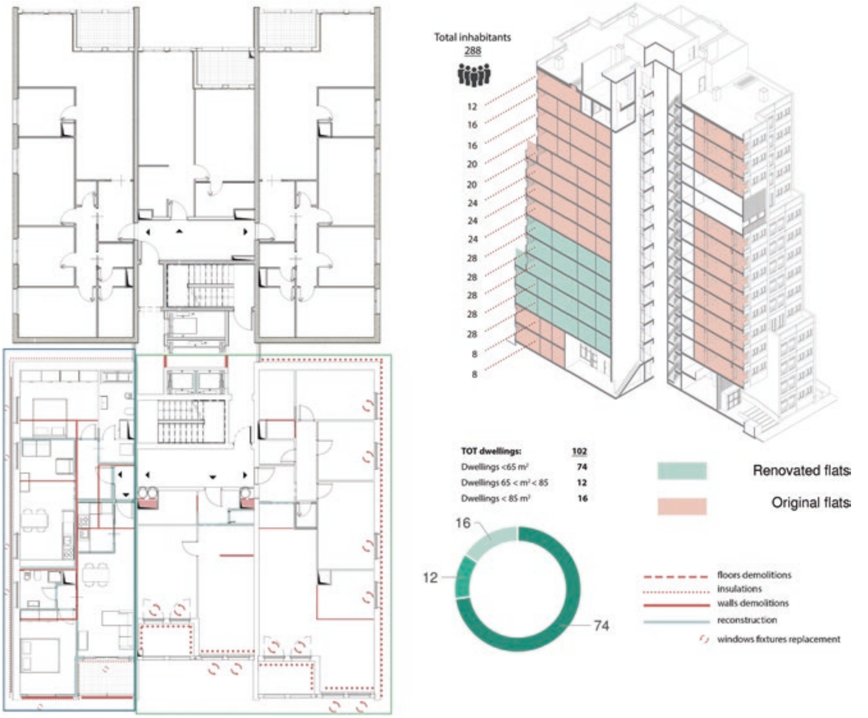


Fig. 16.5 Typical plan comparison: the actual situation with the retrofit scenario A (green) and scenario B (blue). Typological refurbishment: renovated and original flats

Geography position and weather station data				Set Points	Thermal conductivity of building materials [W/m K]
Rome: Lat. 41.953459, Long. 12.531514		topography (GIS)		heating: 20 °C	concrete cast in-place: 1.046
	monthly average temperature	monthly daily hours	temperature mean daily range	cooling: 26 °C	windows fixture aluminium: 230
March	13°C	170	9°C		wall gypsum: 0.42
June	27 °C	320	11°C		bricks walls: 0.54
September	24 °C	280	10°C		insulation panels: 0.35
December	10°C	130	8°C		ceramic tile floor: 0.80
Building Space Type		Space		Space Type settings	Lighting and Power Load Schedule settings
user type: multy-family, multi-storey building		thermal zones: living room, restroom, bedroom, kitchen, stairs		lighting/power load density [W/sm]: living room 10/6 kitchen 10/12 restroom 8/11 bedroom 8/6 stairs 6/2	lighting: home occupancy power: home occupancy
occupancy schedule: home occupancy - 24 hours		service type: conditioned / unconditioned		sensible heat gain per person: 60 W	
system type: centralized heating, residential heating boiler		occupancy factor: 24 hours		latent heat gain per person: 40 W	

Fig. 16.6 Main settings of the energy simulation (left) and building occupancy profile (right)

performance of the building envelope. Furthermore, in order to maximize system performance, a high-efficiency heating pump was introduced.

The economic sustainability of each retrofit action within the scenarios has been analyzed, in order to select the cost-optimal design solution. The costs of building

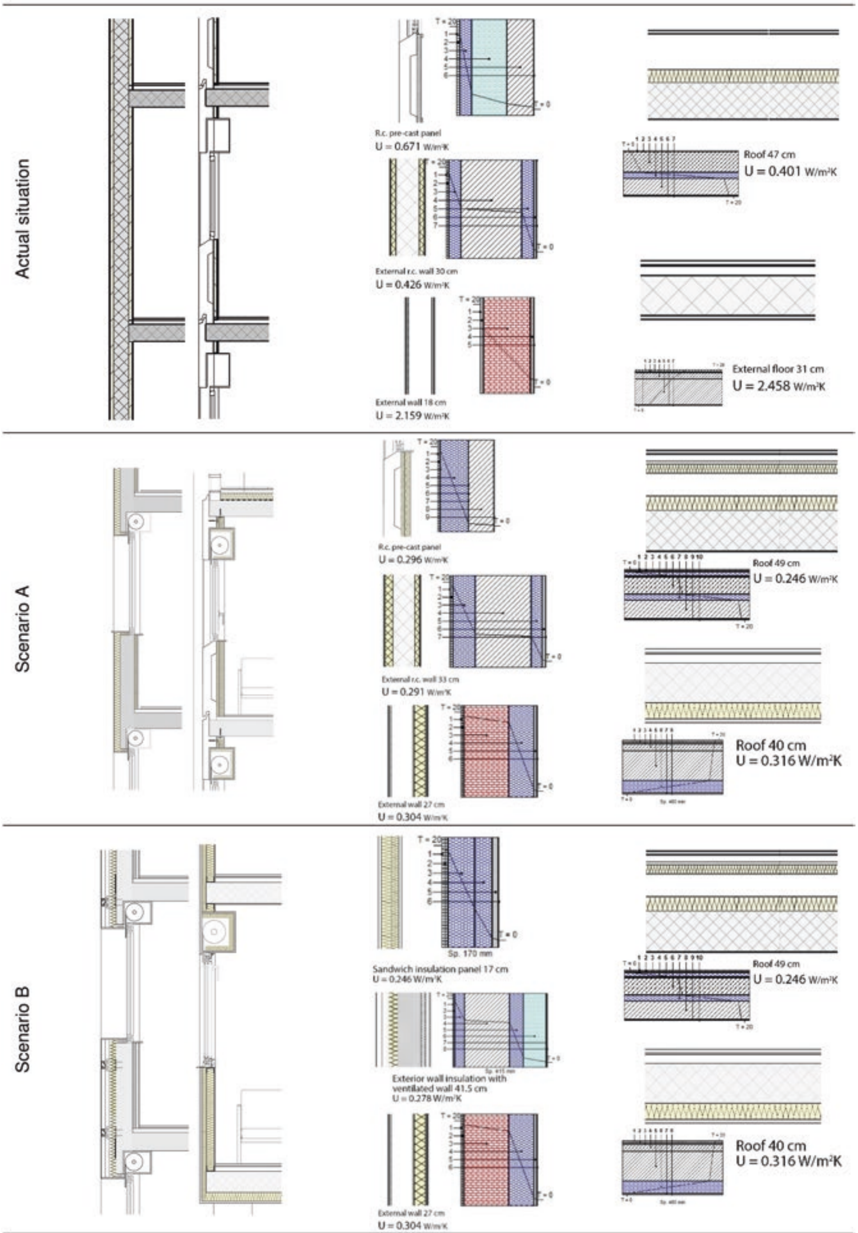


Fig. 16.7 Scenario comparison: façade sections (left) and details (centre); roofs and external floors (right)

retrofit were calculated in an analytical way—regarding the façades and structural works—and parametrically, for the internal refurbishment works. In the latter case, two values have been estimated: 600 euros/m^2 for scenario A and 750 euros/m^2 for scenario B. The costs related to the structural works are excluded by the cost-optimal analysis, as this aspect lies outside the purpose of this paper.

The estimation of global and residual cost, considering the Italian public incentives *ECO-bonus*, is proposed and discussed. The energy analyses have been performed by generating an energy model in Revit. Urban obstructions and topography have been imported from GIS to the model. The most relevant data settings concerning the energy simulation (climate, user type, occupancy profile and system specifications, natural ventilation, internal loads, etc.) as well as thermal properties of the building envelope are presented in Fig. 16.6. Heating design data related to each building elements (walls, windows, floors, infiltrations, lights and equipment) have been calculated with *EnergyPlus* using *Insight plug-in*. This plugin permits to control the economic aspect during the design phase and to compare energy retrofit interventions. Annual dynamic energy simulations have been performed with *Green Building Studio*, using the *DOE-2* simulation engine. As the building does not have a cooling system, in order to compare the actual situation with the proposed scenarios, the energy consumption for cooling has been excluded from the analysis.

Results and Discussion

In this section we present and discuss the results in terms of annual energy consumption (kWh/m^2 year), energy costs (euros/year), payback period (years) and cost (euros) of building renovation for both the actual situation and the scenarios. The section is divided into two parts: the energy performance and the cost analysis.

Energy Performance

Through the dynamic energy analysis of the actual situation, carried out with Green Building Studio, a total energy consumption of 100 kWh/m^2 year emerged (D energy rating) as shown in Fig. 16.8. The results demonstrate a significant utilization of natural gas (52.5% for space heating and 47.5% for domestic hot water). Electric consumptions are the largest proportion in the global consumptions: 63% for lighting and 35% for electronic devices.

The heating load component analysis highlights that exterior walls and windows are responsible for most of the thermal losses through the building envelope: 45% for walls and 24% for windows (Fig. 16.11). This is due to the combined effect of the building typology with the low-quality construction materials and to the little

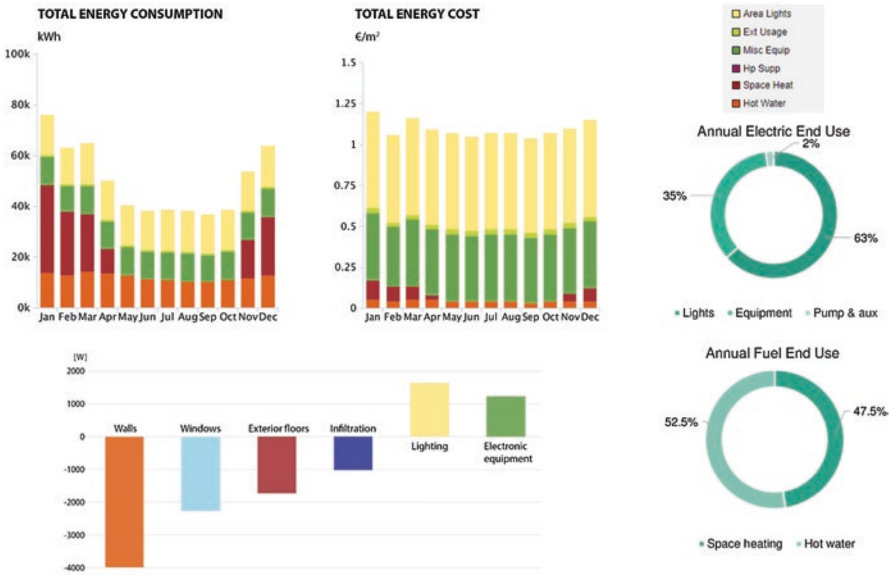


Fig. 16.8 Results of the dynamic analysis for the actual situation: total energy consumption and total energy cost (top-left), energy consumption in terms of electric energy and natural gas fuel (right) and heating load analysis of building components (bottom-left)

attention to the thermal performance of the envelope. Form and typology of the building (in particular, plan depth and width) reduce direct heat gains in winter and natural lighting. Even though each façade has minimum thermal insulation panels (5 cm of thickness), the low thermal properties of reinforced concrete and windows, as well as the presence of thermal bridges in most of the nodes between floors and façades, produce very low thermal performance.

The energy retrofit solutions of scenario A have been analyzed in terms of global consumption reduction separated into building elements and systems: façades, roofs and external floors, heating system and lighting (Fig. 16.9). In the first case, by introducing thermal insulation on walls and replacing the existing windows, it is possible to obtain an energy consumption reduction of 10% (90 kWh/m² year). In the second case, the thermal insulation of floors and roofs decreases consumption of 6% (94 kWh/m² year). The replacement of the heating system with an efficient condensing boiler (90% AFUE) contributes to breaking down the total energy consumption by 17%, reducing the great part of natural gas demand. Finally, the introduction of LED lighting to replace the existing lighting system reduces energy consumption by 15% and electrical loads by 80% (85 kWh/m² year).

Through a balanced combination of the above-mentioned retrofit solutions, it is possible to achieve a global energy savings of 52% (763,256 kWh) compared to the actual situation (1,393,094 kWh) and to achieve the B energy rating (48 kWh/m² year).

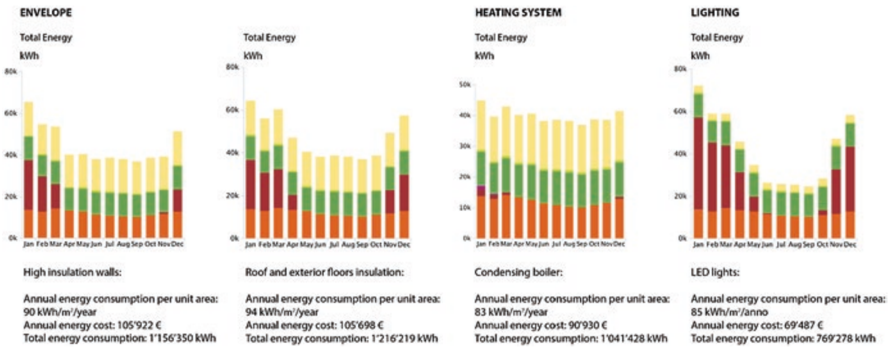


Fig. 16.9 Selected energy retrofit actions of scenario A: monthly and annual energy consumptions and costs

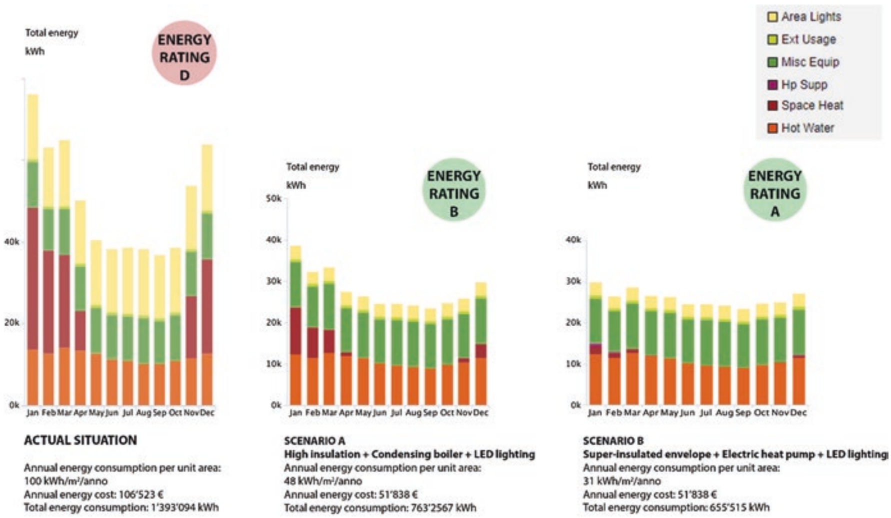


Fig. 16.10 Energy ratings and energy consumptions for actual situation (left), scenario A (centre) and scenario B (right)

The combination of energy retrofit solutions in the scenario B determines an annual energy demand of 31 kWh/m^2 year (A energy rating). Thus, it is possible to save up to 69% of the energy consumption and to obtain an additional 17% of energy savings compared to scenario A. Also in this case, the final consumptions are due to the combined effect of the single energy retrofit measures and in particular to the super-insulation of the envelop and to the heating systems, as highlighted in Fig. 16.10. In the same figure, it is possible to notice that the great part of the energy consumption in the renovation scenarios is due to DHW and electronic devices: two factors independent from architecture characteristics and construction features of the building.

Cost Analysis

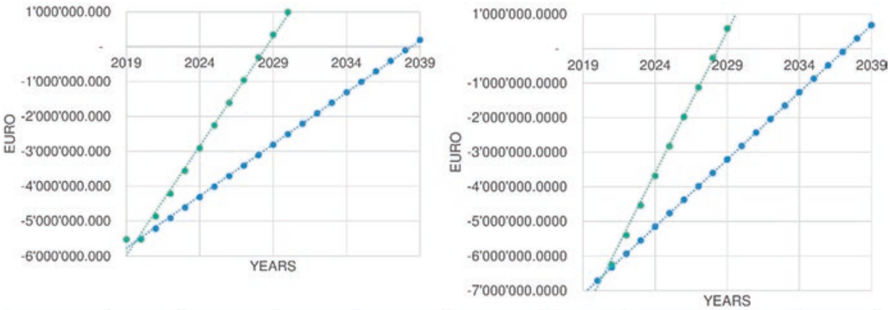
The main results of this section are presented in Fig. 16.11 and Fig. 16.12. The annual energy cost of each tower building in the actual situation is about 106,000 euros/year, of which the 94% is due to electric energy (100,000 euros/year). It is significant to notice how effective is replacing of the lighting system with LEDs that consents a 65% cost reduction. In addition, the selection of the heating system should be driven by a combination of the energy and the economic benefits and balanced in relation to the whole design solutions of each scenario. In fact, the high-performance condensing boiler reduces the annual cost by 15%, while the electric heating pump increases the annual energy cost by 21%, up to 134,811 euros/year. In both cases of usual and deep renovation, results show similar values of annual energy cost: about 52,000 euros, with a reduction of 51.3% for scenario A and 50.6% for scenario B. The main difference between the scenarios is the annual cost for natural gas—with 42% of saving in scenario A and 53% saving in scenario B. The annual cost for electric energy is reduced by 51% in both scenarios. Therefore, in economic terms, the application of an electric heat pump combined with other energy retrofit interventions would not be as effective as in the case of one single retrofit action. This highlights the importance of a holistic approach in the selection of the optimal design strategies in the renovation of social housing.

The global costs of building renovation are:

- Scenario A—5,517,311 euros, of which 1,655,711 euros for energy retrofit actions (30% of the global cost)

Total Energy annual cost [euro]	**Actual Situation**	**Retrofit scenario A**	**Retrofit scenario B**
Energy cost	106'523.00	51'838.00	52'653.00
Fuel cost	6'304.00	3'629.00	2'943.00
Electric cost	100'219.00	48'209.00	49'710.00
Total Energy annual cost by intervention [euro]			
High insulation wall and windows		105'922.00	
Roof and floors insulation		105'635.00	
Super-insulated envelope			105'549.00
90% AFUE condensing boiler		90'930.00	
Electric Heat Pump			134'811.00
LED lighting		69'487.00	69'487.00

Fig. 16.11 Annual energy cost and costs of retrofit actions: comparison between actual situation and scenarios



SCENARIO A	Grand Total Cost [Euro]	Grand Total Cost Energy Retrofit [Euro]	Grand Total Cost Internal Refurbishment [Euro]	Cost recovered by means of incentives [Euro]
ECO - BONUS 65% Incentives (10 years)		1'655'711		1'076'212
Tax deduction 50% (10 years)			3'861'600	1'930'800
TOT	5'517'311			3'007'012
		Cost recovered by means of energy savings [Euro/year]	Energy savings gain at 10th year [Euro]	Cost with incentives + energy savings gain [Euro]
		350'480	3'504'800	- 994'501
	TOT [Euro]	Residual Cost	[Euro/m2]	
TOT SCENARIO A without incentives	5'517'311		819	
TOT SCENARIO A with incentives	2'510'299		372	

SCENARIO B	Grand Total Cost [Euro]	Grand Total Cost Energy Retrofit [Euro]	Grand Total Cost Internal Refurbishment [Euro]	Cost recovered by means of incentives [Euro]
ECO - BONUS 65% Incentives (10 years)		2'278'125		1'480'781
Tax deduction 50% (10 years)			4'827'000	2'413'500
TOT	7'105'125			3'894'281
		Cost recovered by means of energy savings [Euro/year]	Energy savings gain at 10th year [Euro]	Cost with incentives + energy savings gain [Euro]
		465'060	4'650'600	- 1'439'756
	TOT [Euro]	Residual Cost	[Euro/m2]	
TOT SCENARIO B without incentives	7'105'125		1054	
TOT SCENARIO B with incentives	3'210'844		476	

Fig. 16.12 Cost analysis: scenario A (left) and scenario B (right)

- Scenario B—7,105,124 euros, of which 2,278,124 euros for energy retrofit actions (32% of the global cost), in particular, 190,412 euros for the naturally ventilated walls and 432,000 for the new sandwich insulated walls

For both cases, the payback period in 10 years was calculated, considering the Italian public incentives *ECO-bonus* (Figs. 16.11 and 16.12). These incentives permit to recover 65% of the costs for energy retrofit actions and 50% of the costs for the renovation works.

The paybacks are:

- Scenario A: 3,007,012 euros, of which 1,076,212 euros for retrofit actions and 1,930,800 for renovation works
- Scenario B: 3,894,281 euros, of which 1,460,781 euros for energy retrofit actions and 2,413,500 euros for renovation works

In addition, energy savings in scenario A and B compared to the actual situation must be taken into account in the cost balance:

- Scenario A: 350,480 euros/year, which corresponds to 6.25% of the global renovation cost
- Scenario B: 465,060 euros/year, which corresponds to 6.55% of the global renovation cost

Considering the 10-year period of the *ECO-bonus*, about 62.5% and 65.5% of the initial investment will be recovered, respectively. The former provides for incentives' payback of 3,007,012 euros and a positive income of 994,501 euros; the payback period is 9 years. Therefore, the cost of the building renovation per unit area drops from 819 euros/m^2 (without public incentives) to 372 euros/m^2. The latter provides incentives for 3,894,281 euros and a positive income of 1,439,756 (about 50% more than scenario A); the payback period is 8 years. In this case, the cost of the building renovation per unit area drops from 1054 euros/m^2 (without public incentives) to 476 euros/m^2. Finally, results demonstrate that the deep building renovation scenario (B) is the cost-optimal investment compared to the usual renovation scenario (A). On one side, with an additional investment of 22%, it is possible to obtain a shorter payback period and a most effective design solution. On the other side, the deep renovation improves the life quality and the well-being of the inhabitants, reduces the energy consumption and adapts the existing flats to the actual social housing demand, taking advantages of the Italian public incentives on energy efficiency and building renovation.

Conclusions

In this paper, we present and discuss selected energy retrofit design solution in three social housing tower buildings representative of the PEEP district of the 1980s. Differences between usual and deep building renovation have been highlighted. A holistic approach, based on the H-BIM process, has been proposed and tested. The renovation of this kind of districts is one of the major opportunities to include non-energy-related aspects in the process and to improve the life quality of inhabitants, as well as reduce energy consumption and give additional economic value to the social housing stock.

The purpose of the method is twofold: on one side, it supports public and private real estate companies in the selection of the cost-optimal design solution for energy retrofit of buildings; on the other side—demonstrating the economic feasibility of such kind of renovation process—it aims at promoting the discussion about the importance of non-energy-related factors, in order to properly evaluate the economic competitiveness of the energy retrofit in the renovation process with a holistic approach.

With respect to the main results, the study demonstrates that deep renovation could be competitive with respect to cost-optimal renovation in the cases of social housing buildings of the 1980s due to a slight increase of the initial investment counterbalanced by faster payback period and a significant reduction in the annual energy costs. In addition, the proposed approach permits to integrate other important aspects that lie outside the scope of this paper, such as the fire safety and seismic retrofit, taking advantage of other incentives, i.e. *SISMA-bonus*.

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Chapter 17
Enhancing Energy Consumption Using BIM: A Case Study of Egyptian Palace

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Introduction

The significance of a whole building analysis in assessing existing and potential performance levels has been demonstrated in multiple studies in which the analysis succeeded in providing building performance information related to the effect of different building variables. Thus, conservation strategies of existing structures could have never been sustainable without the reliance on valid building simulation tools that have been recently developed to interplay with point cloud data and BIM tools. Numerous research papers [1, 2] used such tools and evaluated performance levels guided with multiple guidelines and rating systems that evaluate the greenness of the building as well. Building thermal and daylight analysis are considered main influential factors in assessing the whole building performance levels. Daylighting simulation tools make it possible to evaluate the quantity and distribution of daylight in a room while taking into account the key influential parameters such as window placement, building geometry, external obstruction, interior divisions, and material properties. Several research efforts assessed the effect of building elements using both thermal and daylighting analysis. Nebia and Aoul [3] studied thermal gain and daylight in residential units and proved their strong connection with the window glazing, apartment unit orientation, and floor level position. Al Qadi et al. [4] developed an approach to create a successful building performance assessment method and investigated the different factors that affect the building energy performance. They utilized a method that aims to reduce the gap between the actual building measurements and the simulated ones.

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Existing buildings should be retrofitted and conserved to become an added value rather than being neglected and later found in a deteriorated state, as in case of the palace under study. Ahmad et al. [5] studied the setting of a sensitive historic museum retrofit, with attention to preserving artifacts, and provided visual comfort at recommended illuminance levels for artifacts. They compared the daylight performance of a flat ceiling and a pitched roof ceiling model of a historical museum. Onuwe et al. [6], on the other hand, reviewed different museum designs to discuss the significance of daylight in providing most desirable and comfortable light for users and mentioned that most museum designers rely on artificial light to avoid the negative effect of glare and high daylight levels on effective artifact preservation. De Luca et al. [7] performed a simulation study on a single floor commercial space to assess building performance, proved that energy savings is possible, ranging from 1.9 to 58.6%, emphasizing that the use of a daylight control element would enhance energy savings higher than 50%. Banfi [8] presented several case studies to study a new tool that is able to model complex historical building forms efficiently and replace the usual simplification of historical models that is not even close to the reality. López et al. [9] extensively reviewed recent BIM-related tools and software involved in historical conservation and documentation procedures. They bridged the historical data retrieval using photogrammetry and scanning, subsequently, the appropriate modeling and analyzing software were used. Recent related publications were categorized according to the software utilized, process, and output data type.

Research Methodology

Simulation was performed using two software in parallel, DesignBuilder for daylighting factor calculations and Diva for Rhino for glare probability analysis. The location and orientation were adjusted in the simulation software to allow current state simulation of the sun angle. Building GBXML file was imported into DesignBuilder Software (see Fig. 17.1a). Modifications were done in the model to ensure smooth building analysis by adjusting the North orientation, removing unneeded elements, merging zones to reduce the zone number for simulation (maximum 50 zones for the evaluation license), and adjusting building construction fabric/occupancy schedule/ventilation type. Sun Path diagram was analyzed in DesignBuilder to provide shading and sun analysis of the building by which solar gain could be further reduced when needed (see Fig. 17.1b). According to the palace parameters listed in Table 17.1, simulation is performed in both software. Initially, the palace was modelled using Autodesk's Revit, then exported as a GBXML file which was finally imported into DesignBuilder. The current skylight was reopened in the model. The current rooms are illustrated by the software into thermal zones. However, the trial version does not include more than 50 zones in the single simulation, and thus zones reduction is done by merging common ones.

(a)

(b)

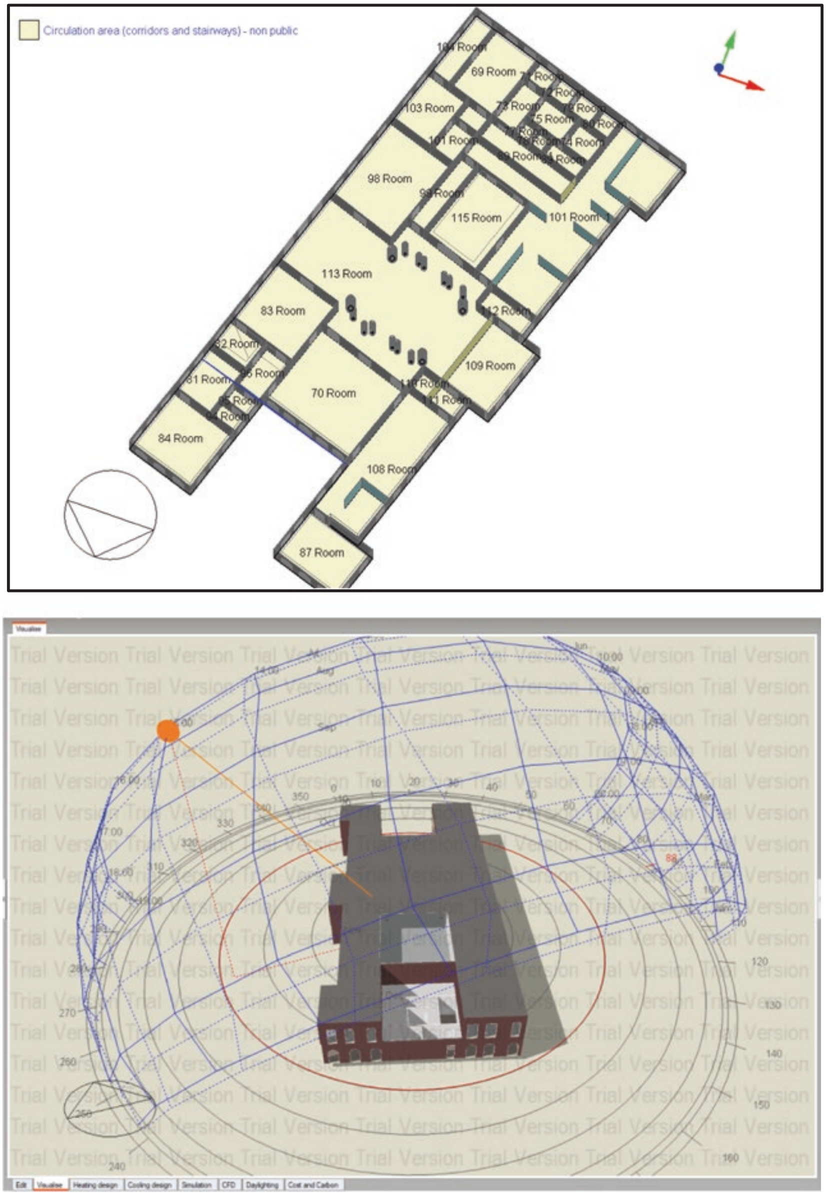


Fig. 17.1 (**a**) GBXML file input in Design-Builder and (**b**) Sun Path diagram of the palace model

The parallel analysis is performed using DIVA which is a tool that integrates daylighting and energy simulations. It uses Rhinoceros as its CAD modeling platform and has a component for its visual scripting environment, Grasshopper. The BIM model was imported to Rhino where additional information are added for Diva analysis.

Table 17.1 Palace model simulation parameters

Palace parameters	
Building type	Heritage residential palace
Building size	13H × 38W × 88L (m)
Operating schedule	9:00–15:00 (5 days/week)
Floor numbers	Two floors
Front entrance orientation	SW
Occupancy	1 person per 10 m^2
Construction materials	
Walls	Single stone block (1 m width in ground/0.7 m width in first)
Roof ceiling	Concrete and wooden board
Main hall floor	Concrete slab with marble
Rooms	Concrete slab with parquet
Internal partition:	800 mm wall-bearing stones
Slab thermal mass	130 mm concrete slab
Internal surfaces materials and reflectance	
Walls: Medium colored	50%
Ceiling: White colored ceiling	80%
Floor: Generic floor	20%
Window and shading parameters	
Window-to-wall ratio (WWR)	85%
Glazing	Single glazing
Window frame	Wooden
Local shading type	Overhang shading
Equipment	
Lighting type:	Candescent light fixtures
Office equipment	No office equipment included
Cooling type	Mixed mode: natural ventilation and HVAC

Simulation Results

Climatic data of the site are installed automatically on selecting the nearest weather station (Cairo International Airport). Local temperature, wind speed, air pressure, and solar heat gain influence the building performance and simulation results. The annual heat gain and energy consumption of the palace according to the current state are shown in Figs. 17.2 and 17.3. It has been specified that the palace is naturally ventilated, has no computers, and minimum building equipment are present, and thus most of the energy consumption is utilized by the electric lighting of the palace as shown in Fig. 17.2. The palace current state performance was evaluated through the monthly and annual energy consumption. In the annual consumption, 3000 MWh of total energy are consumed by the palace in one year that includes almost 1000 MWh for cooling if electric cooling is used to achieve occupants thermal comfort in hot days and includes 900 MWh of solar gain of existing windows. Such results mean that glazing areas act as an large source of heat gain and affect energy consumption greatly.

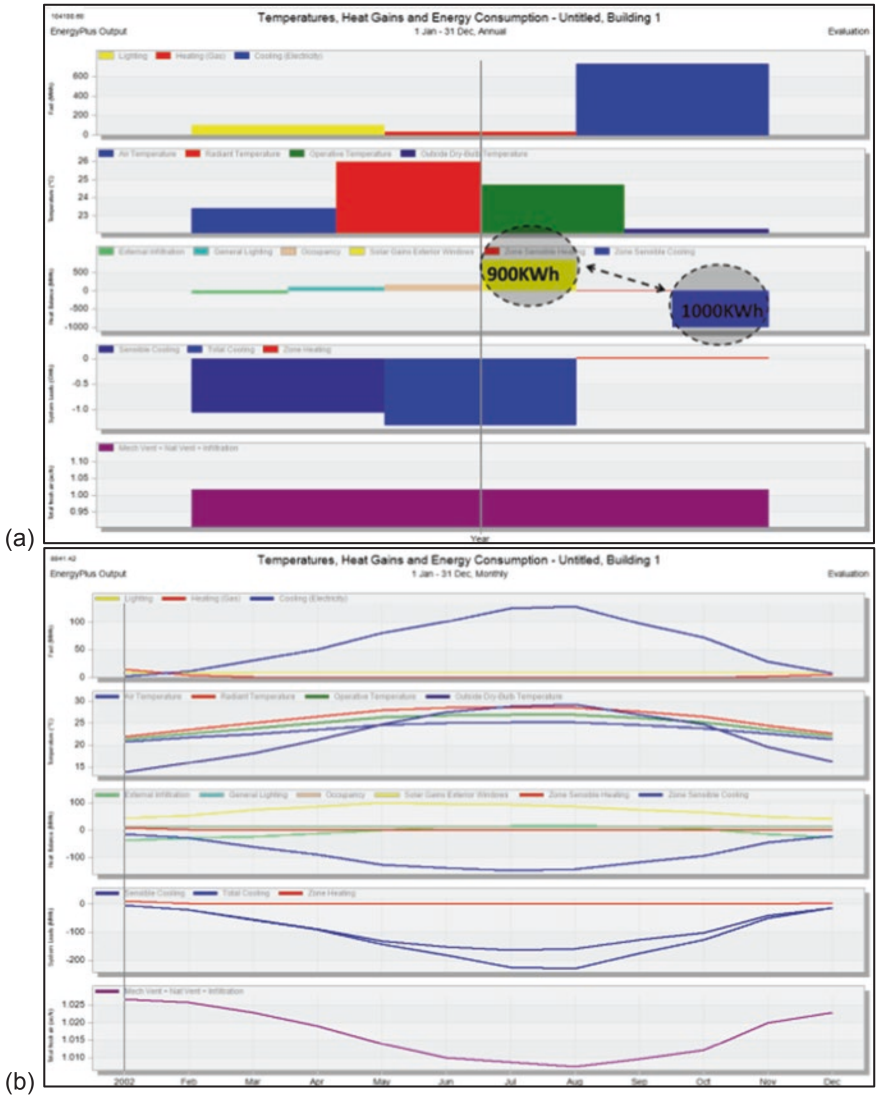


Fig. 17.2 Annual (**a**) and monthly (**b**) heat gain and energy consumption of palace. However, to fully understand the behavior of the palace during the hottest day in the year, a simulation is performed on 15 July to demonstrate the main sources of heat gain and temperature rise as shown in Fig. 17.3. The solar gain through exterior windows reaches 400 kW in peak hours of the day in a cooling design strategy performed by the software to propose possible solutions to overcome heat gain during the hottest day in the year

Considering the palace daylight analysis, whole building illuminance analysis was carried out using two metrics; the daylight factor (DF) and annual glare analysis. DF is the ratio of the light level inside a structure to the light level outside and is shown in Fig. 17.4.

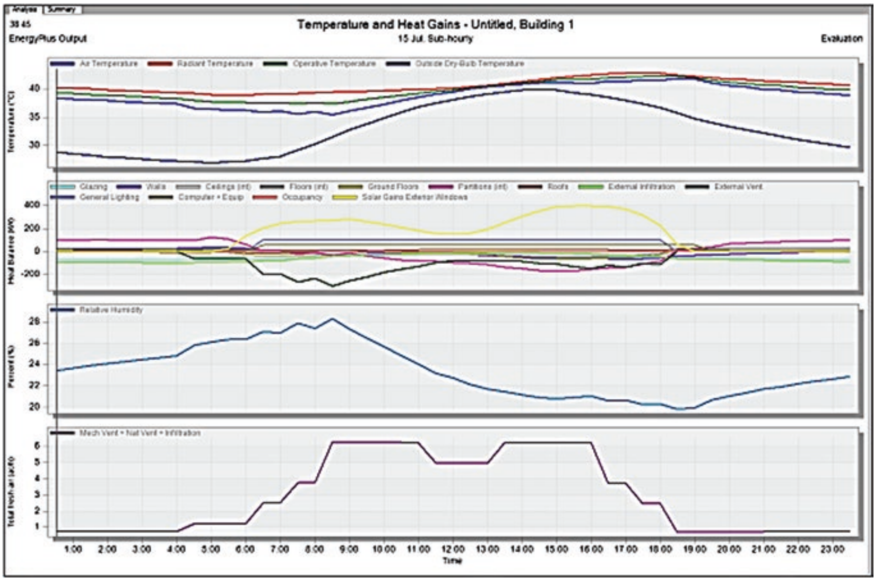


Fig. 17.3 Palace cooling design in 15 July

It is clear from Fig. 17.4 that DF is inadequate in most inner spaces (highlighted in gray color) that reaches 2.0 in the darkest regions while very high daylight factor reaches 10 beneath the skylight and close to the windows. As for building performance assessment systems, Green star and LEED rating systems are used for sustainable performance evaluation of buildings [1, 10–12]. Both systems are embedded in the software for compliance check, as shown in Fig. 17.5.

The analysis of the palace current state failed to meet both rating system requirements. Thus, further investigation by other daylight analysis tools that use validated engines such as Daysim and radiance engines was needed. Hence, based on the preliminary reports from DesignBuilder, Diva for rhino was used to perform an annual glare analysis so as to visualize the main problem with daylight in the palace. In Fig. 17.6, it is clear that the main daylight problem in the palace is the high glare probability and visual discomfort risk for occupants. Thus, enhancements to reduce glare and redistribute direct sunlight will be essential to achieve proper daylight distribution in the palace. Also, the results revealed that the main source of direct sunlight is the enormous skylight opening in the middle hall.

Discussion and Conclusion

Finally, a parametric and optimzation study is performed in DesignBuilder in terms of both minimizing energy consumption and increasing occupants thermal comfort (see Fig. 17.7). The parametric configuration performed by DesignBuilder shown in

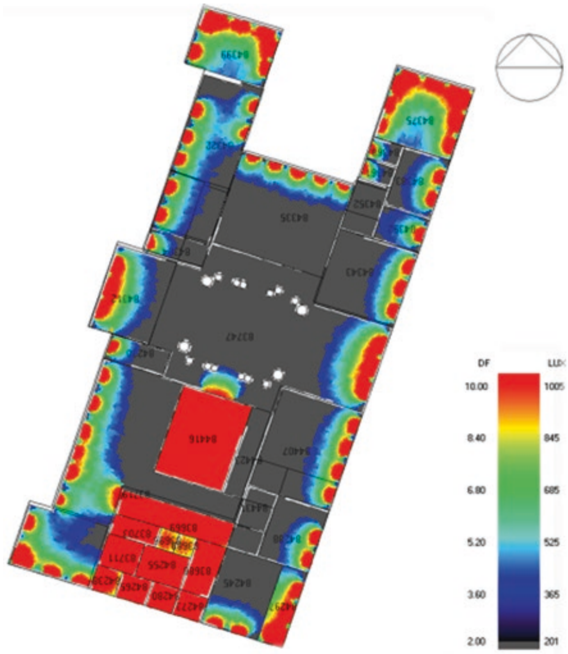
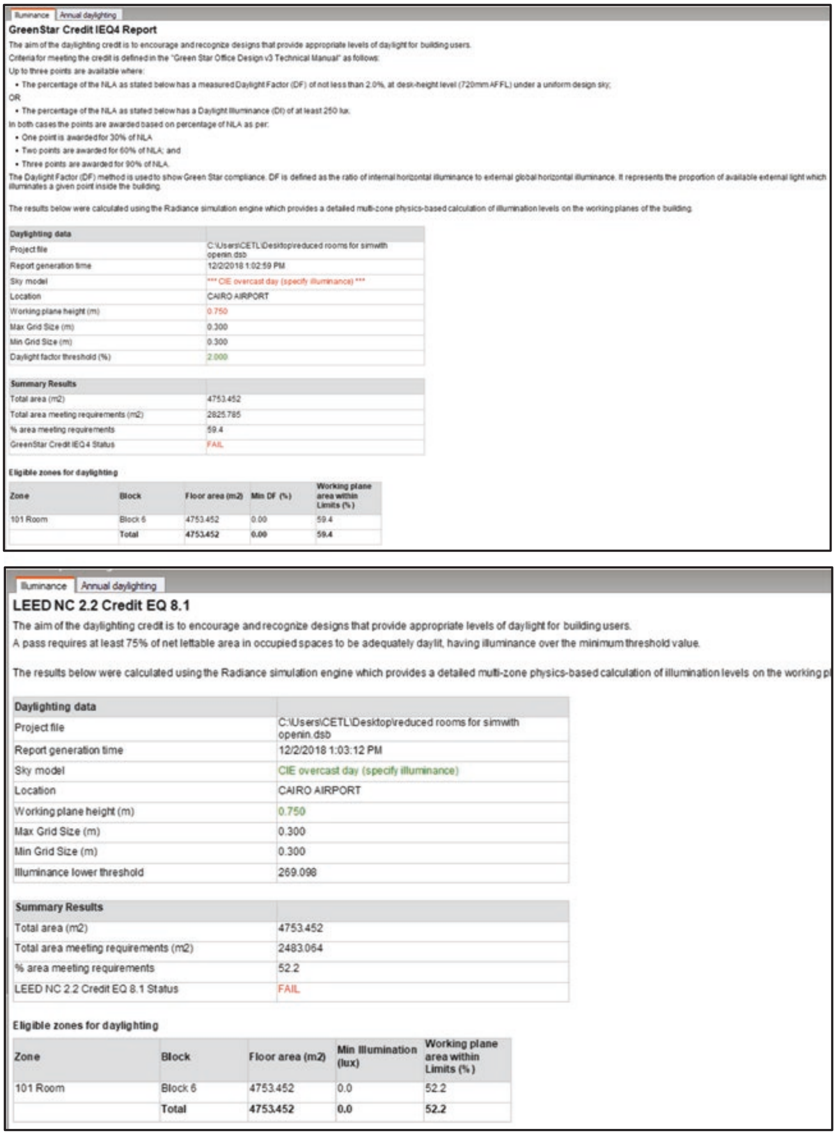


Fig. 17.4 Daylight analysis for palace in terms of daylight factor (DF)

Fig. 17.7a gives a comprehensive overview of the possible energy performance related to the different proposed WWRs. In the total energy consumption (kWh) through the whole year, it is shown that the maximum of 900 kWh will be reached on the utilization of WWR of 20% or more. Only below 20% WWR was a recognized decrease in the total energy consumption obtained.

Optimization analysis of the palace, shown in Fig. 17.7b, reveals the optimum design in terms of thermal comfort and energy consumption. It shows that the optimum case lies around the WWR of 40%, cooling set point of 26.4 °C, and heating set point of 20.4 °C, producing 353,796.7 CO_2 (kg), and total discomfort hours of 2554 during the year. Highlighted with the red bar is the optimum point that reveals the intermediate successful points that lies on the Pareto-front curve which satisfies the optimization criteria. The optimum configuration is able to achieve minimum building CO_2 production and minimum occupant discomfort hours. Thus, it is concluded that appropriate reduction in the total external glazing area will provide higher comfort levels to the users, reduce cooling loads, and possibly participate in eliminating the visual discomfort from the high daylight levels. Further optimization and integration of different design parameters to increase users' comfort will increase the performance efficiency of the palace, and minimize the direct sunlight and heat gain through the reconfiguration of the skylight to enhance the users' comfort through passive design as shown in Fig. 17.8.



(a)

Illuminance | Annual daylighting

GreenStar Credit IEQ4 Report

The aim of the daylighting credit is to encourage and recognize designs that provide appropriate levels of daylight for building users.

Criteria for meeting the credit is defined in the "Green Star Office Design v3 Technical Manual" as follows:

Up to three points are available where:

- The percentage of the NLA as stated below has a measured Daylight Factor (DF) of not less than 2.0%, at desk-height level (720mm AFFL) under a uniform design sky;

OR

- The percentage of the NLA as stated below has a Daylight Illuminance (DI) of at least 250 lux.

In both cases the points are awarded based on percentage of NLA as per:

- One point is awarded for 30% of NLA
- Two points are awarded for 60% of NLA; and
- Three points are awarded for 90% of NLA.

The Daylight Factor (DF) method is used to show Green Star compliance. DF is defined as the ratio of internal horizontal illuminance to external global horizontal illuminance. It represents the proportion of available external light which illuminates a given point inside the building.

The results below were calculated using the Radiance simulation engine which provides a detailed multi-zone physics-based calculation of illumination levels on the working planes of the building.

Daylighting data	
Project file	C:\Users\CETL\Desktop\reduced rooms for simwith openin.dsb
Report generation time	12/2/2018 1:02:59 PM
Sky model	*** CIE overcast day (specify illuminance) ***
Location	CAIRO AIRPORT
Working plane height (m)	0.750
Max Grid Size (m)	0.300
Min Grid Size (m)	0.300
Daylight factor threshold (%)	2.000

Summary Results	
Total area (m2)	4753.452
Total area meeting requirements (m2)	2825.785
% area meeting requirements	59.4
GreenStar Credit IEQ4 Status	FAIL

Eligible zones for daylighting

Zone	Block	Floor area (m2)	Min DF (%)	Working plane area within Limits (%)
101 Room	Block 6	4753.452	0.00	59.4
	Total	**4753.452**	**0.00**	**59.4**

(b)

Illuminance | Annual daylighting

LEED NC 2.2 Credit EQ 8.1

The aim of the daylighting credit is to encourage and recognize designs that provide appropriate levels of daylight for building users.

A pass requires at least 75% of net lettable area in occupied spaces to be adequately daylit, having illuminance over the minimum threshold value.

The results below were calculated using the Radiance simulation engine which provides a detailed multi-zone physics-based calculation of illumination levels on the working pl

Daylighting data	
Project file	C:\Users\CETL\Desktop\reduced rooms for simwith openin.dsb
Report generation time	12/2/2018 1:03:12 PM
Sky model	CIE overcast day (specify illuminance)
Location	CAIRO AIRPORT
Working plane height (m)	0.750
Max Grid Size (m)	0.300
Min Grid Size (m)	0.300
Illuminance lower threshold	269.098

Summary Results	
Total area (m2)	4753.452
Total area meeting requirements (m2)	2483.064
% area meeting requirements	52.2
LEED NC 2.2 Credit EQ 8.1 Status	FAIL

Eligible zones for daylighting

Zone	Block	Floor area (m2)	Min Illumination (lux)	Working plane area within Limits (%)
101 Room	Block 6	4753.452	0.0	52.2
	Total	**4753.452**	**0.0**	**52.2**

Fig. 17.5 Illuminance reports based on Green star (**a**) and LEED (**b**) daylight compliance rating systems

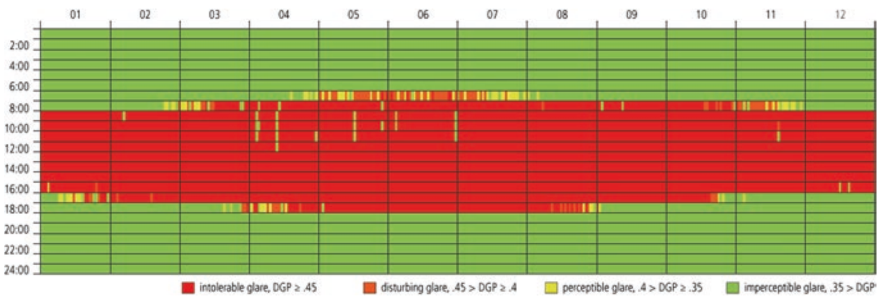


Fig. 17.6 Annual glare analysis in Diva for Toson Palace

(a)

(b)

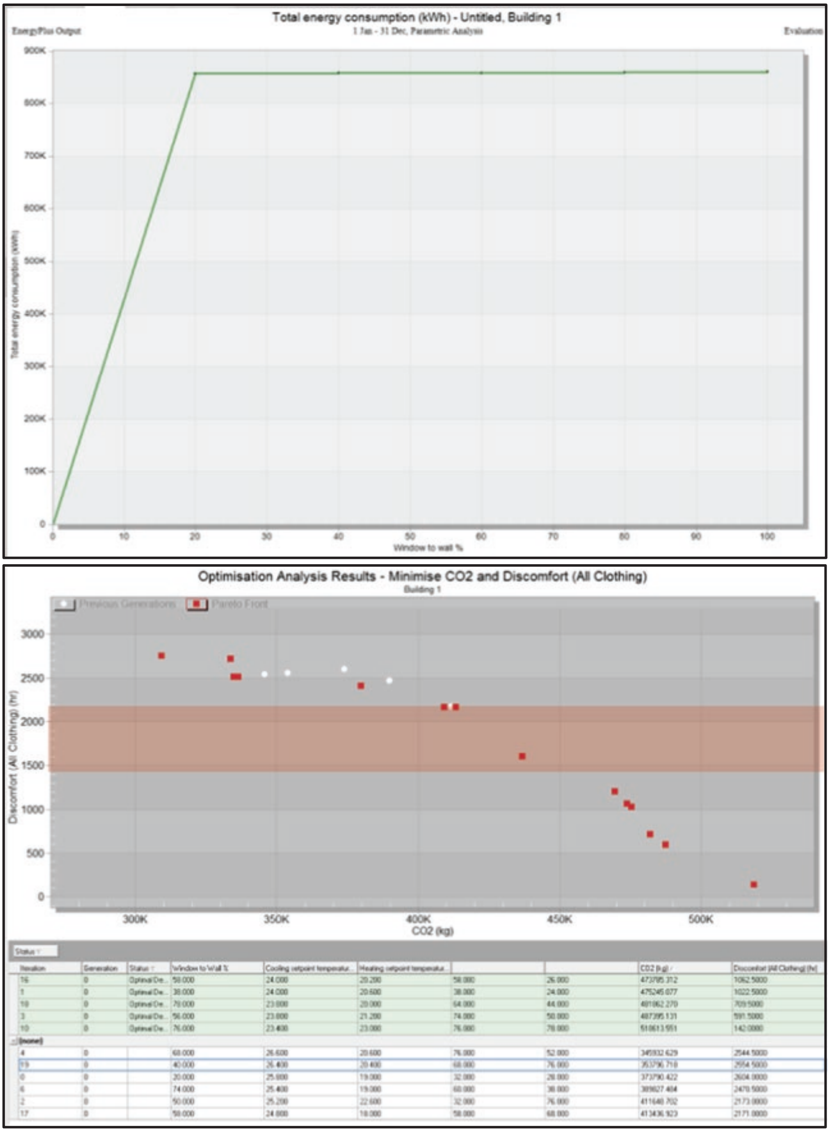


Fig. 17.7 (**a**) Parametric configuration of the palace WWR and energy consumption. (**b**) Optimization of the palace thermal comfort and carbon emissions

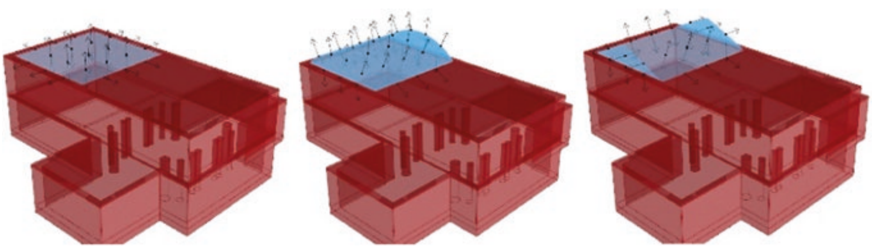


Fig. 17.8 Different shapes of the main hall skylight in Toson Palace

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Chapter 18
Passive Design Strategies of Colonial Mosques in Malaysia

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Introduction

Malaysia is a multi-religion country but Muslims are the highest percentage among the population. Therefore, mosques are found in every rural and urban area, varying in sizes and architecture styles. It is a religious institutional building where Muslims perform their prayers and gather for social activities and religious education. Many mosques in Malaysia have significant aesthetic value in their design, and some had become an icon or a landmark to the respective city or state [1]. Despite having built for the same function and purpose, mosques design in Malaysia comes in different architectural styles. The most significant architecture styles are vernacular, colonial, and modern. Vernacular style mosques were influenced by their tradition and regional culture. Meanwhile, colonial style mosques were influenced by Moorish architecture with classical features. Some of them also portray Art-Deco influence. Modern style mosques were influenced by the modern and innovative structures and constructions [2].

Malaysia architecture styles developed over different eras (Table 18.1). However, although the building designs adopted the architectural styles of their eras, most were designed in response to its context and Malaysian climate.

Colonial architecture styles came in during the British occupancy, which influenced the building designs built between eighteenth and twentieth centuries. There are various building typologies, such as colonial schools, shop houses, and mosques. Sanusi et al. (2019) carried out a study on colonial style school buildings. It concluded that colonial style school buildings were designed and built with Malaysian climatic adaptation, which responded well with its context and microclimate [4]. Therefore, this study is intended to study the passive design strategies of three royal colonial mosques in Malaysia, namely, Ubudiah Royal Mosque, Perak

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Table 18.1 Architecture styles in Malaysia over different eras [3]

Architectural styles	Eras
Indian Kingdoms	Seventeenth to fourteenth centuries
Traditional Malay Vernacular	Pre-fifteenth century until present
Straits Eclectics	Fifteenth to mid-twentieth centuries
Chinese Baroque	Nineteenth to early twentieth centuries
Colonial	Eighteenth to twentieth centuries
Modern	1950s until present

Fig. 18.1 Ubudiah Royal Mosque, Perak

Fig. 18.2 Pasir Pelangi Royal Mosque, Johor

(Fig. 18.1), Pasir Pelangi Royal Mosque, Johor (Fig. 18.2), and Sultan Ibrahim Jamek Mosque, Johor (Fig. 18.3). Johor is in the Southern part and Perak is in the Northern part of Malaysia.

The study comprises two objectives. Firstly, to identify the passive design elements found in three case studies of royal colonial mosques in Malaysia. Secondly, the objective is to evaluate the significance and effectiveness of the passive design strategies adopted by colonial style mosques in Malaysia.

Fig. 18.3 Sultan Ibrahim Jamek Mosque, Johor

Royal Colonial Mosques in Malaysia

Among the colonial mosques, which were built between the eighteenth and twentieth centuries, there are some that were built as royal colonial mosques. Figure 18.4 shows the images of colonial mosques in Malaysia, built during the Colonial era.

Most of the colonial style mosques were designed and supervised by British architects who were working in the Public Works Department (JKR). Colonial style mosques differ from vernacular style in its form, scale and proportion and building materials. The designers intended to portray Islamic image onto the mosques by combining Moorish architecture with Classical architecture. Some of the common features found in colonial mosques are the onion or top-shaped domes, classical columns, pilasters, verandahs, and pointed arches. Towards the end of the era, Art-Deco design was implemented in Sultan Sulaiman Mosque (1932) and Jamek Mosque in Johor (1938). The square facades reflect its Art-Deco influence (Fig. 18.4) [2]. However, as stated earlier, this study limits its scope to three case studies: Ubudiah Royal Mosque, Perak, Pasir Pelangi Royal Mosque, Johor, and Sultan Ibrahim Jamek Mosque, Johor.

Ubudiah Royal Mosque, Kuala Kangsar, Perak

Ubudiah Royal Mosque was built in 1912 within the proximity of the Perak state royal palace. Therefore, its physical appearance became a symbol of grandeur and sovereignty at the same time and reflects variety of influences to its design. It was influenced by an eclectic style of architecture, a style that incorporates at least two architectural styles in a single piece of work [5]. It may be a mixture from the previous historical styles which eventually creates an adaptive architectural style that is new and original. Throughout the years up to today, Ubudiah Royal Mosque has experienced renovation and expansion works, but the colonial character of the

Fig. 18.4 The timeline of Colonial Style Mosques era

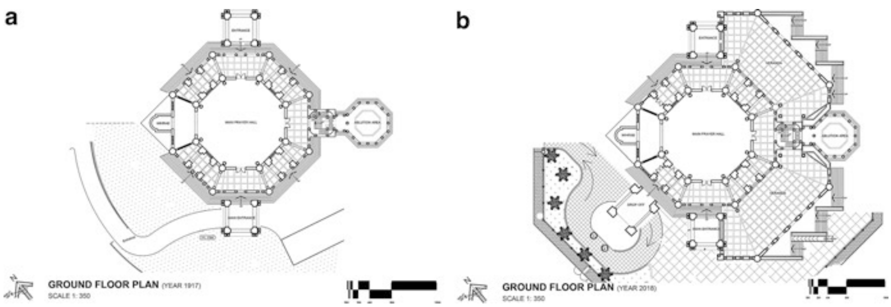


Fig. 18.5 Floor plans of Ubudiah Royal Mosque in 1917 and current [6]. (**a**) Ubudiah Royal Mosque floor plan in 1917. (**b**) Current condition of Ubudiah Royal Mosque

mosque remains intact. Some features had been added to increase the level of comfort and convenience of the people (Fig. 18.5) [6].

Äesthetically, Ubdiah Royal Mosque adopted Moorish and Mughal-Gothic designs as its primary architectural styles [2]. The architectural style that was implemented in the design of Ubudiah Royal Mosque can be seen in many of its elements. This includes the doors, windows, decoration, and ornamentation. Figure 18.6 shows the exterior view of the mosque, with the domes placed above the main prayer area, and Fig. 18.7 shows the interior view of the mosque.

Fig. 18.6 Ubudiah Royal Mosque

Fig. 18.7 Interior view of Ubudiah Royal Mosque main prayer hall

Pasir Pelangi Royal Mosque, Johor Bahru, Johor

Pasir Pelangi Royal Mosque is one of the mosques that was built with prominent colonial style, yet adapting the vernacular passive design strategies for tropical climate. Located at Jalan Pasir Pelangi, Johor Bahru, Malaysia, Pasir Pelangi Royal Mosque was built in 1920, initially to serve the Muslim Chinese, Indian, and Javanese workers who worked for the Sultan of Johor. Currently, the mosque is still used by the royal families of Johor and the people living around the area. The masjid could accommodate about two thousand (2000) worshippers at a time [7].

Throughout more than a century of its life, Pasir Pelangi Royal Mosque has experienced numerous renovation and expansion works, but the colonial character of the mosque remains intact. The architecture of Pasir Pelangi Royal Mosque has unique features of colonial architecture, where there are apparent amalgamation of the neoclassical architecture and the Malay vernacular architecture. The Mosque is a single-story building and has a rectangular plan shape. The uniqueness of Pasir Pelangi Royal Mosque could be seen in the façade design, the arches design, the ornamentation, and the special colonial features of its single Minaret. Figure 18.8 shows the

Fig. 18.8 Pasir Pelangi Royal Mosque

Fig. 18.9 Pasir Pelangi Royal Mosque's interior view

exterior view of the mosque, with the single minaret placed at the frontage, and Fig. 18.9 shows the interior view of the mosque. The mosque has a simple floor plan that can hold a congregational prayer at any prayers time (Fig. 18.10).

Sultan Ibrahim Jamek Mosque, Muar, Johor

The construction of Sultan Ibrahim Jamek Mosque commenced in1925 and completed in 1930. Sultan Ibrahim Jamek Mosque is a historical mosque in a small town named Muar in Johor, Southern state of Malaysia. The mosque is situated along the Muar River. Originally, it was a vernacular style timber mosque named Jamek

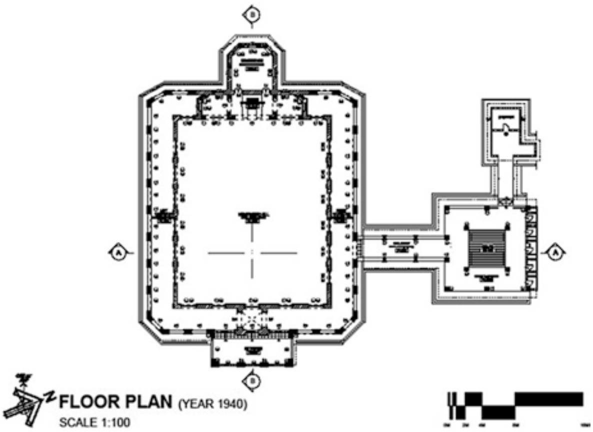


Fig. 18.10 Floor plan of Pasir Pelangi Royal Mosque [7]

Mosque Muar. The timber Jamek Mosque completed its construction in 1884 and can hold up to a maximum of 50 people at one time. Through time, with the increase of number of visitors, it could no longer afford to hold such regular congregation. In the 1920s, a committee was formed to consider building a new Jamek Mosque for Muar, which is the Sultan Ibrahim Jamek Mosque [8].

Following a bid to raise funds from the public, the committee in charge of building the new mosque successfully raised RM10,000 for the said purpose. The committee then put forward the people's aspiration to the Sultan and obtained the royal consent. The cost to build this mosque had been sponsored by the state Government of Johor and the *Khairat* members of Johor Darul Takzim.

Sultan Ibrahim Jamek Mosque was first named as Jamek Mosque Muar, and also the oldest mosque located in Muar. The mosque was regularly visited by royal visitors and local people. Studying the mosque provides further understanding on the culture and environment of the royalty and locality during its period.

The uniqueness of this building is visibly seen from the minaret, which highlights the symmetrical architectural composition of the east and west. Classical Revival column with order are used on the interior and exterior of the mosque.

The significance of Sultan Ibrahim Jamek Mosque is that it was designed and built within the era of British rule. It is one of the major landmarks for the Royal Town of Muar, Johor. Its design was majorly influenced by the hybrid British Colonial and Malay architecture—a mixture of English Victorian style from the Classical Revival period, Malay and Moorish design features to suit the Malaysian climate. Its neo-classical design influence also includes Palladian and Byzantine elements. Figure 18.11 shows the exterior view of the mosque and Fig. 18.12 shows the interior view of the mosque. Similar to Pasir Pelangi Royal Mosque, Sultan Ibrahim Jamek Mosque has a rather simple floor plan that is also longitudinal shape (Fig. 18.13).

Fig. 18.11 Sultan Ibrahim Jamek Mosque

Fig. 18.12 Sultan Ibrahim Jamek Mosque's interior view

An Overview of Passive Design Strategies in Malaysia

According to Malaysian Standard MS1525:2014, the fundamental approach towards good passive design is to shade the building from intense solar radiation, to insulate from solar heat gain, to ventilate indoor environment, and to provide adequate daylight into the buildings. Malaysian Standard MS1525:2014 is a Code of Practice on Energy Efficiency and use of Renewable Energy for Non-Residential Buildings.

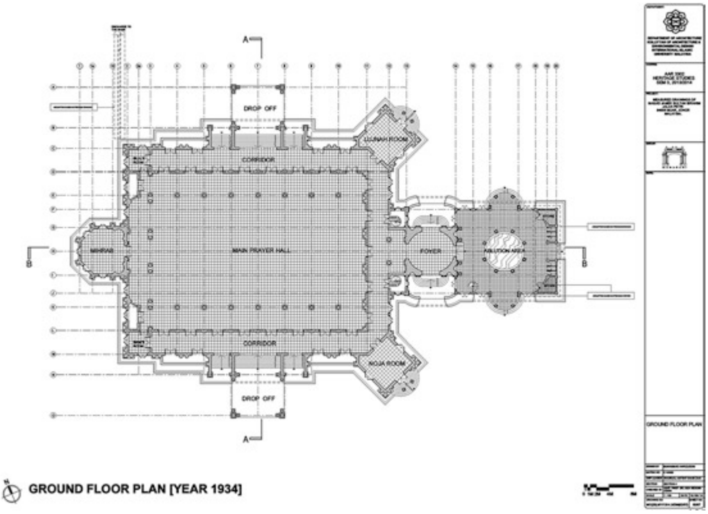


Fig. 18.13 Floor plan of Sultan Ibrahim Jamek Mosque, Muar, Johor [8]

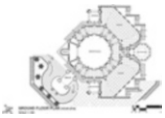
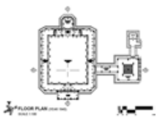
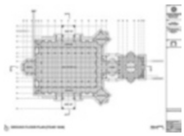
Table 18.2 Passive design strategies of MS1525:2014 and Carl Mahoney [11]

Passive design strategies	
MS1525:2014	Carl Mahoney
1. Site planning and orientation, preferably long axis facing North and South	1. Building layout and orientation
2. Daylighting	2. Spacial arrangement
3. Façade design	3. Air movement
4. Natural ventilation	4. Opeing size
5. Thermal insulation	5. Opeing position
6. Strategic landscaping	6. Protection of opening
7. Renewable energy	7. Wall and floor materials
	8. Roof design
	9. External building features

Therefore it is very much related to the case study buildings. MS1525:2014 stated seven significant factors to be considered in passive design, which are site planning and orientation, daylighting, façade design, natural ventilation, thermal insulation, strategic landscaping, and renewable energy [9].

Carl Mahoney has listed nine recommendations for passive design strategies for buildings in hot and humid climate [10]. They are in the aspects of layout, spacing, air movement, opening size, opening position, protection of opening, wall and floor materials, roofs, and external building features. In summary, both MS1525:2014 and Carl Mahoney passive design strategies are shown in Table 18.2. Table 18.2 was utilized to form Table 18.3 that indicates the passive design strategies adopted by the three case studies of colonial mosques in Malaysia.

Table 18.3 The mosques' compliances of tropical passive design strategies

No.	Requirement of passive design strategies in tropical countries	Compliances		
		Ubudiah Royal Mosque	Pasir Pelangi Royal Mosque	Sultan Ibrahim Jamek Mosque
1	Layout • Orientation North and South (long axis east–west)	× 	✓ 	✓ 
2	Spacing • Open spacing for breezes	✓	✓	✓
3	Air movement • Single banked room for permanent air movement	✓	✓	✓
4	Opening sizes • Large opening, with 50–80% of facades	✓	✓	✓
5	Opening position • In North and South walls • At body height	✓ ✓	✓ ✓	✓ ✓
6	Protection of openings • Full permanent shading • Verandah	✓ 	✓ 	✓ 
7	Walls and floor • Light and low capacity materials	× Thick masonry walls	× Thick masonry walls	× Thick masonry walls
8	Roofs • Light and low capacity materials	×  Concrete roof dome	✓  Clay tile for roof	✓  Clay tile for roof

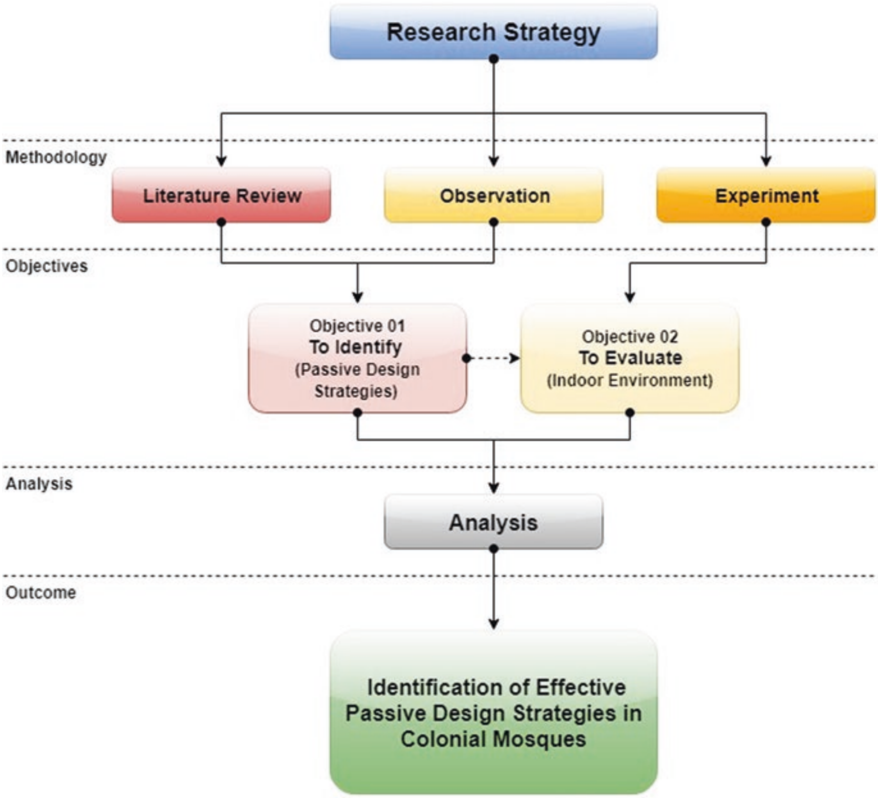


Fig. 18.14 Methodology chart

Methodology

In order to achieve the two objectives, the study was carried out according to the following methodology structure (Fig. 18.14). The methodology comprises literature review of passive design strategies and colonial style mosques in Malaysia, observation of the three case studies of royal colonial mosques, and experiment on the airflow and indoor air temperature of the three case study mosques, Ubudiah Royal Mosque, Pasir Pelangi Royal Mosque, and Sultan Ibrahim Jamek Mosque.

Identification of the Passive Design Elements

Tropical climate requires Malaysian buildings to have passive design strategies, including for those mosques that were built using the colonial style. This study identifies the passive design elements found in the three case studies. Table 18.3 shows the mosques' compliance to the requirement of passive design strategies in tropical region, based on the summary of MS1525:2014 and Carl Mahoney's design recommendation for hot humid climate of Malaysia.

Based on observatory analysis, the design of Pasir Pelangi Royal Mosque and Sultan Ibrahim Jamek Mosque have complied seven out of eight of Mahoney's bioclimatic design and MS1525:2014 recommendation. For item number 7 in Table 18.3, the design of Pasir Pelangi Royal Mosque and Sultan Ibrahim Jamek Mosque do not have light and low capacity materials for walls simply because both mosques was designed with colonial style, that is characterized with the appearance of thick plaster brick walls. Nevertheless, this issue of noncompliance to the requirement has been well adjusted with the provision of large openings on three sides of the masjid's walls that provides continuous cross ventilation for cooling effect.

However, Ubudiah Royal Mosque has only complied five out of eight of Mahoney's bioclimatic design and MS1525:2014 recommendation. Similar to the other two case studies, Ubudiah Royal Mosque also does not have light and low capacity materials for walls due to colonial style design. Nevertheless, this issue of noncompliance has been also well adjusted with the provision of verandah and more than 50% openings to walls percentage. Apart from that, Ubudiah Royal Mosque does not have a façade on the North and South. This was resolved by having verandah all around the main prayer hall (Table 18.3, item no. 1).

Evaluation of Indoor Environment

This study evaluates the indoor air temperature and air ventilation of the main prayer hall. The experiments were carried with intention to find the effective passive design strategies adopted in the design of the three royal colonial mosques, Ubudiah Royal Mosque, Pasir Pelangi Royal Mosque, and Sultan Ibrahim Jamek Mosque. The experiments were carried out using Autodesk Flow Design and Autodesk Ecotect computer software.

Indoor Air Temperature of the Mosques

Indoor air temperature was obtained from computer modeling simulation. There are three measurements for each mosque: outdoor, main prayer hall, and verandah. The date was set to 23rd of March, one of the warmest day of the year. The outdoor DBT was obtained from the Meteorology Department [12]. The outdoor temperature on the 23rd of March ranges from 25.4 to 34.4 °C.

The average temperature of Ubudiah Mosque Verandah ranges from 27.4 to 34.0 °C. There is not much temperature reduction in the Ubudiah Mosque verandah. However, the indoor temperature of Ubudiah Mosque prayer hall ranges from 27.2 to 31.1 °C. There is a temperature reduction of up to 3.4 °C from the outdoor to its prayer hall (Fig. 18.15).

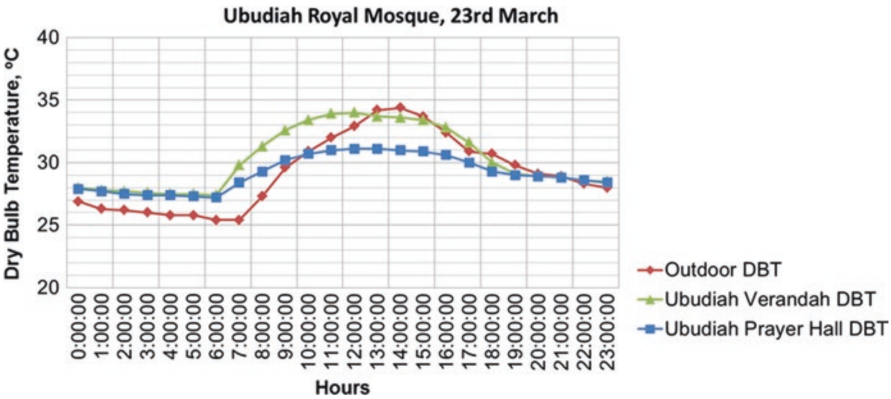


Fig. 18.15 Dry bulb temperature of Ubudiah Royal Mosque during the warm and dry season

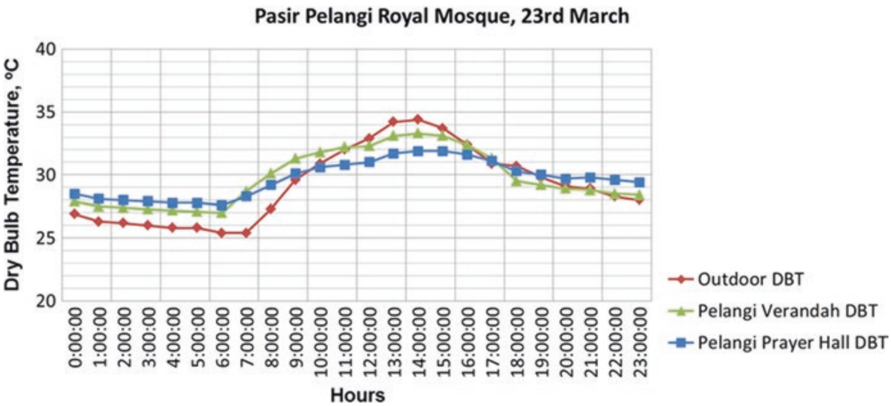


Fig. 18.16 Dry bulb temperature of Pasir Pelangi Royal Mosque during the warm and dry season

The average temperature at the verandah of Pasir Pelangi Mosque ranges from 27.0 to 33.3 °C. There is only up to 1.2 °C of temperature reduction at the verandah. Meanwhile, the indoor temperature of Pasir Pelangi Mosque prayer hall ranges from 27.6 to 31.9 °C. There is a temperature reduction of up to 2.5 °C from the outdoor to its prayer hall, which is slightly less than the prayer hall of Ubudiah Mosque (Fig. 18.16).

The average temperature at the verandah of Sultan Ibrahim Jamek Mosque ranges from 25.5 to 36.4 °C. There is an increment of temperature at the verandah. Meanwhile, the indoor temperature of Sultan Ibrahim Jamek Mosque prayer hall ranges from 28.6 to 32.5 °C. There is a temperature reduction of up to 2.9 °C from the outdoor to its prayer hall, which is quite significant (Fig. 18.17).

The result shows that the verandahs in all the three mosques are warmer than the indoor prayer halls. This shows that the verandah acted as protection to the indoor prayer hall from the outdoor air and solar radiation. Therefore, verandah is a significant and effective passive design strategy.

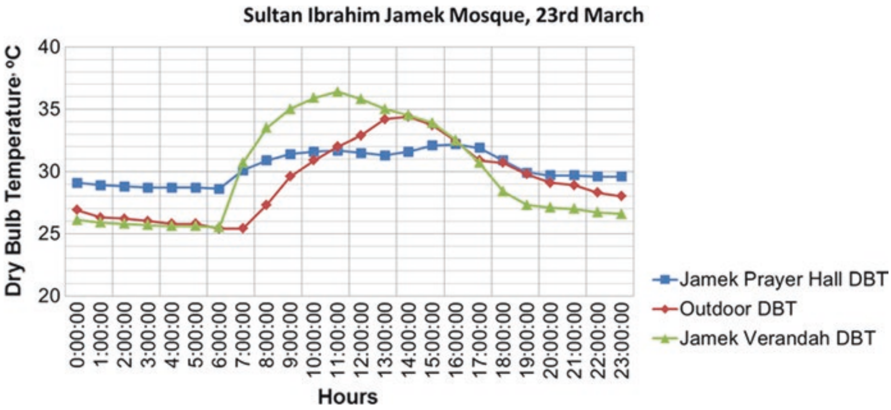


Fig. 18.17 Dry bulb temperature of Sultan Ibrahim Jamek Mosque during the warm and dry season

The results show that the Ubudiah Royal Mosque prayer hall has the most temperature reduction from the outdoor air temperature, as compared to the other two mosques. Ubudiah Royal Mosque differs from Pasir Pelangi and Sultan Ibrahim Jamek Mosque in terms of the roof design. Ubudiah Royal Mosque has a dome, which provides a larger roof space above the prayer hall ceiling. The air gap gives insulation to the roof space and reduces solar radiation penetration into the prayer hall.

Airflow Through the Mosques

Figure 18.18 shows the simulation of airflow through the interior of Ubudiah Royal Mosque. A stacked effect occurred at the higher openings on the left and right of the prayer hall. Figure 18.18 shows that the prayer hall is adequately ventilated by cross ventilation and stack effect. However, the center part of the prayer hall has less airflow. The airflow could be increased with the help of a mechanical fan.

Conclusion

The first objective is to identify passive design strategies of royal colonial mosques. There are five passive design strategies that were adopted by all three mosques. They are (1) open spatial layout, (2) permanent air movement through cross ventilation, (3) more than 50% of openings to walls area, (4) different positions of openings from the low level to the ceiling level, and (5) verandah for full protection of openings.

The second objective is to evaluate the significant and effectiveness of the passive design strategies adopted by all the three royal colonial mosques. From the findings,

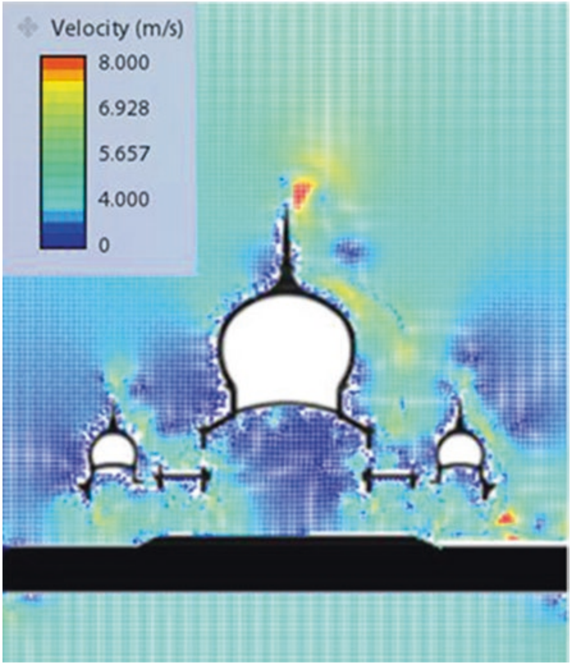


Fig. 18.18 Airflow through the interior of Ubudiah Royal Mosque

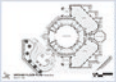
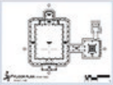
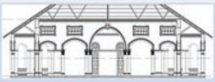
this study concluded that the most significant and effective passive design strategy of the royal colonial mosques is the verandah. The air temperature of the main prayer hall was reduced less than the air temperature in the verandah. The verandah became a permanent shading element for the main prayer hall of the mosques.

Secondly, the large openings are also significant and effective. In addition to the passive design strategies listed in Table 18.3, this study finds that the volume of roof space above the ceiling can also be a significant and effective passive design strategy adopted by the mosques. Despite noncompliance of the first passive design strategy, which is building orientation, Ubudiah Royal Mosque has the lowest maximum air temperature. This was because of the large roof space above the main prayer hall ceiling, which was created by the dome. The dome protects the main prayer hall from solar radiation transmission. Therefore, the introduction of dome or a large roof space is a significant and effective passive design strategy for cooling the indoor space of colonial mosques in Malaysia Table 18.4.

Recommendation

Further study should be carried out in evaluating the passive design strategies in other colonial mosques in Malaysia to support the current findings.

Table 18.4 Passive design strategies requirement

Passive Design Strategies Requirement by MS1525:2014	Passive Design Strategies in Ubiduah Mosque	Passive Design Strategies in Pasir Pelangi Royal Mosque	Passive Design Strategies in Sultan Ibrahim Jamek Mosque
1. Site planning and orientation, preferably long axis facing North and South	 Longer façade facing NS and prevailing wind	 Longer façade facing NS and prevailing wind	 Longer façade facing NS and prevailing wind
2. Daylighting	 Low and high level openings provide natural daylight	 Series of door openings provide natural daylight	 Low and high level openings provide natural daylight
3. Façade design – Verandah	 Verandah protects from solar heat gains	 Verandah protects from solar heat gains	 Verandah protects from solar heat gains
4. Natural ventilation	More than 50% openings to wall area	More than 50% openings to wall area	More than 50% openings to wall area
5. Thermal insulation	Thick masonry walls	Thick masonry walls	Thick masonry walls
6. Roof design	 The dome creates a large air gap above the ceiling	 Pitch roof creates an air gap above ceiling	 Pitch roof creates an air gap above ceiling

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Chapter 19
Winery and Oil-Factory Recovery and Regeneration in Veglie: Bioclimatic and Sustainable Principles

Dora Francese

Introduction

Within the Mediterranean region, and in particular in South Italy, a number of ancient farms and factories of arts-and-craft kind are to be found, which create a landscape of a very interesting and peculiar image. The original shape of these structures, being molded for matching the local old-times requirements, still saves a peculiar identity, which connotes the architecture as well as the landscape itself. But the most interesting and—at the same time—weak aspect is due to the material culture which still can be recognized within and beyond these structures, under the shape of peculiar technologies, local materials, handcrafted and sometimes even artistic architectural components. The need of rehabilitating these structures together with regenerating their life through a suitable destination as well as an attracting use actually emerges from the study of the regions. One of the approaches which can be considered appropriate to this regeneration procedure is without doubt the sustainable one, which will take into account the environmental care, the social issues, and the economic aspects. In fact not only the construction process is important, but also the maintenance and the use that of the building will be made after the actual physical refurbishment and recovery [1]. In fact following the dismantling of these fabrics, for they became obsolete, being the industrial processes innovated and transformed, the present spaces, volumes, and rooms are no longer suitable for the new activities and usually are abandoned and neglected. The sustainable methodology, aimed at their reuse, needs first of all to find another use destination which could achieve at least the three main goals capable of conserving the architecture and at the same time the life, which, as just said, cannot be run if there is no use; the first goal is that of saving the integrity of the historical as well as eventual artistic value of the whole complex. The second is integrating the space with a suitable use,

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and the third is ensuring a continuation of activities, so as to give life and function, which could help for conservation and maintenance. The use should be suitable to the fabric itself, trying to avoid any kind of activity which could ruin, decay, or spoil the culturally good; the third goal means to create some social opportunity within the fabric, which could help the local community as well as improve the subsidiarity. These goals can be achieved only by means of a sustainable approach, of soft technologies and natural and local materials [2].

Methodology of Sustainable Regeneration of Old Factories

The methodology that should be followed according to these sustainable principles is one which starts with a very deep analysis aimed at a full knowledge of the existing conditions. The history of the region, of the place, of the fabric evolution, of the activities which have been carried out upon time within the structure, and, last but not least, the climatic behavior of the whole constructed complex: these are some of the main studies to be carried out on the system. Besides those, in order to deepen the energy and comfort performances of the indoor spaces, some measurements could be run, such as the humidity levels, the temperature swing, the radiation and eventual incoming and storage of sun, air movement and wind potential, and the results should be compared with the technological solutions' performances, so as to evaluate the existing present situation of the fabric as far as its potential of working as an efficient system is concerned. The best experimental investigations should be those of the monitoring process which could return available data under an elapsed length of time in which continuous measures were taken. Once these analyses have provided interesting results in terms of spaces' behavior and constructed elements' performance, a preliminary idea of possible use destination and technological solutions for the rehabilitation project could be advanced, and the suitability of the design strategies could be tested with some simulation procedures. In general, the two critical points of the design process for a rehabilitation of an ancient factory are those of the materials selection and of the compatibility of the technological solutions with the identity of the old fabric. In fact they should be first of all suitable to the existing structure, both in terms of structural behavior and weight, and in terms of technical compatibility, in order to be sure that no rejection or increasing decay would overcome, once the works have been completed. Then they should be chosen according to the bioregionalism and biocompatibility of their prime matters.

The Case Study: An Old Winery in Veglie, South Italy

The case study with which this methodology has been tested is an old winery and oil production factory, where the artisan character was evident in the peculiar structures built for running the various productive activities. In fact, the region is very rich from the agricultural point of view as far as olive and grapes are concerned. The first part of

Fig. 19.1 Aerial picture: winery today (left); view of the production rooms in Lecce stone (right)

Fig. 19.2 Façade in Lecce stone with framed windows and doors; drawing (top) and picture (down)

the structure has been built in 1930 and later on has undertaken various transformations, aimed at adjusting the construction to the new productive chain. Some of these new additional parts are not very valuable, for they do present neither high architectural nor technical quality, and also the materials are very common, not local and not at great naturality, being in metals or concrete. Conversely, the original complex is built in the very well known Lecce stone, which has great performances and a beautiful aesthetic value, being white and compact with slightly ochre veins (Fig. 19.1).

Besides the materials, also other artistic and functional devises characterize the building, such as the gable over the windows and the doors of the main facade, and the internal peculiar vaulted ceilings, which is a technology found only in this region (Figs. 19.2 and 19.3).

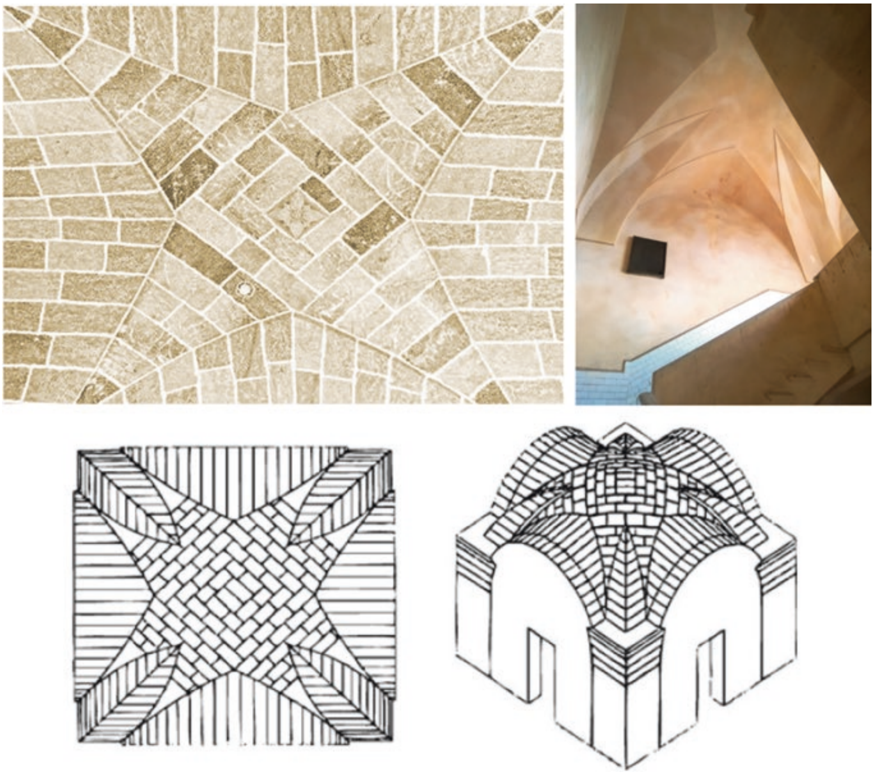

Fig. 19.3 Vaulted ceilings: pictures (top); tridimensional drawing (down)

Some portions of the building used to be destined for winery distillation, and some others were devoted to oil production from the well-known olive harvest of the whole Puglia region. The building has been object of a degree thesis in Architecture by Adriano Vetrugno [3], during the processing of which a number of studies and investigations have been run, aimed at knowing the bioclimatic behavior and the potential of being employed for another use destination. Solar radiation and wind presence over the site have been investigated, as well as the technological analyses aimed at evaluating the performance of the structures (Figs. 19.4 and 19.5).

The results have shown that the orientation of the internal rooms, even being right as protection from wind and for the industrial production of oil, is not actually wholly suitable to other activities in which more people should sojourn, while on the other hand the thick and massive walls of Lecce stone behave very well in terms of climatic and acoustic comfort, for they have a good thermal conductivity as well as capacity (Fig. 19.6).

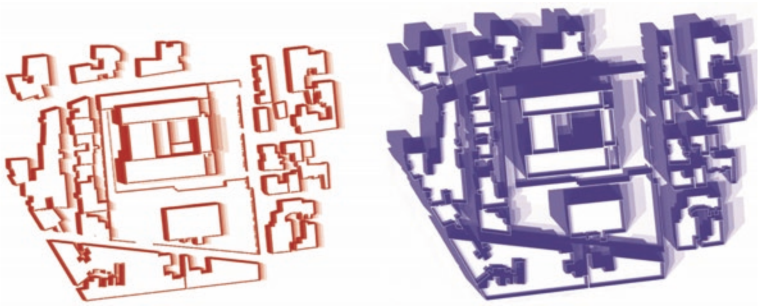

Fig. 19.4 Summer (left) and Winter (right) Solstice, shading at noon

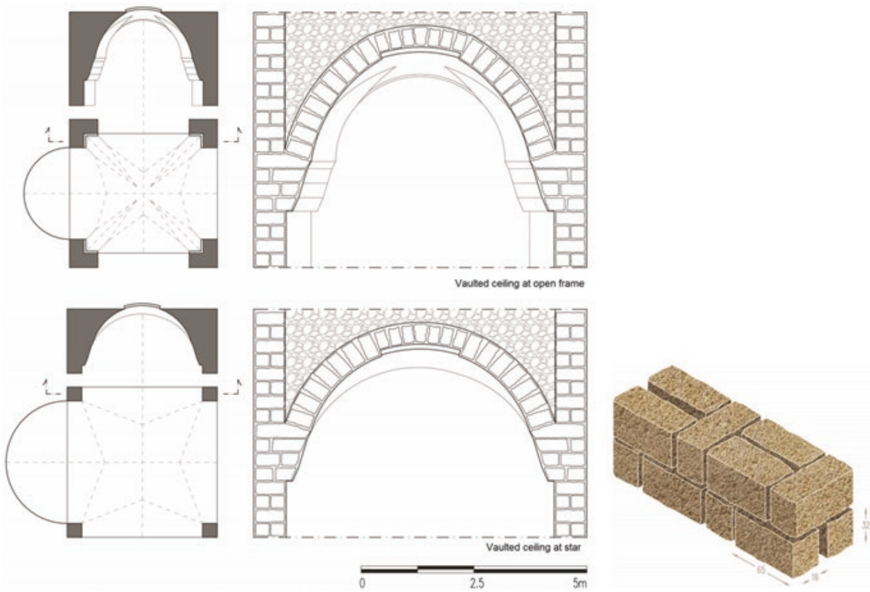

Fig. 19.5 Construction technologies: vaulted ceilings in Lecce stone (left) and sample of the wall at full blocks (right)

Regeneration Project of the Winery and Sustainable Solutions

Since most of the spaces were not suitable to human activity, as aforesaid, a number of uses cannot be run indoor, at least leaving the building as it is. So the project was aimed at valorizing the presence of the ancient signs of the memory of the past, and at the same time at modifying, according to the planning regulation, some portion of the whole fabric. The use destination which the design procedure had proposed was that of a social container aimed at diffusing the knowledge of both the land and

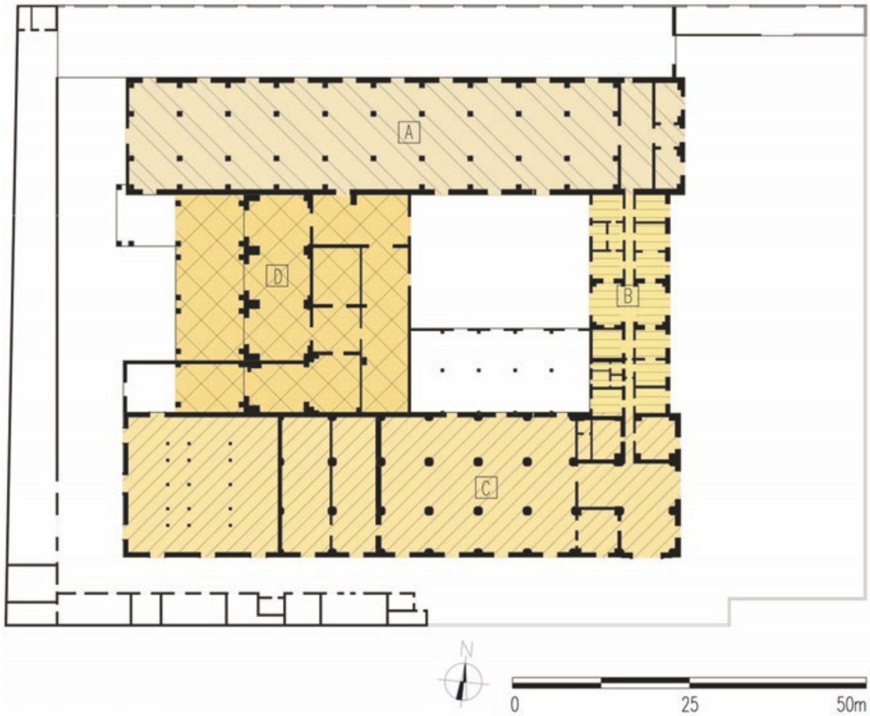

Fig. 19.6 Thermal behavior of the winery: (**a**) Absorbance of sunrays and transparent collecting windows in summer; cold and wet in winter. (**b**) Absorbance of sunrays and transparent collecting windows in summer and winter. (**c**) Thermal storage and conservative model. (**d**) Absorbance of sunrays and transparent collecting windows in summer; cold and wet in winter

the local agricultural products, because this use could allow to enjoy the cultural good values and at the same time to utilize some of the existing structures: in fact the activities such as wine museum and enogastronomic path are compatible with both building's characters and man's requirements satisfaction. For example, the Northern wing which was added recently is proposed to be modified, by demolishing some of the existing fabrics—in particular those already mentioned, which do not present high quality—and defining new arrangements: in some areas the space will be let free of construction and a public space will be developed, designed for enhancing the external perception of the old farm, and for creating more open interchange between the internal rooms and the outdoor space (Fig. 19.7).

At the same time a new extension could be edified, aimed at hosting some activities, i.e., those useful for an education center, such as lecture rooms, a library, and others. In particular, there will be the following activities: at the ground floor, an info-point at the entrance, a quick consultancy of newspapers and magazines, some PC workstations for web research; at the first floor, some small rooms for reading and the library book deposit. This new body could actually improve the internal comfort, being provided with some bioclimatic devices such as, for example, the windows' special shutters which can redirect the solar radiation from outdoor and so

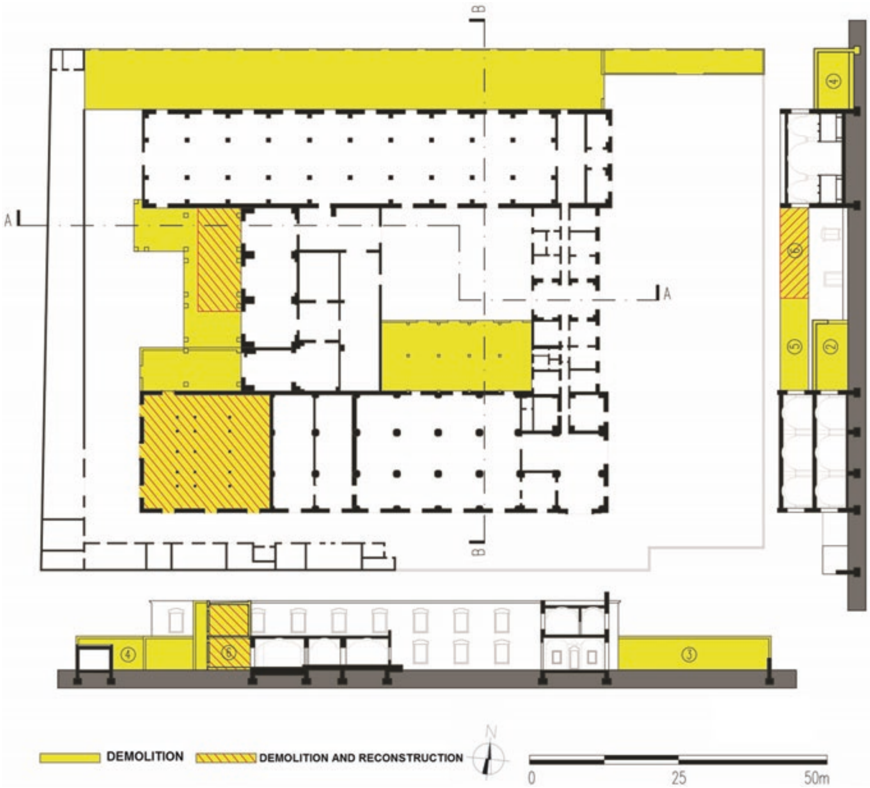

Fig. 19.7 The ground floor plan with demolition and reconstruction

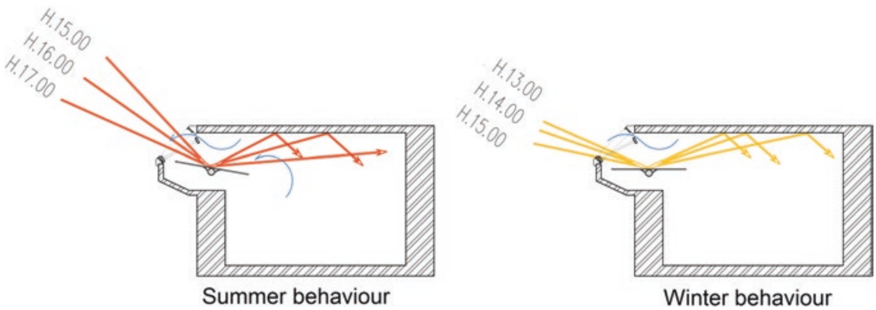

Fig. 19.8 Details of the light device for the windows in the new body

increasing the brightness of the rooms, as well as avoiding the direct entry of the rays to the users, and the relative glare (Fig. 19.8).

In particular, this new fabric body has been thought in rammed earth, rather than in a more conventional material, such as concrete or bricks, so as to create a more healthy, sustainable, hosting, and warm milieu. At the same time, the choice of the earth is meant also for differentiating the new architectural intervention from the original old monument in Lecce stone (Fig. 19.9).

Moreover according to the project decisions, on one hand the internal spaces have been arranged so as to be integrated with the old structures, and on the

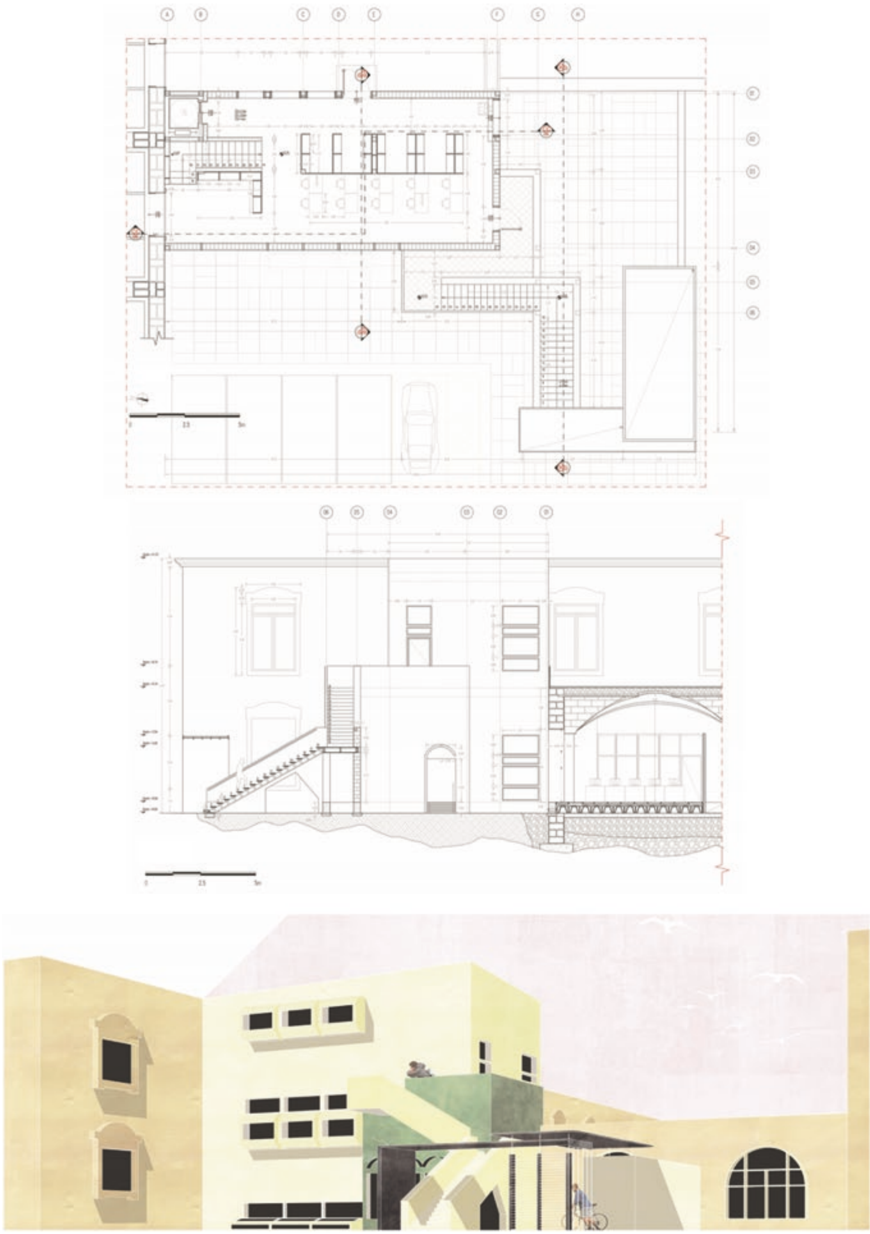

Fig. 19.9 The architecture of the new body (top: first floor plan; center: Section D Down: 3D view from South West)

other hand a completely different design, shape, and technological solution have been developed, matching the users' requirements and the building's conservation needs.

Conclusion

Being the site landscape spread with a number of other fabrics of this kind, the idea of recovering them with sustainable approach, principles, and technologies could be reproduced, hence developing a consciousness among the local inhabitant about social, economic, and environmental sustainable issues.

One example of a similar design procedure can be found in Mallorca, where the architects team, so-called Aulets, composed by the two architects Francisco Cifuentes and Sebastian Martorell, had proposed a project for an oenological building, and had adopted sustainable approach as well as care for the local context [4]. Similarities of the two winery farms can be found both in the existing fabric and in the design approach and choices. For example, in the Italian case study of Veglie there is a beautiful stone facade on the main entrance with peculiar window frames (Fig.19.2) and in the Mallorca winery, "… grand stone doors frame … and local hydraulic tiles" [4] can be observed (Fig. 19.10). As far as the project in the Aulets case is concerned, a number of solutions can be found which are ecological as well as respectful of the original structure, such as, for example, the refurbishment of the existing windows, recycled and re-employed, after the needed upgrade for adjusting them to contemporary comfort standards; the selected materials, for example, cork for insulation and ceramic block for the partitions (Fig. 19.11), being made up with local prime matters, are all parts of the architecture which "… offers a solution from

Fig. 19.10 Main façade of the Mallorca winery [4]

Fig. 19.11 Mallorca winery refurbishment using cork and ceramic blocks

the global to the local, …. global in terms of the use of materials that reduce Carbon Dioxide, and at the local level that the buildings are designed …. so as to take advantage of the climatic resources of the place" [4].

In fact the cultural heritage of ancient buildings widely found in Mediterranean regions actually enriched the landscape, and created an identity to the place, which cannot be deleted by demolishing the fabrics themselves, when they become eventually obsolete and thus neglected and unused. In fact not only they are valuable as evidence of the past history and traditional material culture, but they also behave in a very efficient way from the thermal as well as the healthy point of view; the thick walls perform as a thermal capacity system storing the heat in a daily and seasonal swing; the vaulted ceilings keep fresh during summer, so cooling up the rooms and the internal users; the big and tall windows allow entrance of quite a lot of light and good air change percentage. Therefore the regeneration project can actually take into account these bioclimatic efficiency so trying to consider it as a potential rather than a restriction to the renewal. The proposed methodology can then get the benefit of valorizing these existing structures, so conserving the identity of the place, and at the same time enhancing their qualities by small modifications and/or extensions aimed at integrating the architecture with new uses, which will help to regenerate and breath new life to the site [5, 6].

In conclusion it can be said, with the words of the "Natural Science Academy" of Philadelphia in 1973, that the ecological principles for architectural and technological design "… should aim at energy and materials conservation,… at altering as little as possible the landscape and moreover, to enhance the natural site in which the building is located; and to reduce to the least water and air pollution" [7].

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Part V
Passive Cooling and Daylighting

Chapter 20
Sustainable Construction Methods and Materials in Hot Arid Climatic Region of Iran

Seyedehmamak Salavatian

Introduction

Sustainability is a significant and multidimensional concept in nowadays architecture and particularly in future architecture. Selection of sustainable materials is a major step toward sustainable building achievement. Building envelopes are human's barrier against external atmospheric conditions and their fluctuations; thus, its optimum configuration strongly affects buildings thermal performance and human thermal comfort.

Sustainability in materials considers their whole life cycle including processes as extraction, production, transportation, installation, operation, and demolition. Life cycle is not similar for all materials. Although they are all originally acquired from nature, their acquisition processes might be simple or complicated. For example, Earth and wood are among the most available materials, directly comes from nature and are utilized with minimum processing which are called environment-friendly. Utilization of materials in their primary form reduces energy and resource consumption as well as environment degradation. In contrast, explosion in quarries is inevitable to obtain materials as cement and metals which ends in destroying the environment. In this way, more complicated production processes affect construction duration as well as energy consumption. Besides, transportation cost is a major portion in construction economics; however, local materials require less storage period and relevant difficulties. Recycling process after materials life time also counts. Compound materials are more difficult to be separated and reused; e.g., stone, clay, and brick are dismantled easily and are used in their initial form while concrete is destructed by impulses making pollution. Also, metals are able to return to recycling process but it costs plenty of time, energy, and pollution.

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There are a number of features enumerated in the literature for sustainable materials: (1) minimum energy consumption during production process, (2) minimum pollution production [1, 2], (3) not threatening the nature by acquisition, (4) being made of renewable primary resources [3], (5) utilizing minimum water resource [1], (6) high degree of durability and providing longer life time for the building [4], (7) lower amount of waste production [5], (8) minimum energy consumption during operation period [6], (9) re-use and recycle possibilities, and (10) easiness of maintenance in operation period [7].

For designers, materials selection is a critical decision; if appropriate materials are not applied, irreparable damages are possible. The main question is which materials are suitable for each climatic region in order to meet minimum disadvantages to the environment and maximum energy efficiency.

History of Iran is filled by valuable lessons regarding smart use of materials. Iran is basically divided into four climatic regions; region one is the dry and hot region, which consists of the largest parts of the Iranian plateau. Region two is the cold and snowy region in north and west of the country. The third one is the hot and humid region which comprises northern shores of the Persian Gulf and the Sea of Oman and the last region is humid and rainy region which embraces the southern shores of the Caspian Sea (as seen in Fig. 20.1) [8]. The largest zone—hot arid region—was chosen for this study. Since 43% of the Earth area is categorized as hot arid and semihot arid climatic zones [9], findings of such researches might be utilized for building sector in similar climates as well. According to Mofidi shemirani et al. [10], vernacular architecture is not defined by national borders, but environmental features; even though the regions are associated to various cultures and civilizations, many of design techniques are common among them. Among the areas linking to this climatic region, Yazd Province (shown in Fig. 20.2) was chosen as the representative location, since it presents the climate's features in the closest way.

In this paper, the focus is on the environmental impacts and energy-efficient processes in vernacular habitats, particularly in their wall envelope configuration, which can be an essential guide for sustainable environmental building design in future. This research aims to provide designers, architects, and building engineers with optimal and competent solutions suitable for this specific climate using traditional sustainable methods and materials.

Vernacular Sustainable Solutions

Main features of this climate consist of low amount of air moisture, intensive sun radiation, little precipitation, and weak greenery. Air dryness in this climate typically ends in a huge diurnal temperature range; temperature extremes necessitate thick insulating walls and roofs to maintain a comfortable internal environment.

Earth is the most spread substance there and brick and adobe walls were made in thick layers in order to bear heavy loads of arches and domes; the right thickness enables them to decrease diurnal temperature fluctuations and perform as a thermal battery [8].

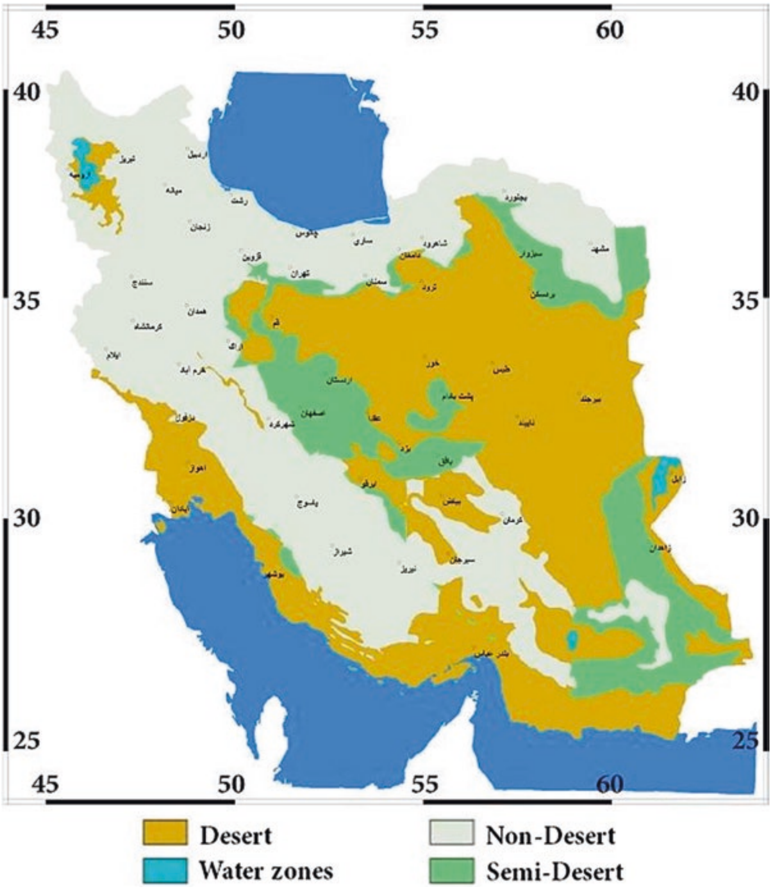


Fig. 20.1 Varous climatic zones of Iran

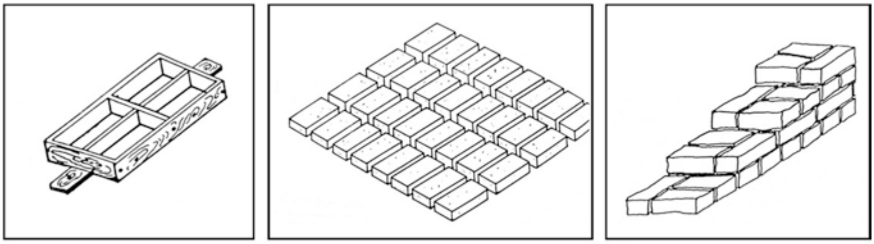
Buildings are mostly faced inward and benefit a central courtyard encircled by important spaces. Outer facades are remained unfinished while inner facades are highly decorated with specially designed windows. Larger buildings have more than one courtyard, as simple cuboids extracted from the overall volume. Water ponds and little gardens help in humidifying the extreme dry air.

Exterior and interior walls are all made of earth which is a key in thermal control inside. Three main earth wall types are common in this land; to build the simplest clay walls, clay mixture with sand and straw are set in water basins for a couple of days. Straw performs as the reinforcement and prevents the clay to be cracked. Also, gravel or lime might be applied to strengthen the material. Likewise, salt keeps vegetation to grow and make the wall resistant to moisture and freezing. When the grains are totally drowned, they are severely blended by hand. Quality of the product depends on a correct mixing process. Masons set the wall by hand; when the wall reaches about 80 cm, it leaves to dry and the next 80 cm is set again. In this way

Fig. 20.2 Yazd Province in hot arid region

the whole wall is built. Wall thickness is about 70 cm at the bottom and 40–50 cm at the top. Wood is solely used for lintels and ceiling beams. Roofs are finished by plant stems and clay. Also, in many cases domes and vaults are built as the roof cover. This construction method, called rammed earth wall, is weak from structural viewpoint and does not resist to earthquake.

Adobe walls are the second types which are the evolved form of clay walls. Adobe mixture includes 20–30% sand and is poured into iron or wood molds by hand and dried in the open air by sun. After 3–15 days, depending on the weather condition, the mixture loses its moisture and adobe production completes. Figure 20.3 shows molding (a), drying (b), and constructing stages (c). Third one, baked adobes or bricks, are used for more important buildings. In this method, molded adobes are dried by low heat and then sent to the kiln. Brick mixture comprises around 10–15% of sand. All forms of earth walls (rammed, adobe, and brick) perform greatly in relation to hot days and cold nights; this is due to their physical properties, mostly admittance value which is directly dependent on density, specific heat capacity, and thermal transmittance (Table 20.1). In the industrialized construction market of nowadays, which is emphasized on light-weight materials, new forms of earth materials to meet recent building requirements as well are accepted.



(a) (b) (c)

Fig. 20.3 Use of adobe: (**a**) molding, (**b**) drying, and (**c**) constructing [18, 19]

Table 20.1 Adobe thermal properties [17]

Thermal properties	Quantity
Thermal transmittance	1.1 W/m°K
Density	1770–2000 kg/m^3
Specific heat capacity	1000 J/kg°K

In the following, focused on the preserved historical houses in city of Yazd, the predominant sustainable techniques to achieve thermal comfort in vernacular hot arid climate of Iran are described and presented in Table 20.2.

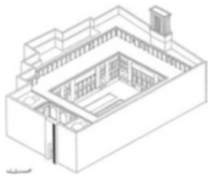
Contemporary Techniques and Materials in Construction Sector

There are plenty of materials available in contemporary Iran and most of the buildings are made of nonvernacular materials with slight attention to sustainability concerns. Urban multistory buildings necessitate concrete or steel structure and advanced value of properties in cities rejects the past thick walls. However, in low-rise buildings of suburb, rural areas, and damaged buildings by earthquake, they are still considered as proper solutions. Reapplying vernacular materials compatible with revolutions of the new decade and modern life requirements demands in-depth knowledge of materials to combine vernacular systems with nowadays technology and upgrade materials' quality.

Design and Construction

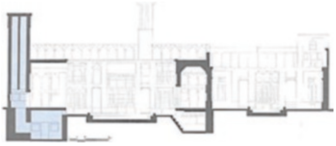
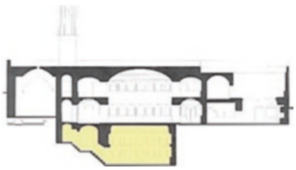
Light-weight materials of today's architecture such as hollow clay blocks, light expanded clay aggregate (leca), and autoclaved aerated concrete (heblex) show much lower thermal capacity; accompanied with thermal insulation layers, they

Table 20.2 Climatic analysis of architectural characteristics and building components [11]

No.	Description	Example
1	*Four-season design;* houses are designed to be thermally comfortable for all seasons. Specific rooms at each side are used in specific times. Northern side of the yard, facing to the sun is employed in winter time while southern side, setting in the shaded part, is dwelled in summer time	 *Mashruteh House*
2	*Central courtyard;* providing flowers bed area and water pool cause evaporative cooling which reduces air temperature significantly	 *Arab Kermani House*
3	*Introversion;* the only linkage to the harsh outside climate is the house entry. The exterior walls are left unfinished while inner facades prosper the favorable microclimate of the house	 *Shafi' poor House*
4	*3-dari / 5-dari;* principal rooms are placed in the shaded or sunlit facades while service rooms/ secondary spaces in lateral sides	 *Arab-ha House*
5	*Eivan;* a semi-open space at the southern side of the courtyard and adjacent to the main room, suitable to be used in warm seasons	 *Mortaz House*
6	*Talar;* ceiling height of summer-time rooms is greater than other sides in order to run the hot air upward and provide more pleasant condition at the living height	 *Kuroghli House*

(continued)

Table 20.2 (continued)

No.	Description	Example
7	*Dehliz;* the access from the hot temperature of the street to the inside humid air is designed as a complex route which prevents any heat exchange	 *Mr. Wye's House*
8	*Wind-catcher;* located above the southern side (summer-time zone) cools the main floor as well as the basement	 *Gerami House*
9	*Orosi;* wide and high wooden windows, mostly at the length of the room. As the weather is pleasant, the panes are rolled upward and the room is connected to the yard immediately and as the sun protection is needed, they are fully closed. Colored glass pieces bring adequate light inside even though panes are down	 *Rasoulian House*
10	*Sardaab;* a deep basement as a well-cooled space due to the earth thermal mass, suitable for hot summer days	 *Lari-ha House*

form thin walls of new buildings. Wall envelopes in new buildings solely consider thermal transmittance regulations required in the relevant building standards. However, two different envelope compositions with equal thermal transmittance might perform differently regarding heat absorption and reflection. This difference is due to their thermal mass properties, which might be very influential when exterior temperatures fluctuate greatly in a 24-h cycle. According to Givoni [12], thermal mass depends on materials' thermal capacity, density, and U-value. Therefore, the simultaneous impacts of thermal mass—as the indicator of dynamic thermo-physical properties—and thermal resistance—as the indicator of static thermo-physical properties—are important; while in new architectural trends, the former is not considered appropriately.

Muhammad [13] in a study carried out in Tehran (Iran) investigated the capability of frequent wall systems in providing thermal comfort of building residents. In conformity with the conducted interviews with experts and practitioners in Iranian construction sector as well as the researcher's field observations, a brief categorization of common materials for wall systems were presented. In this paper, the simultaneous effects of thermal insulation and thermal mass on the envelopes behavior in Tehran are studied. Findings showed that U-value is not the sole criteria to the acceptable thermal performance. It also states that there are different behaviors in summer and winter.

Building Regulations

In Iran, 19th chapter of national building regulations is allotted to the energy preservation issues in buildings and is the principal reference for insulating necessities. The national mandatory requirements regarding building envelope design consider thermal transmittance of external envelopes and recommendations for building thermal mass, which directly impact on thermal inertia, are missed. Therefore, setting equilibrium between a proper insulating and an agreeable effective mass in each climate is left to the knowledge of designers and simulation tests during the design process. For city of Yazd, the maximum thermal transmittance of 1.01 W/m°K is determined for attached residential buildings under constant use [14].

Evaluation of Optimized Model

Design Builder software evaluates the building under dynamic environmental conditions. For this purpose, a four-story building over piloti—as frequent for urban apartment buildings in this region—was modeled (Fig. 20.4). Effects of materials and envelope configurations in the exterior wall on the interior temperature were investigated. According to the recommendations for building orientation in Yazd, the building was inclined to South-East (25° of inclination) to have a better performance in terms of sun gain and natural ventilation [15]. A bedroom in 3 m width and 4 m depth in the south east side is the base space of comparison among alternatives, since this facade receives the greatest amount of sun radiation and is influenced the most.

Selected materials for ceilings, floors, and internal walls are all considered constant. Double-glazed UPVC windows filled by argon gas was selected for window types and are the same in all tests. The internal slabs between stories are made of concrete in 10 and 30 cm thick for medium and heavy mass alternatives, respectively. In this way, effects of thermal mass in interior temperatures were also evaluated. Other intervening parameters in the envelope thermal performance were not considered in the software setting; including internal gain as occupants and equipment. Besides, heating and cooling are not assumed since this simulation is carried

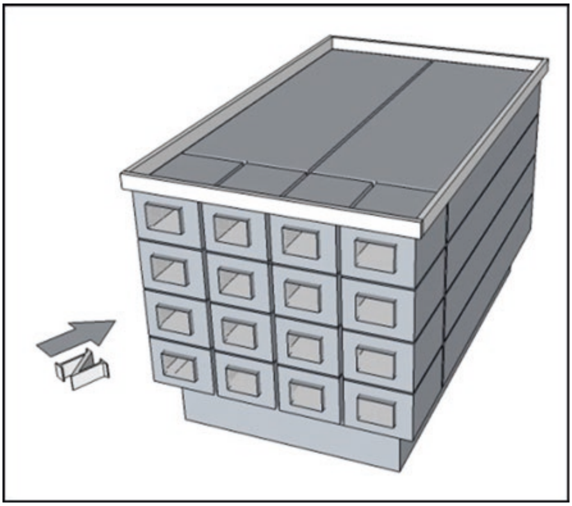


Fig. 20.4 3D model of a typical urban apartment building

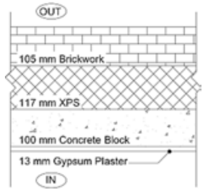
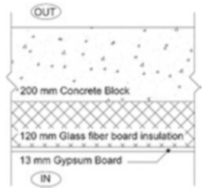
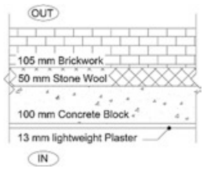
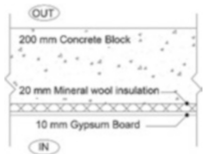
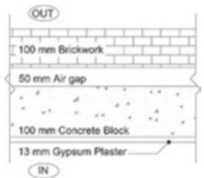
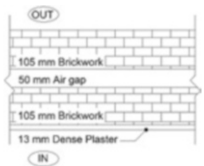
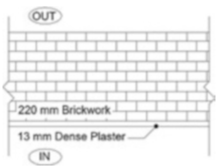
out to purely evaluate the building performance regarding energy systems. A typical summer and winter weeks are determined as the time durations for this study. Table 20.3 shows the various types of wall envelopes testes and compared. They comprise the most common configurations in the construction sector and cover a wide range of thermal transmittance from 0.25 W/m^2 K, which is lower than the requirements—to 2.18 W/m^2 K—which is not allowed in regulations.

Envelope Thermal Performance

Simulating the model, internal air temperature of the base room in various modes of wall configuration were achieved and analyzed. In Fig. 20.5, temperature adjustment in summer with various envelopes is observed. *U*-value has an increasing trend from Type 1 to Type 7, while the weaker envelopes-in term of thermal resistance-perform better in temperature balancing; e.g., Types 5, 6, and 7 which their thermal transmittance are all higher than the determined values in regulations has a better performance than Types 1 and 2 which benefit great thermal resistance. This behavior is due to their higher thermal capacity as thicker layers of dense materials like brick.

Figure 20.6 depicts the same test in a typical winter week. It is noticed that walls behave mostly based on their *U*-value in winters. According to Givoni [12], thermal capacity shows the most efficacies as the environmental conditions are unstable. In this climate, the intensity of sun radiation on the south side facades is less in winters. Unlike summers, in which the heat exchange is two-sided in a daily cycle—the internal air is always warmer than outside in winters. Therefore, the role of thermal capacity to save the heat as a battery weakens and envelopes with higher thermal resistance show better performance to protect inside against cold winter weather.

Table 20.3 Wall envelope types

No.	U-value (W/m^2)	Thickness (cm)	Detail drawing
T_1	0.25	33	
T_2	0.26	34	
T_3	0.57	27	
T_4	0.57	23	
T_5	1.50	26	
T_6	1.56	27	
T_7	2.18	23	

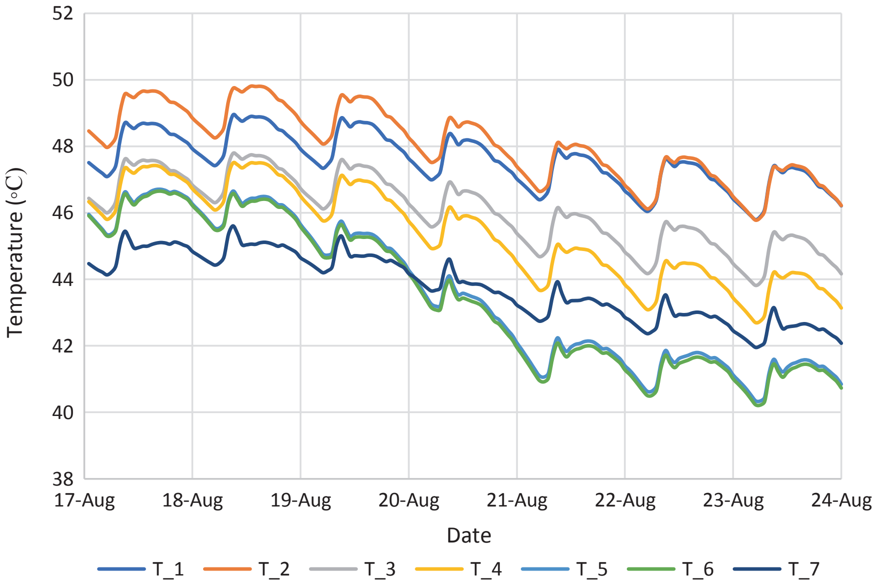


Fig. 20.5 Internal air temperature in a typical summer week

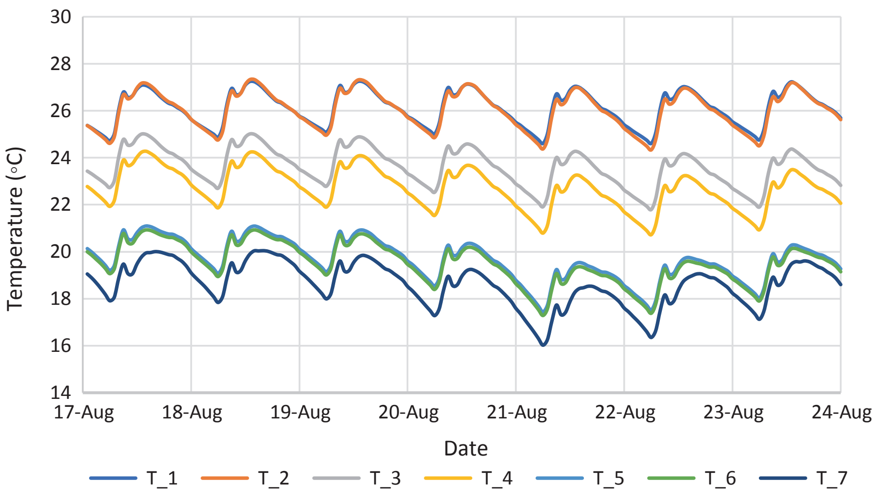


Fig. 20.6 Internal air temperature in a typical winter week

Figure 20.7 shows performance of wall Type 1 in medium and heavy modes in which building envelope is fixed while other building components benefit moderate to high thermal mass, respectively. It is illustrated that with a constant envelope, higher thermal capacity of internal floors and walls would improve temperature modifications indoor.

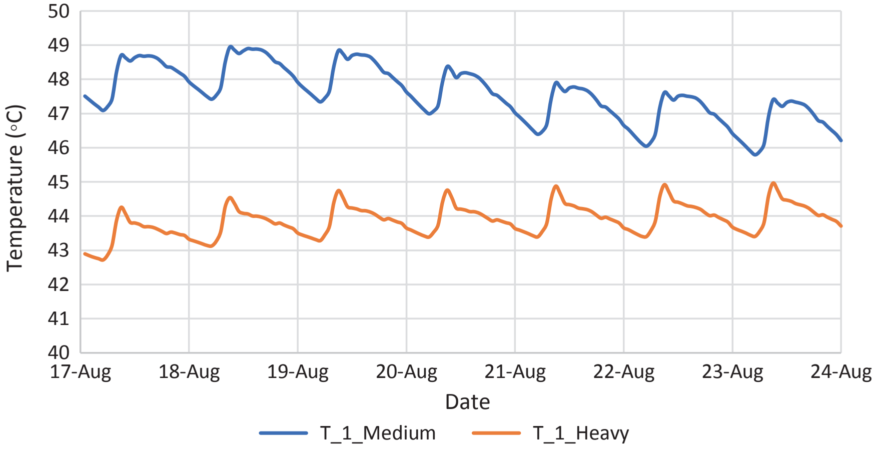


Fig. 20.7 Effects of building components thermal mass with fixed envelope

Hence, earth-made materials or mineral insulations as glass wool are preferred to materials as concrete or industrialized insulations mentioned earlier due to the lower environmental impacts in a life cycle assessment.

Conclusion

In this research, use of various building envelopes compatible with new regulations in the hot arid climate of Iran is investigated. In the traditional architecture, the major potential of exterior walls was to utilize high heat capacity of materials to adjust great fluctuations of outdoor temperature. Moreover, materials are all local and directly extracted from nature. They provided the minimum embodied energy and with the recyclability potentials made the maximum level of sustainability for buildings.

Reviewing the significant climatic features of vernacular architecture of the region, the considerable effects of thick earth walls were perceived which had an astonishing impact on occupants comfort in this unfavorable climate.

To evaluate new wall configurations and their performance regarding temperature modification inside, a comparison among the envelopes with different thermal resistance and mass was carried out. Studies showed that the sole parameter of U-value is not the preference factor in building envelope design in hot arid climate. Results stated that thermal insulation and thermal capacity play different roles in the envelopes. In summers, particularly in the south side, use of a well-insulated envelope is not necessarily the best decision in terms of air temperature adjustment. In contrast, envelopes with higher thermal mass are more successful to lower the internal air temperature. However, in winters which sun radiation reduces, envelope insulation works more effectively to decrease heat exchange.

Consequently, it is found out that thermal capacity values should be considered as well as *U*-value for building envelope design in such climates and be predicted in the relevant regulations. In addition, each of the aforementioned parameters is effective in different periods of the year. Although providing thermal comfort in summer season is a more important challenge in this climate, it is desired to find a solution to benefit advantages of both parameters in all seasons to increase buildings sustainability levels.

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Part VI
Eco-materials and Green Technologies

Chapter 21
Impacts of Exploiting Nanocoating on Buildings' Façades to Improve Air Quality in Megacities, Mitigate Climate Change and Attain Livability

Ehsan M. Elhennawi and Mohsen M. Aboulnaga

Introduction

Megacities face colossal challenge, mainly urban air pollution due to transport, large number of inhabitants' activities, and energy use in all sectors. In cities, air is the main component of atmosphere; all humans, animals, plants, and other living organisms depend on it for survival. In the last decade, health concern became an important issue in megacities due to high level of air pollution. Sources of air pollutants in developing countries are variable: resulting from emissions of vehicles, industrial activities and open burning of agricultural and municipal solid waste; all of these are causing several economic and health damages to human and ecosystem [1]. According to the World Health Organisation (WHO), at least 96% of the populations in large cities are exposed to $PM_{2.5}$ which exceeds the WHO air quality guidelines levels. Thus, improving air quality is one of the major steps needed to enhance livability in megacities both in developed and developing countries. Several research studies conducted during the previous years indicated that the use of nanotechnology to solve air pollution problems, where nanocoatings are used to purify air entering into buildings, showed significant signs. For a megacity like Cairo, the causes of air pollution may be different depending on the geographical location, temperature, wind, and weather factors, so pollution is dispersed differently [2].

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Objectives

The aim of this work is to present a review study on identifying nanocoatings' types to reduce the concentration of air pollution in cities and to improve air quality in buildings through the use of nanocoatings. The study focuses on buildings that incorporate titanium dioxide as a self-cleaning (photo-catalytic) coating outside buildings. Figure 21.1 shows the objective and sub-objectives of the study.

Issues and Challenges [6]

The problem of air pollution, especially in big cities, is one of the main global challenges in the current century and the continuous manifestation of climate change impact around the world is foreseeing long-term damages and economic losses. Nonetheless, a new generation of treatments that mitigates different pollutants in the air has recently emerged. These challenges must be brought into consideration when sustainable materials are used; the potential of photocatalysis against CO_2 and other major contributors to pollution is addressed [3].

Methodology

The study methodology depends on inductive and analytical approaches: the first part includes a review on the nanotechnology and nanocoating, whereas the analytical part encompasses an assessment of global models for nanotechnology. The study also analysed different buildings globally that applied different types of nanocoatings [4].

Nanotechnology and Nanocoating

Science-based approach to nanotechnology materials with morphological characteristics are studied on the nanoscale, especially those with special properties arising from their nanoscale dimensions [7]. These are divided according to the uses

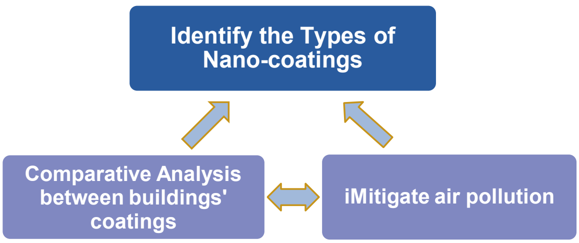

Fig. 21.1 Sub-objectives of the research

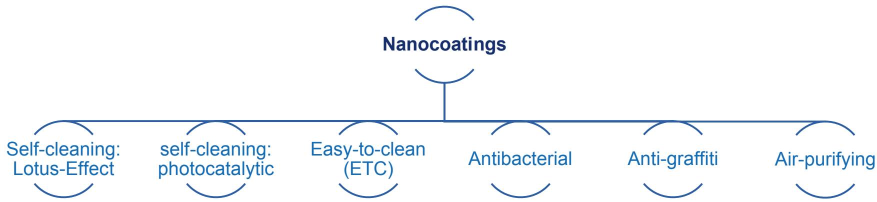

Fig. 21.2 Nanocoating types

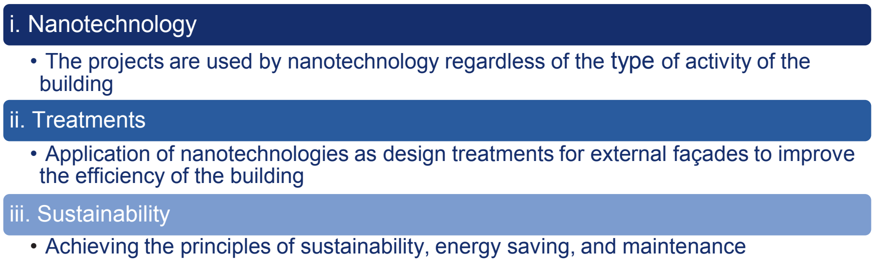

Fig. 21.3 The criteria for assessing the selected projects

of buildings as illustrated in Fig. 21.2. Nanocoating can be used as a technology to build the skin of buildings' façades where a coating is basically a membrane/film applied onto the surface of an object. The purpose of the application may be decorative or functional paint or both. Nonetheless, coatings can be found on exterior/internal walls and on all kinds of wires, prints, circuits, outside buildings, and much more. In addition, the decorative façades of the paint expand to a large extent [8].

Global Models for Nanotechnology

By studying the nanocoating techniques, it was found that the self-cleaning (photocatalytic) has been widely used in buildings and has potential in the market. Its main applications would be on the external and internal buildings' façades. Also, it has an effect on the development of the material properties and the external atmosphere of the buildings with the purpose to improve the efficiency of these materials such as concrete, iron and wood [9]. In addition, it enhances the material used in buildings' finishing materials, including paints and glass. There is an evolution of buildings' façades that intended to improve the efficiency of their components. The criteria taken into account when assessing these projects using self-cleaning (photo-catalytic) coating are shown in Fig. 21.3. The comparative assessment between buildings that incorporate this coating is illustrated in Table 21.1 and Fig. 21.4 illustrates the countries where such technologies are exploited in buildings and urban areas.

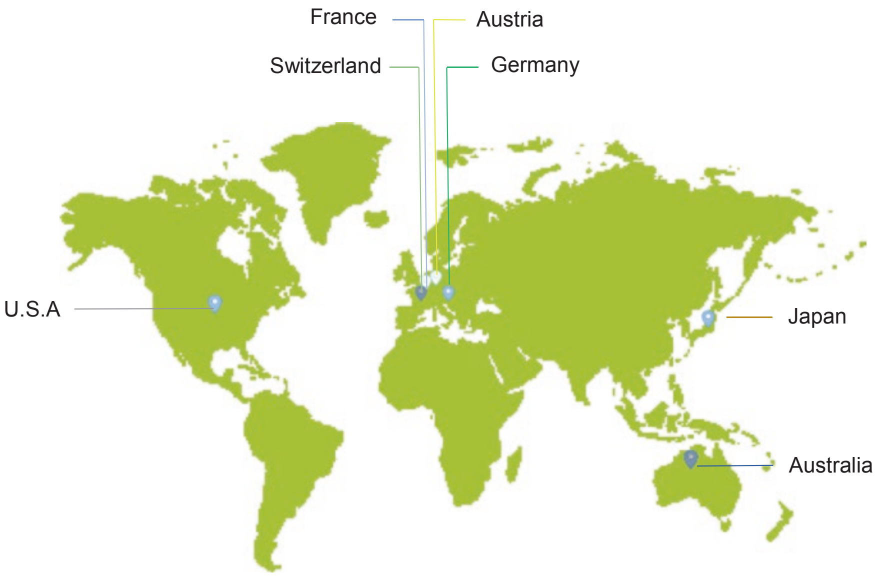

Fig. 21.4 Countries using self-cleaning: photo-catalytic coating

Results of Comparative Global Models

Self-cleaning (photo-catalytic) is commonly used in all types of buildings, including residential, hotels, sports, cultural, and religious as well as commercial (offices and banks), and its application are mainly in glazing, paint, ceramic and membrane as shown in Fig. 21.5. Based on the above assessment, these nanocoatings (self-cleaning) are widely applied onto finishes of the building's façades and the most common country where such application is used is Japan. Figure 21.6 shows that residential building is the most type where self-cleaning (photo-catalytic) coatings are applied and also self-cleaning (photo-catalytic) coatings are widely used onto the glass of the buildings' façades.

Air Pollution in Megacities

In megacities, air pollution is reaching an alarming rate exceeding the WHO recommended level. Most of the populations in big cities are exposed to $PM_{2.5}$ which exceeds the air quality guidelines levels set by the WHO as illustrated in Fig. 21.7 [10]; thus, causing morbidity and mortality. Improving the quality of air in cities is one of the major actions immediately required to ensure livability in mega-cities. Several research studies, conducted during previous years, indicated that the use of nanotechnology solves pollution problems, where nanocoatings are used to

Table 21.1 Comparison between buildings that used photo-catalytic self-cleaning

No.	Country and city	Building's name and type	Building's image	Coating type	Similarity	Difference
1	**Germany** Heilbronn	AKT—Am Kaiser's TXirm Heilbronn Cultural		Photo-catalytic self-cleaning	Used on glass	No
2	**Germany** Hamburg	East Hotel St. Pauli Hotel				
3	**Germany** Duisburg	MSV Arena Soccer Stadium Sports				
4	**France** Lake Leman	Evian Mineral Water Head Office Office				
5	**France** Cluses	Nautical Centre Service				
6	**Austria** Graz	Sparkasse Graz Bank Bank				
7	**Switzerland** Frick	Disabled-access housing Residence				

(continued)

Table 21.1 (continued)

No.	Country and city	Building's name and type	Building's image	Coating type	Similarity	Difference
8	Australia McMaster's beach	Glass Tee House Residence		Photo-catalytic self-cleaning	Used on glass	No
9	Australia Adelaide	Watkins Residence Residence				
10	USA Louisville	Muhammad Ali Center MAC Cultural			No	Used on ceramic tiles
11	Japan Tokyo	G-Flat Residence			Used on glass	No
12	Japan Nishinomya	Kurakuen private residence Residence			Used on paint	No
13	Japan Osaka	Senri New town private residence Residence				
14	Japan Hiroshima	House on Creek Residence				
15	Japan Osaka	Hyatt Regency Garden Chapel Religious		Photo-catalytic self-cleaning	Used on membrane	No

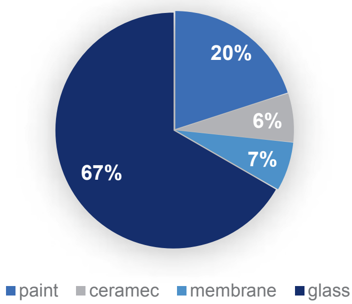

Fig. 21.5 Self-cleaning (photo-catalytic) coatings application

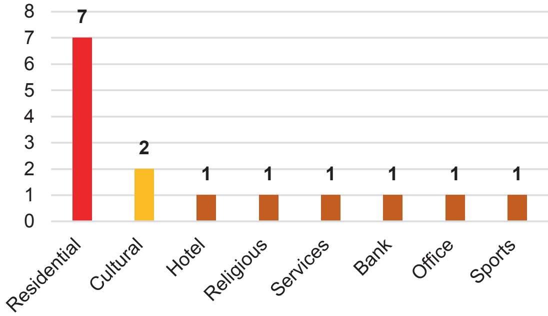

Fig. 21.6 Type of buildings applied Self-cleaning (photo-catalytic) coatings

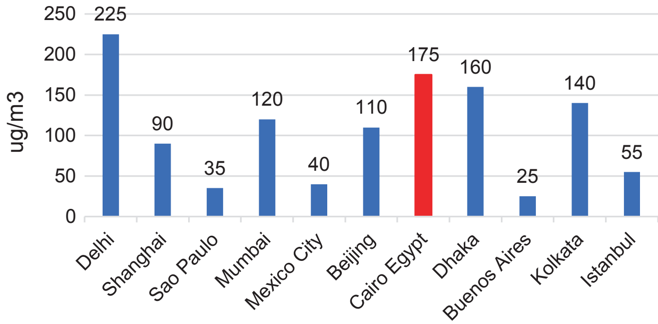

Fig. 21.7 Air pollution level—PM10 for available megacities. *Source*: The 2016 version of the database by WHO

purify air before entering into buildings [11]. The exact causes of pollution may be different and depend on many factors as illustrated in Fig. 21.8.

Evidence from the WHO reports highlighted that the levels of the six main pollutants are determined by the concentration of the common pollutants level [12]. The main primary pollutants from the various activities are supplemented by the following: particles suspended vestibular (PM_{10}–$PM_{2.5}$), Nitrogen oxides NO_2,

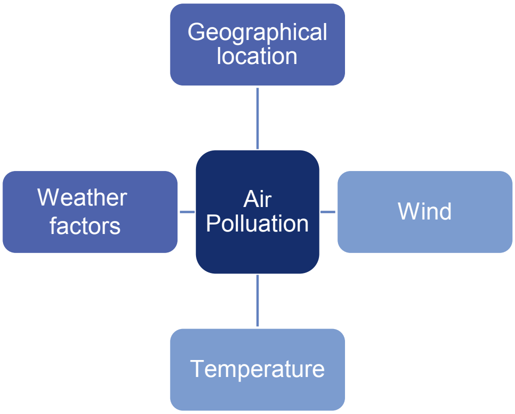

Fig. 21.8 Factors that cause air pollution to differ in each country. *Source*: http://www.wind.arch.t-kougei.ac.jp/info

Table 21.2 Maximum limits for contaminants of ambient air in Egypt

Polluted	Region	Maximum concentration (μg/m³)			
		Hour	8 h	24 h	Year
PM_{10}	Urban areas	–	–	150	70
	Industrial areas	–	–	150	70
NO_2	Urban areas	300	–	150	60
	Industrial areas	300	–	150	80
SO_2	Urban areas	300	–	125	50
	Industrial areas	350	–	150	60
CO	Urban areas	30 mg/m³	10 mg/m³	–	–
	Industrial areas			–	–
	Industrial areas	300	–	–	–
O_3	Urban areas	180	120	–	–
	Industrial areas	180	120	–	–
$PM_{2.5}$	Urban areas	–	–	80	50
	Industrial areas	–	–	80	50

Sulphur dioxide SO_2, Carbon Monoxide CO and Ozone O_3. Studies have shown that these pollutants greatly affect the public health of humans and the surrounding environment and must work to address the sources of these pollutants to reduce them by all means technical and scientific. The maximum permissible limits for average of external air pollutants in Egypt are shown in Table 21.2 [1]. Air pollution can affect our health in many ways in the short term and long term. Different groups of individuals, especially elderly and children suffer from and can be affected by air pollution in different ways and are more sensitive to pollutants than others. Carbon dioxide (CO_2) may be not classiffied as pollutant, but it is found that its concentrations affect human health as presented in Fig. 21.9 [13, 14]. It also causes global climate change.

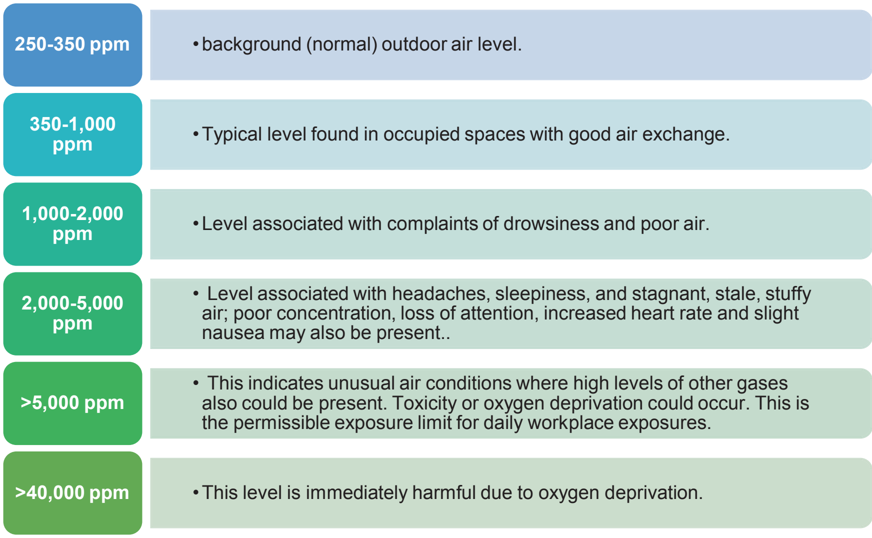

Fig. 21.9 Carbon dioxide levels and potential health problems. *Source*: https://www.climate.nasa.gov/climate_resources/24/graphic-the -relentless-rise-of carbon-dioxide/

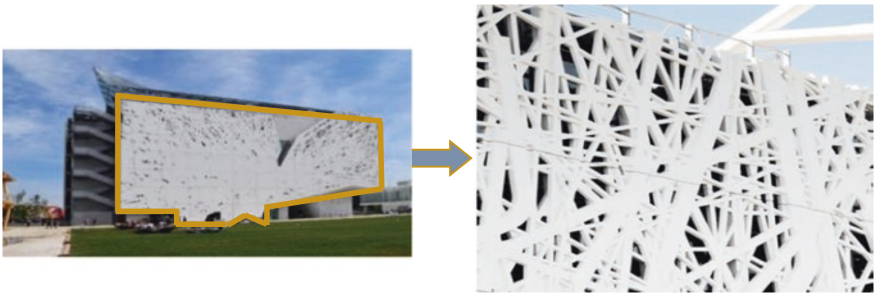

Fig. 21.10 Biodynamic concrete over 700 branched panels in Italy Pavilion at Milan Expo. *Source*: https://www.archdaily.com/630901/italy-pavilion-milan-expo-2015-nemesi

Nanocoating and Air Pollution in Megacities

The buildings that are using self-cleaning: photo-catalytic coating in their treatments was reviewed (Table 21.1). It was found that the coating was used for more than one purpose. In some buildings, used as self-cleaning and some used to reduce pollution [15, 16]. Examples of these are the Italian Pavilion at Milan Expo 2016 and Torre de Especialidadesis hospital in Mexico City.

In the Italian Pavilion at Milan Expo, the design façade of photoelectric glass covering the facade is decorated with more than 700 active BIODYNAMIC concrete panels with the patented Ital Activee Active TX technology as shown in Fig. 21.10.

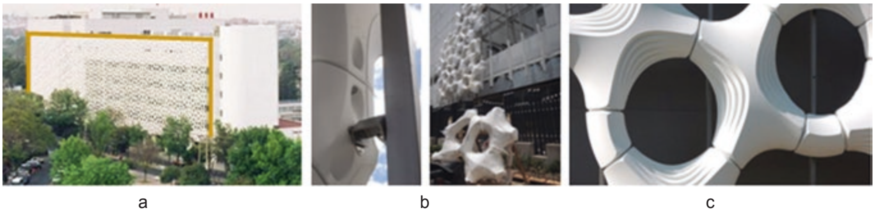

Fig. 21.11 Façade of Torre de Especialidadesis hospital with Prosolve 370e coated with TiO_2. (**a**) Torre de Especialidadesis hospital. (**b**) Placement of Prosolve 370e. (**c**) Plastic material called Prosolve 370e. *Source*: https://blog.visualarq.com/2014/03/07/rhino-projects-a-smog-eating-facade/

When the material comes into contact with the ultraviolet rays, it can "pick up" pollutants in the air and turn them into idle salts, and hence reduce smog levels in the air [17]. The Torre de Especialidadesis hospital has a double façade (a double skin of pieces) made of a lightweight plastic material called Prosolve 370e, which is covered with a very thin layer of titanium dioxide (TiO_2) powder [18] as presented in Fig. 21.11.

Results

Self-cleaning: photo-catalytic coatings can be used extensively and adapted to achieve an inventive and a visionary architecture that has proved from the examples shown above the possibility of exploiting such technology on different façades. It also helped architects to create new destinations using different units, whether concrete or plastic units that contributed to the use of paint effectively to perform its job and reduce the pollution in the atmosphere, but not to reduce one compound. It was found in studies that it is effective in reducing the various elements of pollution and it can be mixed with cement and carbon dioxide absorption [19, 20].

Conclusions

Different buildings around the world that applied different types of nanocoatings were analysed. Also buildings that were divided according to their types of nanocoating, the country where most common types of buildings used and the country that has similar matching to Egypt's climatic conditions were presented and assessed. The assessment of each building facades was useful to extract the nanotechnologies, especially self-cleaning (Photo-catalytic) that mitigate air pollution. In addition, the percentage of pollutants worldwide was assessed to identify the most important pollutants that are classified as top contaminants threatening human health and highlighted relationship of CO_2 to human health, if the concentration in the internal spaces exceeds the limits recommended globally. The Ministry

Environment, Egypt, report was discussed and the maximum limits of pollutants at the global scale was also presented, which led to the extraction of requirements to reduce contaminants in the internal spaces of buildings using titanium dioxide as self-cleaning (photo-catalytic). Results show the potential of titanium dioxide as a self-cleaning (photo-catalytic) to mitigate the level of pollution in Egypt.

Nanotechnology works to extend the futuristic life of the buildings and enhances livability in cities and has supported the society with ideas and techniques that provide aid to solve the air pollution problems and external facades. Nanotechnology has provided many materials in the field of construction. With unique characteristics that changed the general concept in the use of buildings' materials. In addition, nanotechnology assists in mitigating air pollution, where self-cleaning: photo-catalytic coatings are commonly used in all types of buildings including residential, hotels, sports and commercial buildings (offices bank). Furthermore, the application of nanocoatings in glazing, paint, ceramics and membrane was indicative. This coating used in various climates, where results show the potential of titanium dioxide, as a self-cleaning (photo-catalytic) to mitigate the level of air pollution, can be significant. This coating can cover any shapes and its effect will not be changed. We can use it onto any buildings façades to purify air before entering into the building. Finally, it is recommended to apply this coating on the façades of hospital and residential buildings in megacities in Egypt such as Cairo due to high air pollution and these buildings' types are considered of high priority.

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Chapter 22
External Insulation Systems for Buildings with Complex Façades in Urban Historic Centers

Paolo Carli, Alessandro Rogora, and Alessandro Trevisan

Introduction

The European cities, and in particular the Italian ones for their historical nature, have to solve the issue of energy retrofitting of the buildings of their historic centers urgently [1]. The interventions to improve in a passive way the energy performance of buildings are mainly based on controlling the amount of thermal energy that the building exchanges with the environment. These interventions are closely linked to the external microclimatic conditions, which vary over time and space; for this reason, especially in temperate climates, where there are significant seasonal and daily temperature variations, it is important to combine heating and cooling needs. This is achieved through the production, collection, and accumulation of heat inside the building and, at the same time, through the reduction of heat losses to the outside. If the first result can be achieved by maximizing the exploitation of solar energy and increasing the free thermal inputs generated inside the building; the second one can be achieved by improving the thermal insulation of windows and walls.

State of the Art

The insulating properties of a wall generally depend on the thickness and thermal conductivity of its materials. The massive walls, which generally characterize the historical building of the center of European cities, possess, thanks to the high thickness of the wall apparatus, a medium level of thermal conductivity, thus ensuring a

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not too bad level of insulation. In the case where, on the contrary, also the thermal capacity of the walls is not sufficient, it is possible to integrate them with appropriate layers of insulating material, greatly improving their thermal performance even with reduced thickness.

However, the addition of an insulating layer on a listed building is an invasive and delicate operation, to be adapted, time to time, to specific conditions of every building and which, above all, is not always possible to achieve, due to the historical and artistic values of the building itself. In fact, it represents an alteration (more or less heavy) of the external elevations, whose compatibility depends on the historical–architectural qualities of the building, since the conservation needs of the morphological systems and the preservation of the building's finishes influence the positioning of the insulating layer in a predominant manner.

Moreover, the addition of a new component to the envelope can allow negative implications on the hygrometric behavior of the walls and potential condensation's formation in the cavities between the existing walls and the new layers. For these reasons, the choice of the thermal insulation must conform to the permeability and breathability of the walls or must be balanced through an increase in natural ventilation which, on the other hand, increases the heat loss.

The systems for increasing the thermal insulation of existing buildings, listed or not, are substantially of three types: from the outside, in the interspace of cavity walls, and from the inside. Insulation from the outside is certainly the most well-known and probably the most effective technology. These are the EIF (exterior insulation and finishing) systems, more often known in Italy as "thermo-insulating coat." This consists of gluing insulating panels to the existing building structure, detaching them from the ground with a starting profile and taking care to stagger the junctions of the panels. Then the smoothing compound is applied and the plaster-holding net is drowned to allow the external finishing's application. Insulating from the outside has several advantages, including the reduction of thermal bridges, the reduction of the risk of interstitial condensation, and the increase in the capacity of the wall to accumulate heat.

Instead, the insulation in the interspace provides the insertion of the new material inside the walls; but certainly in Italy, cavity walls are not the most widespread. However, it is a matter of insulating by insufflation of loose-fill insulation material in the interspace of the cavity walls. With the use of loose fill, it is important to take into account the effect of compaction to not allow insulation voids inside the walls or the accumulation of the loose-fill insulation material in the lower part of the walls, with the consequent worsening of the building's energy efficiency. Insufflating the insulation in the cavity, however, the problem of thermal bridges arises, as the insulation stops at pillars and beams.

But often in historic or very dated buildings, at least in Italy, the masonry is not equipped with the necessary cavity and therefore it is essential to build a micro-ventilated layer between the external finishing and the insulating material applied to the building's masonry system.

Critical Aspects

It is therefore for these reasons that the strategy of the insufflation of insulation is not widespread in the context of the energy adaptation of historic buildings. It follows that the most widespread thermal insulation system on historic buildings is the one from the inside, in other words the adding lining to the walls and all the surfaces from the inside. However, this solution subtracts useful floor surfaces from the rooms and can increase the risk of condensation between the internal face of the walls and the insulation layer.

Moreover, with this technology the capacity of the wall to accumulate heat is not exploited because, as soon as the heating plant is switched on, the environment heats up quickly, but just as quickly cools down when the heating plant is turned off.

However, it has considerable advantages such as the simplicity of installation, the possibility of intervention on buildings with façades subject to historical or architectural constraints (e.g., facing bricks and ashlar), and the possibility of intervening only on some specific building units.

Nevertheless, the EIF systems also have problems linked to their constructive aspects.

In fact, in order to build an external thermal insulation system for a building, it is necessary to prepare a scaffolding along the whole height of the building, with considerable costs both on occupation of public land, a particularly relevant case in the historical centers of Italian and European cities, and costs of safety for people (construction workers and citizens) and also for security about anti-intrusion of thieves in the apartments.

Moreover, with respect to façades of buildings that are particularly complex in terms of decorations, projections, overhangs, etc., and obviously leaving out the listed buildings, the EIFS presuppose a simplification of the new façade and, at the same time, an unsatisfactory adherence between the panels of insulating material and external existing wall, due to the difficulty of shaping the panels to the intrados in suitable forms to avoid involuntary formation of cavities and irregularities of adherence.

This is a huge risk that we must try to avoid in any way, because in EIF systems that are not ventilated, the formation of internal condensation in cavities or irregularities can lead to phenomena of superficial rotting of the walls and of the panels themselves, due to the humidity that can form there.

Starting from these three critical issues (the occupation of public land, the costs of safety in the organization of scaffolding, and the risk of condensation in cavities and irregularities), numerous researches have been carried out throughout Europe, with particular attention in northern countries and in countries, such as Italy, with temperate climates. The selected case studies are found in the Netherlands, in the Province of Milan, and in Bolzano (BZ).

The objective of these researches is to study EIFS that should guarantee, in addition to the achievement of the required energy consumption class, to be easy and very rapid, typically modular, prefabricated in workshop but simple to install, easy to carry, respectful of the original façades of buildings, and, above all, repeatable on other buildings without major engineering adjustments. Although innovative and interesting, the three case studies are applied to buildings with very simple façades, without elements of discontinuity and decorations, a limit that the EIF system currently being studied by this paper's authors is trying to overcome, as will be seen later in the conclusions.

Study Cases

Energiesprong

The Energiesprong Netherlands Project: process innovation for repeatable redevelopment models (Figs. 22.1, 22.2, 22.3, and 22.4) [2]. The energy renewal on a large scale of the big existing building heritage necessarily involves questioning the current operating methods of refurbishment and rethinking a new method capable of identifying the building as no longer as a construction to which apply a renovation project, but rather as an industrial product to approach through the engineering of the entire recovery process. We must recognize the Dutch experience of Energiesprong, the ability to have implemented nearly Zero Energy Retrofits on a large scale, through the application of a system that, thanks to process innovation, was able to implement repeatable models and independent of external factors (national incentives and energy costs) [3].

Energiesprong Netherlands was established in 2010 when, appointed by the national government, it negotiated an agreement between social housing companies and contractors to convert 111,000 housing units into near Zero Energy buildings

Fig. 22.1 Project by Ron van Erck for energy redevelopment with prefabricated panels. *Source*: Centomila case riqualificate in 10 giorni, a Rebuild il super-sistema dell'olandese van Erck—by Mila Fiordalisi, Edilizia e Territorio—Sole 24 ore, 25 June 2015

Fig. 22.2 Handling of the prefabricated panels according to the project of Ron van Erck for the energy requalification with prefabricated panels. *Source*: Centomila case riqualificate in 10 giorni, a Rebuild il super-sistema dell'olandese van Erck—by Mila Fiordalisi, Edilizia e Territorio—Sole 24 ore, 25 June 2015

Fig. 22.3 Energiesprong requalification of a multistory building. Ante- and ex-post-intervention. *Source*: *"Energiesprong Italia: un "salto energetico" per il retrofitting del futuro"* edited by aZero in collaboration with Thomas Maiorin, aZero n. 24, pp. 48–57—EdicomEdizioni

by means of a rapid construction intervention financed by the reduction of energy costs itself. Today, and in very few years of experience, the energy performance of the system has been doubled, intervention costs have been halved and execution times have been reduced: from 2 weeks to a single day for conditions that can be replicated in sequence.

Fig. 22.4 Prototype of the wall block used to wrap the Arnheim row house (NL) in 2014. *Source*: *"Energiesprong Italia: un "salto energetico" per il retrofitting del futuro"* edited by aZero in collaboration with Thomas Maiorin, aZero n. 24, pp. 48–57—EdicomEdizioni

The Energiesprong Netherlands system involves the construction of façade elements integrated with the windows and doors to be applied to the exterior of the existing walls, without thereby interfering with the normal living conditions [4]. The same solution is applied on the roof, where, in addition to the increase in performance of the thermal insulation, the insertion of photovoltaic panels contributes actively to the reduction of energy costs. The Dutch experience has now been exported to several European countries (England, France, and Germany) including Italy, where the establishment of Energiesprong Italia coordinated by Habitech, the Trentino Technology District for Energy and the Environment, allows our country to fully join into the international Energiesprong's network.

Envelope Approach to Improve Sustainability and Energy Efficiency in Existing Multistory Multiowner Residential Buildings (EASEE)

The EASEE project—"Envelope Approach to improve Sustainability and Energy efficiency in Existing multistory multi-owner residential buildings" (Call identifier FP7-2011-NMP EeB, EeB.NMP.2011-3 "Energy saving technologies for buildings envelope retrofitting") [5], presented during the Impact Workshop for the Energy-Efficient Buildings Public-Private Partnership, held by the European Commission in

Bruxels in the 2016, is one of the most interesting work on the scene of the researches about buildings' energy retrofit, due to the high number of the EIF solutions designed and tested with a view to a real application (Figs. 22.5, 22.6, and 22.7).

Fig 22.5 View of the north-east wall of the demonstration building. *Source*: "Soluzioni prefabbricate per la riqualificazione energetica dell'involucro" by Graziano Salvalai, aZero n. 20, pp. 56–69—EdicomEdizioni

Fig. 22.6 Application of the insulating covering panels and detail of the wall anchoring system. *Source*: "Soluzioni prefabbricate per la riqualificazione energetica dell'involucro" by Graziano Salvalai, aZero n. 20, pp. 56–69—EdicomEdizioni

Fig. 22.7 View of the final result. *Source*: "Soluzioni prefabbricate per la riqualificazione energetica dell'involucro" by Graziano Salvalai, aZero n. 20, pp. 56–69—EdicomEdizioni

The refurbishment of the envelope, which aims to reduce thermal dispersion of the façade, is based on the use of prefabricated modular elements to be installed without temporary structures as scaffoldings and without interfering with the residents' activities, preserving at the same time the original appearance of the façades.

The prefabricated modules, 300 × 150 cm sizes, are characterized by an EPS core, 10 cm thick, inserted between two layers of TRC (textile reinforced concrete), a polymeric fiber-reinforced concrete, with a thickness of 1.25 cm each and overall thickness of 12.5 cm.

Before applying the concrete for the finishing by sprinkling, punctual metal connection elements, four units per panel, are fixed in order to be incorporated into the next panel and thus become the anchor points with the existing structure.

The demonstration building chosen to apply the prototype and test the validity of the solution was identified within the variegated real estate assets of ALER (Azienda Lombarda Edilizia Residenziale—Lombardy Agency for the Public Housing) in a multistory residential building, built in 1971, in the municipality of Cinisello Balsamo (MI), with reinforced concrete façades, useful as a case study for other buildings and solutions.

After the laying of the 186 insulating panels and their completion to obtain the correct sealing of the laying joints, the building was monitored, reporting as final result a reduction of 36% of the energy requirement for heating in the winter season [6].

SINFONIA

The Italian experience that more than any other describes today's technological and industrial experimentation applied to the redevelopment of entire building complexes is the SINFONIA project (Figs. 22.8, 22.9, 22.10, 22.11, and 22.12), acronym of "Smart Initiative of cities Fully cohesive to iNvest In Advanced large-scaled energy solutions," funded under the FP7—7th Framework Programme for Research and Technological Development [7], which is underway in Bolzano, a pilot city in collaboration with Innsbruck, in the neighborhood of Passeggiata dei Castagni.

The five-year initiative aims to implement, in some medium-sized European cities, wide, integrable, and scalable energy solutions, defining case studies and related intervention procedures, to be tested and approved by all the public and

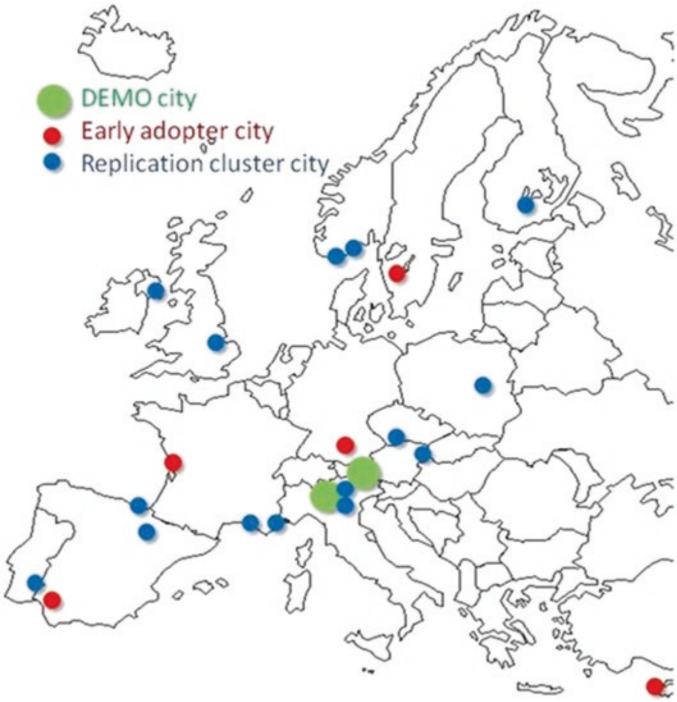

Fig. 22.8 Map of the cities involved in the SINFONIA project. *Source*: http://www.europaregion.info/en/sinfonia.asp

Fig. 22.9 View, before and after, of the intervention in Passeggiata dei Castani in Bolzano (BZ), Italy. *Source*: https://www.agenziacasaclima.it/it/progetti-di-ricerca/sinfonia/sinfonia-risanamento-via-passeggiata-dei-castani-1783.html

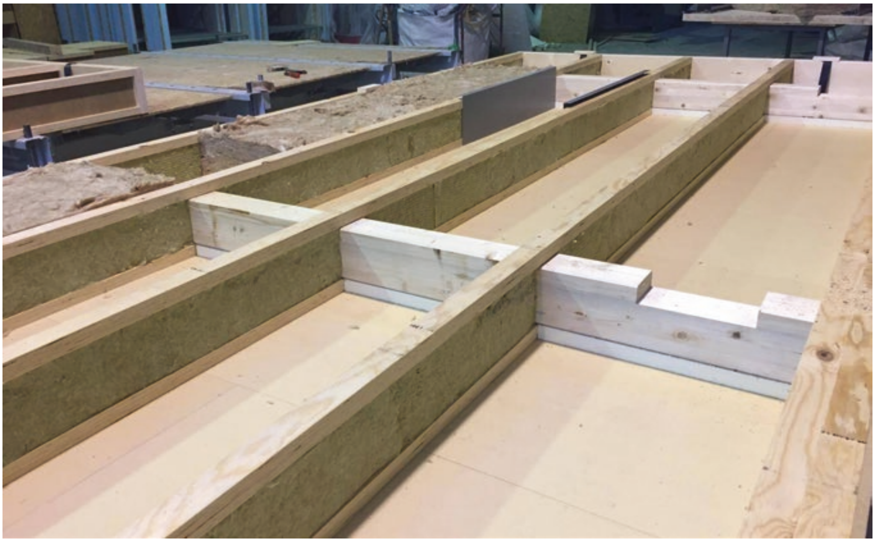

Fig. 22.10 Construction of the self-supporting wooden frames that constitute the insulation elements of the façade. *Source*: https://www.agenziacasaclima.it/it/progetti-di-ricerca/sinfonia/sinfonia-risanamento-via-passeggiata-dei-castani-1783.html

private actors involved, not only in Innsbruck and Bolzano, but also in five other cities, defined as "early adopters," which actively participate in SINFONIA project: La Rochelle (FR), Rosenheim (DE), Pafo (CY), Sivigilia (ES), and Borås (SE) [8].

Italian experimentation involves 37,000 m^2 of public housing built from the 1950s to the 1990s (66,000 m^2 in Innsbruck), and aims to save about 50% of primary energy through a façade retrofitting technology characterized by 224 prefabricated modular panels crafted in a workshop [9]. The modular panels have a

Fig. 22.11 Close-up of the junction elements between the façade and the EIF system. *Source*: https://www.agenziacasaclima.it/it/progetti-di-ricerca/sinfonia/sinfonia-risanamento-via-passeggiata-dei-castani-1783.html

Fig. 22.12 Laying of the façade elements. *Source*: https://www.agenziacasaclima.it/it/progetti-di-ricerca/sinfonia/sinfonia-risanamento-via-passeggiata-dei-castani-1783.html

self-supporting frame made of wood and rock wool, integrated with new frames, to be applied directly to the existing façades. The system will then be completed with a ventilated structure, while on the roof, the use of renewable energy sources for the production of electricity, thermal energy, and sanitary hot water will allow increasing the production by renewable energy sources about 20% [10]. Today there are already 16 administrations of European cities that have joined this model of energy redevelopment that, through a monitoring period that it will verify the feasibility in each city, will replicate the results in the coming years [11].

Conclusions: Towards an Innovative EIF System

The state of the art of the existing technique refers, as already written, to the known solution of the "thermal coat" or EIF, that is the application of single insulating panels of small dimensions (typically 60 × 120 cm), then finished with a surface layer of plaster. The recent experiments illustrated in the previous paragraph require the manual realization of self-supporting panels with a height equal to the stories of the buildings to be redeveloped, and a length up to about 10 m, made by a wooden frame system with interposed insulation and then a wooden finishing or a cladding panels system that can be plastered or not. However, this is a technology that is limited to simple buildings, characterized by regular walls, absence of moldings, bas-reliefs, and decorative apparatuses.

In addition, traditional EIF systems are subject to an ever-expanding variety of types of insulating panels, glues and fixing plugs, distribution nets, joints, reinforcement elements for punctual loads, etc., which have made a must the training of specialized technicians and workers that have to be able to identify both the correct EIF system and its better onsite construction system, specific for any type of intervention. In the absence of these skills, instead of achieving the expected benefits, the risk is to obtain worse results, such as condensation, mold, and rotting of the inner layers.

Among the further problems, we recall the need to set up the building site with a full-height scaffolding along the entire perimeter of the building for a long period, a particularly invasive condition as regards obtaining authorizations and the costs of land occupancy, the need for extended execution times, the difficulty of pursuing the removal of all thermal bridges, the difficult dialog with technical elements present on the façade such as idronic pipes, gas pipes, electrical systems, as well as the induced discomforts for the inhabitants, such as the risk of thefts facilitated by the presence of the scaffolding on the façade and the presence of dust or debris, typical of the building construction traditional processes.

A first answer to these problems seems to have been already given by the experiments previously mentioned. However, these experiments draw on a traditional, totally manual, mode of execution, just delocalizing the construction phase and exclusively aimed at simple, regular building volumes, without moldings or reliefs.

Instead the EIF system currently being studied by us, concerns an insulation system, made by prefabricated thermo-insulating, self-supporting, and reversible shells, for the energetic retrofit of the envelope of existing buildings that have overhangs, cornices, moldings, decorations, and covers, both of simple design and of complex articulation. The field of the proposed system is the "Industry 4.0" for the automated building prefabrication.

This term indicates a direction of industrial automation that integrates new production technologies and new business models, increasing productivity and production quality. Industry 4.0 is based essentially on the concept of "Smart Factory," divided into three key elements: a new collaboration between operator, machines, and tools (*Smart Production*); the integration between the IT infrastructures and the techniques that allow the integration of the systems (*Smart Service*), and finally the attention to energy consumption, creating more performing systems and reducing energy waste (*Smart Energy*). It therefore presupposes decentralization and collaboration between systems, in particular between cyber-physical systems (CPS) and computer-based ones.

In fact, the EIF system under study proposes the integration of information technologies, such as laser scanners and 3D printing with construction technologies for energy savings. The laser scanner is currently the fastest and most accurate technology for recording and creating 360° 3D models of the surrounding environment, including every single physical element that compose it. In fact, by measuring the spatial position of tens of thousands of points per second at very high speed, it allows a containment of the costs of relief and a reduction in the costs of downtime of the construction sites.

Whatever the laser scanning technology used (in the architectural field, the most advanced is the phase scan), the result is a very dense cloud of points from which it is possible to obtain an impressive number of data and processings. One of these processings allows, through the 3D printing of the shells, to shape the insulating material according to a very precise offset of the façade of the existing building, so to faithfully showing outside any decoration or element of the façade and, at the same time, absorbing internally the thickness of any technical elements, such as downspouts, cables, pipes, etc., or even the adding of new systems.

This is a crucial aspect for the redevelopment of the historic centers of European cities; the system currently under study, above all, allows energy redevelopment operations also on listed buildings, thus resolving any thermal bridges without affecting the architectural and aesthetic quality of the buildings. It also aims to design a construction process delocalized and totally automated, with the aim of reducing the construction costs of a traditional EIF system, thanks to the use of industrial processes to make the market for energy renewals of existing buildings accessible on a large scale.

Since the shell system is self-supporting and modular, it also guarantees great ease of construction and ease of assembly, thus avoiding the installation of scaffolding during the installation time and therefore limiting the induced risks, as like thefts in apartments, fallen of debris, low level of safety for workers, or other typical dangers.

Also this last is an important aspect of the topic of the energetic renewal of our historical centers, since the EIF system that we propose allows the redevelopment of the building envelope in very short times, limiting the typical inconveniences of construction phases extended over time, especially in small spaces as like the ones in city centers, and allowing—finally—the regeneration of the urban environment, thus restoring the building envelopes that are degraded without losing those morphological features that make our cities attractive.

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Chapter 23
European First Recyclable Façade System with Reclosable Fastener Fixation: Research Development, Grants of Patents, Pre-certification Testings and Product Publication of Façade System StoSystain R

Ferdinand Oswald

Introduction

The aim of the façade research project facade4zeroWaste is to develop a fourth-generation façade. Man-made structural envelopes have passed through three major stages of development in the past:

1. The main purpose of the first structures was protection from the weather (Fig. 23.1a).
2. The next stage began with conscious design of the envelope that took visual aspects into account (Fig. 23.1b).
3. Due to the energy crisis in the 1970s, the third step was towards reducing heating energy by means of thermal insulation (Fig. 23.1c).
4. Triggered by the climate change debate, the construction industry has for some time been exploring the topic of sustainable building. This ushers in the next, and thus the fourth stage of development: the aim of the façade research project facade4zeroWaste is to develop a sustainable, efficient successor for the currently predominant exterior insulation finishing systems (Fig. 23.1d). As one of the market leaders in exterior insulation finishing systems (EIFS), STO is thus the ideal partner for developing and introducing such a façade system on the market.

The name of the project is the fourth-generation façade, Façade Four Point Zero Waste. The 4.0 included in the title is thus to be seen as the first version of the next generation of façades. facade4zeroWaste combines design qualities such as appropriate surfaces (textures) and a high level of variability with the simplicity of EIFS in terms of installation, adding the characteristics of sustainability which will become increasingly important in the future.

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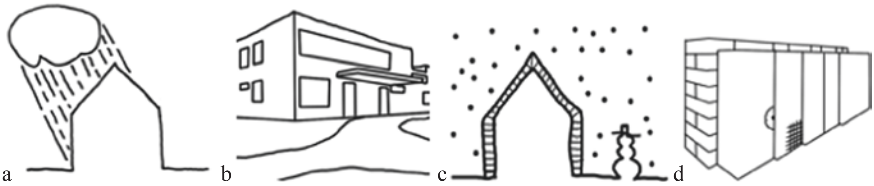


Fig. 23.1 (**a**) Protection from weather [1], (**b**) visual aspects [2], (**c**) reducing heating energy with thermal insulation [1], (**d**) insulation finishing systems (EIFS) and facade4zeroWaste with fastener fixation [2]

Fig. 23.2 Demolition of EIFS (Source: https://www.immoclick24.de/wp-content/uploads/2015/07/MM05-13_2_500x400.jpg)

Examination of the problem

The status of EIFS is that there is no sustainability assessment of the entire life cycle (including profitable separation, disposal and recycling) and no positive recycling behaviour of building components at the end of the period of use (recovery of resources) (Fig. 23.2).

Methods of reutilization for EIFS are:

1. One method is the reutilization of materials that the materials and macromolecules can survive. This works with a shredding process than the extraction of EPS fragments (extruded polystyrene insulation). This is the so-called solvolysis process (solvent liquids). After doing this solvolysis process, the extraction of polystyrol is possible. This is a very rare method because the procedure is expensive by making it in small amounts.
2. A very common procedure is energetic reutilization. It is the combustion of macromolecules by burning them by extraction of gas, electricity and vapour.

3. The aim of the research project "facade4zeroWaste" was to develop a product which can be recycled. Aim is then the separability of facade components, the recovery of resources and easy clean separation—a sorted recyclable EIFS. In detail, the target was recycling and reuse of facade components like the insulation and mechanical fixation.

Research and Development

Fixation Without Glue/Mortar (Sorted Component Recycling)

First idea prefabricated click-insulation façade module with reclosable fastener fixation (Fig. 23.3). This "click" façade system works like parquet floor. The disadvantage of this façade system was that it is reusable but no recyclable. There is no chance of separability of facade components because insulation and surface plaster are glued together.

But in this façade concept the idea was born to develop a façade system without using glue, but fixation with reclosable fastener and mechanical fixation.

Reclosable Fastener for Façade System

What is reclosable fastener and is it useful for a façade system?

The simple fixing of grip fixing system is inspired by the burdock plant from nature (Fig. 23.4). The prickly heads of these plants are noted for easily catching onto fur and clothing, thus providing an excellent mechanism for seed dispersal.

The first artificial reclosable fastener fixation, the "hook-and-loop fastener", was conceived in 1941 by Swiss engineer, George de Maestra. The hook-and-loop fasteners are known as Velcro® in the USA, and in German speaking countries as "Klett".

Fastening systems as the presented one have been used in different fields of economy in the past years and decades, such as automotive and aerospace industry,

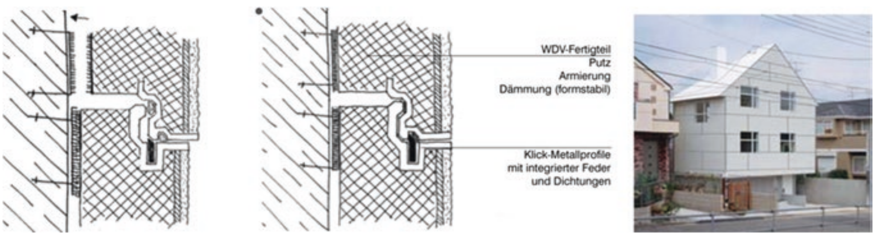


Fig. 23.3 Prefabricated click-insulation facade module with reclosable fastener fixation [3]

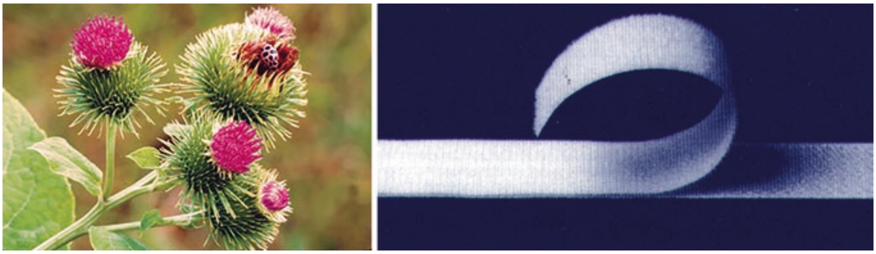
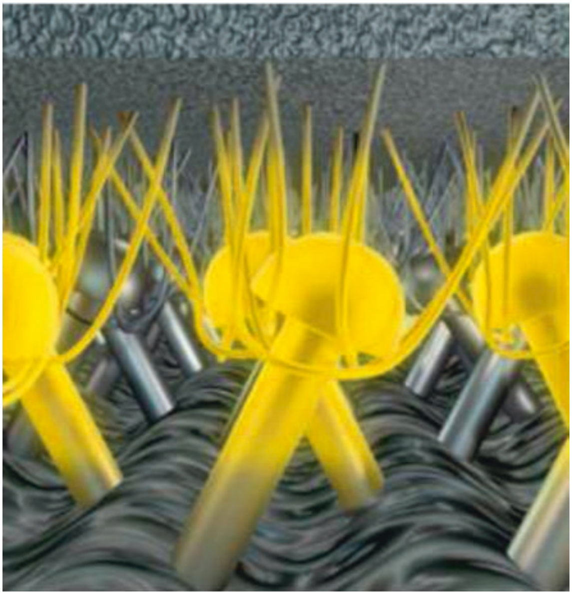


Fig. 23.4 Burdock plant, loops of the plant [4] and hook-and-pile fastener [5, 13]

Fig. 23.5 Hook-and-pile fastener [13] for the facade4zeroWaste system [3]



medical engineering and textile industries. Moreover, applications in the building construction industry have been recently established.

We made a deep analysis of different reclosable fastener fixations to find the perfect one for a façade system. There are many different types of them like metal fasteners, pile–pile fasteners (mushroom-shaped heads), touch fasteners, hook-and-loop fasteners and hook-and-pile fasteners. Criteria for the decision for the perfect Klett have been thermal conduction and heat expansion, very high grip performances for heavy loads, easy to remove, etc. Finally, in cooperation with a hook-and-loop fastener manufacturing company we done the decision for the hook-and-pile fastener, because it is possible to have fixation on different stages (Fig. 23.5). Users can contact softly and then it is possible to repeat calibration (piles integrated in fleece). Also the hook-and-pile fastener hast very high shear stress performance, this is important to compensate the vertical façade loads. With the fastener manufacturing

Fig. 23.6 Evaluation bonding force [6]

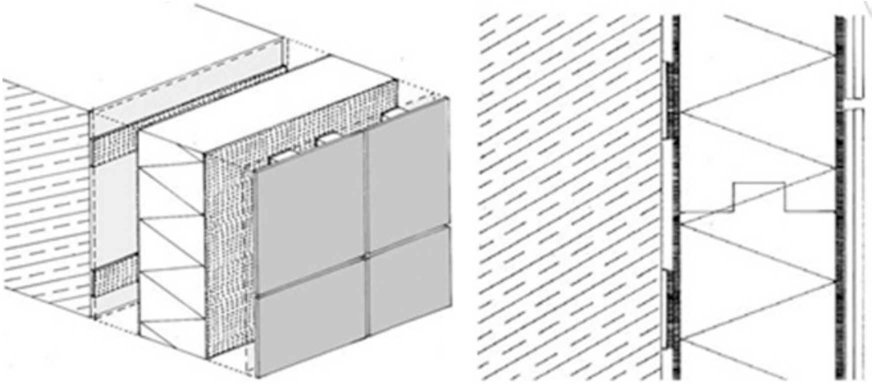


Fig. 23.7 Different façade system concepts with fix hook-and-pile fasteners [3]

company have been done test realization in the laboratory due to closing force, bonding strength, cohesion strength (Fig. 23.6). Even the micro-structure of the bonding strength have been investigated with computer tomography (CT).

Dismantling and Sorting by Component Type for Recycling

It was a crucial question how we can fix the hook-and-pile fasteners on different building components. We made a huge study to verify the different possibilities to fix hook-and-pile fasteners on insulation, loadbearing walls, façade panels or use additional a mechanical fixation and we developed different façade concepts with hook-and-pile fasteners (Fig. 23.7).

Tolerances Compensation

A significant problem needs to be solved: loadbearing walls—the main application for the proposed developments—regularly show small irregularities that could hamper the application of insulation systems in general. Such irregularities can be,

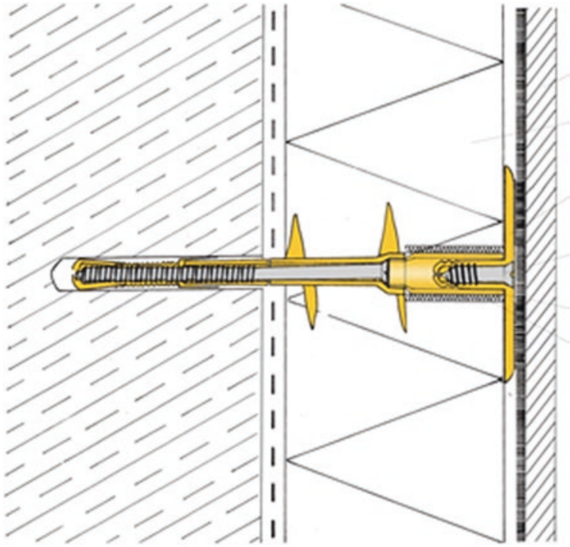


Fig. 23.8 "Stellfuch" (adjust fox) to adjust tolerances between insulation and wall [3]

for instance, caused by not totally planar surfaces. Glue does compensate tolerances in EIFS between insulation and wall. In a façade system without glue there isn't this function and benefit any more. Therefore, we first tried to find a solution with the German product called "Stellfuch" (adjust fox) to adjust these tolerances between insulation and wall (Fig. 23.8). This mechanical fixation system has a screw thread and therefore can adjust these tolerances between insulation and wall by moving the insulation forward and backward. The mistake here is that after adjusting there can arise air gaps or even worse ventilation slits between insulation and wall. This rise up the problem of reducing the insulation performance at the façade system.

To find a solution to compensate irregularities of the load-bearing wall, we developed a façade system with a façade panel and a new specific mechanical fixation element (Fig. 23.9). On the façade panel are integrated the hook-fasteners. The mechanical fixation element is round shaped (rotunda) with pile fastener and has a screw thread for adjusting irregularities of the load-bearing wall by moving the façade panel forward and backwards. There is solely a thin layer of air outside of the insulation and irregularities of the load-bearing wall can be balanced (±1.5 cm) (Fig. 23.10).

Prototypes have been manufactured in different manufacturing techniques like laser sintering, laminated object modelling and CNC milling. In the development phase of the project we commissioned companies in Germany and the Institute for Production Engineering at TU Graz, Austria to produce these prototypes. Later a huge anchor company was integrated into this research project for serial production (Fig. 23.11).

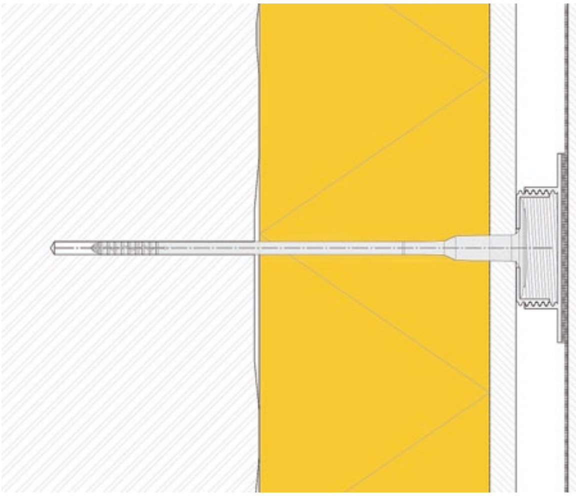


Fig. 23.9 System with façade panel and mechanical fixation to adjust tolerances [3]

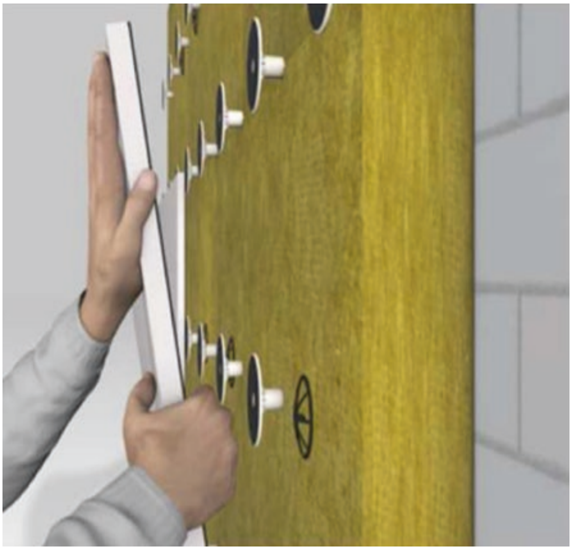


Fig. 23.10 Façade panel and mechanical fixation element (round shaped) during assembly [7]

Patent Grants

Different patents have been granted at the European Patent Office (EPO) for this project, like *fixing element, fixing system and facade system, it* was published on 4th of April 2012 with the European patent number: EP 2436851 A2 (Fig. 23.12).

Fig. 23.11 Prototypes manufacturing techniques of mechanical fixation: laser sintering, laminated object modelling and CNC milling [3]

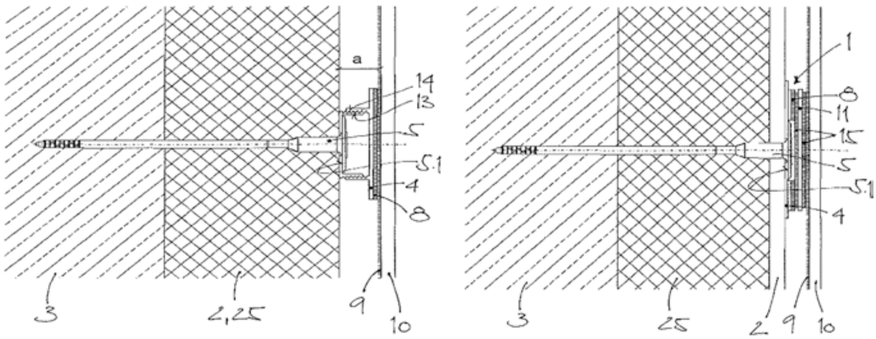


Fig. 23.12 Patent grants: fixing element, fixing system and facade system [8]

Pre-certification

Under the leadership of Institute of Architecture Technology, TU Graz has been made several initial tests to become the pre-certification of the new façade system. It was the implementation of fire tests, construction statics tests, weathering tests, building physics simulations and trial installations.

Test Constructions

In the realization of many trial installations we would like to find out the conformability of the craftsman with the construction details and construction workflow. Secondly we would like to proof the detailing of the construction and architectonical design opportunities.

We adapt the construction details due to the conformability for the craftsman's like the handling on construction site and the simplicity of assembly (Fig. 23.13). Also the development of crucial details like corners and openings detail-situations has been made. For example, the EIFS has at the corners a surface bonding with glue. The façade4zeroWaste-system has only a mechanical fixation. Therefore we developed a simple fastener-fixation-corner-angle to have the corner detail fixation (Fig. 23.14).

Also the architectonical relevance should be evaluated, which means, which architectonical design opportunities are possible with this system. In Fig. 23.15 there is a façade design example with visible gaps.

Structural Laboratory Tests

By the implementation of construction statics tests we realized a wind suction and pressure test due to ETAG 017 (European Technical Approval Guidelines) (Fig. 23.16). The tests have been made at Laboratory for Structural Engineering at TU Graz and we commissioned Prof. Stefan Peters from Institute of Structural Design, TU Graz to supervise the tests and results evaluation. In comparison to the

Fig. 23.13 Trial installations for conformability of craftsman [3]

Fig. 23.15 Architectonical relevance design opportunities, façade design example with visible gaps [3]

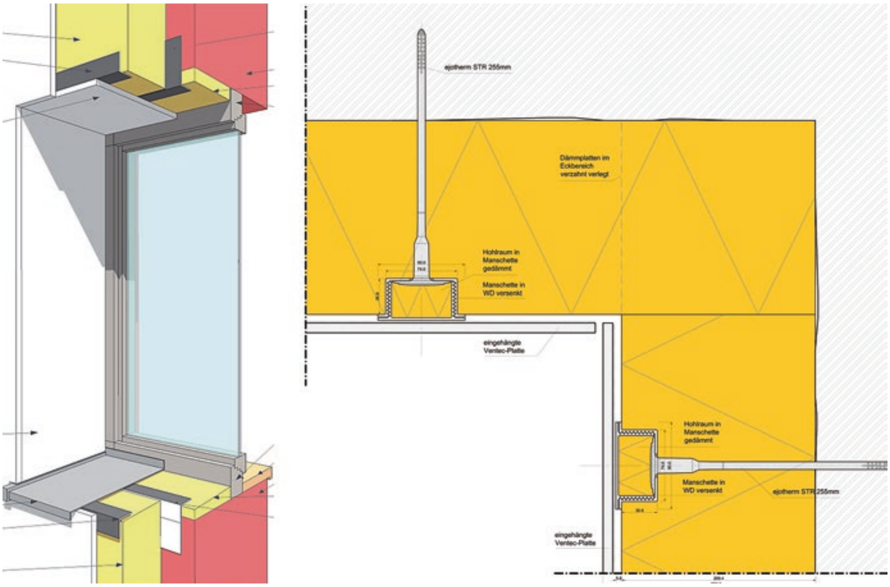


Fig. 23.14 Fastener-fixation-corner-angle for corner detail fixation [3]

EIFS System which has a surface bonding with glue, here the façade system is a mechanical fixation only with fastener fixation/Klett. In many sequences we had wind load assumptions of suction and pressure. The full wind load pressure was +5.232 Pa and the wind load suction –4802 Pa. The result has been very positive, because mainly the anchor damage (red points) and there was no removals at the fastener fixations (Fig. 23.17).

Fig. 23.16 Implementation of construction statics tests wind suction and pressure test [3]

Weathering Experiments

The implementation of EOTA test application (European Organization for Technical Assessment) was made with weathering tests due to ETAG 04 (European Technical Approval Guidelines). The tests carried out at Sto SE & Co. KGaA laboratories in

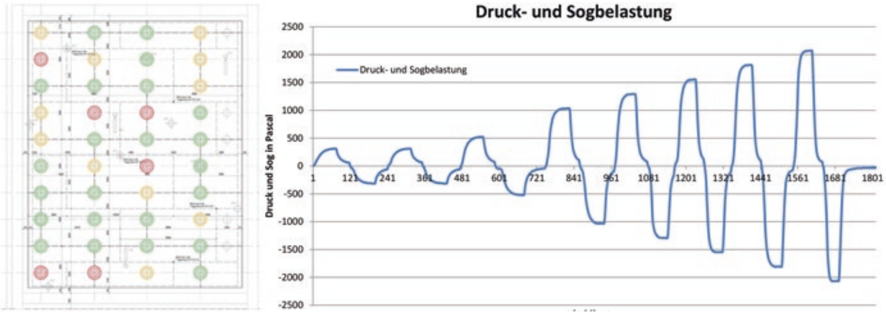


Fig. 23.17 Left: Construction statics tests: anchor damage (red marked), right: Sequences wind load assumptions of suction and pressure [3]

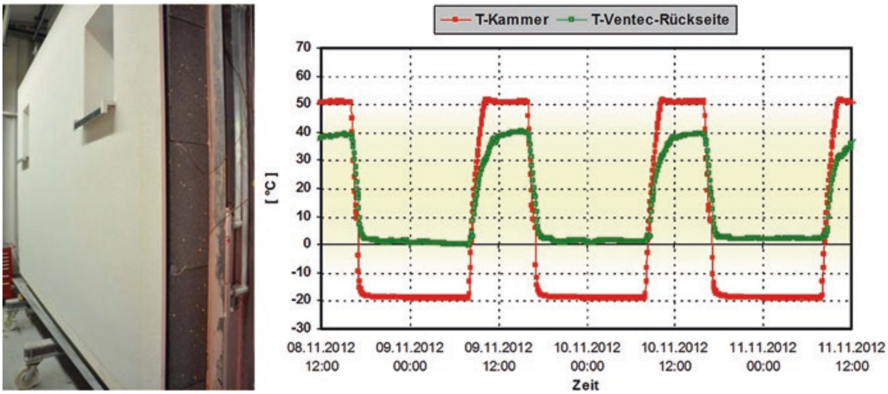


Fig. 23.18 EOTA test application (European Organisation for Technical Assessment) weathering tests due to ETAG 04 (European Technical Approval Guidelines) [9]

Stühlingen, Germany. Here the hot and cold temperature cycles have been tested in a simulated long-term test (Fig. 23.18). The temperature ranges have been from –15 till +50 °C and ran in fast and high sequences (Fig. 23.19). The test result was very positive and it was without affect or destroying any component of the façade system. Additionally the building physics behaviors has been examined and calculated by the Consulting Engineers Rosenfelder and Höfler. There is no risk of condensation or similar danger within the façade system [12].

Fire Testing

By the implementation of fire tests to evaluate the hazard category it was made a *single burning item (SBI)* at *IBS—Institute for Fire Protection and Safety Research* in Linz, Austria (Fig. 23.20). The SBI tests were made due to the *ÖNORM EN*

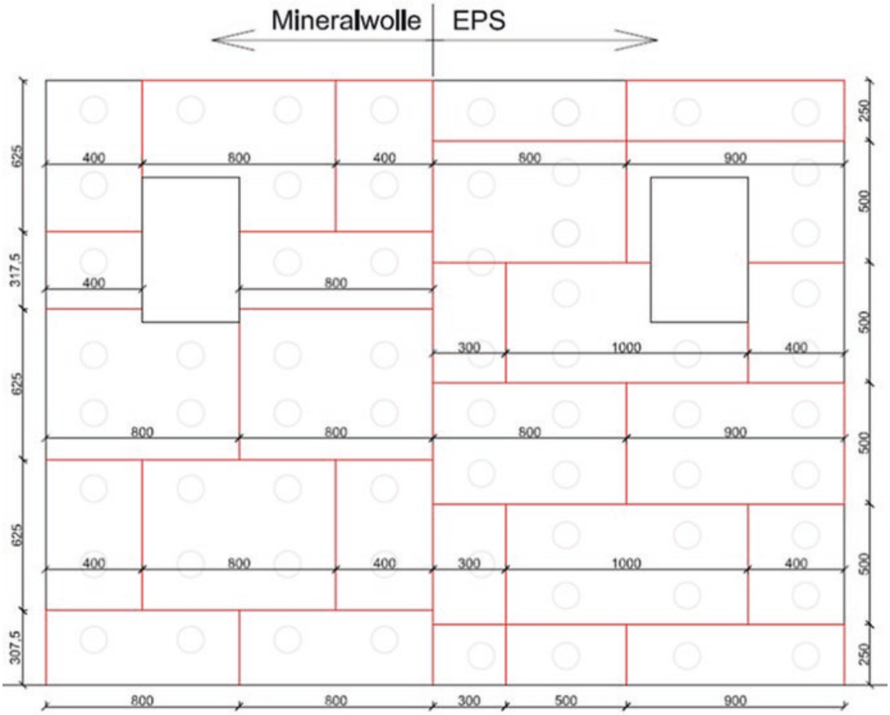


Fig. 23.19 Drawing of façade construction for EOTA test application: left mineral wool and right extruded polystyrene insulation (EPS) [3]

13823-2011-01 [1]. We used two types of the insulation material for the façade construction: extruded polystyrene insulation (EPS) and mineral wool (Fig. 23.21).

The official result of the façade construction with EPS insulation was B-s2, d0, which means limited smoke emission and no combustible drips/no dropping.

Utilization Testing

Installation

The assembly is craftsman conform. It has very good handling requirements on construction site. Finally the assembly time is very short. This is because it is a dry construction site and there is no need for drying time. In contrast to EIFS there is the need of drying time for the glue. This is a huge benefit because it is the reduction of construction time and in the same way than reduction of costs for workmen (Fig. 23.22).

Fig. 23.20 Implementation of fire tests single burning item (SBI) at IBS—Institute for Fire Protection and Safety Research [3]

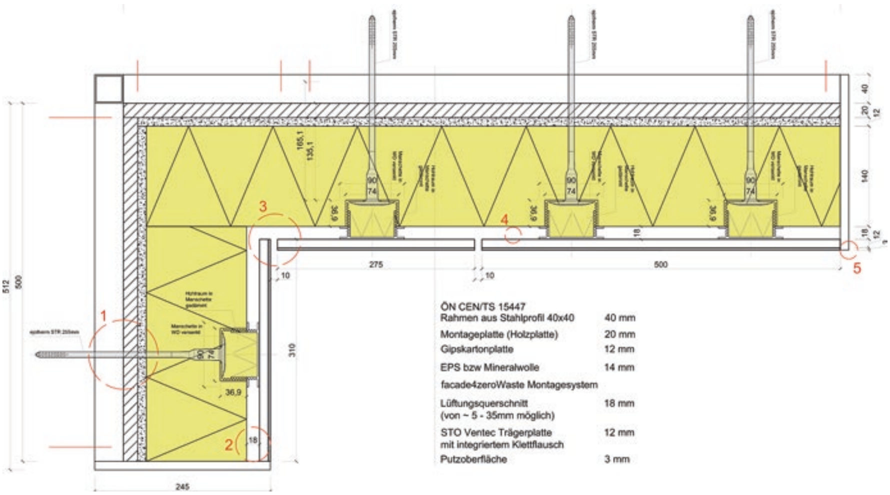


Fig. 23.21 Drawing of façade structure, fire tests single burning item (SBI) due to ÖNORM EN 13823-2011-01 [3]

Disassembly/Dismounting

The disassembling is possible without specific construction instruments. The removal process is possible with common instruments like palette knives or triangles (Fig. 23.23). For disassembling the facade4zeroWaste façade system we also granted a patent as shown in Fig. 23.24.

Fig. 23.22 Fast assembly time because dry construction site (no glue) [3]

Regardless of Weather Conditions

The assembly is regardless of weather conditionings. We tested the winter assemble with temperature –10 °C (the lowest processing temperature of each single component has to be consider). With that cold temperatures assembling and dis-assembling works without any problems because it is a dry construction site and there is no need for glue and drying process. This is a great advantage regarding construction do not need to stop in wintertime. Another benefit of having a façade system without glue is the avoidance of pollution and dirty water by cleaning construction equipment. It is a clean and dry construction site (Fig. 23.25).

Sorting Component Uniform for Recycling and Reuse

The dismantling is simple, dust- and noise-reduced and it has nearly unmixed separation as well as reuse and recycling of the system components (Figs. 23.26 and 23.27).

Conclusion

The idea of a recyclable facade insulation system that can easily be dismantled after its lifetime and reused thanks to an innovative grip fixing system consisting of mushroom-shaped heads and loops—grip fixing instead of adhesive. The benefits at a glance:

Fig. 23.23 Disassembly with common instruments [3]

- Nearly unmixed separation as well as reuse and recycling of the system components.
- Free choice of insulation material.
- Surface variety with individual render surfaces from StoSignature.
- Render carrier board made of recycled glass.
- High-quality mushroom hook and loop grip fixing technology for increased reliability and durability.
- Simple fixing thanks to grip fixing system inspired by the burdock plant.
- Simple, dust- and noise-reduced dismantling.

The facade system *facade4zeroWaste* won the award of the EQAR—Recycling Prize 2015. The prize ceremony was held at 8th May 2015 at the "Congress of Construction Material Recycling in Europe" in Rotterdam, Netherlands (Fig. 23.28). *facade4zeroWaste* was also nominated for the Green Tech Award 2016 in Germany. In January 2017, the façade system was presented from Sto SE & Co. KGaA Germany as the product *StoSystain R* on the building fair BAU 2017 in Munich (Fig. 23.29).

Fig. 23.24 Disassembly patent [10]

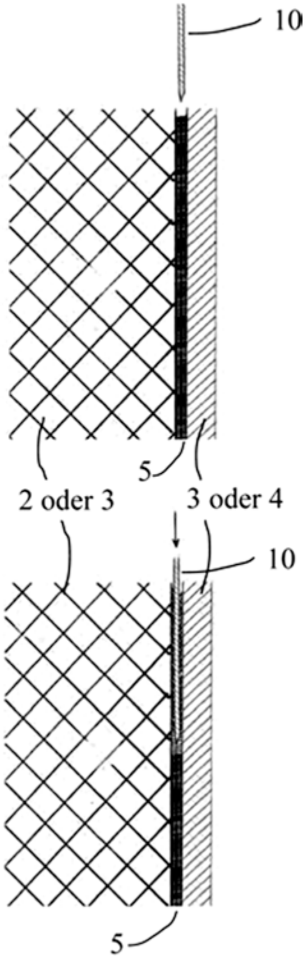


Fig. 23.25 Weather independent assembly tested winter −10 °C [3]

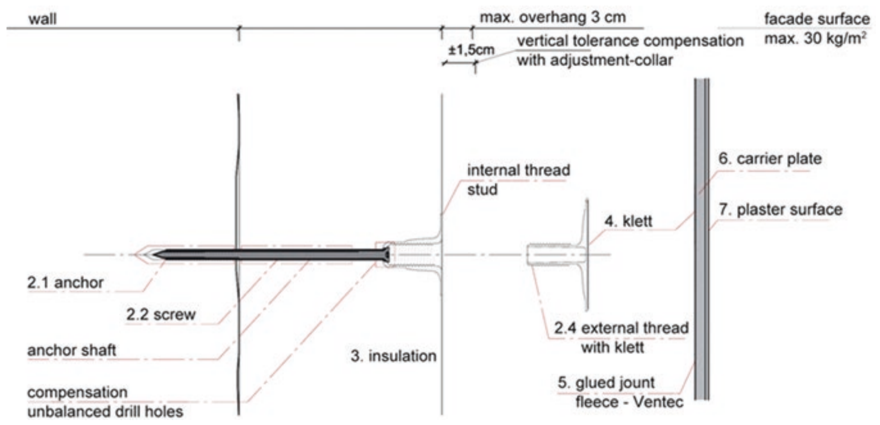


Fig. 23.26 Overview of facade4zeroWaste façade system [3]

Fig. 23.27 Sorting by component type for recycling + reuse and transportation, StoSystain R façade system [7]

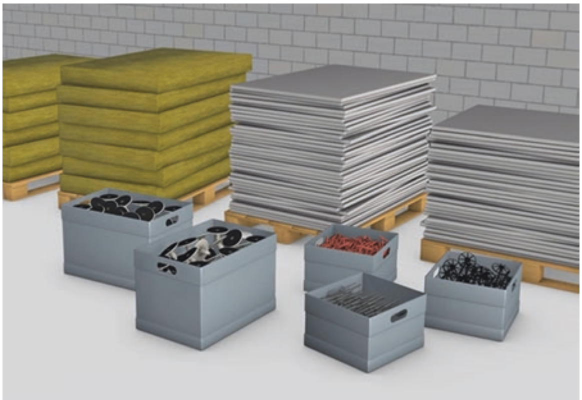


Fig. 23.28 Prize ceremony EQAR—Recycling Prize 2015: from left: E. Messow (Sto), G. Gretzmacher (EQAR and BRV) and F. Oswald (TU Graz) [1]

Fig. 23.29 StoSystain R on the building fair BAU 2017 in Munich [7]

There the façade system was getting the award: *Innovation Award for Architecture and Building* [11]. The first building projects with the *StoSystain R* system were realized already in year 2017 and in the near future objects with *StoSystain* with visible gaps are planed [5].

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Chapter 24
Impact of Traditional Architecture on the Thermal Performances of Building in South Morocco

Karima EL Azhary, Mohamed Ouakarrouch, Najma Laaroussi, Mohammed Garoum, and Majid Mansour

Introduction

In countries where climatic conditions are generally arid, there is an acute housing crisis whose thermal comfort has often been neglected by designers, the concern to build quickly in large quantities has favored the collective housing model. This rapid residential development has been done without considering the issue of climate integration, which results in significant energy consumption.

The residential sector in Morocco reached a consumption of nearly 6.5 million TOE (tonne of oil equivalent) representing 33% of national energy consumption [1].

Morocco, with its geographical and climatic diversity, represents a relevant example of empirical practices for adapting its built environment to its different natural environments.

As a result, vernacular or traditional architectures, such as ksour and traditional medina-type houses, have always met certain environmental challenges by perfectly adapting to the different climates: humid, semiarid, arid, and desert [2]. These architectures are described as sustainable constructions using local thermo-regulating materials such as earth, stone and wood, thick walls and massive flat roofs creating inertia and comfort inside, well-ventilated designed environments avoiding overheating due to solar gains and compact architectural forms in old fabrics that are also compact. The impact of developments on the traditional heritage has not been taken into consideration although the latter represents a rich resource for sustainable building practices. Many researches have been carried out to study the impact of bioclimatic designs on the thermal performances and building sustainability using different

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configurations design in traditional architecture. Sayigh et al. [3] treated several case studies in realizing green building while examining sustainability, energy, and architecture design factors. Aboul Naga et al. [4] studied different environmental sustainability assessment of buildings in hot climates based on the UAE case study. Barozzi et al. [5] presented an overview of adaptable envelopes and shading systems applied in contemporary architecture, where a study of different design approaches and a brief analysis of exemplifying case studies were done. Soflaei et al. [6] analyzed the socio-environmental sustainability in traditional courtyard houses of Iran and China. Dayaratne et al. [7] proved that orientation and traditional architecture are key factors on energy efficient features in vernacular architecture for improving indoor thermal comfort conditions in Sri Lanka. The investigation of traditional architecture is always related to measure the thermal properties of different local construction materials used, where the Earth adobe, wood, and stone constitute a main element. El Azhary et al. [8, 9] proved the ability of earth material in resisting to the hard climatic conditions, moreover, to ensure good thermal comfort during winter season. Lamrani et al. [10] investigated the thermal properties of a new ecological building material based on peanut shells and plaster. Another work of Lamrani et al. [11] concerns thermal study of clay bricks reinforced by three ecological materials in south of Morocco. The present study is devoted to the investigation use ways of energy by showing the impact of traditional architecture on the thermal comfort and the building energy consumption according to the variation of the outside temperatures.

This work is a contribution to valorize the use of traditional architecture and environmental construction materials resisting to the hard climatic conditions by improving its thermal proprieties and its impact on the energy performances and the thermal comfort of the occupants.

Case Study: KSAR EL FIDA

In order to study thermal behavior and measure the perception of comfort in traditional buildings, we opted to work on the Ksour configuration design, which is one of the most popular residential architectures in the arid and semiarid regions of Africa and which are the impregnable fortresses erected on the major caravan routes that linked north to south sub-Saharan Africa. The province of Errachidia in Morocco is chosen for its representativeness of the semiarid environments found in the south of the country. It was home to more than 400 ksars and Kasbas, which form an impressive chain bordering the valley of Ziz de Gheris and Guir in the middle of the lush palm groves, built in rammed earth and adobe as shown in Fig. 24.1. These ksours are characterized by a few features that give them exceptional value, such as their adaptation to climatic conditions, their fusion and integration into the surrounding and environmental landscape. The Fida ksar located in the city of Rissani is a residential complex that meets the needs of a community with common interests, such as guaranteeing housing for families, including animals, ensuring the conservation of crops, defending the population and its property, and sheltering the religious, social, and economic life of the same community.

Fig. 24.1 View of Kasr El Fida

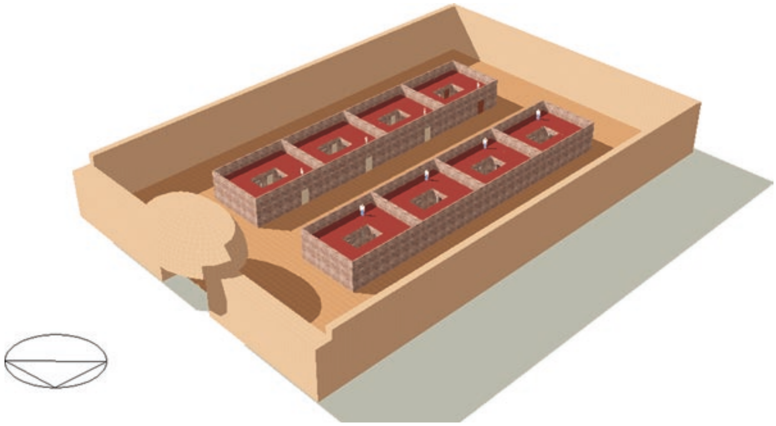

Fig. 24.2 Spatial distribution of building

Description of the Studied Building

The study concerns traditional housing samples of Ksar El Fida in Rissani City, which have a light urban typology. Figure 24.2 shows a residential construction, in which eight buildings of similar architectural design are used as case studies. The housing compound is surrounded by an enclosure wall of 1 m in thickness. Each building is covering a surface area of 80 m^2. Windows are facing to the Patio, which is an open-air courtyard around which are articulated the various components of the house, it is a temperature regulator, source of lighting and sunshine (Fig. 24.2).

The building set is in the form of ground floor, with a ceiling height of 3.07 m, the size of windows is 1.20 × 1.40 m according to the various building parts. It occupies 17.46% of the facade exposed to the Patio (32.34% of the floor surface). The windows are characterized by a wooden joinery and simple glazing of 3 in. thickness. The spatial distribution of typical building is represented in Fig. 24.3. The building

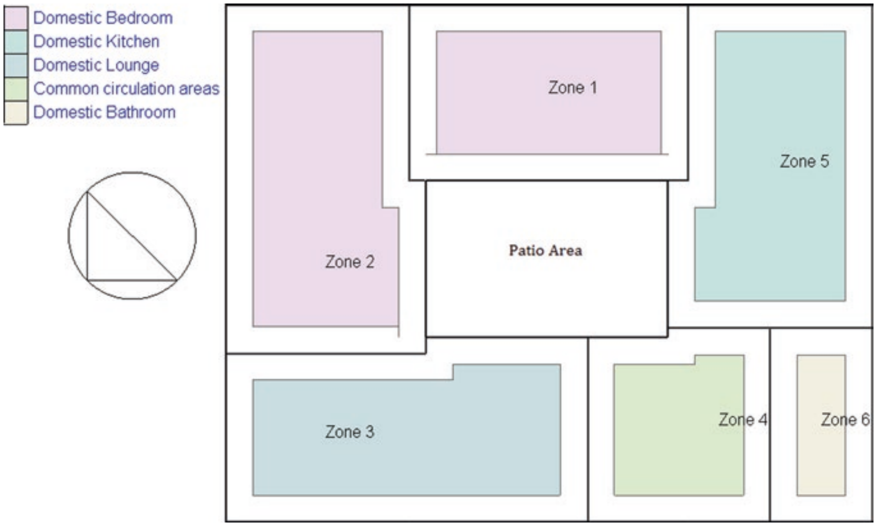

Fig. 24.3 Spatial distribution of building

benefits from two modes of natural ventilation, namely horizontal ventilation through windows and vertical ventilation created by the opening of the building on the patio, which represents an effective ventilation system in arid regions, known for its ability to ensure a cool breeze in the building and limit overheating in summer.

The natural ventilation rate including infiltration is about 36 m^3/h/pers with density occupancy of 0.14 pers/m^3. No heating or conditioning system is used. Each building is divided into six thermal zones according to their activity as presented in Fig. 24.3. The average number of occupants per housing, which represents the inhabitant occupancy rate, is equal to four persons.

Climate Analysis of Rissani City

The city of Rissani of Errachidia Province is located in southeast Morocco, at latitude of 31°55′53″ North and a longitude of 4°25′35″ west. It rises to an altitude of 1039 m above sea level. The high temperatures present a large part of the year vary from 28.5 to 40 °C. The climate of Errachidia Province through the data presented in Figs. 24.4 and 24.5 is a cold climate in winter and hot and dry in summer. It is expressed by intense solar radiation, with very high temperatures in summer with a maximum average of 41.6 °C during the month of August. This climate is characterized by an average relative humidity, a considerable precipitation in winter and almost rare in summer, with a very significant difference in the daytime temperatures.

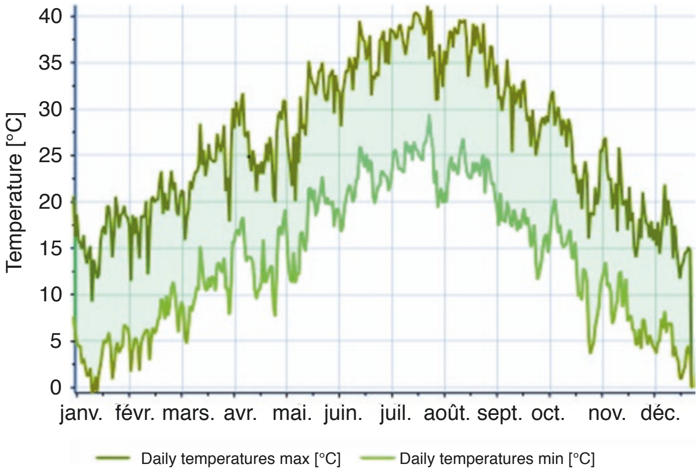

Fig. 24.4 Global solar irradiation [12]

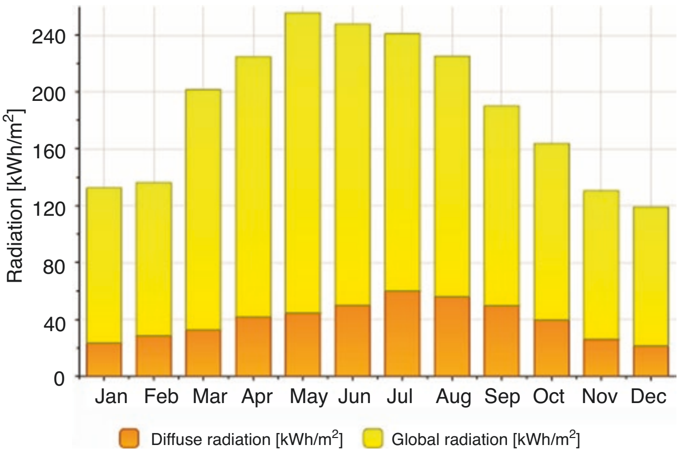

Fig. 24.5 Indoor daily temperature [12]

Description De L'enveloppe de Bâtiment

An effective choice of building materials contributes to reduce the ambient air temperatures inside building spaces. Their thermal effects depend on two main qualities, thermal resistance and heat capacity. Figures 24.6 and 24.7 illustrate a description of different layers of materials that make up the exterior roof and exterior wall of each studied building. Identification of thermo-physical properties of used material have previously been the subject of an experimental studies [13, 14] (Table 24.1).

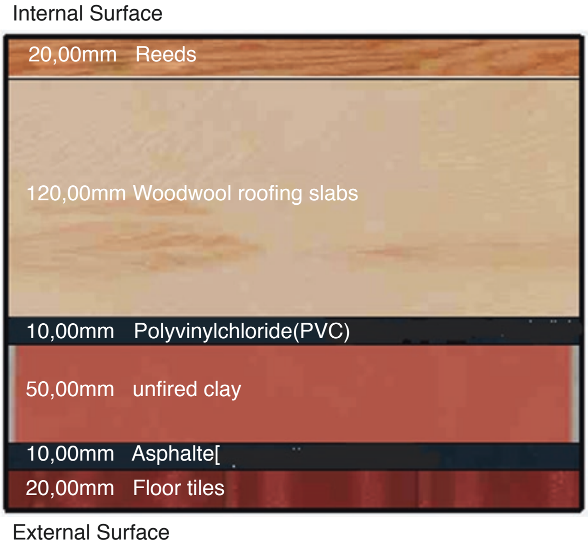

Fig. 24.6 External roof layers

Fig. 24.7 External wall layers

Table 24.1 Thermal characteristics of the building envelope

	External roof	External wall
Thermal resistance (m^2 K/W)	1.43	1.3
Thickness (cm)	23	65
Heat transfer coefficient, U (W/m^2 K)	0.7	0.85

Thermal Dynamic Simulation1.20

The analysis of thermal performances was carried out running the software Design Builder with EnergyPlus code which developed thermal modeling software for building simulation [15]. It offers a simulation of the hourly behavior of building. The thermal dynamic simulation used in this study is carried out during a typical summer week, 7–14 of July, and typical winter week, 1–7 of January [12].

Results

In order to study the role of the external enclosure as a bioclimatic component in the thermal protection of indoor buildings, it is necessary to carry out dynamic thermal simulation of the residential complex on the basis of two main cases:

- Case A—concerns a thermal simulation of indoor temperature inside the studied buildings without considering the external enclosure.
- Case B—concerns a thermal simulation of the indoor temperature inside the studied buildings while considering the external enclosure.

Figures 24.8 and 24.9 illustrate the results of the dynamic simulation according to the air temperature exchange between outdoor and indoor surface during the coldest week in winter and hottest week in summer. The outdoor air temperature during July can reach 41.5 °C while the lowest temperature recorded in R region is –1.3 °C in January. The variation in indoor temperature range between case A and B is about 3 and 2°C during summer and winter, respectively. The analysis of indoor temperature variation revealed that during the hottest and coldest month,

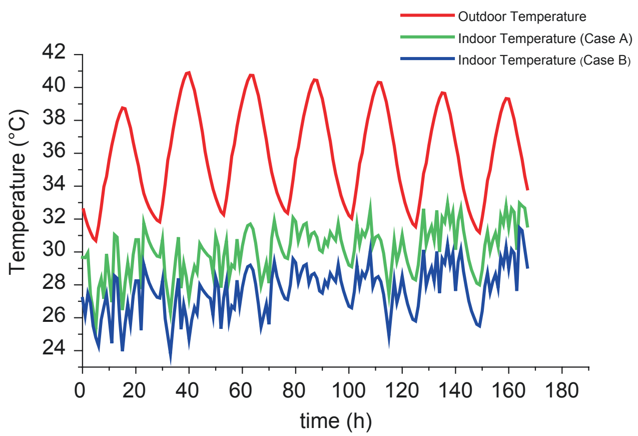

Fig. 24.8 Variation of Indoor and outdoor temperatures during July

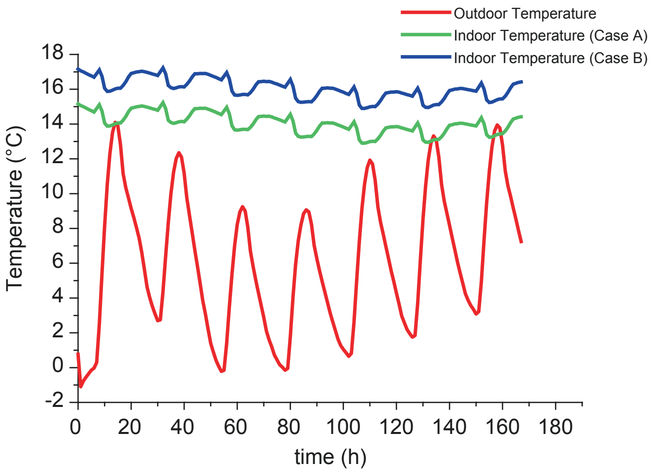

Fig. 24.9 Variation of indoor and outdoor temperatures during January

the external enclosure permit to reduce the outside temperature fluctuations by providing the necessary solar protection.

The increase in outdoor surface temperature in summer is mainly caused by lack of shade and protection. The effect of reflected solar radiation from external surfaces plays an important role in this increase. The more the wall is exposed to solar radiation, the higher the heat flow through the external wall. These results highlight the thermal inertia of external enclose in guaranteeing the occupants comfort on coldest and hottest season.

Conclusion

The present study was devoted to obtain the thermal comfort in the habitat through the judicious use of clay-based building materials. The results of the present investigation show that climate can be a determining factor in architecture. The control of architecture design factors in relation to solar radiation, wind, and shade contribute to the thermal behavior of indoor spaces, and to the creation of a comfortable atmosphere. It appears that the impact of the orientation and use of sustainable building materials is perceptible in the creation of indoor comfort, and depending on the degree of exposure of the façade to direct solar radiation that directly influences the rise in indoor temperature.

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Chapter 25
Assessing Optimal *U*-value in Residential Buildings in Temperate Climate Conditions Considering Massive Dynamic Simulation and Statistical Uncertainty

Giacomo Chiesa, Andrea Acquaviva, Lorenzo Bottaccioli, Mario Grosso, Francesca Pacella, Annalisa Pelati, and Stefania Titone

Nomenclature

BIM	Building information modelling
CNV	Control natural ventilation
EAM	Energy analysis model
RMSE	Root mean square error

Introduction

The need to reduce energy consumptions as well as the relevant GHG emissions in the building sector without reducing comfort conditions is an essential aspect of current European and international regulations [1]. The building sector is, in fact, responsible for about 40% of total primary energy consumption [2–4], with space heating, cooling, and ventilation as an essential part of this percentage [5]. While adopting strict regulations at European and national level to reduce the heating energy needs, the energy need for cooling is growing worldwide since the past

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decades due to several causes including global warming, international style of buildings, and improvements in comfort expectations [6, 7]. So it is important to start considering not only the reduction in heating energy needs, but also cooling energy needs in balancing sustainable design choices between these two aspects to prevent summer overheating [8, 9]. In some cases, in fact, specific choices to increase solar heating gains and prevent thermal losses (e.g., high insulation levels), may negatively affect summer seasonal performances [9–11]. Fortunately, technologies have been improved and several methods are proposed for energy need optimization [12]. For example, in the ICT field, to manage the energy in residential buildings effectively, several efficient energy control systems have been developed, capable of decreasing the total energy need without compromising the user-preferred environment inside the building—see, for example, the results of EU project such as SeemPubs or DIMMER [13]. Nevertheless, a lack of approaches to consider all these aspects in building design, since early-design phases, is evident, especially when hourly simulation analyses are needed (e.g., for passive solutions) being the simplified monthly and steady state methods not sufficiently reliable in all cases [9, 14]. Some previous approaches were studied for environmental and technological design, based on simplified tools derived by advanced simulation and testing results—e.g., see the approach to calculate the wind wake core (wind shade core) proposed in [15]—allowing to include since early design the potential effect of design choices on the expected energy needs and environmental performances. Nevertheless, a full application of the potential of using the results of massive dynamic simulations driven by scripts and analyses using statistical and genetic optimization tools was suggested—see also [16, 17]—, but is still far to be fully applied, even if recent studies have demonstrated the potential of these approaches [18, 19]. Nevertheless, recent analyses were conducted by the authors and some early result was published [20, 21]. Therefore, this paper has been done in order to model the relationships between thermal insulation of the residential building stock envelope, i.e., walls and windows, and the energy needs for both space heating and cooling, to correlate these aspects by also considering a simple economic evaluation to optimize this variable including energy and economic aspects. Furthermore, natural cooling solutions, such as natural controlled ventilation, were also included in this analysis.

This paper follows the environmental building programming approach—see, for example, the description in [22]—which is based on the performance-driven methodology that suggests, since its early definition, the usage of algorithms and programs to optimize building performances [23, 24].

Hence, the analysis presented in this paper is about the developing of an algorithm with the aim of optimizing, through dynamic energy simulation, the energy and technological definition of a building envelope—focusing on the insulation layer—, such that the energy needed in a residential building can be minimized by also considering the related economic impact. The analysis has been carried out taking into account not only the heating season, such as it is generally done in regulations for the definition of minimal insulation values, but also the summer season.

This study is strongly innovative introducing a new approach to dynamic simulation usage for design purposes, thanks to the development of specific scripting procedure to produce regression-based models to be easily used by professionals of the architectural fields.

Methodology

The aim of this analysis is to develop a method and a tool to define the best configuration of building vertical envelope elements (opaque and transparent) considering the thermal insulation requirement. This requirement is tested to minimize the energy needs (target variable) in a residential building, taking into account (input variables):

- Seasonally changing conditions (cooling and heating comfort thresholds)
- Presence/absence of ventilative cooling systems
- Orientation of the building with respect to the north direction
- Different design choices—window *U*-values and thickness of wall and roof insulation layer

Furthermore, the analysis also considers the effect of random occupancy variations to simulate the potential effect of internal gains changes in real environments and test statistically the obtained regression models by previous simulations conducted under reference occupancy schedules. Finally, an economic study was conducted to consider the costs of different insulation layers and the related effect on the predicted costs for space cooling and heating. This last analysis can be used to optimize the design choices in a NZEB vision including not only energy optimization, but also an economical one.

In order to optimize this variable, a large database of dynamic energy simulation results was produced by using *EnergyPlus*. To manage this activity, a support code in Python has been implemented to change dynamically the input file used by the program (∗.*idf*), varying some input variables that play a fundamental role in the envelope thermal design and affect the *U*-value. In particular, it changed the thickness of the insulation layer for opaque elements and a series of specific window systems for the transparent ones. In addition, on/off activation of the CNV (controlled natural ventilation) system were considered in summer to test the effect of this passive/low-energy cooling technique. The study has been performed for a residential building located in *Torino*, Italy (temperate climate conditions), assuming a sample residential unit of about 70 m^2. The apartment was considered as a two-person flat in accordance to suggestions by architects' manuals [25]—considering entrance, kitchen, bathroom, and two rooms, even if for the purpose of this analysis internal spaces are assumed at the same temperature and scheduling being a unique thermal zone. Figure 25.1 shows the position of the considered unit in a residential building assuming a critical condition where three vertical faces and the roof are exposed to the external environment. The remaining vertical face and the floor are assumed to confine with spaces at the same temperature and consequently no thermal changes are expected by these surfaces.

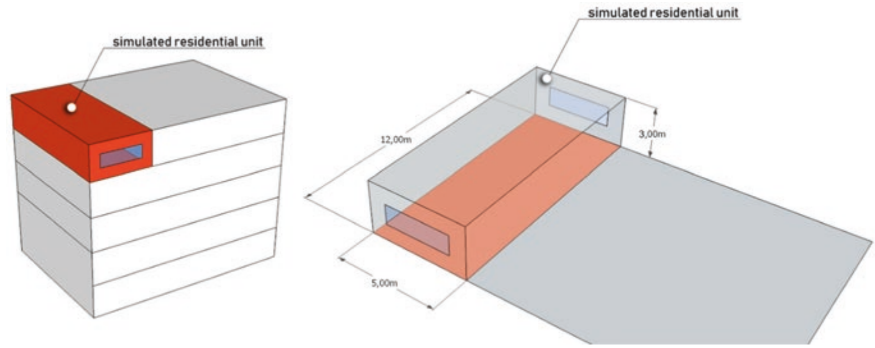

Fig. 25.1 The sample simulated residential unit and the considered sample building

Comfort threshold for system activation are assumed to be, respectively, 20 °C for winter and 26 °C for summer. Internal power density was assumed to be 10 W/m^2 in accordance to small office and residential unit suggestions [26]. Occupation schedule for the reference case was assumed to be the residential dwelling unit (with kitchen) by the ASHRAE database implemented in DesignBuilder.

In order to support the study development, the basic configuration was built in DesignBuilder and furthermore the EnergyPlus input file was changed via a Python script in order to generate large amount of simulations by changing the described input variables. Defined the models, by statistically analyzing the massive amount of produced results, uncertainty effects were added to test the ability of these polynomial regressions to face perturbation phenomena. In particular, a random variation of internal gains—i.e., occupancy—was introduced and statistical checking was performed to choose the best curves. Finally, a simple economic model was applied to obtain models to suggest the optimal points to be used by architects and designers in order to optimize, since early-design phases, the level of insulation in comparison to local boundary conditions considering a whole economic and energetic approach.

The following steps define the procedure used to reach the aim of this analysis:

- *Building reference model development*. Residential building development in DesignBuilder to export the first ∗.idf files for different situations of CNV (on/off), different orientations and considered types of window (see Table 25.1). Window *U*-values are in fact assumed according to commercial solutions for three typical configurations: single glass, double glass LoE Argon infilled, and triple glass LoE Argon infilled. As it is shown in Fig. 25.2a, the unit was defined to be 5 m in width, 12 m in length, and 3 m in height. The two shorter opposite facades have a window, while the other external vertical one is only opaque in accordance to the building typology. For this first step—DesignBuilder starting ∗idf. definition—the insulation layer was fixed equal to 0.0001 m—see Table 25.1 and wall and roof configurations in Fig. 25.2b, c—being further changed by the Python script. ∗.Idf files for each orientation of the building and for each season

Table 25.1 Simulation changed variables

Variable	Description	Value
Thickness of the insulating layer	Insulating layer composed by XPS extruded polystyrene	Variable value in the range {0,35} cm
U-value for different insulation thickness	Each thickness of insulation corresponds to a wall *U*-value and a roof *U*-value	Insulation thickness = 0.0001 m → wall *U*-value = 2.970 [W/m² K]; roof *U*-value = 1.539 [W/m² K] Insulation thickness = 0.35 m → wall *U*-value = 0.094 [W/m² K]; roof *U*-value = 0.091 [W/m² K]
Type of window's glass	Single Clr Double LoE Clr, Arg Triple LoE Clr, Arg	SHGC = 0.819; *U*-value = 5.778 SHGC = 0.568; *U*-value = 1.493 SHGC = 0.474; *U*-value = 0.780
CNV	Ventilative cooling producing air changing (naturally or fan-forced)	On/off On mode: 6 ac/h. operating ambient temperature thresholds in the range {18,24} °C, activation threshold difference (internal–external temperature) assumed to be equal to 3 K [27]
Occupancy	Average number of people per floor area	$\mu = 0.037$ [people/m²] $\sigma = 0.0225$ [people/m²]

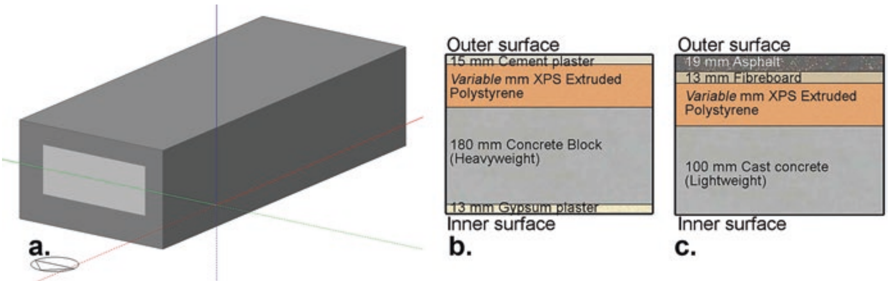

Fig. 25.2 (**a**) Design Builder's external view of the simulated unit. Three vertical walls and the roof are exposed to external conditions, while the last wall and the pavement are assumed as adiabatic, (**b**) configuration of wall layers, and (**c**) of roof layers. The insulation layer is the one whose thickness is automatically changed through the Python code

have been generated in DesignBuilder and further used as inputs for running EnergyPlus. Results are saved to be used in the analysis steps.

- *Python script implementation* to dynamically generate different ∗.idf input files for EnergyPlus by automatically varying the values of the thickness of the insulation layer of opaque surfaces which correspond to a *U*-value variation—see Table 25.1.
- *Python script development to* iteratively *run simulations* considering all ∗.idf files generated before. EnergyPlus obtained results are collected and data plotted in figures. The EnergyPlus run was done by setting, through the Eppy Python library, the ∗.idd file, the ∗.idf file, and the ∗.epw file in order to create

a link between Python simulations and the EnergyPlus software. The last file (∗.epw) is the one referring to local typical meteorological year for dynamic energy simulations and is assumed for this analysis by the EnergyPlus Weather Database.

- *Noise addition to test the effects of uncertainty phenomena on results*. The Python script was upgraded to add a noise contribution by changing, for each insulation thickness value, the average building occupancy following a Gaussian normal distribution with mean μ equal to two persons and an equal variance σ value, such that the occupancy may variate from 0 up to 4 average number of persons present in the building during the simulation. Nevertheless, the general time schedule was not changed. Occupancy average values are reported in Table 25.1.
- *Economic analysis* to evaluate how parameters variation influences the expected household expenditure and energy analysis to find the best combination in terms of potential energy saving.
- *Polynomial regressions* were performed in order to find the best fitting curve, which represents the energy need distribution, and evaluate the RMS (root mean square) error between curve points (model) and the simulated ones (test) using additional simulation runs.

The main considered input variable is hence represented by the *U*-value, which represents the thermal transmittance, and is the rate of transfer of heat through a structure divided by the difference in temperature across that structure [W/m^2 K]. This value is compatible, in the architectural technology design approach based on the performance-driven methodology, to requirement No. 39 of the UNI 8290-2: 1983. The *U*-values [W/m^2 K] of each window configuration used for simulations are defined in Table 25.1, such as was mentioned before, while the *U*-value of opaque surfaces can be deducted by the thickness of the insulation layer by using the well-known expression (25.1):

$$U_{\text{value}} = \frac{1}{\frac{1}{h_{\text{i}}} + \sum R + \sum \frac{s}{\lambda} + \frac{1}{h_{\text{e}}}} \tag{25.1}$$

where *R* is the thermal resistance of a layer [m^2 K/W], *s* is the thickness of a layer, and λ is its thermal conductivity [W/m K]—*R* or s/λ are used alternatively according to layer definition—$1/h_{\text{i}}$ and $1/h_{\text{e}}$ are, respectively, the surface resistances of the internal surface and the external one, which can be assumed to be 0.13 and 0.04 for horizontal flow (vertical opaque closures), 0.1 and 0.04 for ascending flow, and 0.17 and 0.04 for descending one in accordance to Italian regulations. Figure 25.3 compares the insulation thickness with the related *U*-values of the opaque vertical wall and the flat roof. The insulation thickness in the roof is assumed to be the same of the wall and consequently the two closures *U*-values vary accordingly even if the different configuration of the other layers causes a similar, but not equal *U*-value.

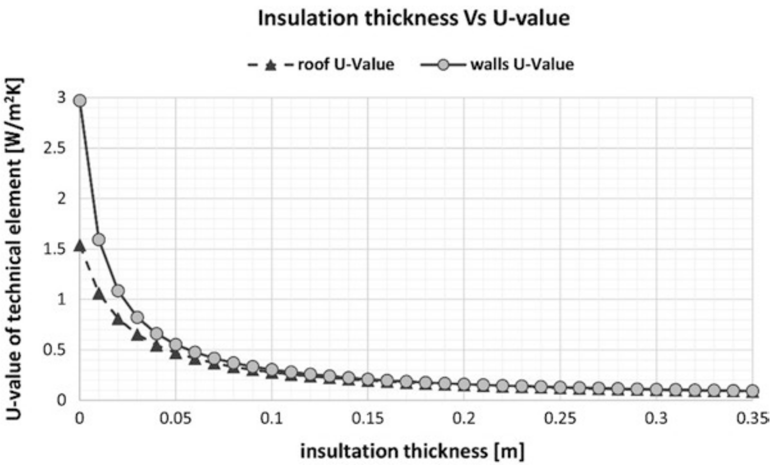

Fig. 25.3 Insulation thickness and related variation in the total *U*-value of the opaque vertical walls and horizontal roof

Analysis

It is known that by choosing a good orientation during the building design phases, combined with other energy efficiency features, it is possible to reduce or even eliminate (according to local climate conditions) the need for auxiliary heating and cooling, resulting in lower energy bills, reduced greenhouse gas emissions, and improved comfort conditions in free-running. Several studies were conducted on this specific aspect in different climate conditions, being one of the classic bioclimatic variables to be optimized according to the specific site [28–30]. For this reason, building orientation in respect to apparent local sun paths was considered relevant for the analysis—see Fig. 25.4a, b. For each orientation, the entire set of simulations was conducted in order to compare results and obtain potential information to be used as early-design strategies according to the chosen configuration. A total of 1296 simulations were run for the base occupation schedule and average number of people.

Winter Energy Needs

In this paragraph, the simulated winter energy needs are reported and discussed for the base case. Figure 25.5 shows the simulated unit behavior considering heating energy needs for different thickness of the insulation layer. Each graph refers to a specific building orientation, respectively with the large exposed opaque vertical closure facing North, Fig. 25.5a, facing East, Fig. 25.5b, facing West, Fig. 25.5c,

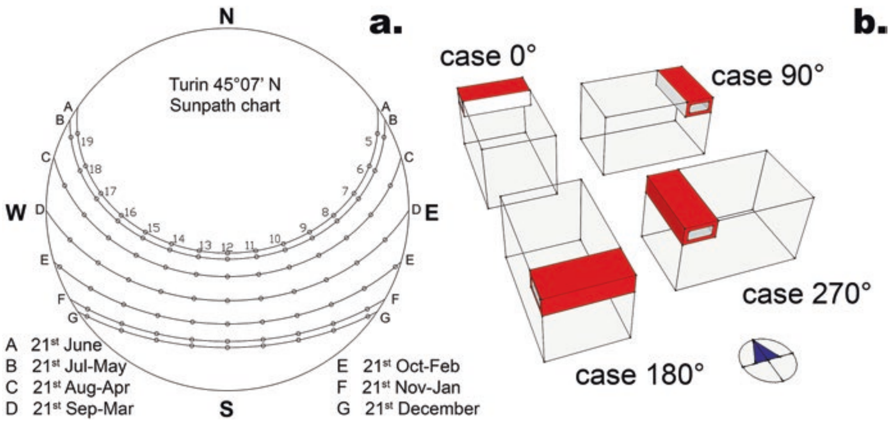

Fig. 25.4 (**a**) The sun paths during different seasons for the considered location; (**b**) chosen orientations of the simulated units (in red), note the orientation of the fully opaque wall exposed to the environment

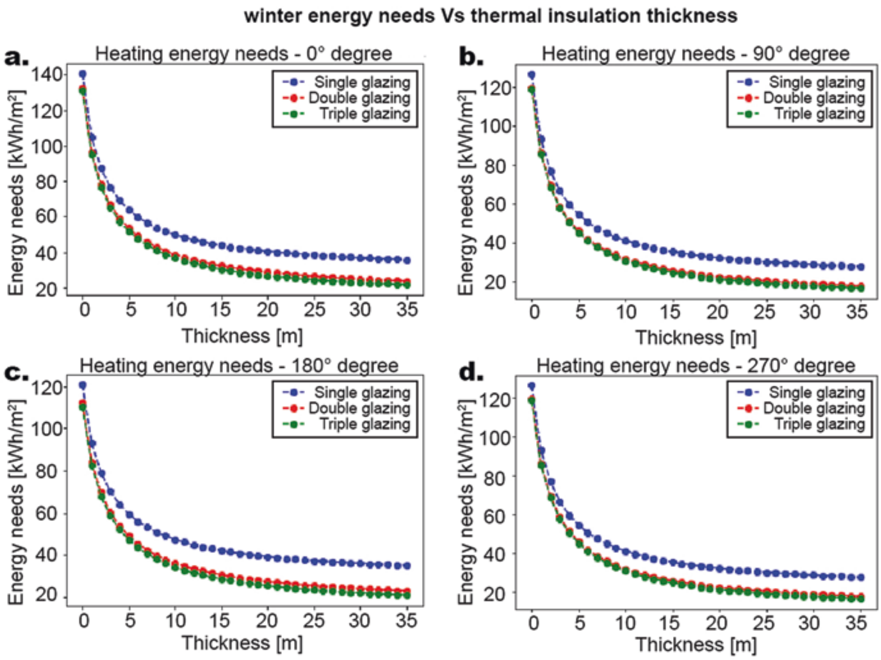

Fig. 25.5 Winter energy needs for the four considered orientations: (**a**) 0 degree—North direction of the long exposed façade (window orientation E–W), (**b**) 90 degrees (window orientation N–S), (**c**) 180 degrees, and (**d**) 270 degrees—see also Fig. 25.4b

Table 25.2 Average saved energy needs in winter—orientation degrees refer to the totally opaque façade confining with the external environment

	0° from North (kWh/m^2 year)	90° from North (kWh/m^2 year)	180° from North (kWh/m^2 year)	270° from North (kWh/m^2 year)
Single glass	100.78	79.34	100.96	79.26
Double glass	77.85	61.73	78.11	61.66
Triple glass	68.42	55.75	68.66	55.67

and facing South, Fig. 25.5d—see also Fig. 25.4b. Furthermore, the effect of the three considered window types is reported in each figure according to the reference line (single, double, and triple window cases). From this figure, it is possible to notice that similar trends in energy needs were obtained for all orientations and all considered window types. At the same time, the main contribute to the obtained energy saving is given by the increase of the insulation thickness (and correlated decrease in the walls *U*-values), while the orientation and the windows type add a smaller but visible alteration. More precisely, the greater effect of insulation is appreciable in the range 0–10 cm of thickness, according to the higher *U*-value variations—see Fig. 25.3.

The highest amount of heating energy needs for low insulation levels was reached by the north-oriented-long-façade case (windows facing E–W)—see Fig. 25.5a. This is an expected outcome, considering that, in winter, the East and West window orientations are interested by a lower intensity in solar gains in respect to the south-oriented one, while the difference in between cases (a) and (c) is due to the exposure of the external-facing wall to north orientation in respect to the south one. On the other hand, in fact, minor energy needs are achieved for the other building orientations. When the internal wall faces the south direction, Fig. 25.5c, the external-facing wall is passively heated by the sun during the whole day, while with orientation 90° and 270°, respectively Fig. 25.5b, c, one window is south-oriented. Furthermore, such as was expected, the higher the insulation thickness, the lower the energy need being a reduction in thermal losses through the envelope a positive strategy for reducing the heating needs. For this reason the minimal and maximal insulation levels were compared. The average saved energy needs applying an insulation layer of 35 cm in all considered orientations and types of glass in respect to the not insulated case are shown in Table 25.2 for the heating season, confirming the above described trends.

Summer Energy Needs (CNV Off)

The behavior of the energy consumption during summer season without ventilative cooling activation is shown in Fig. 25.6 for the same building orientations of Fig. 25.5, the same types of window and walls insulation thicknesses of the previous analysis.

Although from 1 to 35 cm the need variations are less evident than for the heating case, it is possible to observe that also in these cases variations occur mainly between 0 and 10 cm in insulation thickness in accordance to *U*-value changes. After these values, the cooling energy needs remain almost constant. Higher insulation levels are correlated to low energy needs for both opaque and transparent closures. Nevertheless, such as was underlined in other works [10, 31], a different effect is expected between wall and roof insulation levels being the last positive (higher solar exposure in summer [32, p. 81]) and the first null or negative being less exposed to solar radiation and able in dissipating the internal stored heat by transmission losses. Nevertheless, for the purpose of this paper, wall and roof insulation thicknesses were changed together—see Fig. 25.3—and for this reason, it is not possible to isolate the effect on the cooling needs of vertical and horizontal insulation. A similar consideration can be done when different types of glass are considered, even if in these cases the insulation effect is also supported by low SHGC (solar heat gain coefficient) values for double and triple glazing systems. The SHGC of the triple glass is, in fact, almost the half of the one of the single one, resulting in a correlated reduction of the correspondent solar gains. For this reason, using a single glass the exchange with the environment will be higher and, without sufficient heat dissipation strategies of solar gain, cooling energy needs increase due to solar gains. On the other hand, triple glasses, even if they reduce the heat dissipation from inside to outside being insulated, ensure a higher solar gain protection. At general level, thermal insulation shows a positive effect on both heating and cooling consumptions (CNV off), although for the last some cases show a very limited opposite trends for very high insulation levels—e.g., in the domain 20–35 cm—such as can be underlined, for example, in the single glass and double glass lines of Fig. 25.6a.

By looking at energy need variations in relation to the building orientation, it is possible to state that lowest cooling needs values were simulated for the orientation of 90°, Fig. 25.6b, and for 270°, Fig. 25.6d. These are the two cases where the wall without windows is facing East and West orientations. Between these two scenarios, a slightly higher consumption was observed for the orientation in which the external long wall faces the West direction. This result is in line with expectations being the west-oriented façade a critical point for cooling purposes receiving solar radiation in the late afternoon when the environmental air is higher in temperature in respect to early morning. Regarding the other cases, the highest cooling energy needs are related to the building orientation in which windows faces both East and West and the external confining wall without window is south-oriented, Fig. 25.6c. Differently, the north oriented case, Fig. 25.6a, reports the lowest needs in the non-insulated configuration, but a lower absolute variation in between maximal and minimal insulation cases. Furthermore, in this case it is possible to see that the greatest variation in energy cooling needs is in the interval 0–5 cm of thickness of the insulating layer. This is because being one of the vertical walls less exposed to solar gains, the heat gain solar prevention due to insulation is less mitigating the losing in thermal dissipation potential from inside to outside spaces.

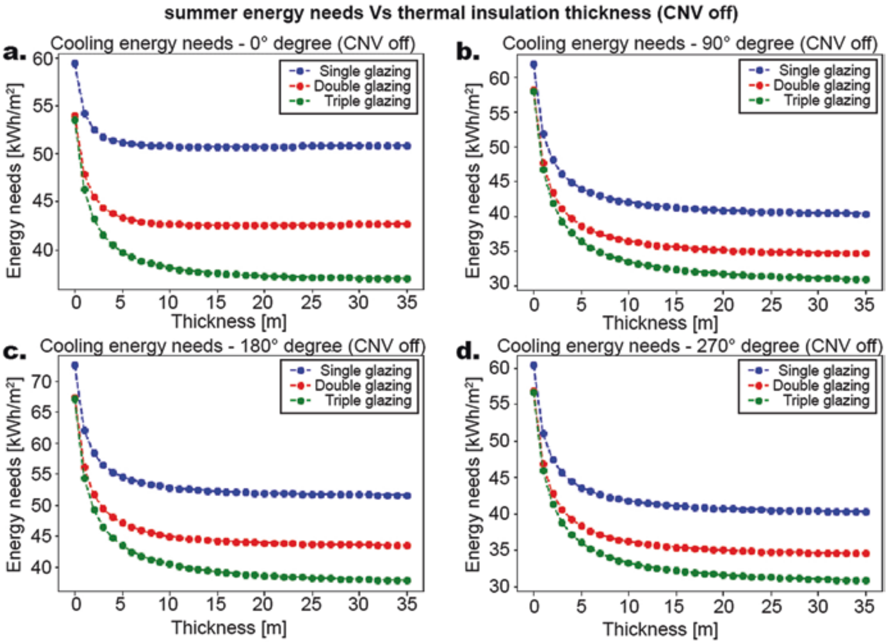

Fig. 25.6 Summer cooling energy needs with orientation of 0° from North direction (**a**), 90°(**b**), 180° (**c**) and 270° (**d**) and CNV off

Summer Energy Needs (CNV On)

In this section the effect of insulation on the cooling energy needs is defined when heat dissipation strategies are adopted. In particular, this analysis refers to the activation of ventilative cooling strategies—CNV—in order to exchange internal air with the external one when the last in lower in temperature and below the comfort threshold—see Table 25.1. Figure 25.7 is the counterpart of Fig. 25.6 when CNV is activated. It is possible to underline that also in this case similar trends are shown by the graphs. Cooling needs to decrease with insulation increase. Nevertheless, in these cases the counter-trends for high-insulated cases slightly visible in Fig. 25.6 are avoided being heat gains dissipated through ventilation. It is possible to note that CNV reduces the needs in all cases. Nevertheless, to study this reduction, Fig. 25.8 was elaborated showing the cooling energy need saving when CNV is activated in respect with configuration CNV off. This figure illustrates that even if for all insulation levels CNV allow to reduce the cooling needs, this reduction is proportional to the thickness of the insulation being more evident at lowest *U*-values. This result was expected, being heat dissipation a strategy to avoid the potential negative effect of heat gains capture of highly insulated spaces. Considering different glazing types, the same consideration is evident. Single glaze is the configuration that better exploits ventilative cooling potential because in this case solar gains and cooling needs are higher.

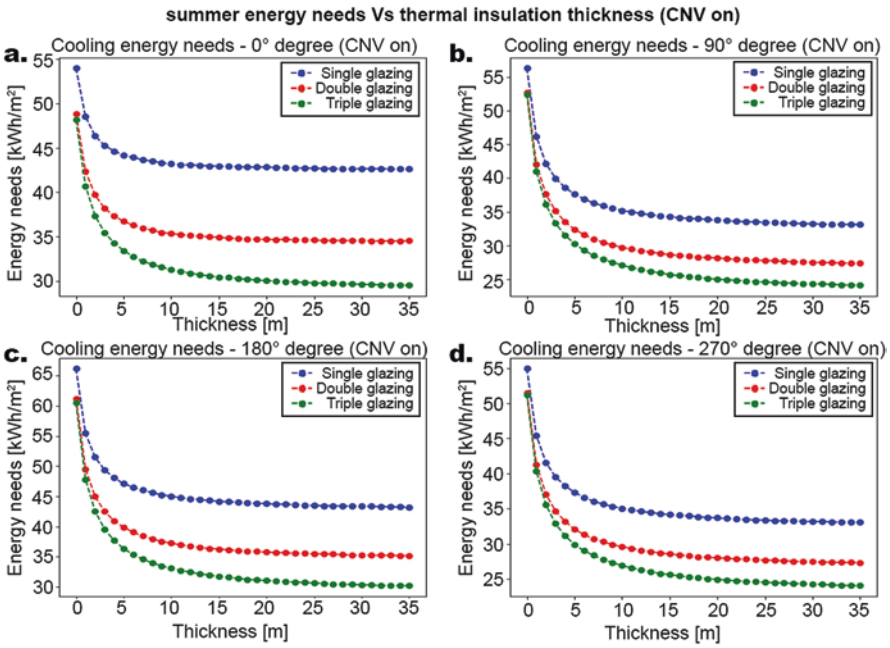

Fig. 25.7 Summer cooling energy needs with orientation of 0° from North direction (**a**), 90°(**b**), 180° (**c**) and 270° (**d**) and CNV on

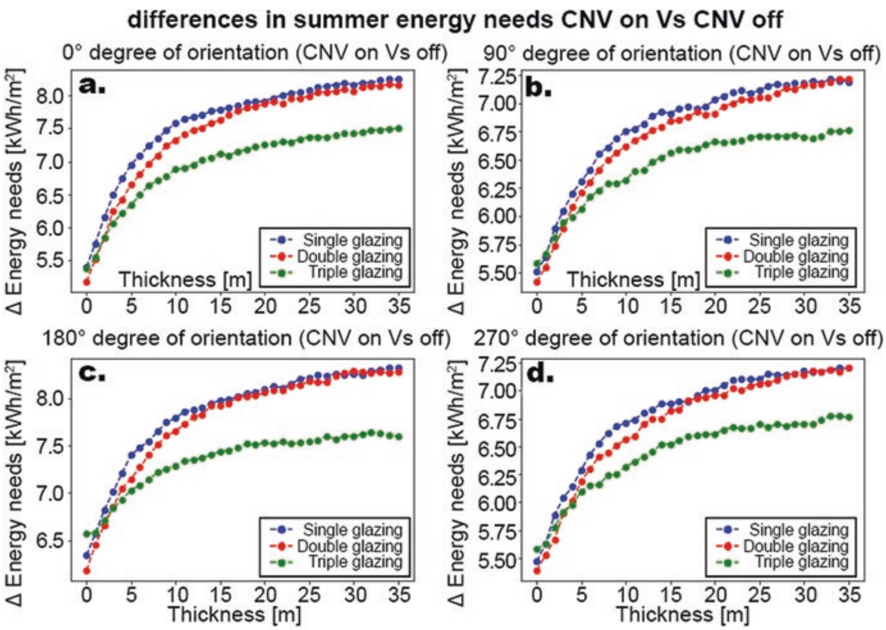

Fig. 25.8 Differences in cooling energy needs between CNV on and off cases for different thermal insulation thicknesses and building orientations

Discussion

1.1. In this section, economic aspects correlated to thermal insulation levels are discussed in section “Economic Analysis” and the application of regression models when random occupancy values are assumed are discussed in section “Regression Analysis”. This last analysis allow to define potential correlation models between thermal insulation and energy needs being able to be used by designers since early-design phases for similar climate conditions. Furthermore, the inclusion of random occupancy variations helps in increasing the strength of the analyses in respect to potential perturbations of the starting set for boundary conditions.

Economic Analysis

The economic analysis was carried out in the following steps:

1. Evaluation of the initial cost of the insulation panels in relation to the various thicknesses used in the energy analysis
2. Estimation of the annual energy saving for space heating and cooling for the various insulation panel thicknesses
3. Comparison between the above two estimates in order to define the optimal thickness whereby the initial cost equals the annual energy saving
4. Calculation of the discounted payback period (DPP) for the various insulation thicknesses

Energy Saving vs. Initial Cost of Insulation Panels

The initial cost, $C_{ins_{th}}$, of an insulation panel with a specific thickness and area of 1 m^2, is given by Eq. (25.2):

$$C_{\text{ins}_{\text{th}}} = \left(I_{\text{ins}_{\text{mat}}} + L_{\text{ins}}\right) \times \text{th}_{\text{ins}} \times A[€] \tag{25.2}$$

where:

$I_{ins_{\text{mat}}}$ = initial cost, per unit of thickness and area, of an insulation panel composed of the considered material (XPS), including VAT [€/m^2];

th_{ins} = thickness of the insulation panel [m];

A = area of the insulation panel [m^2];

L = labor cost, lumped estimated based on an interview with construction workers (35% of the selling cost).

For the present analysis, $I_{ins_{\text{mat}}}$ = 0.70 €/cm$_{\text{th}}$,m^2 and the total unitary cost, including labor, is 0.95 €/cm$_{\text{th}}$,m^2.

The annual energy cost for space heating and cooling, $C_{ins_{th}}$, related to each insulation panel thickness, was calculated using the following Eq. (25.3):

$$C_{en_{th}} = \left(E_{heat_{th}} + E_{cool_{th}}\right) \times C_{un_{el}} \; [€] \tag{25.3}$$

where:

$E_{heat_{th}}$ = annual energy need for space heating of the considered building unit, related to the use of a specific insulation panel thickness [kWh];
$E_{cool_{th}}$ = annual energy need for space cooling of the considered building unit, related to the use of a specific insulation panel thickness [kWh];
$C_{un_{el}}$ = unitary cost of the delivered energy, depending of the source, here considered as electricity for both heating and cooling [0.20 €/kWh].

The intersection between the two curves, occurring at a thickness of about 6 cm, represents the value of the insulation thickness for which there is a one-year return on investment (simple pay back period)—see Fig. 25.9.

Discounted Payback Period

The discounted payback period (DPP) of the investment related to the application of insulation panels, i.e., the period of time required for the accumulated net savings due to the annual energy need reduction, to equal the initial cost of the insulation panels, with all figures expressed in present values, can be calculated using the following Eq. (25.4), while results are shown in Fig. 25.10.

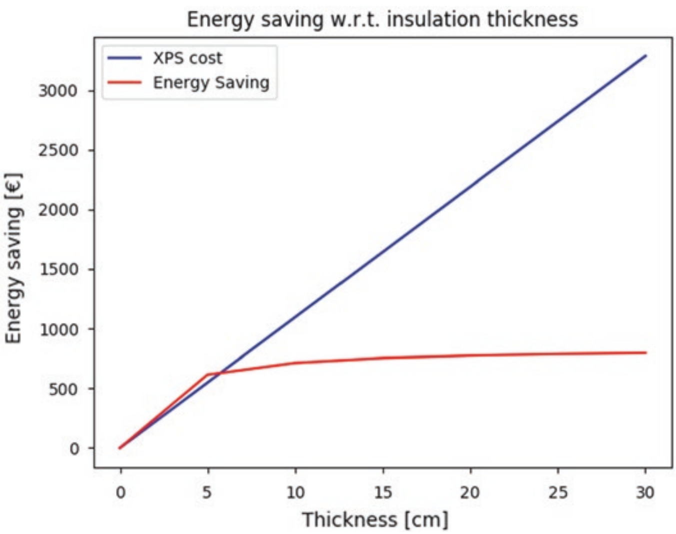

Fig. 25.9 Energy cost saving (red line) and initial cost of insulation panel (blue line) as a function of insulation panel thickness

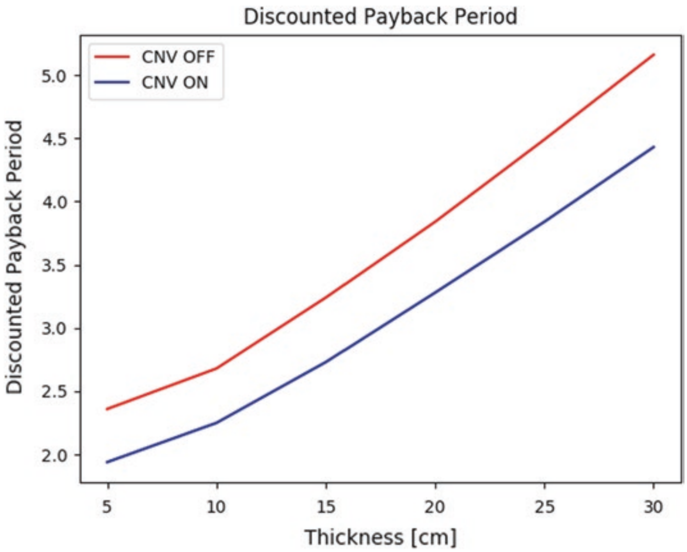

Fig. 25.10 DPP (years) of the initial investment related to the application of insulation panels of various thickness, for both configurations, with and without CNV

$$DPP = \frac{\ln\left(\dfrac{1}{1-\left(\dfrac{IIC \times i}{NAS}\right)}\right)}{\ln(1+i)} \tag{25.4}$$

where:

IIC = initial investment cost; *NAS* = net annual saving; *i* = interest (discount) rate expressed as a decimal considered = 0.01.

Regression Analysis

Using the reference building and the base ∗.idf files, a random variable has been added to the original scenario in order to obtain a train and a test dataset and evaluate, based on a regression technique, the polynomial degree of the function that better approximate the energy need behavior of the previous scenarios. Ten variations were considered for all simulated case in the base analysis for 12,960 *EnergyPlus* simulations. Considering the dimension of the dataset, the subdivision of results in between train and test was of 50% each in order to prevent overfitting risks on the training database. As mentioned in section “Methodology”, the randomness has been introduced by varying the average number of people in the building; the distribution of this parameter has been chosen as a random Gaussian distribution with a mean value of two people and a variance such that occupancy values are in the domain {0–4} persons. Starting from the original ∗.idf files, thanks to the Python library Eppy, the occupancy value has been changed and, for each new value, the EnergyPlus simulation has been run. It is worth to notice that this assumption for the data randomization is consistent: the presence of people in a building influence the consumption in both scenarios being the human body a source of heat. For the winter case, it has been verified that the energy consumption decreases by crowding up the building while, in summer simulations, more people are in the cooled space and more will be the cooling needs. Finally, in order to be able to compare all different considered scenarios (orientation and windows), the same random-generated occupancy matrix was used to generate all the simulations for the train database, while another matrix was used for simulating all the test samples.

Considering heating energy needs, Fig. 25.11 plots the results for the single glass window considering all orientations. As was expected, being the behavior of the four-orientation scenarios really close to each other, the best polynomial degree is the same for all cases—see Table 25.3. Nevertheless, these four scenarios differ in

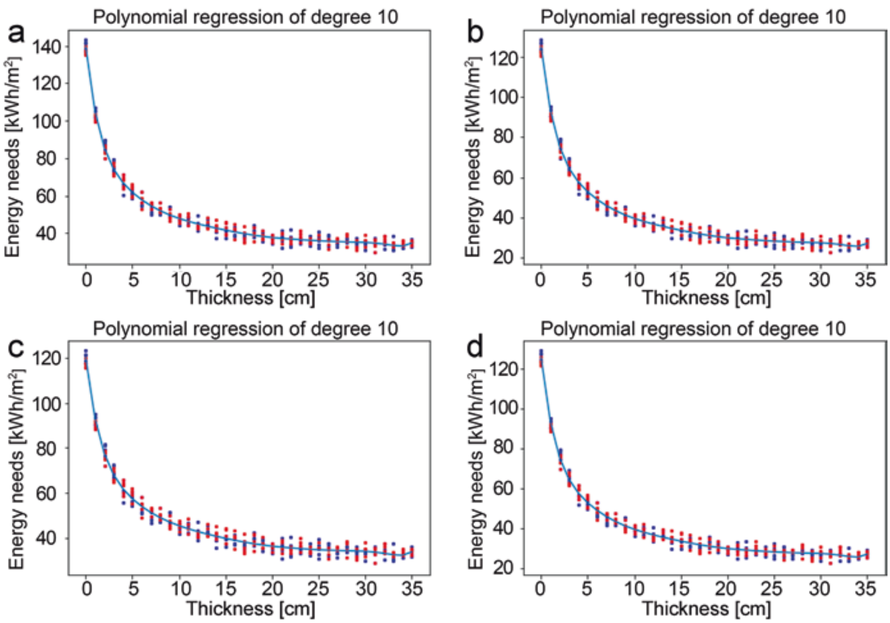

Fig. 25.11 Regression for winter scenarios with single glazing window

Table 25.3 Heating case, single glazing—best polynomial degree and related RMSE

Orientation	RMSE	Polynomial degree
0°	2.41	10
90°	2.23	10
180°	2.36	10
270°	2.23	10

Table 25.4 RMSE for each calculated degrees of polynomial regression curves (the reported sample case refers to the single glazing window, 0° in orientation)

Polynomial degrees	RMSE Test dataset	RMSE Train dataset	Polynomial degrees	RMSE Test dataset	RMSE Train dataset
1	14.12	14.71	8	2.49	2.49
2	9.07	9.62	9	2.43	2.48
3	6.25	6.53	*10*	*2.41*	*2.46*
4	4.55	4.65	11	2.44	2.44
5	3.48	3.50	12	2.47	2.41
6	2.87	2.81	13	2.47	2.41
7	2.63	2.62	14	2.47	2.41

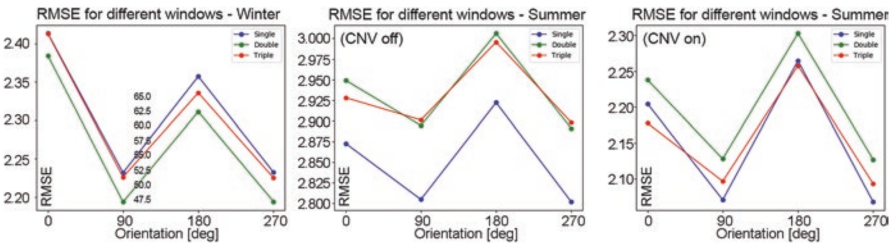

Fig. 25.12 (**a**) RMSE of best polynomial degree curves in the winter simulation database; (**b**) same analysis for summer cases with CNV mode off; (**c**) summer cases with CNV mode on

the RMSE due to differences in the weight of occupancy internal gain component in respect to the solar one—which is the one that varies with orientation. The best polynomial degrees (scenarios) have been selected considering their RMSE values by looking at the smallest one before that RMSE values start to increase again. This behavior is called overfitting and happen when the model starts working very well with the train dataset, but its performances decrease when it is compared with a test dataset. Table 25.4 clearly shows this behavior for the winter heating energy needs in the single glass window and a 0° of orientation. As can be seen, after the tenth degree, the model better fits with data of the train dataset while the RMSE between the obtained values and the test dataset start to increase again.

The best regression model of each case was also plotted in Fig. 25.11.

The same approach described for the single glazing case was applied to all considered window and orientation configurations in both seasons. Figure 25.12a shows how the RMSE value for the best polynomial degree changes for all window types and orientations considering the winter heating energy need.

Differently, for cooling needs it is possible to see simulation results for the single glazing windows in Fig. 25.13 for the case without CNV. In this scenario, the best polynomial degree results to be the eight for all orientations, while the RMSE ranges around 2.8–2.9 for this degree being higher than the one reached during the heating need analysis. The same statement is even more evident for double and triple glazing systems—see Fig. 25.12b. This is due to the fact that summer energy

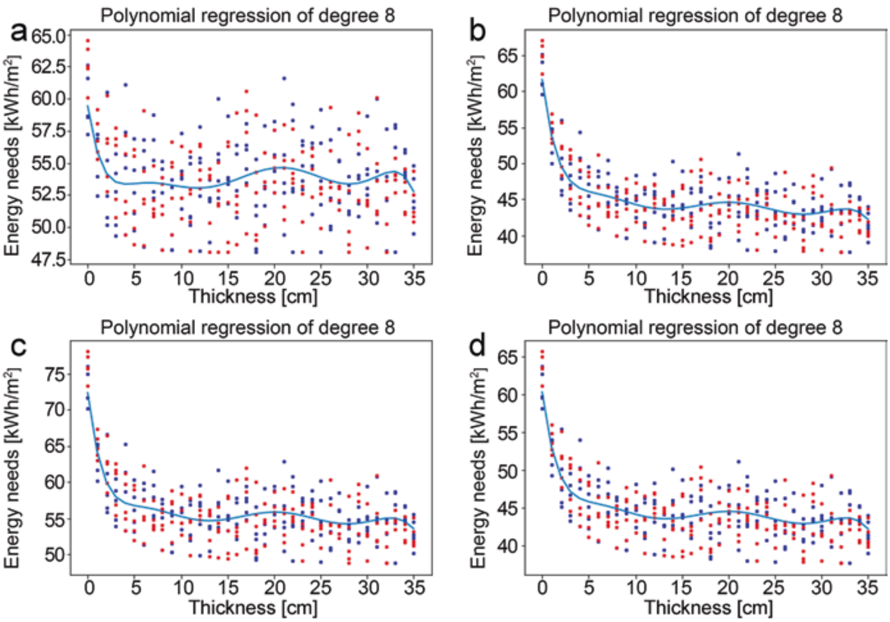

Fig. 25.13 Regression for summer scenarios (CNV off) with single glazing window

needs are highly influenced by internal gains in comparison to the heating season because the discrepancies between comfort threshold and environmental air temperatures in winter are higher than the opposite ones in summer. Nevertheless, the analysis and the regression model under the perturbation effect of random internal gains confirm the general trends underlined for the base case, even if with higher occupancies the effect of insulation may be less positive. Especially for case with orientation 0°, it is evident that when solar gains are limited (the long exposed façade is north facing), variations in the internal ones may sensibly affect the potential of high levels of insulation.

Furthermore, when CNV mode is on, the same analysis performed on single glazing systems shows a polynomial behavior similar to the base case—see Fig. 25.14. As was expected, and in line with literature considerations, when CNV is activated, variations in internal gains—e.g., random presence of people—is impacting less the results due to the fact that ventilative cooling acts as a natural dissipative technique. In these cases, in fact, the RMSEs for all orientations are considerably lower than the previous summer database such as it is underlined in Fig. 25.12c. For this reason it is possible to state that CNV is a good opportunity not only to reduce the cooling energy needs, but also to potentially absorb discrepancies between expected and obtained needs when people occupancy levels change, such as may arrive in real building operation. Figure 25.15 compares two of the obtained graphs for these two CNV modes—off in Fig. 25.15a and on in (b)—including all calculated polynomial curves, from degree 1 to 15. These graphs confirm what was mentioned before.

Figure 25.16 Summary of final results including best chosen polynomial curves

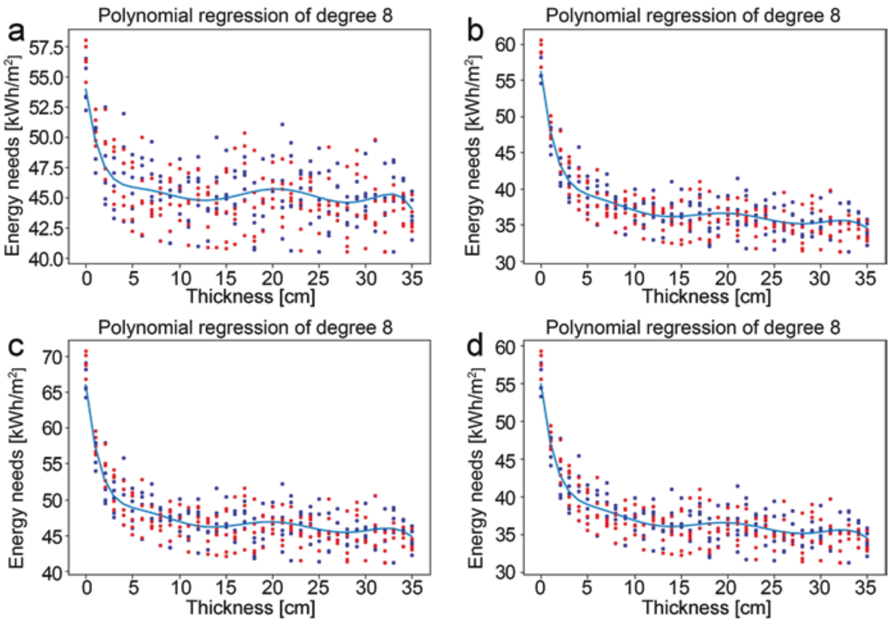

Fig. 25.14 Regression for summer scenarios (CNV on) with single glazing window

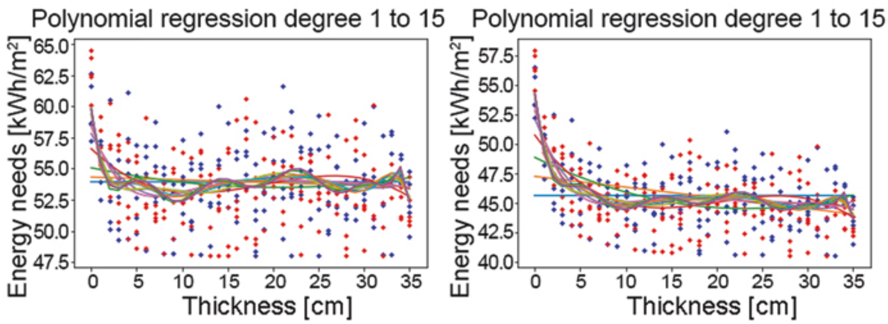

Fig. 25.15 Comparison between summer scenarios for single glazing window orientation 0° including all calculated polynomial curves and considering (**a**) CNV off, and (**b**) CNV on

Conclusions

The paper represents one of the first applications of an innovative performance-driven approach to environmental and technological building design, expanding the methodology of the need-performance design method, proper of the Italian architectural technology field, thanks to the exploit of actual potential of current calculation tools and machine related to IT (information technologies) instruments. The proposed approach is based on the usage of massive amount of simulations

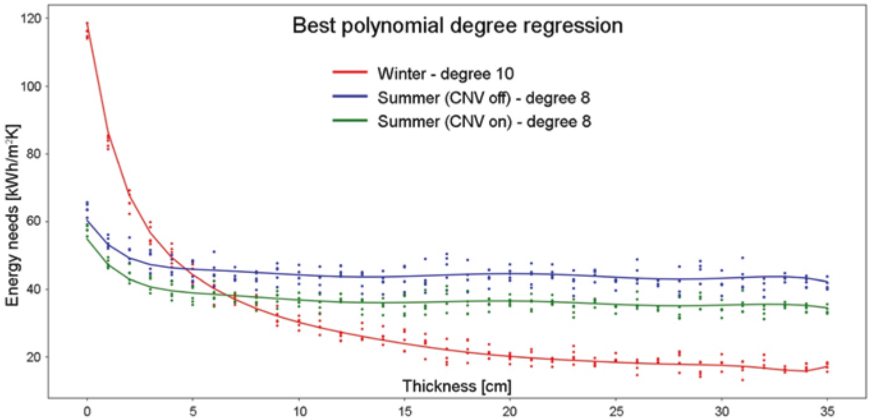

Fig. 25.16 Summary of final obtained results including the best calculated polynomial curve for heating, cooling (CNV off), and cooling (CNV on)

driven by Python coding and evaluated for tend model definition using statistical polynomial regressions and noise variable management.

A sample application based on a reference residential unit of about 70 m^2 was simulated using EnergyPlus to optimize thermal insulation levels considering both cooling and heating energy needs, together with the potential effect of CNV activation and different orientations. The effect that random variations on specific simulation variables, differing from the target and main input ones, was analyzed to test statistical significance of results and correlated suggestion for early-design choices in order to test their resistant to perturbation phenomena that may arrive in real building operation. By results it was underlined that thermal insulation has a positive impact on both cooling and heating energy needs for the case studied located in Turin, when both wall and roof insulation thickness are changed equally. Furthermore, it was confirmed the importance of ventilative cooling solutions to (1) reduce the cooling energy needs, and (2) reduce the risk of overheating and overcooling consumptions under random occupancy variations.

Results only explore a first part of the potential of the proposed methodological approach and suggest that further investigations on this topic may bring innovative models suggesting to designers the best optimization strategies for technological choices. This approach shows also that it is nowadays possible to fully expand the methodology of the performance-driven design based on the programming of the users → activities → needs → requirements ← performance design flow. Further researches on this field are hence under development by authors.

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Chapter 26
Evaluation of Multifunctional Aspects of a Green Roof in Mitigating the Negative Effects of Urbanization in Mediterranean Environment

Martina Pratesi, Fabrizio Cinelli, and Giovanni Santi

Introduction

Green roofs represent an alternative solution to traditional constructive technologies and their numerous benefits have allowed a rapid diffusion. The positive effects of vegetative cover can be found in various areas of interest such as energy and environment. Therefore, they are an eco-sustainable solution that can mitigate the negative effects of urbanization [1, 2], increase in rainwater retention [3, 4], reduce the temperature changes and improve the energy performance of buildings [5–7], and it has been possible to appreciate this positive effects both on the urban scale and on the architectural scale. This study aims to analyse a technological installation of a green roof on a flat terrace, applying temperature sensors and a rainwater recovery system. The focus of the study concerns the choice of plan species suitable for Mediterranean environment, the thermal and stormwater run-off aspects related to a vegetated green roof, as they are the cause of the biggest problems in Italy and generally in a Mediterranean latitude.

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Materials and Methods

The Study Area

The installation is placed in Livorno, a city of Tuscany (Italy). The green roof was built on a flat terrace in an industrial area and is free on three sides (North–South–East) while on the west side is defined by a wall of the building (Figs. 26.1 and 26.2). Livorno is characterized by Mediterranean climate with mild summers due to the proximity to the sea and non-rigid winters. Specifically, the temperatures fluctuate from 3 °C in winter and to 30 °C during the summer season, rarely going below −1 °C. Walter and Lieth thermo-pluviometrical diagram of Livorno shows summer drought lasts 2 months (July and August) (Fig. 26.3).

In addition, a MeteoSense 2.0 weather station was installed recently (Fig. 26.4). The weather station is equipped with an anemometer, temperature sensor rain gauge allowed to check the data recorded directly on site about temperature, wind, humidity and rainy events. The data is updated every 10 min and can be downloaded via a dedicated web page. Measurements are archived and it is possible to compare the various graphs to analyse each individual event.

Green Roof Design and Plant Material

The green roof is designed into two prototypes of 1.40 × 1.65 m each one, for a total area of about 4.60 m^2. Different vegetations were planted: in the first prototype, that we call A, we included plants with grey leaves and in the second one, named B, plants with green leaves (Fig. 26.5). The different vegetation will allow us to evaluate how the covering affects temperature, especially in summer period, ability to filter pollutants and retain water. In order to adopt the most suitable vegetation for the location, a preliminary study had been carried out to choose the different species to be included in the project. Some native plants were selected for the Mediterranean climate, then a more in-depth analyses were carried out concerning the physical and performance

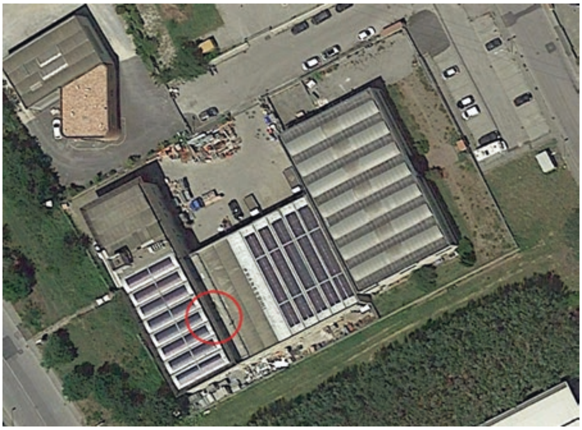

Fig. 26.1 Aerial view of the area of intervention

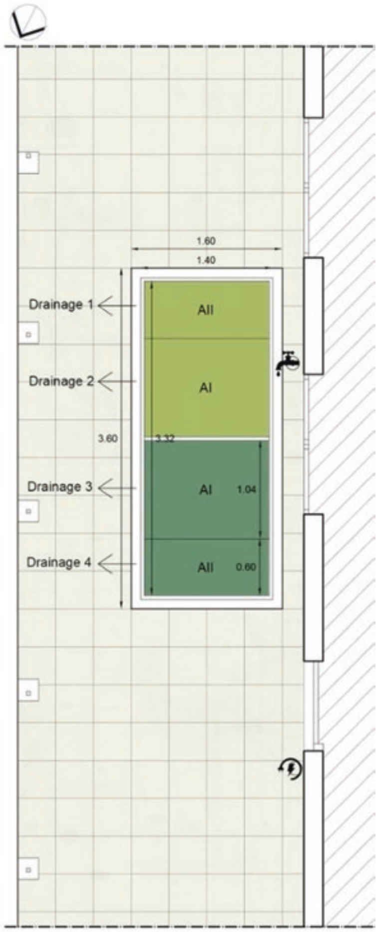

Fig. 26.2 Project plan

characteristics of each species [5]. Aspects such as roots growth, drought resistance, light requirements and maintenance have been taken into consideration. For each specimen, the leaf area index (LAI) was determined as a very important parameter to calculate evapotranspiration of green roof. LAI is the main indicator that affects the performance offered by a plant layer and it is defined as the leaf area per unit ground surface area. The LAI of the selected species was obtained by disassembling three plants for each species and leaf total area of every plant was calculated through digital scanned images (EPSON WF-7620, Japan) by ImageJ processing software [7]. The mean value of three replications per species was calculated.

In sector A, we find 26 grey-leafed plants, so devised 12 *Senecio cineraria* DC, 9 *Lavandula angustifolia* Miller., 5 *Helichrysum italicum* (Roth) G. Don. In sector B, we have instead 29 plants: 12 *Rosmarinus officinalis 'Prostratus'*, 12 *Thymus vulgaris* L., 2 *Thymus x citriodorus* (Pers.) Schreb. and 3 *Satureja hortensis* L. The various selected species are characterized by a diffuse development of the root system, good resistance to drought, adapted to dry soils without water stagnation, to neutral or basic pH and poor organic material.

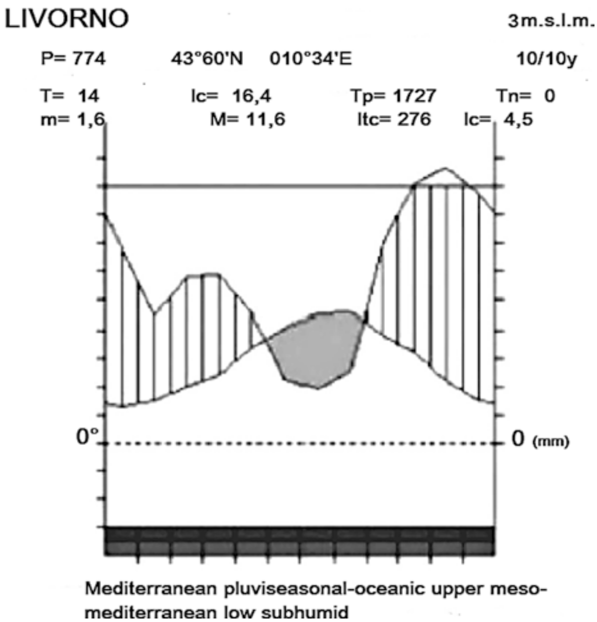

Fig. 26.3 Walter and Lieth climate diagram of Livorno

Substrate and Water Analyses

Fig. 26.4 The green roof (left) and the Netsense 2.0 weather station

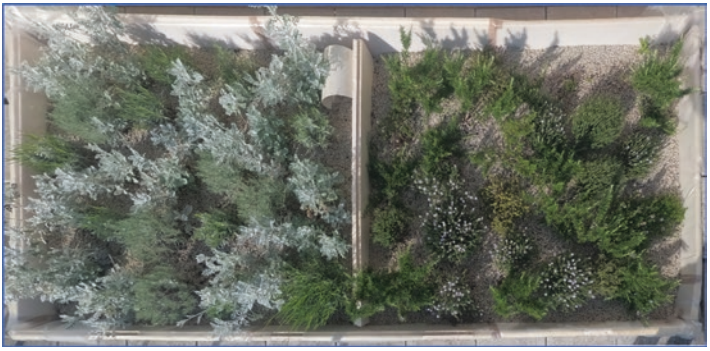

Fig. 26.5 The green roof subdivided into two prototypes, (**a**) (left) and (**b**) (right)

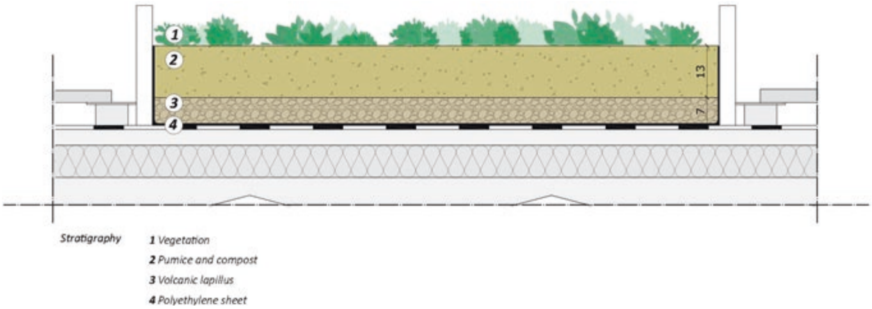

Fig. 26.6 Stratigraphic composition of the green roof

For the useful characteristics of the vegetal substrate, it was considered appropriate to choose a mixture that has lightness and good water retention characteristics. We realized a simple and cheap substrate formed of 20% of lapillus, 65% of pumice and 20% of compost. The stratigraphy with the relative measurements of both prototypes is as follows: polyethylene sheet, volcanic lapillus (7 cm), pumice plus compost (13 cm) and vegetation at the top (Fig. 26.6).

This substrate favours the plant nutrition process while remaining within the limits for which excessive water stagnation does not occur. A simple fertilization was performed with a fluid compound, a solution of PK 30-20 (30% phosphoric anhydrite and 20% potassium oxide), to establish plants.

The single components and their mixture (substrate) were analysed for physical and chemical properties. The bulk density was calculated as the ratio of the dry mass (dried at 105 °C) to the volume of the undisturbed sample. Bulk density (at maximum water holding capacity) was measured as per FLL guidelines [8] and mineral element by chemical methods was measured according to ASA-SSSA [9].

Thermal sensors were used to monitor the substrate temperature. Three data loggers (Tinytag Ultra 2) were located to monitor the external surface temperature and what is recorded under the substrate of each type. These three probes record the

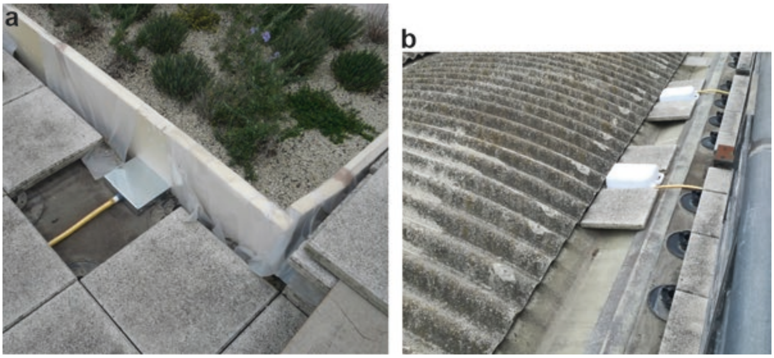

Fig. 26.7 The green roof and the pipe system to collect rainwater excess. (**a**) application for the collection of percolation water from a sector; (**b**) view of the percolation water collection tanks from the two sectors

temperature data with a temporal interval of 30 min. By means of the dedicated software it is possible to view the graph of the temperature trend and download all the single recorded data.

Moreover, a rainwater collection system was also set up to study the ability of the green roof to provide water retention and to filter pollutants present in the precipitations. In March 2019, the green roof was equipped with a water collection system (Figs. 26.6 and 26.7). The two green roof prototypes have two side openings for draining excess water. One of these openings was equipped with a water recovery system so that half of the water percolated from the substrate could be recovered with every rain. A metal conveyor connects each sector (A and B) of green roof to the corresponding tank through a pipe. The division in two collection systems allows us to assess the water retention of the two sectors of the green roof. Conductivity and pH were determined by conductivity meter HI 8033 and pH meter HI 99121 (Hanna instruments), respectively. In addition, the collected rainwater will be analysed to verify the presence of polluting substances as Pb, Zn, Cu, Mn, Cr, N and P.

Results and Discussion

A calculation was carried out on the loads acting on the coverage derived from the installation of the green roof and those existing before the removal of the floating floor and the related supports. In this case the green cover is lighter than the current flooring (Table 26.1).

The physical and chemical properties of the single components and their mixture (substrate) are showed in Table 26.2.

Table 26.1 Comparison of the loads before and after the implementation of the green roof

	ρ (kg/m^3)	Thickness (mm)	Load (kg/m^2)
Non-woven geotextile	200	2	0.4
Insulating panels in XPS	30	40	1.2
Lapillus	900	30	27
Pumice	600	100	60
Compost	450	30	13.5
	(kg/plant)	**(plants/m^2)**	
Plants	1	10	10
Additional loads	–	–	**112.1**
	(kg)	**(quantity/m^2)**	
Flooring	15	7.6	113.5
	(kg/support)	**(supports/m^2)**	
Floor supports	0.555	5	2775
Removed loads	–	–	116.23
Resulting additional load	–	–	**−4.13**

Table 26.2 Characteristics of different substrate components and green roof substrate

Parameters	Volcanic lapillus	Pumice	Compost	Mix
Particle size (mm)	10–15	3–5	0.5–1	3–10
Dry bulk density (kg/m^3)	830	310	120	550
Bulk density (at maximum water holding capacity, kg/m^3)	1810	930	430	915
Water holding capacity (kg/m^3)	58.4	26.7	10.8	39.2
pH	9.0	8.3	7.1	7.9
Conductivity (µS/cm)	150.3	19.5	130	82.4
Na (mg/L)	6.5	5.5	12.6	8.6
K (mg/L)	1.2	0.50	52.0	10.8
Ca (mg/L)	3.5	0.40	0.75	1.78
Mg (mg/L)	1.8	0.07	0.30	0.60
Fe (mg/L)	2.5	0.02	0.35	0.68
Cu (mg/L)	0.06	0.01	0.23	0.08
Zn (mg/L)	0.03	0.02	0.36	0.08

At the beginning of experimentation, three plants of each species were analysed by measuring plant dimension, foliage, total dry weight and canopy area (Table 26.3). Then the mean total leaf area per m^2 (LAI) was calculated for estimation of evapotranspiration of the green system. After 5 months from planting, the percentage of vegetation cover in prototypes A and B is 72.3% and 73.7%, respectively.

The mean LAI values result very similar but higher ones are observed in green-leafed plants that have smaller and thinner leaves, but leathery, with respect to grey-leafed plants with larger and hairy leaves. As observed by Berardi [6], the cooling effect with green roof retrofits on microclimate increased with the increase

Table 26.3 Summary table of plant size, weight, area and LAI of the leaves of various plants

Species	No. of plant	Plant dimensions (cm)	Dry weight (g)	Dry foliage weight (g)	Area (m^2)	LAI	
Senecio maritimus	1	20 × 20 × 13	75	15	0.1019	2.55	2.8
	2	20 × 20 × 13	70	15	0.1192	2.98	
	3	20 × 20 × 13	76	16	0.1259	2.86	
Lavandula angustifolia	1	19 × 18 × 10	50	21	0.1034	3.02	3.0
	2	19 × 18 × 10	50	21	0.0973	3.18	
	3	19 × 18 × 10	40	21	0.0899	2.78	
Helichrysum italicum	1	30 × 25 × 28	119	37	0.2124	2.83	2.6
	2	30 × 24 × 26	113	33	0.2009	2.62	
	3	37 × 24 × 31	156	35	0.2397	2.31	
Thymus vulgaris	1	20 × 20 × 15	70	15	0.1352	3.38	3.5
	2	20 × 20 × 15	65	13	0.1450	3.62	
	3	20 × 20 × 15	68	14	0.1346	3.36	
Rosmarinus officinalis 'Prostratus'	1	20 × 20 × 30	101	30	0.1472	3.68	3.6
	2	20 × 20 × 30	98	30	0.1483	3.71	
	3	20 × 20 × 30	95	28	0.1462	3.65	
Satureja hortensis	1	15 × 15 × 10	43	18	0.0585	3.04	2.9
	2	15 × 15 × 10	40	15	0.0604	2.68	
	3	15 × 15 × 10	48	20	0.0656	2.91	

of LAI, so to investigate this parameter for the Mediterranean species becomes important to study the fitness of green roofs in urban warm climates. The building energy consumption after retrofitting was found more influenced by the soil depth than the LAI of the green roof, and this assumption is also confirmed in this experiment where the substratum depth of stratigraphy is 20 cm and bigger LAI is on average 3.3 (m^2/m^2) (green-leafed species).

In the first 5 months of measurements, the probes recorded temperature differences of around 2–3 °C during the thermal peak and warmer than the same amount at the minimum external temperatures, with variability due to the humidity of the substrate and the colour of the vegetation. Since February temperatures have increased with peaks even higher than 25 °C and minimums of 4 °C, green roof showed to be able to maintain an average temperature between 20 and 6 °C approximately (Table 26.4 and Fig. 26.8). Differences in temperatures up to 11 °C occurred in March and April.

As expected, the grey leaf plants reflected the solar rays (greater albedo that we will still have to measure in the next summer months) and therefore the temperatures recorded below the substrate showed a restricted range.

The graph was elaborated through the Netsens Live Data software and shows the rainy events in Livorno in March and April (Fig. 26.9).

Table 26.4 Maximum and minimum temperatures recorded at the surface of substrate (external) and under the substrate in green roof prototypes A and B, for 5 months

		Temperature (°C)	
		Maximum	Minimum
December	External	17.4	−0.1
	Internal (A)	13.4	3.4
	Internal (B)	13.1	3.9
January	External	14.6	−3.5
	Internal (A)	12.1	3.4
	Internal (B)	11.9	4.3
February	External	26.4	0.3
	Internal (A)	13.9	4.8
	Internal (B)	13.6	5
March	External	34	2.3
	Internal (A)	16.5	9.6
	Internal (B)	17.7	9.6
April	External	32.6	5.6
	Internal (A)	20.3	9.9
	Internal (B)	21.3	9.5

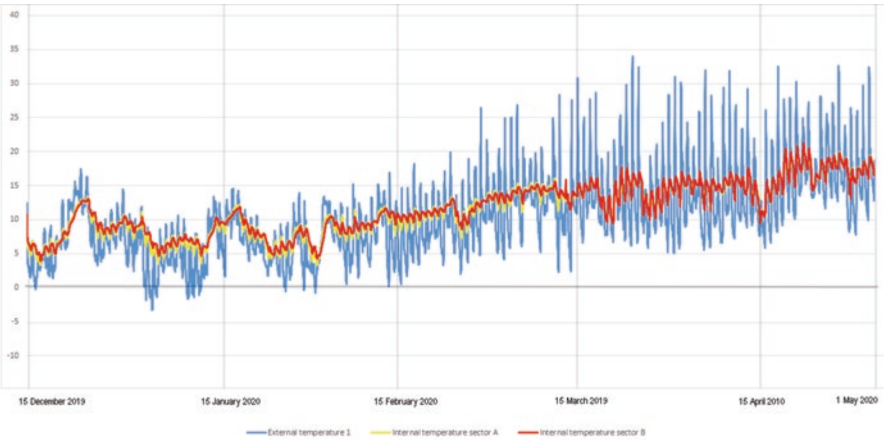

Fig. 26.8 Graphic with overlapped temperatures recorded by the probes during the monitoring period (December–April 2019). External temperature (blue), Internal temperature of sector A (yellow), internal temperature of sector B (red)

Rainwater accumulation from 1.25 to 32.5 mm occurred during this period. The data collected by weather station were compared with those provided by the regional weather monitoring centre of Tuscany for further verification.

Table 26.5 summarizes the results of analysis carried out on rainwater concerning pH, conductivity and salinity.

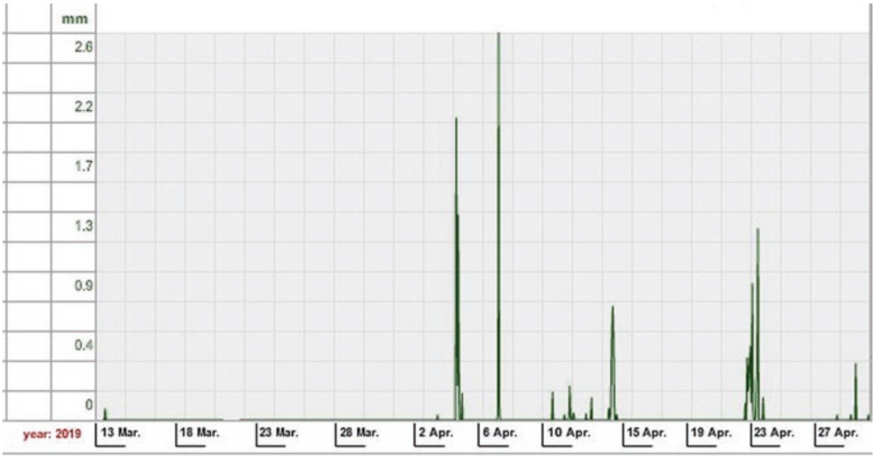

Fig. 26.9 Rains recorded by the weather station from March13th to the end of April

Table 26.5 Rain accumulated on rainy days and parameter analysis

Data	Accumulation (mm)	pH	Conductivity (mS/cm)	Salinity (‰)
4 April	32.50	6.62	66	0.03
22 April	10.75	5.90	46	0.02
23 April	25.00	6.50	30	0.01
29 April	2.75	5.78	80	0.03

Considering that there are no standards to regulate the runoff quality from green roofs, the results obtained from this study were compared to standards proposed by the US Environmental Protection Agency for freshwaters [8, 9]. Until now the percentage of water retained by the roof approaches 50–80% depending to event intensity and only two rain events permitted to collect water samples, useful to determine pH and salinity (Table 26.6). The collection system did not work well due to scarce slop of the terrace and collection of only half the water, so it will be necessary to improve the system in the coming months by collecting percolation water from all four side openings of the green roof. In this way we will collect enough water to carry out analyses on pollutants.

So now, there are no useful data to evaluate the effect of the substrate and the type of plants on the reduction of pollutants in the percolated water. Considering the Mediterranean conditions and the problems that increasingly occur in the hot months (sudden stormwater and drought, increased air pollution) the system will be exploited in the next summer to evaluate the behaviour of plant species and the delayed runoff, including decreased loading of contaminants, as reported by various authors [12–14] in different climates and sites.

Table 26.6 Comparison of runoff from green roof assembly with US EPA recommended freshwater standards [10, 11]

Contaminant/parameters	EPA recommended freshwater standards	Rain water	Level found in sector A	Level found in sector B
			During actual and useful rain events	
pH	6.5–9	6.2	6.2	6.3
Conductivity (μS/cm^2)	Nil	0.02	0.04	0.05
NO^{3-} (mg/L)	10	–	–	–
PO_4^{3-} (mg/L)	0.05	–	–	–
SO_4^{2-} (mg/L)	250	–	–	–
Cl^- (mg/L)	230	–	–	–
F^- (mg/L)	4.0	–	–	–
Na (mg/L)	Nil	–	–	–
K (mg/L)	Nil	–	–	–
Ca (mg/L)	Nil	–	–	–
Mg (mg/L)	Nil	–	–	–
Al (mg/L)	0.087	–	–	–
Fe (mg/L)	1.0	–	–	–
Cu (mg/L)	0.013	–	–	–

Conclusion

These preliminary results collected up to now are encouraging and still insufficient given the brief period of observation and analysis. From the point of view of the loads acting on the roof, an estimate was made on those currently present due to the pavement and those that were added with the implementation of the new stratigraphy: it was determined that, by removing the flooring and installing the green package, the loads on the floor are reduced by 0.04 kN/m^2; for this reason interventions on the structure to increase the load capacity are not necessary. The temperature reduction has been appreciable, and the substrate temperature has been stable for the whole duration of the short monitoring. The water retention capacity of the roof should be observed for longer period and with different intensities of precipitation in order to record more statistically significant data. Since the collected rainfall water was not enough until now to perform analysis of pollutants, due to malfunctioning of the collection system, future work will be focused in detail on the ability of the green roof to abate contaminants and retaining rainwater.

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Part VII
Renewable Energy in Buildings and Cities

Chapter 27
Solar and Wind Energy Will Supply More Than 50% of World Electricity by 2030

Ali Sayigh

Global Warming and Climate Change

It is now indisputable that climate change and global warming are happening and they are happening on a vast scale that we cannot ignore. In many parts of the world the situation is causing blackouts, more than 3000 self-ignited fires, glaciers are melting faster than predicted and flooding is happening everywhere. In the Antarctic, sea ice has been melting at an alarming rate and shrank by 1463 km^2 between 2010 and 2016 (Fig. 27.1).

Many UN meetings in the last three decades have warned of the dangers of global warming and have urgently called for carbon emissions to be significantly reduced. Targets have been set, targets have been agreed, targets have been cut back, and targets have been ignored. Yet the economic and social costs and environmental dangers have increased. Global warming has accelerated while it has been disputed or ignored. Those who pay the price are the elderly and the young, and overwhelmingly the poor.

It is estimated that 10,000 old people in France died in 2014, a year when Europe experienced a record breaking heatwave. During August 2017 the daytime temperature reached 54 °C in Kuwait while in January 2019 the coastal nondesert regions of Australia experienced prolonged temperatures of 40 °C, where formerly it rarely exceeded 27 °C. Global warming is happening, faster than expected (Fig. 27.2).

I remember in July 2012 Prof. Neil Ferguson of Harvard gave a BBC radio Reith lecture about the Rule of the Law. He was unable to come up with a solution to the complex problem of how to apply the rule of law across different cultures and varying economic systems and concluded that perhaps the answer lay in asking our children what they would do, perhaps, he surmised, they would have the answers.

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Australia (1) Forest Fire (2) Flooding in USA(3) South Pole melting(4)

Fig. 27.1 Climate change. Australia [1], forest fire [2], flooding in USA [3], south pole melting [4]

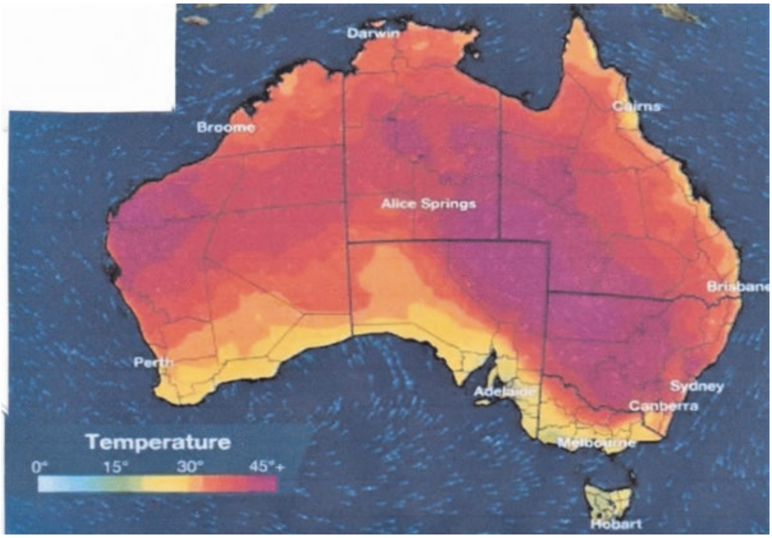

Fig. 27.2 Global warming in Australia

Now it has taken 16 year old Greta Thunberg to wake up the world about climate change and global warming. She told UK members of Parliament, "We children have no future because of global warming," and on another occasion in Sweden, she said "We cannot wait to 2030 to do something about it, I shall be 28 years old?" Out of the mouth of babes ….

See her picture in Fig. 27.3.

Another major problem of which we have only recently become aware of its scale is that of the melting of the permafrost in the north and south polar regions. The exposed ground will release millions of tons of methane and CO_2 [5]. Globally, there is much less methane in the atmosphere than carbon dioxide, but it traps heat at about 20 times as efficiently as carbon dioxide. What are the methods of methane in the polar regions? "The first source of methane is called methyl clathrate. Methyl clathrates are molecules of methane that are frozen into ice crystals. They can form deep in the Earth or underwater, but it takes very special conditions, with high pressure and low temperature, to make them. If the temperature or pressure changes,

Fig. 27.3 Greta Thunberg

the ice that imprisons the methane will break apart, and the methane will escape. We're not sure how much methane is trapped in methyl clathrates, or how much is in danger of escaping." The other major source of methane in the Arctic is due to decayed and buried organic matter, such as dead plants and animals, frozen in permafrost for thousands of years. As long as they remain frozen, they will stay in the permafrost. However, if they thaw, they will further decay, releasing carbon dioxide or methane into the atmosphere [5].

Furthermore, it is important to realize that even if we stop the use of fossil fuels it will only result in 50% cut in CO_2 emissions because the other 50% is due to our methods of producing food on an industrial scale and current farming policy and methods. It is due to soil carbon sequestration. It is imperative that we all think of how not only to reduce GHG emissions but also how to rationalize our electricity consumption. It is a myth beloved of twentieth century political economists that growth can and should occur in each and every year. It is commonsense that this cannot be sustainable or true ad infinitum. It is this myth that drives climate change denial. Each one of us must think positively of how we can reduce GHG emissions, how we can reduce our personal electricity consumption; we can demand and use public transport, walk or cycle to our workplace, and cut back our meat and dairy consumption.

It was a wonderful achievement when plastics were developed in the petrochemical industry in the 1960s but their indestructible nature was not foreseen, a truly tragic case of unforeseen consequences. Most plastics in common use commercially and domestically are nonbiodegradable. Our profligate use of the 'friendly' product has resulted in pollution of land and sea on a monstrous scale which impacts on the health and viability of humans, plants, and sea and land animals, in other words our natural environment, see Fig. 27.4. In the UK alone 2.28 million tons of plastics were produced in 2018 [6].

A- Plastics in everyday life in the UK B- Projection of mismanaged plastics in 2025

Fig. 27.4 (**a**) Plastics in everyday life in the UK. (**b**) Projection of mismanaged plastics in 2025

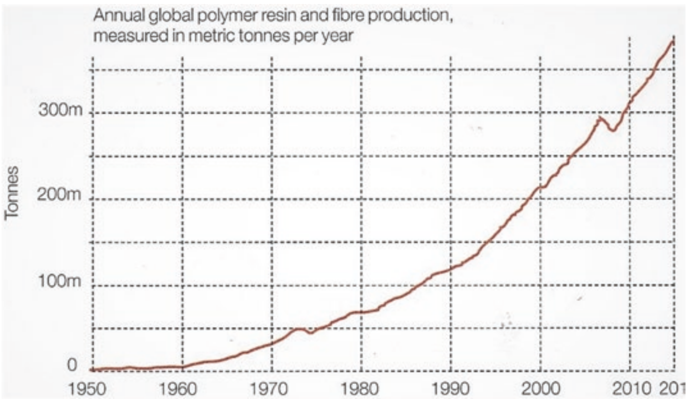

Fig. 27.5 Polymer resin and fiber annual production globally in 2017 was 381 million tons [6]

Another example [7] is that of 2015, the global polymer and resin production was 381 million tons, see Fig. 27.5.

Reality of Using Renewable Energy to Reduce the Effect of Climate Change

All countries are waking up and taking action and moving towards actively using renewable energy, mostly in the form of electricity. Some of them are seriously replacing fossil fuels with clean energy sources. For example, if we take the Gulf

Fig. 27.6 Dubai renewable energy drive

Table 27.1 Power percentage generated in the UK by 2029

Energy source	Percentage
Gas-fired power station	40.7
Renewables	28.1
Nuclear plants	22.5
Coal-fired power station	1.3
Electricity imported	7.4

region, Saudi Arabia has pledged to have 40 GW capacity from renewables by 2030. Presently its power generation is 55 GW, 8 GW from renewable energy. Dubai electricity power supply in 2017 was about 10 GW mostly from gas [7]. It is planning to have a solar park of 5 GW by 2020 from renewable energy. The Emir recently announced that Dubai will have 75% of its power generated from renewables by 2030, see Fig. 27.6.

UK Substantially Changing to Renewable Energy

UK power capacity in 2019 is 37.44 GW, 28.1% from renewable energy, while about 51.1% is from fossil fuels. This is planned to change with the new drive by the UK Government to make offshore within renewable energy wind will supply more than 30% of electricity by 2022, It is expected by 2030 that offshore wind will supply 30 GW of power and 70% of UK electricity will be generated from low carbon sources [8]. The Government has pledged that by 2050 no fossil electricity will be available. Table 27.1 shows the power percentage generated in the UK during 2019.

Presently the UK has the largest offshore wind farm capacity in the world of 8 GW. Wind farms now generate nearly14.0 GW of electric power [9] (Fig. 27.7).

For the first time in 2018, no coal was used to generate electricity for 1000 h. Figure 27.8 shows some of the PV applications in the UK.

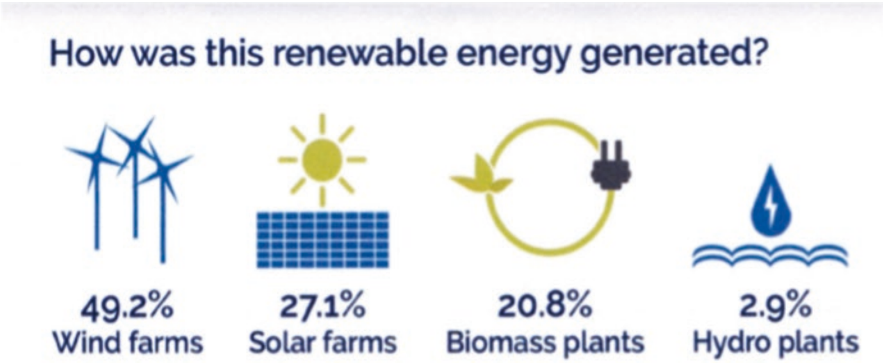

Fig. 27.7 The renewable energy types supplying 28.1% of UK electricity in 2019 [9]

Fig. 27.8 Blackfriars Bridge 5 MW, London and solar farm near Reading

India Renewable Energy Program

India has started to actively generate electricity by solar and wind energy. The government plans to have 227 GW by 2022. Both onshore wind and solar will form the backbone of this plan. However, offshore wind is expected to supply 30 GW of power by 2022.

The electricity sector in India has one main National Grid with an installed capacity of 356.100 GW as on 31 March 2019. Renewable power plants which also includes large hydro, constituted 34.5% of total installed capacity. It is clear that by 2030, India will have more than 50% of its electricity from renewable energy.

Australia Renewable Energy

One of the most effective programs in renewable energy is the Australian one. It plans to install 2 GW PV on rooftops in 2019, see Fig. 27.9 [10]. From Fig. 27.9 it can be seen that Australia has a vast potential to turn away from fossil fuel usage since it has one of the highest levels of solar energy intensity.

Fig. 27.9 Rooftop installation in Australia and Solar Radiation Map (4.00–6.75 kWh/m^2/day) [11]

Fig. 27.10 300 MW PV farm installed in Brazil in 2019 at a cost of US$ 300

At the end of 2018, 14.8 GW of new generation had been built and the finance of $24.5 billion (Australian Dollar) in investment had created more than 13,000 jobs [12]. In 2018, power generation was 29.8 GW. It is clear that renewable energy is already generating more than 50% of its electrical power.

Brazil Renewable Energy Program

Brazil was the third largest installer of PV after China and India during 2017 and 2018. By the end of 2018, alone Brazil had installed more than 2.0 GW PV. Figure 27.10 shows one of the largest installations in Brazil [13]. Brazil has 137

GW of electric power so far in 2019. This compares with expected growth of global PV installation capacity of 505.2 GW by the end of 2019, and by end of 2022, it could reach 1026.2 GW [13].

According to the report in "The Brazil Business," hydro power can supply 65% of Brazil's energy needs but only 25% is utilized. PV supplies 2 GW and wind energy supplies only 2.2 GW, while the potential supply is 140 GW. Biomass can provide 7.5% of Brazil's power. Thus renewable energy could easily meet more than 50% of its electricity demand in 2030 [14].

China Trying to Reduce Emission by Using Renewables

In 2017, China declared that it would invest $360 billion in renewable energy by 2020. It will scrap the plan to build 85 coal-fired power plants. In March 2017, Chinese authorities stated that the country was already exceeding official targets for implementing energy efficiency, carbon emission reduction, and its increasing share of clean energy sources. China is experiencing an energy transformation, which is being driven by technological change and the falling cost of renewables. China is not just investing in renewables to phase out coal, but aims to be a major exporter of renewable energy. In China, various other factors have been introduced, including increased energy efficiency in residential, industrial, and commercial buildings, and lowering energy demand for transportation, owing to the increase of autonomous vehicles and ride sharing, similar to that of Cuba [15].

China has been investing yearly $100 million in its energy sources since 2017 which is twice of that of USA, of this $32 million was on renewable energy. China expects to invest more than $360 billion in renewable energy by 2020. China has more than 1000 companies manufacturing renewable energy equipment. Figure 27.11 shows the export record of one of the leading PV manufacturers.

China's renewable energy capacity reached 728 GW by the end of 2018 [16]. It is estimated that 65% of power generation in China comes from hydro. It is worth noting that China is leading the rest of the world in using electric cars, see Fig. 27.12.

China is number one in using PV; in 2018 it installed more than 44.1 GW [18], while the global figure was 174.63 GW. During the first 3 months of 2019 China installed 5.2 GW [12]. Thus by 2030 more than 50% of its electricity will be generated by renewable energy (Fig. 27.13).

United States of America

Despite the present president of the USA not agreeing to sign Climate Change UN Treaty and being anti-renewable energy, 45 main cities out of 57 are doubling their renewable energy applications [12]. Figure 27.14 illustrates this drive to double their facilities in 2019.

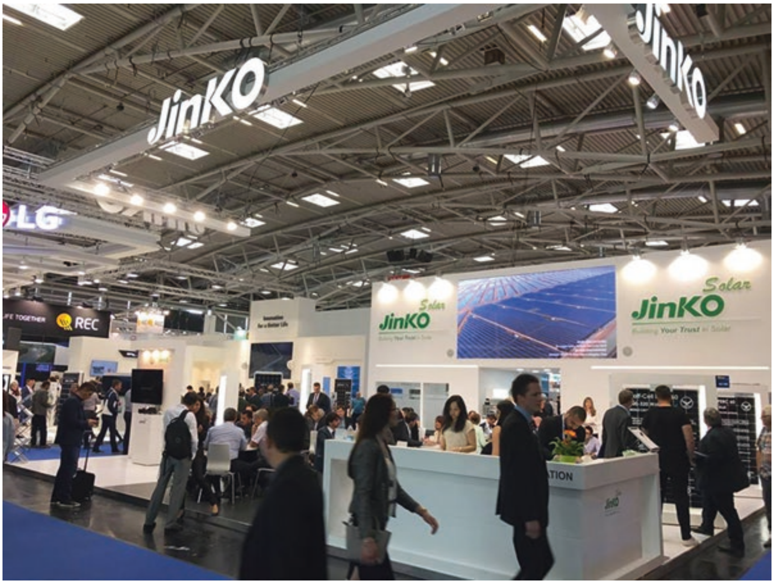

Fig. 27.11 JinKO PV major Chinese PV company

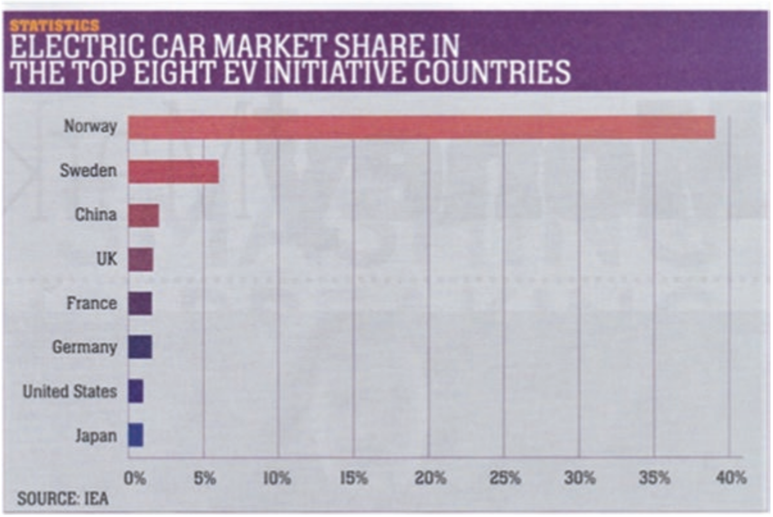

Fig. 27.12 Electric cars percentage used in the top eight countries [17]. If one takes EV number of cars, then: China = 1200,000, Europe = 1000,000, USA = 850,000, rest of the world = 150,000. The total exceeds 3 million cars

As of April 2019 the USA has more than 60 GW of PV.

California set the scene for the rest of the USA by announcing that all their power will come from renewable energy by 2045. This is a great challenge for them to achieve (Ref. S&P Intelligence Report). Presently, renewable energy supplies

Fig. 27.13 Large PV installation in China

Fig. 27.14 Los Angeles Department of Water and Power (LADWP) plant

35% of California power. Coal has already been phased out and nuclear power is going to be phased out by 2024. The only remaining fossil fuel to provide power is gas. Wind and solar, however, do require storage in order to be a viable continuous supplier of energy and this is being tackled actively. Also hydro and geothermal resources are sufficient to supply a base load in California. Therefore, the prediction of 50% power supply from renewables in the USA could be easily achieved when the current policy under President Trump is replaced by green technology policy.

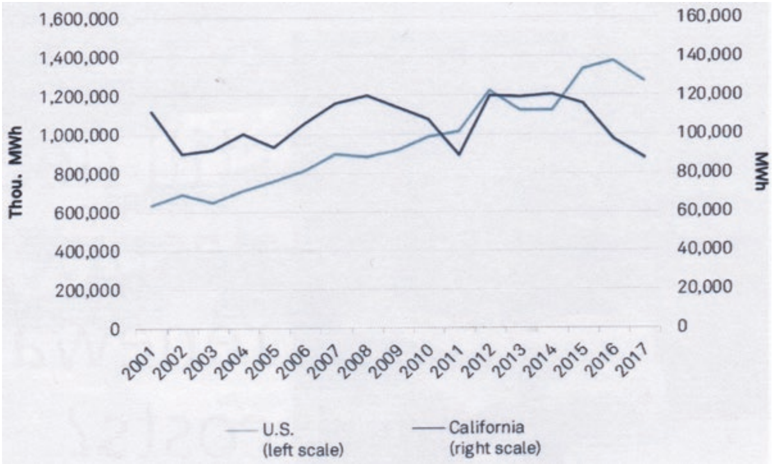

Fig. 27.15 Power generation in the USA and in California in 2017

Figure 27.15 shows the power generation in the USA and in California. US power production in 2017 is about 1300 GW. In 2019, 260 GW will be generated from renewable energy [20].

Wood Mackenzie predicts the USA to have 3 million solar installations by 2021 and 4 million by 2023. Currently, in May 2019, the number of solar installations in the USA has reached more than 2 million, according to Wood Mackenzie Power & Renewables and the Solar Energy Industries Association (SEIA). This represents more than 70 GW of capacity [29].

Many regions are promising to reach 100% renewable power to cover their needs by 2050; these include Nigeria, Puerto Rico, Hawaii, and California.

Recently Iraq has announced a tender to install 755 MW of PV to be built by 2020 across five provinces of Babel, Wasit, Karbala, Al- Muthanna, and Diwaniyah. This will meet approximately 50% of their present electricity generation. The Minister of Energy has said that Iraq aims to be a global center of renewables [21].

Chile Renewable Energy Program

Most South American Countries have very active programs in renewable energy and Chile is no exception. One scheme is to use floating PV in a small mining community, see Fig. 27.16, [22]. Chile installed 715 MW of renewables into their electricity system in 2018, which is 92% of all electricity installation in that year, which was divided between solar 59% and wind 32%. Presently, only 12.8% of total electricity in Chile comes from renewables [23].

Fig. 27.16 Chile floating 84 kW, PV farm on lake north of Santiago supplying 153 MWh a year to the mining community at the beginning of 2019

Fig. 27.17 400 MW PV as part of 1.6 GW solar park in south of Egypt

Egypt Renewable Energy Program

Egypt has a substantial hydro power generation, notably the Aswan Dam, but during the last 5 years it has invested in wind energy and is now pressing ahead with PV applications, Fig. 27.17 [24].

Egypt has managed to produce a National Wind Atlas, which shows that Egypt enjoys strong wind at an average speed on 10.5 m/s. This has led the Egyptian

Fig. 27.18 Wind farm in Egypt

government to aim to provide 12% of generated electricity (the equivalent of 6.8 GW) through wind energy by 2022; this goal is part of Egypt's 2030 strategic plan to have no coal-based electricity. Siemens will also deliver up to 12 wind farms in the Gulf of Suez and west Nile areas, comprising around 600 wind turbines and an installed capacity of 2 GW. Currently, 29 solar power projects have been financed at a total investment of $1.8 billion, producing almost 1.8 GW of solar power, on a 14.3 mile^2 plot of land. Egypt is buying the electricity at a rate of 7.8 ¢/kWh for 25 years (Fig. 27.18).

The hydro power currently generates 2.64 GW, while Benban Solar Park generates 1.6 GW. It is expected that by 2030 Egypt will have more than 18 GW from renewables [25]. At the moment, total power electricity in Egypt is about 32 GW.

Examples from Other Countries

Figure 27.19 shows examples from various countries. For example, at the end of 2018 the Netherlands had 4.4 GW PV and 12.7 GW from wind power [18]. Oman has signed an agreement with the Saudi Arabian authority, ACWA, to build 500 MW PV jointly with the Gulf Investment Corporation, west of Muscat, [26]. Poland PV installation has reached a capacity of 603 MW at the end of March 2019 [19]. Zimbabwe is planning with a US Labacorp Power to build a solar project of 900 MW [27]. PV in the Netherlands is 4.4 GW and wind power has reached 12.7 GW.

PV in Netherlands 4.4GW

Wind Power reached 20.7GW

Zimbabwe is planning with a US Labacorp Power a solar project 900 MW

Fig. 27.19 Netherlands PV and wind energy and Zimbabwe gathering

Conclusions

According to IRENA Report [28], at the end of 2018, renewable energy power reached 2351 GW: hydro-power accounted for nearly 50% of this (1293 GW), wind power 564 GW, solar power 486 GW, biomass 115 GW, geothermal 13 GW, and marine power 0.5 GW. The total represents 33% of global generating power. If the aim is to have 50% of power generated from renewable sources by 2030 then we have just over a decade left to achieve this. This will mean significant changes in energy and agricultural policies and consumption patterns and the removal of fossil fuels from the power equation. Should we fail to achieve this then we are faced with a very bleak future and a terrible legacy to hand on to our children and grandchildren. As far as humans are concerned vast tracts of the planet on which we currently depend will have become virtually uninhabitable and the oceans and air polluted.

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Chapter 28
Feasibility Study of a Low-Carbon House in Tabriz, Iran

Hossein Mirzaii and Sanaz Hariri Shabestari

Introduction

With Iran ranking the fourth largest oil reserve and the second largest natural gas supplier in the world, it is not surprising that oil and petroleum products account for the largest fraction of greenhouse gas emissions. Hence, the Iranian government was required to reduce by 12% its greenhouse gas (GHG) emissions by 2030 [1]. This reduction in CO_2 emissions must be implemented in the building sector as it contributes highly to carbon emissions. A house needs to meet certain criteria to be considered a passive house such as the space heating energy demand (must not exceed 15 kWh/m^2 of net living space per year), the renewable primary energy demand (must not exceed 60 kWh/m^2 of treated floor area per year), thermal comfort (for all living areas all year round with not more than 10% of the hours in a given year being over 25 °C), and airtightness (a maximum of 0.6 air changes per hour at 50 Pascal pressure) [2]. These requirements were implemented in this project alongside an active design for the proposed house to meet the energy demand. The main aim of this project is feasibility study to design and develop a low-carbon emission building in Tabriz, Iran, by using low embodied energy materials and to see if this house is financially viable to build or not. This project is therefore separated into three parts as its objectives.

The objectives were as follows:

1. To design a house by considering a passive natural cooling system.
2. Design and analysis of the active system to meet the maximum energy demands for the house.
3. Financial analysis of the active system.

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Passive Design of the House

A 3D model of the house using architectural software was designed, and low embodied carbon materials were used in order to reduce carbon footprint.

Construction Materials

Wall Structure

The different varieties of the construction materials used in Iranian buildings such as stones, wood, and gypsum are based on the seismological conditions, climate and local availability. Natural stones like granite, shell rock, and marbles are used as load bearing and decoration for external walls. Timbers such as pine are usually used for ceilings and wall framing, especially in seismically active areas. Therefore, a highly insulated wall with low-carbon materials is required to work in extreme climates like Tabriz [11]. A breakdown of designed wall structure is shown in Table 28.1. The *U*-value for this wall is found to be 0.153 W/m^2 K which meets the passive house design standards.

Windows

Natural wood such as timber has a high structural quality and is used in building sector worldwide. The amount of operational energy, its low-carbon footprint and the significant environmental benefit of timber over concrete and steel makes timber a sensible choice as a building material in doors, wall structure and window frames in the house [3]. The windows are triple-glazed, 44 mm with argon filling with a *U*-value of 0.6 W/m^2 K, as supplied by the window manufacturer [12].

Table 28.1 Double-stud wall structure

Material	Thermal conductivity (λ) W/m°K	Thickness (l) mm
Exterior wall		
Wall cladding (granite stone)	1.76	30–40
0.5 in. gypsum sheathing	0.65	12.7
4.75 in. cellulose insulation	0.038	121
0.5 in. ply wood	0.106	12.7
4.75 in. cellulose insulation	0.038	121
0.5 in. gypsum board	0.65	12.7
Total		315.1

Floor

Concrete's strength, great thermal mass and energy efficiency can provide environmental benefits that offset the energy needed during the manufacturing process. The amount of carbon in concrete can be affected by the different designs and specifications required during the manufacturing process [13]. A low-energy reinforced concrete slab, which is made from low energy concrete, low-energy reinforcing steel and other non-structural elements such as floor finish, paints and renderings, has been used in the flooring of the house [14].

Insulation

Plenty of natural and low embodied energy insulation materials such as cellulose, wood fibre, wool, hemp, hempcrete, straw and cane are available on the market. Their performance and other properties such as ease of insulation, shrinkage and compaction, protection against moisture, affordability and availability are very important when choosing the right low embodied energy insulation material. Cellulose insulation is made from recycled shredded newspapers. It is resistant to mould, insects, vermin and fire. Thermal conductivity of cellulose in walls is 0.038–0.040 W/m°K with an embodied energy of 0.45 MJ/kg and a thermal resistance of 2.6 K m^2/W at 100 mm thickness. Cellulose, therefore, is an ideal insulation material in walls [4].

The House Orientation

A building's correct orientation is important in order to increase its energy efficiency and reduce its negative impacts on the environment. The orientation of the house, from south to east, means it receives the maximum amount of solar radiation which increases the energy efficiency of the building [5]. Also, based on the sun's movement, in the northern hemisphere, large triple-glazed windows are placed on the south side of the building to face the sun and receive the maximum solar radiation in order to light and heat the building during the winter, as shown in Fig. 28.1 [6].

Fig. 28.1 The south side of the proposed house

The main heat gain will be solar gain through windows. Designed shading and surrounding landscapes in the south side of the house, double roofs with space between for air circulation, can help to reduce the cooling load of the building [7].

Passive Cooling Design Using Pool House and Solar Chimney

Space cooling has become a very important consideration for a building in an excessively warm climate such as that in Iran. Pool houses have been used in traditional Iranian buildings, which are located in the basements of two-storey buildings, in order to employ the cooling property of the soil. The central pond of the pool-house and the entering air flow from the northern side are used to create more effective cooling by promoting evaporation of the water which then transfers cooled air into the rooms above, the same as a passive cooling system, as shown in Fig. 28.2 [8].

A solar chimney, as seen in Fig. 28.3, is a simple way to improve natural ventilation in buildings by encouraging the convection of air upwards. The glass on a solar chimney—as a solar absorber—allows the heat to be transferred into the air in the chamber of the solar chimney, by convection. The heated air expands and rises. The created upward airflow sucks the air into the inlet located on the north side of the house, after which the warm air then flows into the ground. The ground acts as a heat sink so that warm air dissipates the heat and the cooled air flows into the house. Due to the airtightness of the house, the airflow is increased by the forced convection of air into the solar chimney [9].

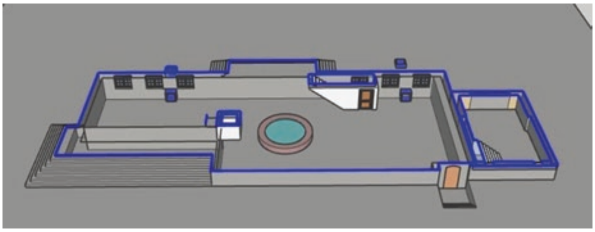
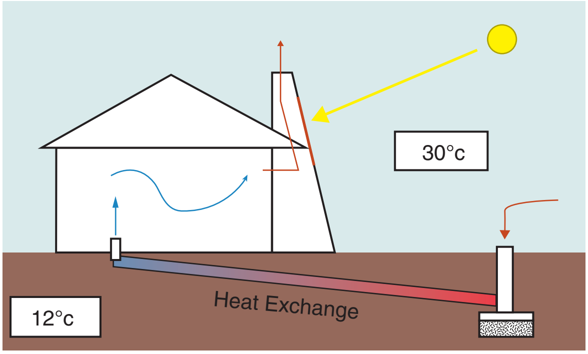


Fig. 28.2 The pool house in the basement of the proposed house

Fig. 28.3 A solar chimney [10]



CFD Simulation for the Designed Passive Cooling System

CFD simulation is used to visualise the airflow in the designed cooling system in order to determine the average air temperature throughout the house. Simulation was set during summer days in Tabriz with the inlet mass flow rate of air being 0.472 kg s^{-1}. Simulations for three different scenarios of airflow were tested. The final design was a top-down cooling strategy—'house with cooling + upstairs vents + top-down cooling'—that takes the cool air directly from the basement to the first floor, as shown in Fig. 28.4a.

The cool air will then spread throughout the first floor and descend to the ground floor, as seen in Fig. 28.4b. This approach equalised the temperatures across the house resulting in a uniform cooling.

The final average indoor air temperature was found to be 23.4 °C where the outside temperature was set at 30 °C, as seen in Fig. 28.5.

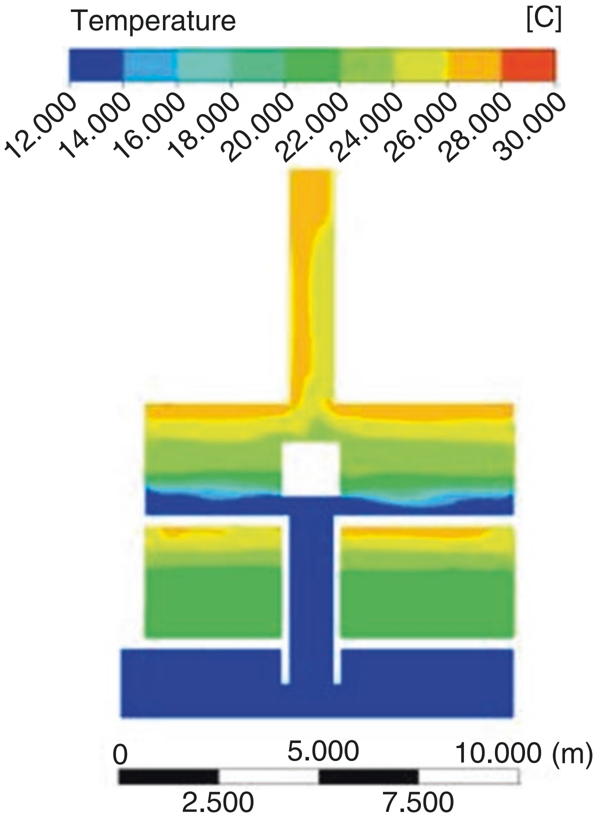


Fig. 28.4 (**a**, **b**) A top-down cooling design by CFD simulation

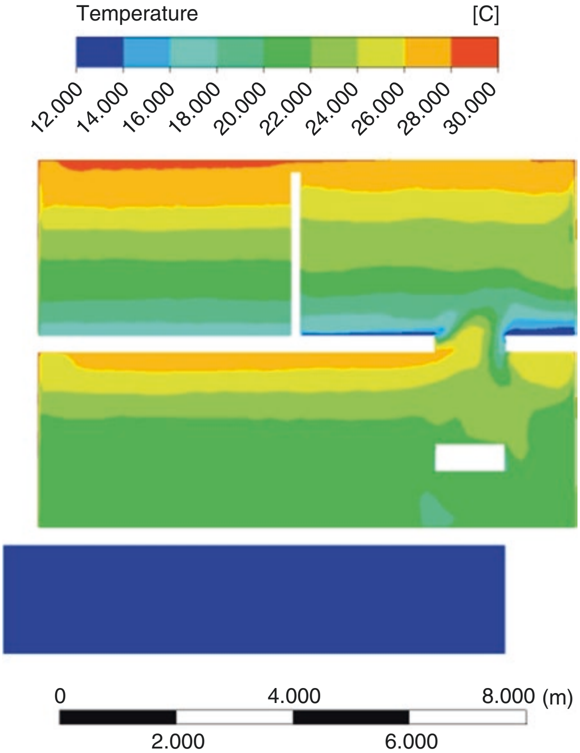


Fig. 28.4 (continued)

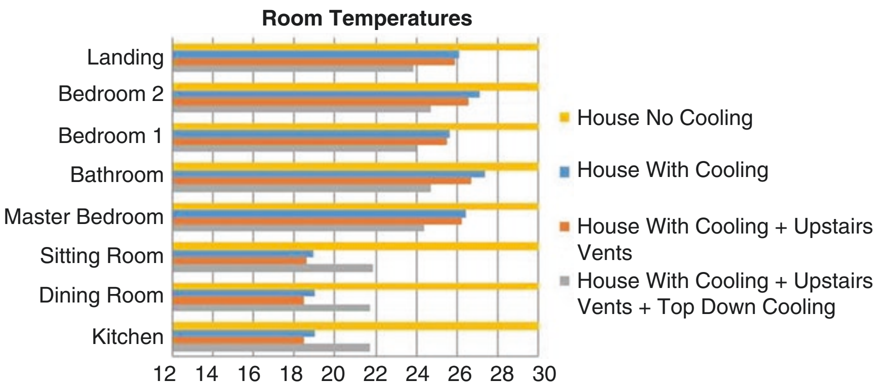


Fig. 28.5 Room temperature results by CFD simulation

The Active Design of the House

The active system was designed based on the size of the house, the electrical energy demands and the heating and hot water demands of the family. The house was designed to have 15 solar PV panels with the total nominal power of 4050 W and three evacuated tube collectors. A heat pump with heat recovery ventilation was also considered to provide additional heat and ensure a high indoor air quality. Polysun software was used to analyse the annual operation of this active system.

The Results by Polysun Software

The total annual electricity production was found to be 6524.8 kWh with 69.1% self-consumption fraction, as seen in Figs. 28.6 and 28.7. The total annual solar fraction of thermal energy was 57.7% with 9069.9 kWh field yields, as shown in Fig. 28.8.

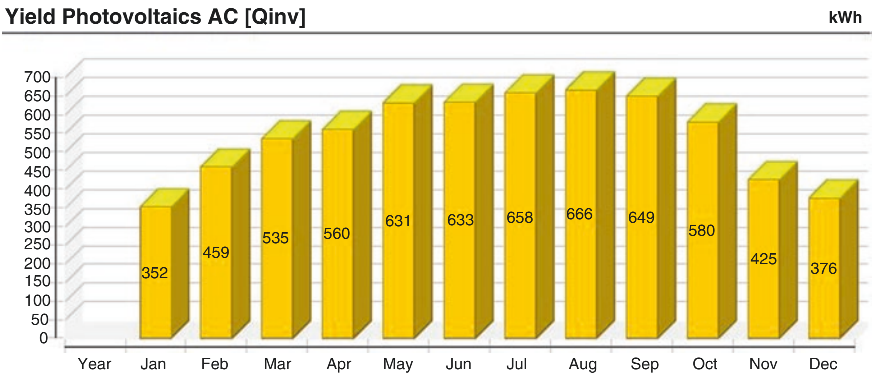


Fig. 28.6 The system photovoltaic yield

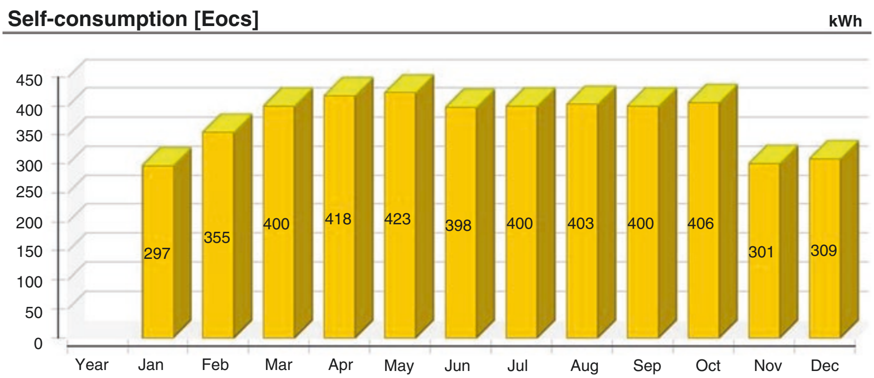


Fig. 28.7 Total self-consumption electricity

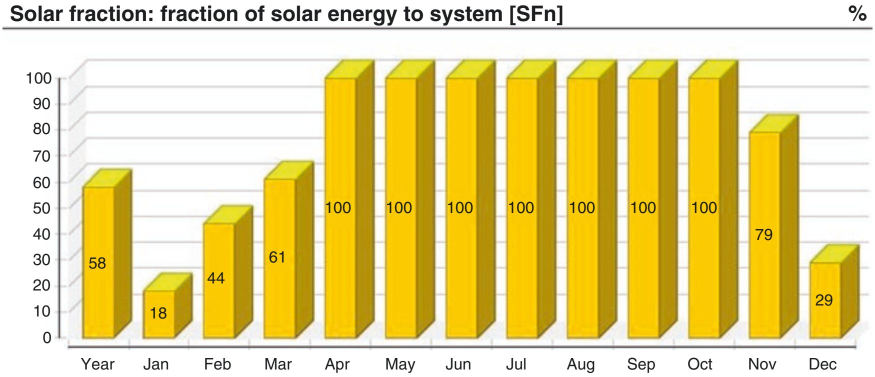


Fig. 28.8 The solar thermal energy to the system

An annual space heating of 19.62 kWh/m^2 was calculated which is slightly higher than the standard requirement for space heating energy demand. Total annual domestic energy demand was found to be 47.19 kWh/m^2 and this is much lower than the minimum standard requirement of the renewable primary energy demand.

Financial Analysis

In order to determine the feasibility of the proposed active system, it is essential to analyse the system by focusing on the income statement, balance sheet and cash flow statement.

Subsidies

PV System

There is only a Feed-in-Tariff (FIT) for exported electricity into the grid which is 8000 IRRS/kWh, equal to £0.15/kWh, by Iran's Ministry of Energy [15]. The total export FIT in year 1 was calculated as £302.40 which is reduced in the consecutive years due to 68% degradation of the solar panels. The Power Purchase Agreement (PPA) contract is also guaranteed over a 20-year term by Iran's Ministry of Energy, therefore the exported electricity will have no more benefit by the beginning of year 21 [15].

Thermal System

There are no financial incentives with regard to the amount of energy generated by a solar thermal system and heat pump.

Payback Payment

PV System

The National Development Fund of Iran loans 75% of the CAPEX with a maximum 5 years return and an 8% interest rate. The annual inflation rate is about 12% [16]. The payback period for the PV system with £1697.85 CAPEX was calculated as shown in Table 28.2.

Thermal System

The payback period for the thermal system with £14,070 CAPEX was calculated and shown in Table 28.3.

Profit

PV System

The total profit of the PV system at the end of year 25 was found to be £7634.95. The PV system could be paid back in the 4th year by looking at its revenues and costs.

Thermal System

Total profit of the thermal system at the end of year 25 was calculated as £12,844.65. The capital cost of a thermal system is very high, and there is no Renewable Heat Incentive (RHI) for solar thermal systems in Iran, so the thermal system cannot

Table 28.2 Payback payment for the PV system

Loan (£)	Fixed payment (£)	Variable payment (£)	Payback payment (£)
1273.39	254.68	101.87	**356.55**
1018.71	254.68	81.50	**336.18**
764.03	254.68	61.12	**315.80**
509.35	254.68	40.75	**295.43**
254.67	254.68	20.37	**275.05**

Table 28.3 Payback payment for the solar thermal system

Loan (£)	Fixed payment (£)	Variable payment (£)	Payback payment (£)
10,552.50	2110.50	844.20	2954.70
8442.00	2110.50	675.36	2785.86
6331.50	2110.50	506.52	2617.02
4221.00	2110.50	337.68	2448.18
2110.50	2110.50	168.84	2279.34

break-even in early years. However, the proposed thermal system is subsidising PV system that on its own does not make good profit.

The Entire Active System

The total profit of the active system at the end of year 25 was calculated as £20,479 that can be paid back by the end of year 11.

Levelised Cost of Energy (LCOE)

The average total expense of building and running a power-generating system over its lifetime divided by the total energy output of the system over that lifetime is called the Levelised Cost of the Energy (LCOE) of the system [17].

$$\mathrm{LEC} = \frac{I + \sum_{n=0}^{N} \frac{\mathrm{AO}}{(1+d)^n}}{\sum_{n=1}^{N} \frac{Qn}{(1+d)^n}}$$

where LEC = levelised energy cost, I = capital investment, AO = annual operations and maintenance cost in the year n, d = discount rate, Qn = energy generation in the year n, n = life of the system.

PV System

The LCOE of the PV system was found to be 3.43 p/kWh that is lower than the current electricity cost of 4 p/kWh. Therefore, the PV system is economically feasible. Its cost can be paid back in the 4th year.

Thermal System

The LCOE of the thermal system was found to be 23.42 p/kWh which is higher than the current cost of domestic natural gas. Generally, the price of energy is very low in Iran. However, the price of energy is rising dramatically due to increased population demand, a weak economy and other contributing political issues. The new cost of energy will, therefore, be levelised with the cost of thermal energy in the coming years.

Conclusion

The proposed house was designed using low embodied energy materials in order to reduce CO_2 emissions. The active system was able to achieve a 57.7% solar fraction from the thermal system and a 69.1% electricity self-consumption fraction from the PV system. The total annual CO_2 saving from the active system was found to be 7553 kg making a good contribution towards GHG reduction. Due to the energy output of the active system and the use of insulation, the total energy used for the domestic appliances was found to be 47.19 kWh/m^2 that is lower than the standard requirement of 60 kWh/m^2. An annual space heating demand of 19.62 kWh/m^2 was calculated that is somewhat higher than the minimum requirement of 15 kWh/m^2 but is much lower than heating demands of a new builds. As a result of the passive cooling design of the house, *a final average indoor air temperature of 23.4 °C* was achieved based on a reference outside temperature of 30 °C. The LCOE of the PV system was found to be 3.43 p/kWh which is lower than the current cost of electricity. It is therefore economically feasible. The LCOE of the thermal system was calculated at 23.42 p/kWh which is higher than the current subsidised cost of domestic natural gas. However, the cost of energy is dramatically going up in Iran due to increasing energy demands, a weak economy and other political issues making solar thermal LCOE more feasible in the coming years, given the environmental and public health benefits. It is important to bear in mind that the proposed thermal system is subsidising the PV system as this alone does not make a good enough profit. Also, this thermal system is improving the air quality by reducing 1806 kg of CO_2 emissions. The active system had a total capital cost of £15,767.85 and after all the financial calculations, the total profit was found to be £20,479. The active system capital cost is paid back in the 11th year.

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Chapter 29
The Development of Renewable Energy in Buildings in UAE

Riadh H. Al-Dabbagh

Introduction

In the past, few years ago, renewable energy prices, especially solar and wind have gone down dramatically. Has the use of renewables increased in equal measures? Now we are seeing a new trend. With the cost decline that we've seen, there are big emerging countries like China and India, coming to the table with massive new targets.

India has just declared that they will install 100 GW of solar and 40 GW of onshore wind by 2022. This is a huge number. The needs in India are immense and their signal is a very powerful one for renewables.

China has pledged 200 GW of solar and 100 GW of onshore wind by 2020. Now, these are remarkable numbers, and they will trigger very dramatic increases in investment in the power generation coming from renewables in the future.

The UAE is the first Gulf country to start on the new energy strategy, which involves the nuclear power and solar energy in addition to natural gas, which covers the majority of the UAE's needs. The country is looking to increase its target for power generation from clean energy to 30% by 2030; it aims to achieve 25–30% of its electricity to be generated from both nuclear and solar.

Strategic Objectives for UAE Regulations

- Reduce UAE Ecological Footprint
- The UAE ecological footprint dropped to 7.75 ha/person last year, down from 11.68 ha in 2006, the decrease was because of improved environmental sustainability, through the country's adoption of the Ecological Footprint Initiative.

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A. Sayigh (ed.), *Green Buildings and Renewable Energy*, Innovative Renewable Energy, https://doi.org/10.1007/978-3-030-30841-4_29

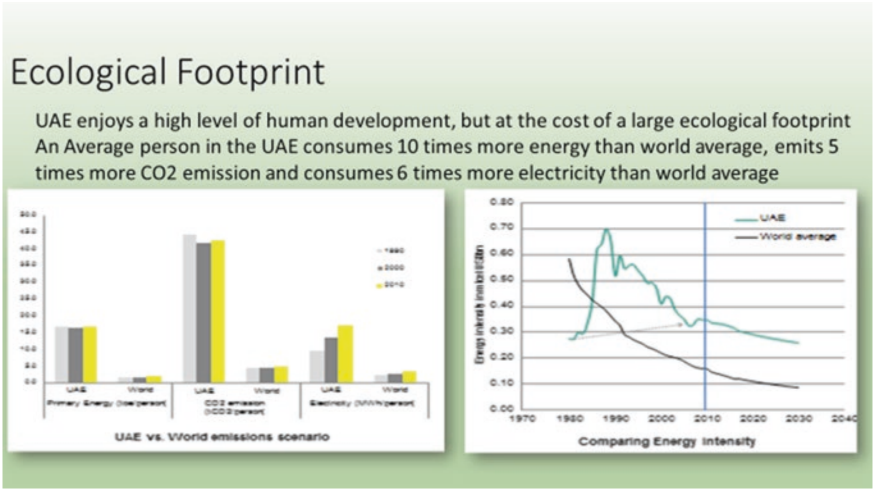

Fig. 29.1 UAE ecological footprint

The UAE is the third country in the world to do so after Switzerland and Japan. According to the 2014 Living Planet Report, five countries—China, the United States, India, Brazil, and Russia—account for 47.2% of the world's ecological footprint.

- Despite UAE urban growth, which brings more carbon emissions and a greater ecological footprint, efforts to promote a greener economy and environmental policies have improved the situation. UAE has set standards to ensure lighting product imports are energy efficient, especially for the housing sector, which represents 57% of the country's ecological footprint. The Government also aims to develop standards for fuel and cars, to reduce carbon emissions (Fig. 29.1).
- Reduce Electrical Consumption by 20%
- UAE aims to cut energy consumption by 20% by 2020 (Fig. 29.2). As it enforces an energy-efficient building project, buildings use 70% of the energy that the country produce, "To get the country green, that needs to target the biggest consumer—the buildings, whether residential or commercial." The efficiency of the program, called the green building project, was started as an initiative in 2008 by the Supreme Council of Energy, Electricity and Water Authority.
- In 2011, it became mandatory for all government buildings to adhere to the program. However, this year it was extended, requiring all new buildings to be energy efficient (Fig. 29.2).
- Reduce Water Consumption by 18%

The Federal Electricity and Water Authority (FEWA) has managed to save 53.44 million gallons of water last year. The 18% reduction in consumption, as compared to that of 2014, followed a nationwide conservation award that saw a stiff competition from housewives, schools, and mosques. Schools set a big example by saving

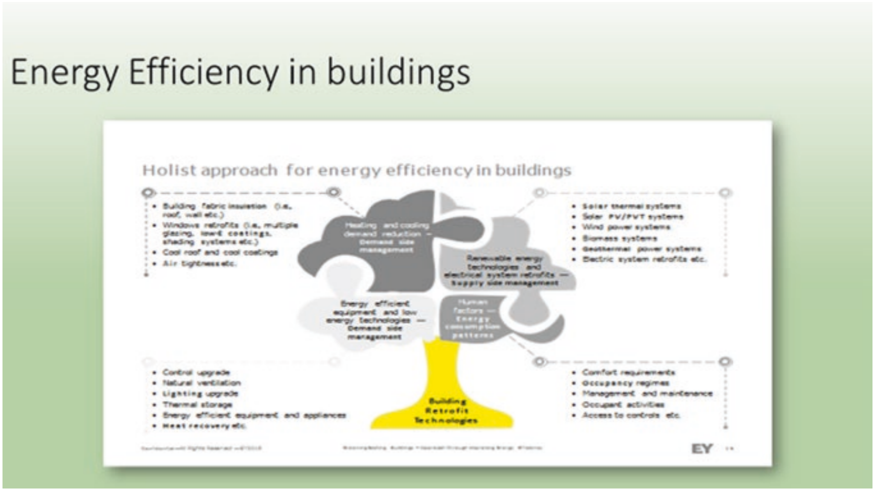

Fig. 29.2 Holist approach for energy efficiency in buildings

up to 35.34 million gallons of water that represented 25% cut as compared to 2014s consumption. Those were followed by the mosques category, which saved 10.04 million gallons of water or 18% drop in comparison compared to 2014's water consumption. "Housewives came third after saving 8.1 million gallons of water that represented 9% reduction in consumption compared to 2014's water consumption. The Eastern region (B) led the country in rationing with 13.42 million gallons of water saved or 30% drop as compared to 2014's consumption." However, the Western region (A) managed to save 16.71 million gallons of water, but that represented 22% drop in comparison to 2014's water consumption (Fig. 29.3).

The Ministry of Justice, represented by the courts in the emirates of Fujairah, Umm Al Quwain, and Diba Al Hisn in Sharjah saved 584,186 gallons of water whereas the Ministry of Interior in Fujairah saved 188,380 gallons of water (Fig. 29.4). The Emirates Conservation Award is meant to promote conservative consumption of water and electricity, and instill the values of rationing in young generations. Participation is open to all nationalities. The list of winners included Emiratis, Arabs, and Asians. The targeted conservation was 12%; however, some families managed to reduce consumption by up to 60% and even 80%.

FEWA, in collaboration with strategic partners, has earlier installed 25,000 water-saving gadgets at 64 mosques and 60 schools. The award, the first edition of the Emirates Conservation Award saw 2810 residential participants, including 506 Emiratis and 2304 expatriates, but only 1124 were qualified. The list of top winners included 18 homemakers—three in each of the six regions involved in the competition.

The difficulties faced by UAE in changing to green:

It's not easy being green, at least in the UAE, where scorching summers make air conditioning as essential as the millions of gallons of desalinated seawater which

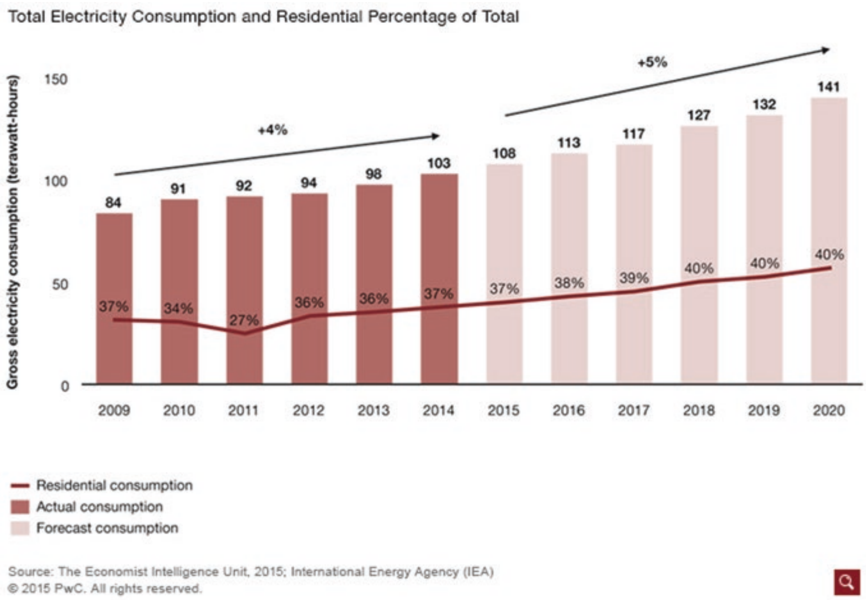

Fig. 29.3 Total electricity consumption, with residential percentage of total

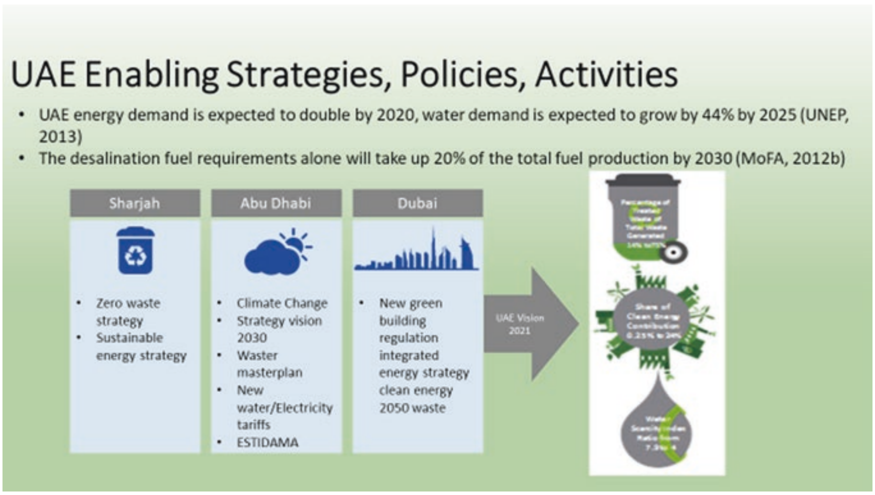

Fig. 29.4 The growth of water demand

keep most of the country's plant life from turning brown and crispy. But while the region has a well-founded reputation for having one of the largest carbon footprints, a number of projects demonstrate how environmental principles are at the foundation of many of the country's most exciting new developments.

Fig. 29.5 Active houses building projects

The prevalence of green buildings is growing all around the world, encouraged and frequently even required by both client demand and government policies. The net-zero energy goals being widely adopted require a significant reduction of building energy consumption as well as the integration of clean and renewable local generation.

Although reducing energy use is important, the truly exciting prospects for managing building energy needs lie with incorporating renewable energy resources into the built environment. Several renewable technologies that are commercially available today can completely cover the consumption needs of buildings. Consisting primarily of photovoltaic (PV) and wind turbine systems, these renewable technologies are, however, variable and intermittent energy producers. To achieve the overall objective of mastering and optimizing energy use while also becoming more independent of the electrical grid, these energy resources can be coupled with storage or other more stable electricity generation technologies, such as combined heat and power generation (CHP). This post examines the various ways to achieve net-zero energy in buildings (Fig. 29.5).

Buildings project focuses on low energy buildings also called active houses, which are not only buildings but also active components in the overall integrated energy systems. The target is to demonstrate affordable solutions for social housing and revitalization of town areas. The solutions will reduce CO_2 at no or negative cost seen in a total perspective. Targeted CO_2 reduction cost can be minus € 80/ton taking the benefits of lower energy bills into account, to even better figures when national grants are included. It is possible to simultaneously save CO_2 and money! Key barrier is the initial investment, see Figs. 29.6, 29.7, and 29.8.

Examples of Renewable energy buildings in UAE:

Fig. 29.6 Active house depending on solar energy

Fig. 29.7 Another example of active house depending on solar energy

The Irena Building

Determined efforts are being made to introduce the first principles of sustainability in many aspects of life. Some of the most significant improvements have been made in construction, best illustrated by the official opening of the Abu Dhabi-based

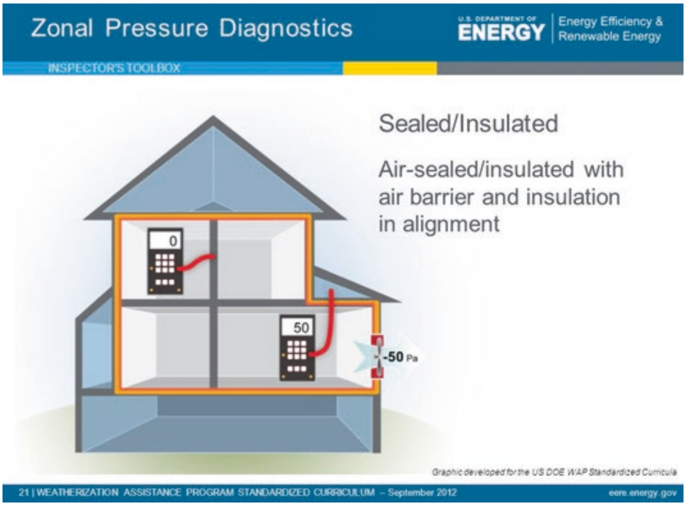

Fig. 29.8 Active house depending on air insulation

Fig. 29.9 Masdar city in Abu Dhabi, UAE

headquarters of IRENA, the UN agency for renewable energy. Located in Masdar, the community which has come to represent the country's community to a cleaner environment, the Irena building use 1000 m^2 of solar panels on its roof to cut its energy needs by 40% and also using half as much water as other typical buildings in the city. As a result, the building has become the first to receive a four pearl rating from Estidama, the certification system which measure the sustainability of new buildings in the emirate from the architects' drawing boards onwards, for everything from villas to schools and offices (Fig. 29.9).

Green Airport

The Midfield Terminal will be the largest expansion in the history of Abu Dhabi International Airport, allowing over 20 million people to pass through each year by the end of the decade.

While the airline industry is often criticized for its carbon footprint, on the ground the Midfield Terminal will be the largest building in the world to win environmental certification. It has already been awards a three pearl design rating from Estidama.

What that means in practice, is that the terminal's design and construction materials will consume as little energy as possible, including a high-performance double glazing to keep out the heat of the sun and "smart" air conditioning, lighting, and ventilation on the inside.

An indoor park, with Mediterranean and desert themes, will use recycled water, with water consumption reduced by 45% and electricity use also significantly lowered.

Even the terminal's construction is better for the environment, using recycled materials whenever possible and keeping up to three-quarters of building waste out of landfill dumps, see Figs. 29.10, 29.11, and 29.12.

Green Museum

Now approaching the final phase of construction, the Louvre Abu Dhabi has also been given a three pearl rating for its design.

Fig. 29.10 Green Airport, Abu Dhabi International Airport

Fig. 29.11 Green Airport Abu Dhabi International Airport

Fig. 29.12 Green Airport Abu Dhabi International Airport

The museum's architecture, as well as being spectacular, is also highly energy efficient.

Much of the structure, on Saadiyat Island, will be covered by a 180 m diameter dome, which can be pierced by the Sun's rays which reduces its heat.

Known as the "rain of light," this feature will shade visitors while reducing energy consumption by a third (Fig. 29.13).

It will also cut heat gain—the heat absorbed by buildings as they bake in the sun, by at least 70%.

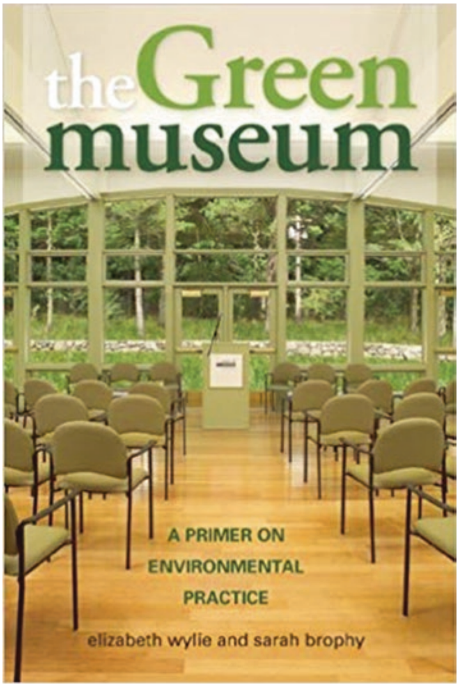

Fig. 29.13 The Green Museum in Abu Dhabi

It is not just the visitors to the Louvre Abu Dhabi who need protecting. The museum will be home to hundreds of precious antiques and artworks, including the only Leonardo da Vinci painting in the Middle East.

To prevent damage, the use of windows has been minimized, along with an energy-efficient ventilation system and an irrigation network for the landscaping around the museum that is expected to reduce water consumption by over a quarter, Figs. 29.14 and 29.15.

Green Mosque

When opened for worship last July, the Khalifa Al Tajer Mosque did not just welcome up to 3500 people, but also opened its arms to environmental principles.

Built in Dubai's Port Saeed district, to Leadership in Energy and Environmental Design (LEED) requirements, it has inevitably been dubbed the "green mosque" and hopes to win silver certification from the US Green Building Council.

Among the innovations in the building's design are controls on the water flow from the ablution taps and using waste water from washrooms to irrigate the plants around the mosque.

Solar panels are used for water heating and the lights that illuminate the mosque, and its 25 m high minarets.

Fig. 29.14 The Green Museum in Abu Dhabi, UAE

Fig. 29.15 The Green Museum in Abu Dhabi, UAE

Inside the building uses LED energy-saving lights, with a control system that automatically dims the interior outside prayer times.

Built by an anonymous sponsor, the mosque claims to be the first of its kind in the Islamic world, with the Awqaf and Minors Affairs Foundation (AMAF), the city's religious authority saying it is looking at a second green mosque in collaboration with the Dubai Multi Commodities Centre in the Jumeirah Lakes Towers area.

Fig. 29.16 UAE's first eco-friendly mosque to be completed in 18 months

Fig. 29.17 The Green skyscrapers in Abu Dhabi, UAE

Tayeb Al Rais, the secretary general of AMAF, has said he hopes the mosque: "remind worshippers of their duty to the environment (Fig. 29.16)."

Green Skyscrapers

Rising to 145 m, the twin Al Bahr Towers have already made their mark on Abu Dhabi's skyline Fig. 29.17, as well as making the top 20 for innovative buildings in the twenty-first century by the Chicago-based Council on Tall Buildings.

Built as the headquarters of the Abu Dhabi Investment Council, the structure's most intriguing and noticeable feature in an exterior covered in what looks like hundreds of parasols.

The umbrella-shaped shades are inspired by something much older; the mashrabiya or lattice screens that were used the shade buildings in the Arab world for nearly 1000 years and which is increasingly being adopted by modern architects.

The "umbrellas" are automatically programmed to open and shut with the rising and setting of the Sun, keeping out the heat while allowing in light.

The facade is said to reduce the heat transfer to the buildings' interior by half, reducing carbon dioxide emission caused by air conditioning by 1750 tons a year. The towers have been given one of the first LEED silver ratings in the UAE.

Green Warehouse

One of the most innovative and experimental projects also uses some of the oldest and most time-tested architectural principles.

Based in Al Ain, the Sabla project aims to solve the problem of food storage in the developing world with the help of the date palm.

The shelter being built is a series of domes and arches from woven palm fronds to create a strong but lightweight building.

It is inspired by the traditional arish homes, once found across the country until the advent of oil made concrete homes, with electricity and air conditioning, the norm.

Using fronds and ribs from the palm, the arish is literally one of the greenest structures ever known. Walls, fences, roofs, and floors can be built from mats of locally harvested palm, along with the ropes that bind them.

It can also be combined with the wind tower, a structure aligned to the prevailing breezes to cool interiors in a natural form of air conditioning.

The team behind the Sabla Project includes craftsmen from Abu Dhabi Tourism and Culture Authority, specialists from BuroHappold Engineering and Sandra Piesek, a Polish architect who has spent 6 years experimenting with arishin Al Ain and Liwa.

What the project shows, she says: "That the material, when combined with modern architectural and engineering thinking, can do other things that are new and innovative."

How Renewable Energy Is Creating Eco-Friendly Cities

As the population of the world is growing, urbanization is developing rapidly in many cities around the world. People living compact in the same area can have many benefits. However, at the same time, pollution continues to increase in these areas. For example, air pollution rises as the demand for energy, transportation, and various industries grows. Energy generation is one of the biggest causes of air pollution which contributes to harmful greenhouse gasses. For instance, these toxic gases get released during the production of energy which involves the combustion of fossil fuels such as coal and oil. Luckily, there are ways humanity can reduces its carbon footprint, with one of them being renewable energy resources. The green movement is a diverse scientific, social, and political movement that addresses issues like harmful greenhouse gasses. By adapting to the green movement and implementing green resources in our cities, we are one step closer to a greener environment.

Clean Energy in Cities

Innovative technology that helps to decrease energy usage on a daily basis is on the rise. Small gadgets and appliances have become more energy efficient, and specific renewable energy sources are being installed on a large scale in urban areas. The goal is to make cities greener through the use of clean energy, smart homes, and green construction. Several types of renewable energy resources are being implemented in urban areas that are slowly transforming our cities.

Solar Energy

By using solar panels, we can harness the energy of the sun's rays that provides our homes with solar energy. This solar energy can be used immediately to power buildings, or it can be stored for later use. Many companies have solar technology under development, which is making it more efficient and affordable for everyone. This renewable energy source has great potential and can turn cities into solar cities that will provide clean energy for everyone (Fig. 29.18).

Fig. 29.18 Fixing solar panels on the roof of the houses

Why Solar Is Still a Top Choice in Alternative Energy

From wind to battery to water, alternative energy technology continues to change how we power our homes, office buildings, and even our cars. But solar power remains a front runner in the alternate energy industry. Solar energy, which is derived from the sun, is harnessed through photovoltaic (PV) cells. These cells directly turn sunlight into electricity, allowing solar energy to be used to power homes and other buildings. And this technology is nothing new. Scientists discovered that sunlight alone could be converted into electric power via solar cells in 1876.

The first commercial solar cells became available in 1956, an US and Russia's space programs used solar to power satellites in the late 1950s and early 1960s. Solar cells became much more affordable starting in the 1970s, and the technology has continued to infuse itself into energy infrastructure around the world since then.

Over the last 10 years, the use of solar energy has grown by 68%. Are you considering having solar panels installed? While change can be hard, switching to solar energy offers numerous benefits. Here are four compelling reasons to embrace the green technology.

1. **Solar Is Eco-Friendly**

   Going green has been a trend for the last few years, and it doesn't seem to be going away any time soon. Unlike conventional power sources, solar power does not emit chemicals that harm the environment.

   Using fossil fuels to power our homes and other buildings causes all sorts of harmful emissions including:

   - Carbon monoxide
   - Carbon dioxide
   - Nitrogen oxides
   - Sulfur dioxide.
   - Heavy metals such as Mercury.

   Solar energy is renewable and, most importantly, clean. With this form of energy, there are no worries of greenhouse gases, increased risk of acid rain, or increases to ground-level ozone. In fact, scientists are working on new solar cells that "use a photosynthetic material in algae to capture solar energy, directly converting it into electricity." Earl Reser writes, "Once these 'living solar panels' are ready for use, they will emerge as an environmentally-friendly and low-cost approach to harness solar power and generate green energy."

2. **Durability**

   While solar panels can cost thousands of dollars, the cost is well worth proven durability. Since solar panels aren't easily damaged and have no moving parts, the risk of something going wrong is very slim. In turn, you can have peace of mind that you'll rarely experience an interruption in service.

   Today's *solar panels* are extensively tested to ensure that they can withstand extreme weather conditions including high winds as well as heavy rain, snowfall, and even hail. In the event that your solar panels were to break, most are covered with a long-term warranty.

3. **Extremely Reliable**

   Solar energy is also extremely reliable. One of the biggest myths about *solar power* is that energy is generated from the sun. The fact is that energy is derived from daylight. This means that even on rainy or cloudy days, the panels are still able to produce energy. Solar panels are meticulously placed to ensure that they can accumulate energy in the morning and afternoon hours, creating electricity that will last for days to come.

   Since your home will remain connected to the grid, excess energy that your home creates is pushed back onto the grid. This causes you to have electricity costs credited to your account. That's right, you can actually make money by having solar panels installed on your roof!

4. **High Return on Investment**

   Many of the home improvements that you'll make to your home will rarely add what you've paid to the value of your home. With solar panels, you will save money on your monthly energy bill which helps to balance out the cost of the panels.

   As an added benefit, solar panels typically add value to your home, which means you can make money when selling your home. In fact, a study found that potential homeowners are willing to *pay $15,000 more for a home* that has solar panels.

   In a competitive market, having solar panels could be the factor that sets your home apart from others in the area. This means less time on the market and a quicker sale!

World's Biggest Concentrated Solar Power Project in Dubai

The cost of producing solar power in Dubai is the lowest in the world today, the goal is for 75% of Dubai's energy needs to be met by clean power by 2050, a goal we gladly embrace (Figs. 29.19 and 29.20). Sustainable development is essential for the prosperity of our and future generations.

Once completed, the Emirati green energy landmark project will altogether generate 1000 MW of clean energy by 2020 and 5000 MW by 2030, with total investments of Dh50 billion (about $13.5 billion).

UAE on List of Top 10 Green Building Nations

The Emirates has "cool" buildings that are more livable and energy efficient, says US-based council. The UAE is ranked ninth among the Top 10 nations with the biggest energy-efficient buildings outside the US, the Green Building Council (GBC) has announced.

Fig. 29.19 Shaikh Mohamed bin Rashid Prime Minister of UAE signing the biggest solar project

Fig. 29.20 World's biggest Concentrated Solar Power project in Dubai

The US-based council, an industry body that promotes cost-efficient and energy-saving buildings, released its ranking for LEED (Leadership in Energy and Environmental Design) outside of the United States. GBC said the latest list, based on figures as of April 2014, demonstrates the global transformation of the built environment into healthy, high-performing structures that benefit its dwellers.

The UAE ranked ahead of Finland. Canada topped the list, followed by China, India, South Korea, Taiwan, Germany, Brazil, and Singapore. However, the UAE currently has nearly ten times the number of LEED-registered projects than Singapore, based on the current projects.

Among the notable projects in the UAE, the council cited, is the Dubai Electricity and Water Authority Headquarters, which has a LEED Platinum rating (highest possible under this system).

The ranking of the top 10 countries for LEED outside of the US is based on cumulative gross square meters (GSM) of space certified to LEED in each nation as of April 2014. In South America, Brazil stood at No. 7 on the list, with 2.85 million GSM, while the United Arab Emirates represented green building success in the Middle East, at No. 9 with 1.82 million GSM of LEED-certified spaces.

Dubai Ranked Third in the List of Most Green Buildings in the World

Emirate's residential segment lags in LEED certification race, Core Savills, in a report titled "Sustainability and Wellness in Dubai," said the emirate has over 550 projects under LEED certification with London and New York leading the race with 2600 and 900 buildings, respectively. Dubai has the highest ratio of projects being certified with 81% of in-progress projects across global cities, which indicates a "burgeoning interest in sustainability" (Fig. 29.21). Overall, the UAE is ranked among the top 10 countries to hold LEED certification outside the United States. China heads the pack followed Canada and India.

Despite buildings being built as per LEED guidelines, headline rents in Dubai remain at par with other noncertified Grade A stock due to developers launching

Fig. 29.21 Dubai is ranked third in the global cities' list with highest number of green buildings

initial project phases at "attractive entry price point" to achieve critical mass for their future phases, and green developments containing to compete with established, centrally located noncertified Grade A stock. Last year, Dubai Municipality made in mandatory for all existing and new buildings to implement green building standards to achieve a smart, sustainable city status for Dubai by 2021.

Conclusion

The expected impacts of using renewable energy in buildings in UAE are as follows:

- 88% reduction in energy use and 0.003 Mt of CO_2 savings per year.
- 50,000 m^2 of new build efficient area.
- 366 dwellings involved and an estimated 970 end users engaged.
- 1500–20,000 people reached by dissemination activity.
- 4% return on investment.
- EUR 50 million investment from project partners.
- Key training actions: training of designers.
- Five technologies taken to market.

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Chapter 30
Green Buildings to Approach Sustainable Buildings by Integrating Wind and Solar Systems with Smart Technologies

Abdul Salam Darwish

Introduction

Sustainable clean energy is the key factor in the economic, environmental, and social growth. It is the core factor of a sustainable urban environment. Governments have therefore to take the initiative to develop and implement sustainable building policies and regulations to support the achievement of the United Nation Sustainable Development Goals (UNSDGs) [1]. These initiatives must be performed by those Governments in order to preserve natural resources and clean environmental strategy in their countries. This is to be achieved by constructing a framework of the vision to provide a sustainable built environment and a modern infrastructure for future sustainable energy-efficient buildings. The policies are to support the preparation of sustainable building legislation to transform conventional buildings' infrastructure to sustainable and environmentally healthy buildings and it will pave the way and encourage all buildings' developers to use in their practice in applying sustainability criteria, through the rationalization of water use and electricity consumption as well as reducing waste quantities and by monitoring air quality. Cities converting their buildings to sustainable buildings will become a coordinated center for advancing sustainable building by increasing general awareness, raising the bar for what is required, helping to engage the stakeholders to deliver high-performance energy-efficient buildings, and rewarding high performers. It will support integrating the sustainable energy-efficient building programs with what is happening in the neighboring communities. The policies define sustainable building vision for the Emirate and provide specific recommendations for improvements, resulting in a path toward a dynamic and coordinated active sustainable building plan. It is essential to have a sustainable source of energy for the selected building in order to consider that building to be sustainable. Energy demand for the residential building includes

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energy consumption for hot water, cooling, lighting, and other essential appliances. Natural gas has been used for urban buildings heating and electricity dependence is in increasing demand for the rest of the power need. Solar and wind technology has been proved efficient when integrated into the buildings [2, 3]. This paper is to present the main benefits and possible combinations for these renewable energy sources use for each building to support its conversion from a conventional building to sustainable [4]. In order to enhance buildings characteristics toward sustainability, key innovation issues are to be added for intelligent buildings include sustainability (energy, water, waste, and pollution), need to be considered [5]. This is to include the implementation of information and communication technology, robotics, embedded sensor technology, smart-materials technology including nanotechnology, health in the workplace, and social change. Technologies of smart buildings will provide large benefits in terms of more efficient energy use, on-site energy demand integration and generation with the grid. These automated green buildings represent a significant opportunity for energy efficiency and mass-scale renewable generation, as well as automated demand–response (DR) systems. Green buildings with smart integrated control systems result in a green-energy ecosystem [6].

Green-Sustainable Buildings

Green buildings encountered a way to build a comfortable lifestyle with beneficial developments for human and environmental health. In order to achieve sustainability for those buildings, green building practices methods to supplement healthier and more efficient materials and strategies throughout the construction process. EPA (Environmental Protection Agency) defined the green building as:

"Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high-performance building" [7]. Approaching the building sustainability will create economic stability generating an increased economic growth and contributes in different ways the unemployment.

Sustainable Building Objectives and Strategies

Three main objectives and strategies are to be initiated when working toward sustainable buildings. They are as follows [8, 9]:

- Resource conservation
  - Energy conservation
  - Material conservation

  - Water conservation
  - Land conservation
- Cost efficiency
  - Initial cost (purchase cost)
  - Cost in use
  - Recovery cost
- Design for human adaptation
  - Protecting human health and comfort
  - Protecting physical resources

Resource Conservation Strategies and Methods for Implementation

- **Energy conservation**
  - Choice of materials and construction methods.
  - Insulating building envelope.
  - Design for energy-efficient deconstruction and recycling.
  - Design for low energy intensive transportation.
  - Developing energy-efficient technological process.
  - Use of passive energy design.
- **Material conservation**
  - Design for waste.
  - Specify durable material.
  - Specify natural and local material.
  - Design for pollution prevention.
  - Specify nontoxic material.
- **Water conservation**
  - Using water efficient plumbing fixtures.
  - Design for dual plumbing.
  - Collecting rainwater.
  - Employ recirculating systems.
  - Designing low-demand landscaping.
  - Pressure reduction.
- **Land conservation**
  - Adaptive reuse of existing building.
  - Locate construction project close to existing infrastructure.
  - Development of nonarable lands for construction.

Sustainable Building-Integrated Wind and Solar Systems

Sustainable energy performances of green buildings design have respective impacts on sustainable developments. This requires identifying and developing efficient energy solutions associated with green buildings for addressing future energy demands. It has been highlighted that the sustainable energy performances associated with integrated technologies and renewable energy systems are still intertwined with significant challenges related to the fundamental parameters of cost, maintenance, and operation. Previous studies put forward a theory representing that the performance of green buildings is substantially related to the level of their environmental assessment [10].

Renewable energy sources including solar, winds, and waves, play a substantial role for sustainable developments [11]. Green buildings (including low energy, ultra-low energy, and zero-energy buildings) are associated with a reduction of the energy demand by implementing renewable energy sources. Wind and solar energy resources have always been a key factor toward the development of green buildings. In conclusion, buildings become an energy (thermal and/or electric) production unit for local needs. They can even contribute to global electricity production.

Building-Integrated Solar Photovoltaics Systems (BIPV)

Photovoltaics system is a stylish means of producing electricity on site, directly from the sun, without concern for energy supply or environmental harm. Distributed applications for implementing solar systems on and around buildings have recently drawn great interest for architects for integration. A building-integrated photovoltaics (BIPV) system consists of integrating photovoltaics modules into the building envelope. The following BIPV system is recognized whether integrated into the façade or in the roof [12].

- *Façade or roof systems added after built* (low powered up to 10 kW).
- *Façade-integrated photovoltaic along with an object* (several transparent module types such as crystalline and micro-perforated amorphous transparent modules. Part of natural light is transferred into the building through the modules), see Fig. 30.1.
- *Roof-integrated photovoltaic along with an object* (the roof is covered with transparent photovoltaic modules. Usually only if the building is small. It is possible to use tiles, which integrate solar cells), see Fig. 30.2.
- *Shadow-voltaic PV system* (shading) (photovoltaic modules serve as Venetian blinds).
- *Solar glazing* (low-iron tempered glass is usually used. Simple glass/glass laminate or as complex isolation glass/glass laminate), see Fig. 30.3.

Fig. 30.1 BIPV system powering Manchester College of Arts and Technology's library

Fig. 30.2 Roof-integrated photovoltaic along with an object [12, 13]

Fig. 30.3 Solar glazing

Fig. 30.4 The Francis Crick Institute in central London [16]

The main benefits are [14]:

- Simultaneously serving as building envelope material and power generator,
- Provide savings in materials and electricity costs.
- Reduce the use of fossil fuels and emission of ozone-depleting gases.
- Add architectural interest to the building.

Figure 30.4 shows BIPV system at the Manchester College of Arts and Technology's library at Harpurhey at sunset. It is a green building incorporating passive ventilation [15]. The system consists of 482, 80 W polycrystalline panels on the south facade and a further 178, 165 W panels on the roof.

Inspirational Examples for BIPVs

The BIPV systems are getting widely of interests with many available examples. One of which is the PV louver array is taking shape on the top of the Frances Crick Institute, next to St. Pancras Station in London, Fig. 30.4. The system is expected to generate around 204,200 kWh/year from a renewable energy source [16].

St. Pancras is Kings Cross Station, which has PV integrated into overhead glazing high up in one of the barrel-shaped halls. This new building-integrated PV is expected to produce 175,000 kWh of electricity each year, saving over 100 tonnes of CO_2 emissions per annum, see Fig. 30.5 [17, 18].

Blackfriars rail station secures half its power from 4400 roof-mounted solar panels, expected to generate 900,000 kWh of electricity every year and to cut the stations' carbon emissions by an estimated 511 tonnes a year, further reducing the carbon footprint of its train routes to the southeast of England, see Fig. 30.6 [19, 20].

Fig. 30.5 St. Pancras King Cross Station BIPV system [18]

Fig. 30.6 Solar panels on Blackfriars bridge in London [19, 20]

Fig. 30.7 Ziekenhuis (hospital) in Aalst, Belgium

Another example is the Ziekenhuis (hospital) Fig. 30.7, in Aalst, Belgium, an eye-shaped atrium is formed from sloping curtain walling system with glass-glass BIPV laminates forming the entire cladding. Cells are spaced further apart to create the desired light transmission [21]. The solar system is 46 kWp, generating 31,000 kWh/year (675 kWh/kWp).

Building-Integrated Wind Technology System

Another promising system that could enhance the energy efficiency and building sustainability transferring it from green aspects is the building-integrated wind turbine (BIWT) systems in addition to the BIPV system. This has been increasingly common as a green building icon to reach the self-powered building. The system has not achieved its optimum design criteria due to the absence of a framework for efficient integration. The main drivers for using this system are [22]:

- Meet targets of green building designers.
- Promote sustainability in the built environment.
- Minimum transmission/distribution losses.
- Accessing greater wind velocities at higher altitudes of 40% increase.
- Replace the existing buildings by self-sufficient energy buildings.
- Satisfy up to 20% of the building's energy needs.
- Ecological power generation in the future of the sustainable building.
- Can play a crucial role in unexpected situations delivering lacking energy.
- New wind turbines are developed quiet, no vibration and high-power output.
- Provide visible evidence to a building owner's commitment to the environment and increase the energy rating for the building performance.
- Wind will complement solar PV-integrated systems and can sustain the energy supply for a sustainable building and could together reach more than 40% of the building demand.

In this respect, it is believed that the proper stages for an efficient framework for the BIWT can be introduced as (see Fig. 30.8) [23]:

1. Determining site suitability
2. Determining suitable integration methods

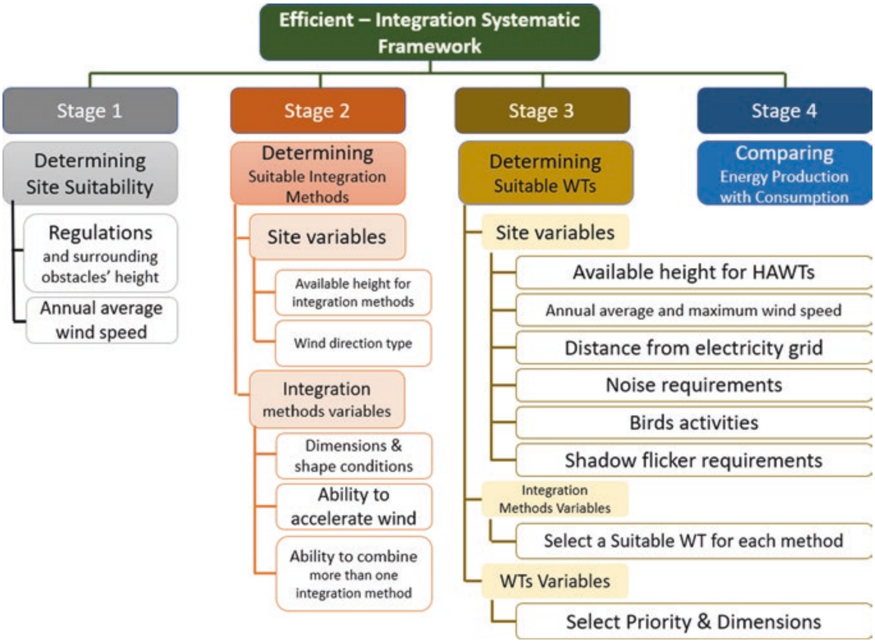

Fig. 30.8 Systematic framework for the efficient integration of WTs into buildings [23]

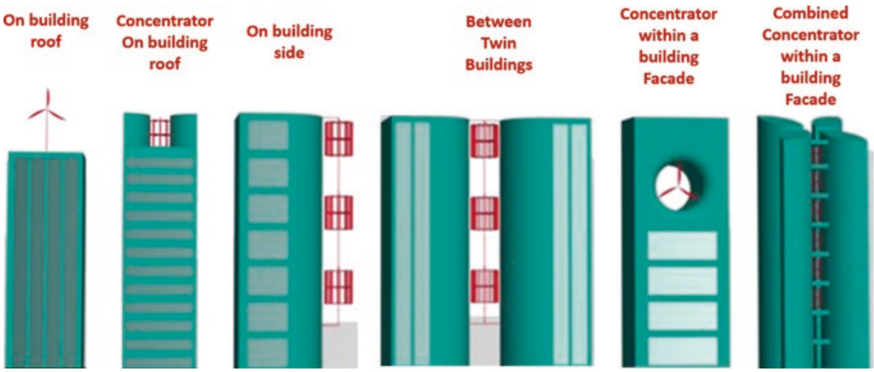

Fig. 30.9 Main methods of wind turbines integrated into buildings [23]

3. Determining suitable wind turbines
4. Comparing energy production with consumption

Main methods of wind turbines integrated into buildings vary depending on nature of the building design features, location, and the prevailing wind direction. Figure 30.9 shows different methods suggested by [23].

The improved system has also been introduced by [24], which consists of an assemblage of many unit modules filling an empty building skin area except for windows. It consists of a guide vane and a rotor as shown in Fig. 30.10, which flow around the building skin and are very complicated. The empty space behind the guide vanes plays the role as a passage for the wind passing through the rotor and creates a pressure difference between the back and forth of the guide vanes [25] around itself due to its form and arrangement with neighboring structures. This system was tested and verified experimentally and proved to be an efficient technique to be implemented.

Inspirational Examples for BIWTs

The first type of BIWTs is the *building mounted wind turbine with horizontal axis rotor type* as shown in Fig. 30.11 [26].

Another type is the building mounted wind turbine with vertical axis rotor type. Examples are shown in Fig. 30.12 [26].

Another example of the building-integrated vertical axis wind turbine is Honeywell Orion Campus—India (Fig. 30.13) [27]. The integrated system consists of 18 vertical axis wind turbines with total generated power of 137,304 kWh/year and 55 kW PV array with a total generated power 68,680 kWh/year.

The third type of BIWT is building-integrated wind turbine with a horizontal axis wind turbine. The practical example is the Strata SE1 residential tower in London (Fig. 30.14) at (57 kW), which was designed by the BFLS and completed

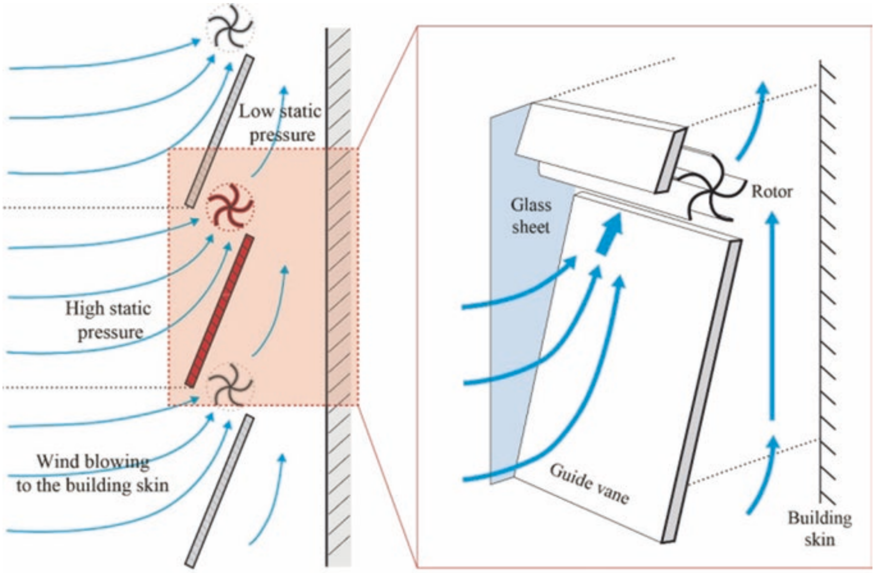

Fig. 30.10 Schematic diagram of the proposed system [24]

Fig. 30.11 Building mounted wind turbine with horizontal axis rotor [26]

Fig. 30.12 Vertical axis wind turbines, roof mounted [26]

Fig. 30.13 Honeywell Orion Campus—India [27]

Fig. 30.14 The Strata SE1 residential tower in London [28]

in 2010. It consists of three turbines (19 kW each) in its crown at 148 m off the ground. It is expected that it can produce up to 50 MWh/year, enough to power (8% of total consumption) [28].

Another type is the *building-integrated wind turbine with vertical axis wind turbine* shown in Fig. 30.15. The figure shows the public utility commission in HQ, San Francisco. Rooftop solar panels were integrated and building-integrated wind turbines. It has achieved LEED Platinum certification. The systems provide 7% of the building's entire energy use [29].

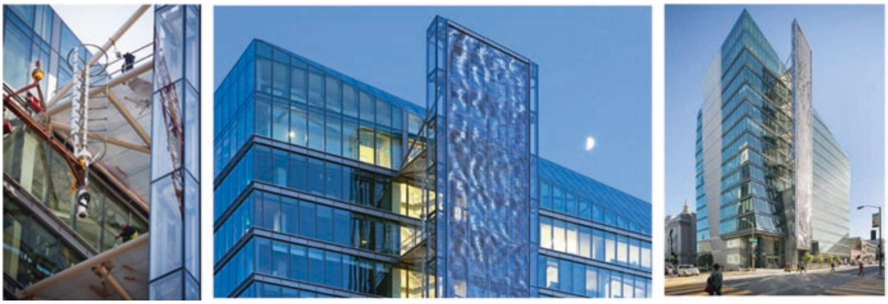

Fig. 30.15 Public utility commission HQ, San Francisco

Fig. 30.16 Building augmented wind turbine, horizontal axis (World Trade Center, Bahrain) [26]

The other type of BIWT is building-augmented wind turbine with horizontal axis rotor type. An example of this is the Bahrain World Trade Center (Fig. 30.16). The system consists of three horizontal axis wind turbines generates 225 kW each, totaling to 675 kW of wind power capacity equivalent to 15% of the total consumption [26].

Conclusion

Efforts have been put forward in order to help achieve the main goals for the United Nations for the sustainable development. It is believed that 70% of primary domestic energy usage being committed to buildings leads to energy and environmental challenges. Then the need for energy-efficient buildings is a prime aim. In order to approach building energy sustainability, sustainable energy resources are essential to be considered. Sustainable building objectives and strategies were discussed with the key successful design parameters. Types of building-integrated solar systems were discussed with practical examples. The main drivers for building-integrated wind technology were explained and systematic framework for the efficient integration of WTs into buildings was introduced with the main design methods. It is recommended that in order to achieve sustainable development goals in regards to the building sectors, building-integrated solar and wind technologies must be considered to support transforming the green building to buildings with energy self-sufficient buildings, which will have a great impact on the environment, economic, and social health and well-being.

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Chapter 31
Energy Balance Analysis for an Island PV Station Used for EV Charging on the Basis of Net Metering

J. K. Kaldellis, G. Spyropoulos, and K. Christopoulos

Introduction

The Aegean Archipelagos is a Greek territory where several remote islands are located. In this European area of the SE Mediterranean there exist more than 30 autonomous thermal power stations (APS) of various sizes [1], starting from 150 kW up to several MW. Until now all these APS are operating using remarkable quantities of diesel or heavy oil (Fig. 31.1), while the corresponding marginal production cost is extremely high, exceeding 1000 €/MWh in certain small islands (Fig. 31.2). As a general picture, the average electricity production cost for the entire Aegean Sea area varies between 250 and 300 €/MWh, being five times higher than the corresponding cost of the Greek mainland [2].

On the other hand, most of the remote islands possess excellent solar potential and very high wind potential in specific island locations. For example, according to the extended long-term measurements by PPC [3], the Hellenic Meteorological Agency [4], CRES [5], and private companies, one may easily conclude that the corresponding annual solar potential ranges between 1500 and 1850 kWh/m^2 at horizontal plane, while the average wind speed in the Aegean Archipelago varies between 8 and 9.5 m/s (see also Fig. 31.3).

On the basis of the above presented data, it is quite obvious that all these islands could modify their electricity generation model using RES-based (mainly solar and wind) power stations instead of oil-based APSs.

Unfortunately, despite the evident financial and environmental advantages of the proposed RES-based solutions, described by several researchers during the last 30 years [6–10], the actual contribution of RES in the remote islands electrification fuel

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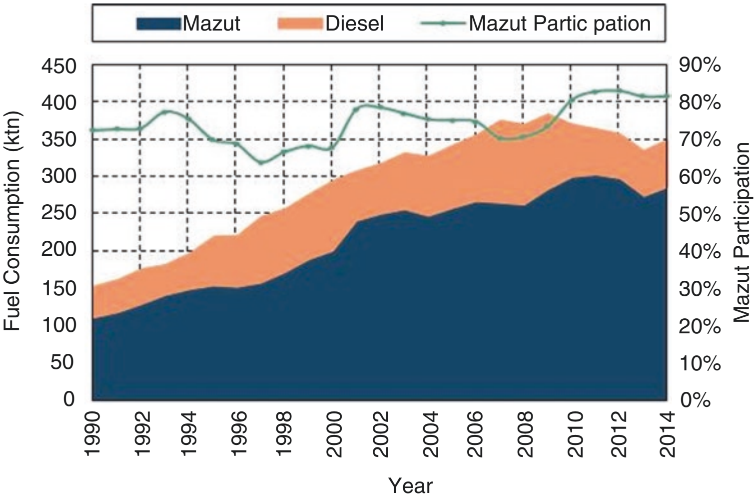

Fig. 31.1 Long-term evolution of fuel consumption for APSs of Aegean Sea

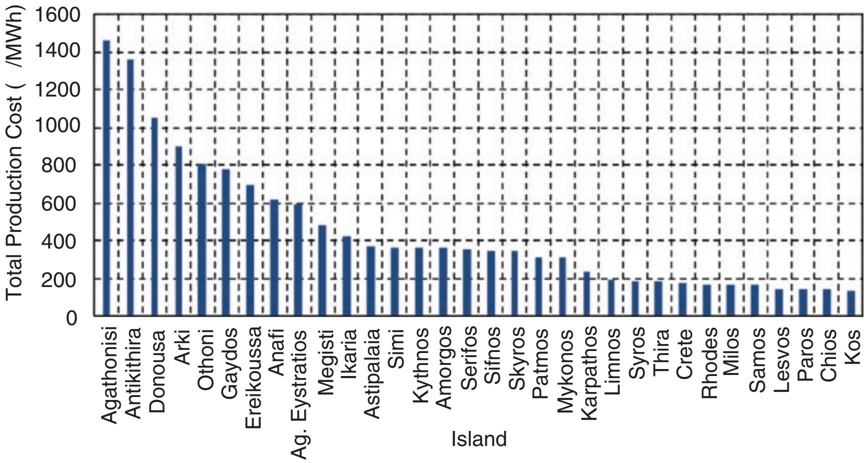

Fig. 31.2 Electricity production cost of Aegean Sea APSs, 2017

mix is poor, thus less than 20% of the electricity consumption is covered by the existing RES-based units for the last 8 years (maximum value of 19% during 2016) (Fig. 31.4).

Moreover the majority of RES-based electricity generation is via wind parks; however, during the last years the PV-based contribution is remarkable (see for example Fig. 31.5). Actually, the ratio between wind and solar electricity generation varies considerably from 6:1 during winter to almost 3:1 during summer.

However, despite the above-described situation the encouragement for new wind and solar power stations is limited for various reasons [11–13]. More specifically,

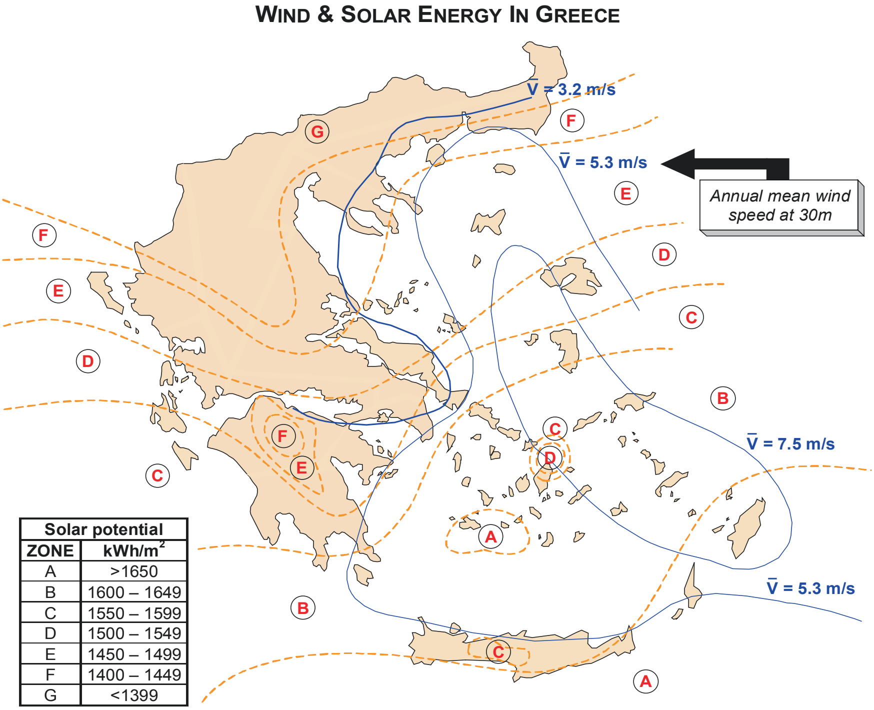

Fig. 31.3 Solar and wind potential in Greece

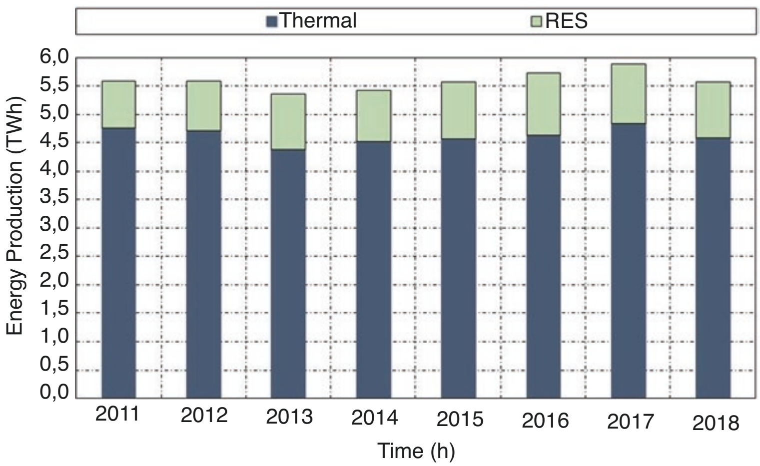

Fig. 31.4 Annual evolution of RES and thermal energy production at the non-interconnected Aegean Sea Islands

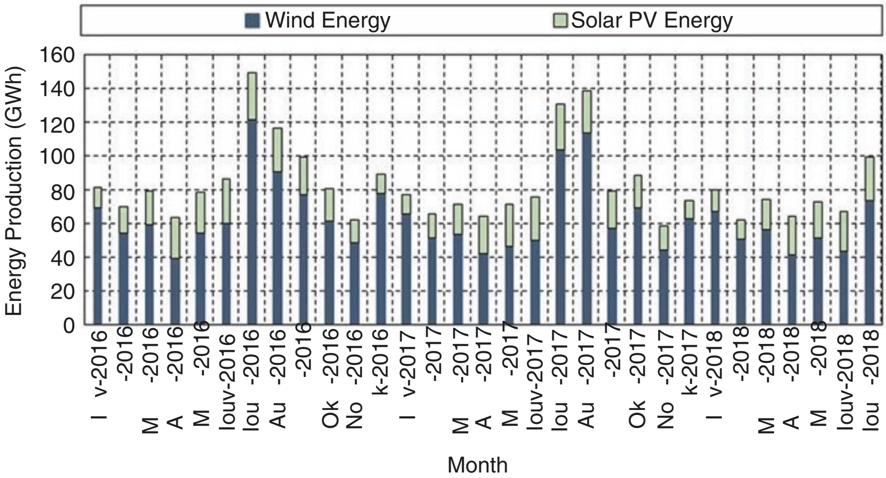

Fig. 31.5 Solar and wind energy production at Aegean Sea non-interconnected islands

medium-sized PV generators are not supported by the Greek State due to grid stability issues, thus the compensation of PV electricity is only 65€/MWh, an extremely low price in comparison with the electricity production cost in the Aegean Archipelagos (Fig. 31.2) and despite the relative high turnkey cost of similar installation in small and remote islands.

In order to increase the clean-green energy portion in the remote islands fuel mix, the idea of using the net-metering technique, recently offered by the Greek State, is examined. More specifically, taking into consideration the availability of the solar potential one may cover his needs using directly small PV generators.

In cases that the electricity requirements of the local consumption are not in accordance with the solar irradiance availability, the net-metering technique can be adopted. Thus the solar electricity production—not directly consumed—is forwarded to the local electrical network, in order to be "stored." Accordingly, during low (or zero) solar energy production and high electricity consumption periods, energy is imported from the local network.

To this end, the energy balance between the PV station production and the respective electricity consumption is estimated on an annual basis. In this way, the end-user is not surcharged by the local electrical operator since it finally consumes its own solar energy production, on an annual basis.

Proposed Installation

The Dodecanese complex belongs to the SE Mediterranean Sea and possesses excellent solar potential (Fig. 31.3). One of the smallest inhabited remote islands of the complex is Tilos island, located NW of Rhodes (Fig. 31.6).

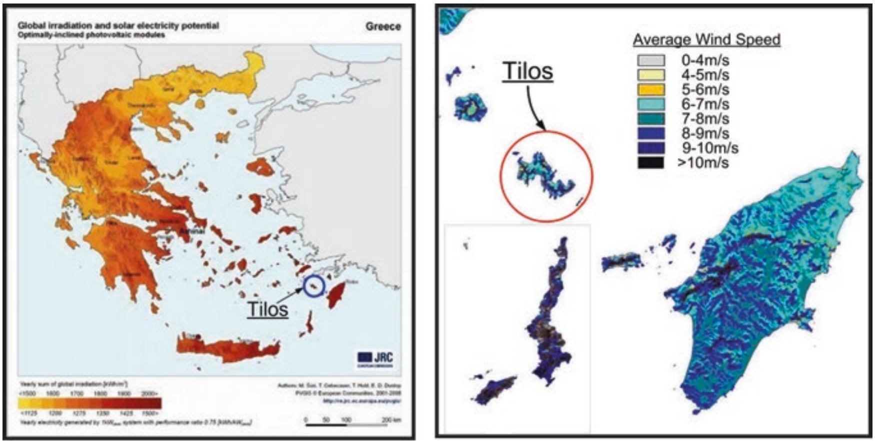

Fig. 31.6 Tilos island location in Dodecanese Complex, along with its solar/wind potential

Fig. 31.7 PV Station at Tilos island

The Soft Energy Applications & Environmental Protection Laboratory (SEA&ENVIPRO) of UNIWA has recently installed a small PV power station in order to offer zero-cost clean energy to the local community.

This decision builds on the collaboration of SEA&ENVIPRO with the Tilos Municipality in several projects in order to encourage the clean-green development of remote islands.

Actually, the PV station has been installed in one of the municipality's buildings, near the seashore, facing however serious shading effects from the nearby obstacles (Fig. 31.7). The scope of this new PV station is twofold, i.e., first to cover the electricity consumption of the municipality building and secondly to meet the lighting (electricity)

Fig. 31.8 Solar-based EV charging station in Tilos island

demand of the coastal street at the island harbor. On the other hand, the PV station is also supporting an electrical vehicle (EV) charging station, installed also in the same building in order to charge two EVs of the local municipality (Fig. 31.8).

More precisely, the Tilos Municipality PV generator is located in Livadia village, on the roof of an old building, consists of 17 PV panels of 290 W (Jinkosolar Eagle MX 60B) at 15° tilt angle and faces ESE (azimuth angle = −70°) due to several shading problems by the nearby buildings. The peak power of the PV generator is almost 5 kW (i.e., 4.93 kW_p), while special attention was paid for the mounting structures of the PV panels to be corrosion protected due to the sea environment of the installation. Finally, the power output of the PV generator is forwarded to the low-voltage network of the village via a 5 kW inverter (ABB UNO DM 5.0 TL Plus).

On the other hand, the EVs charger is a Schneider EV Link Wallbox EVH2S of 7.4 kW and 40 A, offered (cost-free) by Schneider and providing two charging points of 8–16 A. The entire installation has been designed and installed by the authors, while the UNIWA covered the total installation cost. Due to several issues related with the licensing procedure and the accessibility problems to this remote island, the entire project implementation lasted for almost 10 months. However, under the existing circumstances this time period is quite rational.

Energy Balance Analysis

On the basis of the available solar irradiance (Fig. 31.9), the annual solar potential at horizontal plane is almost 1750 kWh/m^2, thus the expected annual electricity generation E_y is approximately 8000 kWh taking into account the shading effects of the nearby buildings and the non-optimum orientation of the PV panels. In this context the corresponding capacity factor CF of the installation is given as:

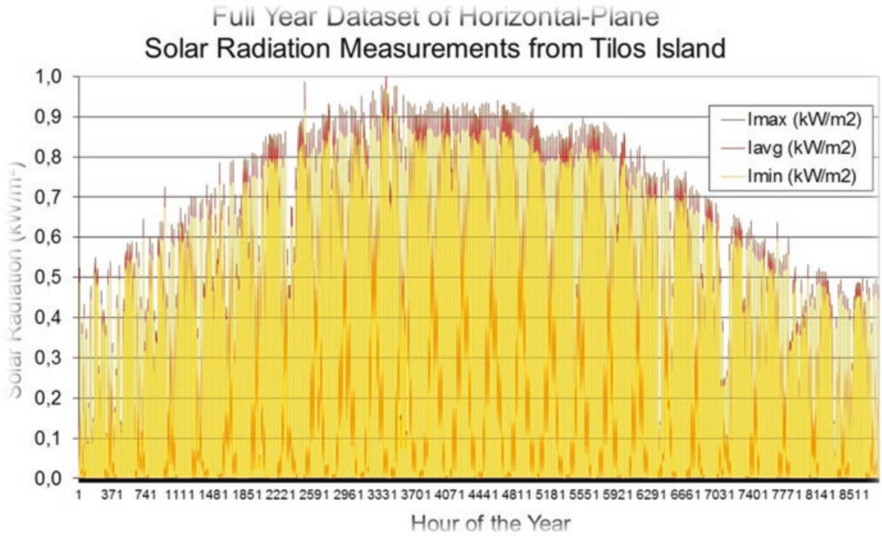

Fig. 31.9 Solar irradiance data for Tilos island [14]

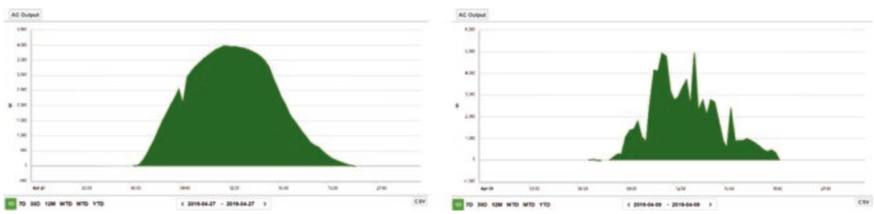

Fig. 31.10 Typical daily PV generator output for Tilos island

$$\mathrm{CF} = \frac{E_y / 8760}{P_{\mathrm{peak}}} = 19.5\% \tag{31.1}$$

where P_{peak} is the peak power of the PV generator.

In Fig. 31.10, one may find the instantaneous output of PV generator for two representative days (one shiny and one cloudy, respectively). As we can see in Fig. 31.10a, the PV generator approached its peak power during noon, while the electricity output follows the typical solar irradiance profile for a representative April day.

The corresponding daily electricity yield is almost 30 kWh, a quite remarkable value for the spring period under investigation. On the other hand, although the power output of a cloudy day is quite variable (Fig. 31.10b), the noon-time output of the PV generator still approaches its peak power of almost 5 kW. However, during

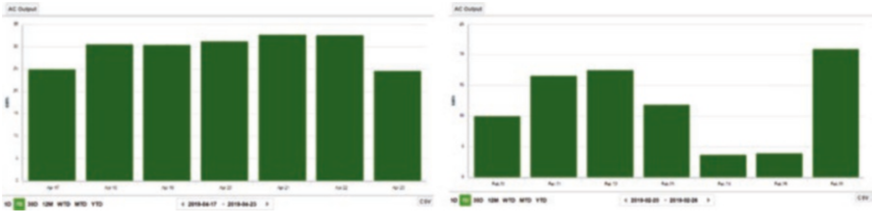

Fig. 31.11 Typical weekly PV generator output for Tilos island

early morning and late afternoon the power output is less than 1 kW. What should be noted is that even during this not very "encouraging" day, the resulting daily energy yield is almost 20 kWh, i.e., two-thirds of the one corresponding to the shiny day of Fig. 31.10a.

In Fig. 31.11, one may find the daily energy production of the PV generator for two selected weeks. In Fig. 31.11a, the daily energy generation of the PV installation is demonstrated for a good spring week, hence the total weekly energy production is almost 210 kWh, while the daily electricity production varies between 24 and 32 kWh. This is not the case for the last week of February (Fig. 31.11b), where the daily electricity production is quite variable, since for two successive days it is less than 5 kWh, while during the following day, more than 20 kWh were produced. This is the worst energy production week since the beginning of operation for the PV generator; however, even during this low irradiance period the total weekly production approaches 85 kWh of clean-green energy.

Finally, in Fig. 31.12a one may find the daily PV generator electricity production for the entire March of 2019. According to the available data, excluding 4 days of March, the energy production of the installation is higher than 15 kWh, while the minimum production appears for two successive days near the end of March. However, even in this case the previous and the following days' electricity production of the PV station is quite high, covering thus any possible power deficit. Closing, one should take into consideration that the total monthly electricity production during March is almost 625 kWh, thus the average daily clean-green electricity production is slightly above 20 kWh/day and the corresponding capacity factor according to Eq. (31.1) is 17%.

The PV generator performance is much better during April (Fig. 31.12b), where for the entire month the electricity production is higher than 15 kWh, excluding the April 6th where problems of the local electrical network almost zeroed the PV station production. It is also interesting to note that even during April (not a very high irradiance month), there are five consecutive days where the PV generator produces more than 30 kWh/day. To this end, the total monthly electricity production during April is slightly above 715 kWh, thus the average daily clean-green electricity production is almost 25 kWh/day and the corresponding capacity factor according to Eq. (31.1) is higher than 20%.

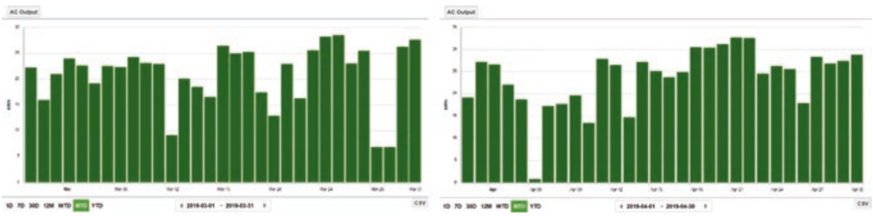

Fig. 31.12 Typical monthly PV generator output for Tilos island

Financial and Environmental Gains

Taking into consideration the performance of the PV installation for the up to now operation period (March and April represent average solar potential months), one may estimate—with adequate accuracy—the expected annual energy yield E_{tot}, which according to Eq. (31.1) is approximately 8000 kWh/year [15, 16]. According to the initial design of the installation, it is assumed that the PV generator will support the charging of two EVs [17, 18]. Due to the size of the island (the biggest road distance is 15 km) the maximum annual distance to be covered is 10,000 km, thus the EV charging station is going to support two EVs or provide electrical energy for a distance D, where $D = 20{,}000$ km/year.

According to long-term measurements of the SEA & ENVIPRO Laboratory [19], the real energy consumption ε of contemporary medium size EVs is 15–20 kWh per 100 km. Adopting the maximum value, the annual electricity consumption E_{mob} in order to support the operation of the two EVs of the municipality is given by Eq. (31.2):

$$E_{mob} = \varepsilon \cdot D = 4000\,\text{kWh} \tag{31.2}$$

The corresponding petrol/gasoline saving F_{mob}, assuming an average specific fuel consumption of 10 L per 100 km, is $F_{mob} = 2000$ L/year.

On the basis of the above-described analysis, the residual electrical energy via the net-metering scheme is used to partially cover the electricity consumption of the Tilos Municipality. Actually, approximately 4000 kWh of electricity (=8000–4000) are absorbed by the electrical loads of the local municipality.

Taking into consideration the current prices of gasoline in remote islands (i.e., $p_g \approx 2$€/L) and the final price of electricity (i.e., $p_e \approx 0.2$€/kWh, including all taxes and VAT), the avoided annual cost *AV-Cost* due to the operation of the small PV generator and the installation of the EV charging station is:

$$\text{AV\_Cost} = p_g \cdot \text{F}_{mob} + p_e \cdot \left(E_{tot} - E_{mob}\right) \tag{31.3}$$

For the specific case analyzed, Eq. (31.3) gives an annual avoided cost of almost 5000€, which is approximately 15% of the commercial, first installation cost of the entire installation [20], leading to a simple payback period of almost 7 years. Keep in mind that the entire installation has been financially covered by the UNIWA, without any cost for the municipality, practically donated by our Lab/University to the local community.

Accordingly, one may equally well estimate the avoided air pollutants due to the replacement of petrol and electricity (produced by thermal power stations consuming diesel oil) with solar energy. In this context the avoided annual emissions *AV-AP* of air pollutant *i* (where *i* may be used for CO_2, NO_x, SO_2, PM, etc.) may be estimated by the following relation:

$$\mathrm{AV\_AP}_i = g_i \cdot D - s_i \cdot E_{\mathrm{mob}} + \left(e_i - s_i\right) \cdot \left(E_{\mathrm{tot}} - E_{\mathrm{mob}}\right) \tag{31.4}$$

where g_i is the gasoline (petrol) engine emissions per km traveled, *D* is the total annual distance traveled by the vehicles, s_i is the corresponding emissions related to the PV generator operation and e_i is the specific emission factor of air pollutant *i* per kWh of oil-based electricity consumed by the municipality loads [21–23].

As an example one may apply Eq. (31.4) for CO_2 emissions, where g_i = 150 g/km, *D* = 20,000 km/year, s_i = 50 kg/MWh, and e_i = 750 kg/MWh. To this end the total annual CO_2 saving is 5600 kg/year, a remarkable quantity for such a small island. Similar calculations may be repeated for every desired air pollutant, using the most accurate values possible for the coefficients involved [24].

On the basis of the above presented analysis one may clearly state that the proposed PV installation under the net-metering scheme and in collaboration with a solar-based EV charging station offers (on a life cycle basis) remarkable financial gains to the Tilos island Municipality (approximately 85,000€ in present values) and significant (almost 120t) (1tonne=1000kg) CO_2 and other air pollutants reduction for the local community.

Conclusions

The proposed study presents the installation procedure of a small PV generator along with an EV charging station in a remote island under the net-metering scheme. Subsequently, the energy balance of the proposed pilot PV–EV charging installation has been analyzed using real-world measurements, validating also its sizing. In this context, and according to the data gathered, it is obvious that the installed PV station has very good efficiency and contributes considerably in covering the electrical needs of the local municipal loads and EVs. To this end, the financial performance (on pure cost-benefit analysis) of the proposed installation is quite attractive, even neglecting that the first installation cost of the entire project is covered by the University. Moreover, there is remarkable avoidance of carbon dioxide emissions as well as notable reduction of sulfur dioxide, nitrogen oxides, and solid particles production otherwise produced by the oil-based internal combustion engines of the local thermal power station operated on the nearby island of Kos. Recapitulating, it is important to mention that the developed clean-green solution may equally well apply in several other similar cases all around the Mediterranean Sea, providing energy at rational production cost, supporting electro-mobility and minimizing the environmental impacts of the energy supply chain.

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Chapter 32
Smart Active Envelope Solutions, Integration of Photovoltaic/Thermal Solar Concentrator in the Building Façade

Lucia Ceccherini Nelli and Alberto Reatti

Highlights

- Hybrid photovoltaic and thermal solar concentrator
- Integration in building smart façades and home automation systems
- New solar modules for the best energy production

Introduction

Various researches have been developed on the topic of the integration of solar generators into buildings using shading devices, but only few analyse the integration of parabolic solar concentrator into shading devices connected with light shelves.

The principal performance of the light shelf is the recognized efficiency in reducing lighting consumption: the application of these shelves makes natural light to go deep into the indoor through reflection and this reduces the need of artificial lighting.

This study aims to investigate the energy performance of a dynamic facade, which acts as an intelligent system able to modulate natural light with reflection and shadowing and produce thermal and electric energy reducing building energy consumption.

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The research combines a light shelf solution with a shading device integrated with a parabolic solar concentrator, with three principal functions: great correlation with depths spaces lighting performance, modulation of solar gains and simultaneous generation of electric and thermal power. The best light shelf dimension to be standardized and to have the best lighting performances is 0.3 m width with adjustable angle, a factor which influences the depth indoor distance that is necessary to be lighted [10].

Methodology

It is assessed in [2] that a wide range of architectural solution can be developed by using light shelves, because these components can be easily modified, can be easily mounted both on the exterior and in the interior of vertical opening, and they also allow for various shapes to be designed, e.g. static flatforms and curved reflective surfaces. A light shelf redirects a controllable amount of sunlight flux towards the ceiling, so that the daylight uniformity is achieved. This makes light shelves a very popular solution.

Shading devices and light shelves are usefully utilized in bioclimatic and green architecture to reduce building heat peaks, moreover natural daylighting is improved and a significant amount of energy which should be spent on cooling is saved. The integration in these shelves of solar concentrators also provides power generation.

The proposed approach shows several advantages, providing architectural shapes with different angles and many benefits to reach the best energy solution:

1. Many different shading strategies with different materials;
2. Integration of one or more concentrator elements into the shading devices (horizontal position);
3. Optimization of the number of concentrators needed in the entire façade, once electric and thermal power generation specifications are given;
4. Natural lighting aspects.

The present study proposes also the energy analysis of few design systems and the consequent energy and lighting evaluations.

The Concentrator Components

The proposed PV/ST solar concentrator basic structure is made by extruded aluminium, which is either anodised or painted. The entire system tracks the sun path during the day, thanks to an electrical drive controlled by sensors, which provide the right rotation and allows the highest thermal and electrical energy generation to be achieved.

The integration of the component in the light shelf facade made by metal structure is a good solution to improve system energy performances for many reasons:

(a) Envelope surface is more reflective than other surfaces and presents a higher albedo;
(b) A good place to allocate the parabola;
(c) Improvement of light factors.

The present study analyses the characteristics for a 31 cm wide, 17 cm height, and 200 cm long aluminium body like prefabricated measures for standardised aluminium shading devices for horizontal assembling.

The integration of the solar concentrator into a horizontal louvre is possible, encapsulating the parabola into an aluminium shell. The device is placed horizontally and angulated in front of the window, in various ways. The best shape, width and height depend on the latitude [4]. The window overhang is usually a horizontal surface that juts out over a window to shade inside from direct sun radiation, this is necessary to reduce glare and solar heat gain during warm seasons. In temperate climates, where there are warm and cool seasons it is more preferable to shade window from direct sun rays during summer time, while in winter it is better to use the sun energy to keep people comfortable without using mechanical systems and, therefore, adopt passive heating (Figs. 32.1 and 32.2).

Metal louvres can provide outstanding control of daylight and reduce heat solar gains. They can be either extruded or prefabricated, and, when needed, be perforated. These kind of louvres are often chosen for offices, schools and sports facilities where they are positioned horizontally. The system can be realises in anodized aluminium or stainless steel.

The Architectural Design of the System

The research analyses the system for the integration in office buildings where, at least in Europe, energy consumption for lighting is more than 30% of the total energy, and, therefore, the improvement of the performance of windows, doors and shading devices results in very significant savings of electricity used in buildings lighting.

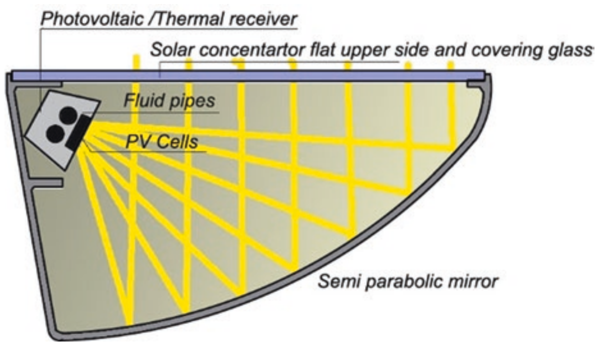

Fig. 32.1 Section of the parabola

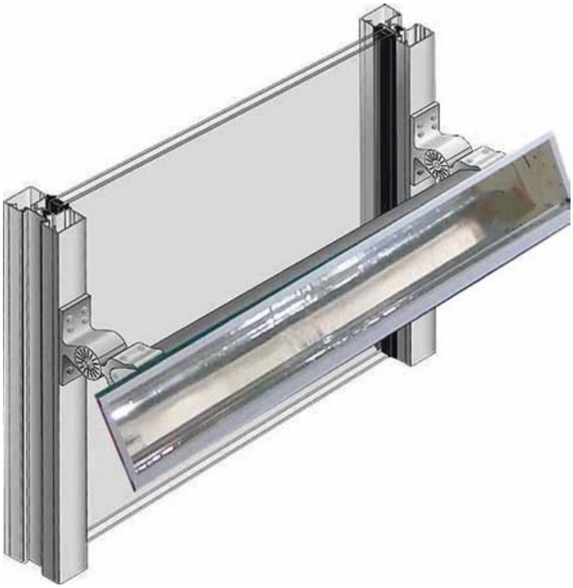

Fig. 32.2 Axonometric view with the concentrator devices used as a deflector

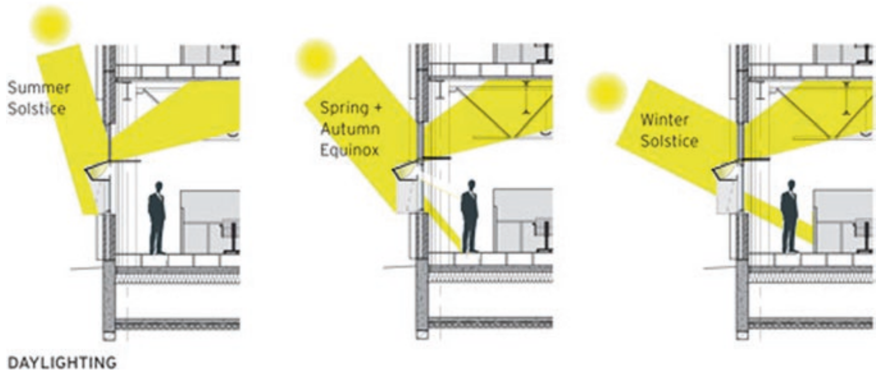

Fig. 32.3. Diffuse sun gains with external horizontal light shelf with 0.5 m depth, under clear sky conditions, sun's elevation 37.8

A variety of studies on the light shelf show that shading device efficiency depends on the dimension (width and height) of the windows surface and the external environment [3]. The dynamic system can be appreciated in office buildings, wherein the inner rooms, far from windows, usually require more artificial lighting, so the system can reflect the solar radiation from the deflector bringing natural light deep into the spaces.

The research consists of different designs solutions aimed to identify the reflection of light by natural radiation in the most internal environments. The integrated component is able to redesign the south façade, like a dynamic window on which it considers the sunblind integrated with the solar concentrator (Figs. 32.3, 32.4, 32.5 and 32.6).

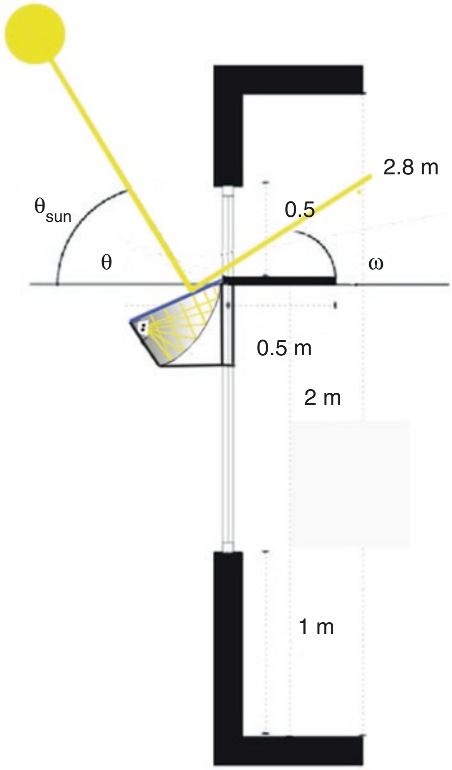

Fig. 32.4 The solar device is encapsulated in the horizontal shading device

Dynamic Analysis

These designs solutions are based on an experimented parabola realized by the University of Florence Department of Information Engineering and Department of Industrial Engineering DIEF; the study considered the electrical and thermal power generated by previous researches on the component [5–9].

The investigated device uses only a mono-direction tracking, so there is always an incidence angle "*i*" between the Sun and the concentrator. This angle is evaluated by two equations for the two tracking orientations:

$$\text{Horizontal device}: i = \text{arcsen}\left(\text{sen}\alpha * \cos\gamma\right) \tag{32.1}$$

The angle α is the altitude and the angle γ is the azimuth of the Sun in a specific time. These data come from the ENEA solar database for the position of Florence, Italy. Figure 32.7a shows the monthly average value of the sun position for every hour, here angle 0° refers to a zero elevation of the sun with respect to the horizontal plane.

Figure 32.7b shows the "sun azimuth" graph, where angle 0° refers to the south direction, −90° and +90° to east and west, respectively [5].

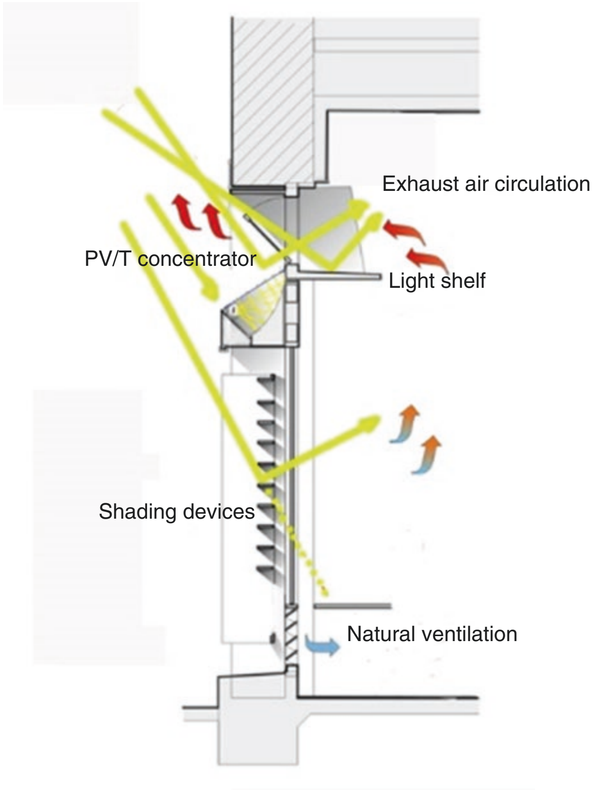

Fig. 32.5 The intelligent window act as a passive façade with smart shading devices, movable openings with sensors and grids for natural ventilation

The power generated when the concentrator is mounted horizontally is based on the equivalent hour of maximal power output. This is done by calculating the average value of sun hours using the sun position angles, the incident angle on the device and the available energy curve, and, finally, considering a 18.3% PV cell efficiency [4]. The calculation also considers the effects of the mutual shadowing among mirrors constituting the solar generator. This allows the reduction of the surface free to receive solar radiation to be taken into account: when at least one-half of the available surface is shadowed and the generated power is considered not high enough and, therefore, neglected [5].

The estimated yearly electric power production is about 115 kWh the East–West tracking.

As reported in [6–8] the thermal energy production is almost five times higher than the electric production: so the yearly thermal production is 560 kWh for a horizontally mounted device.

A conventional photovoltaic plant, with 1 kWp installed and a nearly 7m^2 occupied area produces about 1200 kWh/year. This means that ten devices as shown in Fig. 32.1 are required to produce the same electricity. Even if the surface required to produce

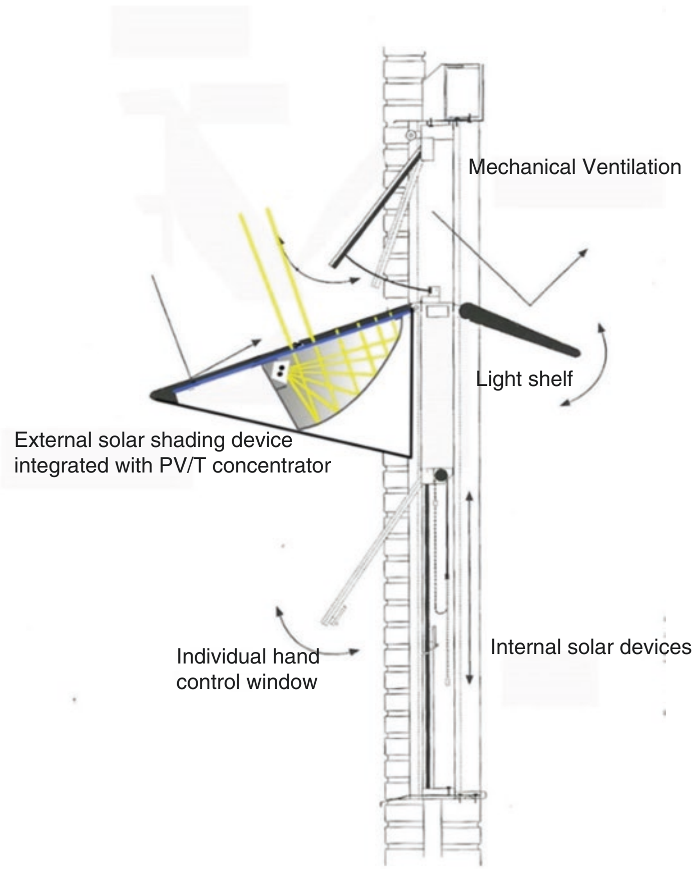

Fig. 32.6 Dynamic solution with external shading device, south-oriented room with dimensions 4 × 6 × 3 m and a window-to-floor ratio equal to 20% equipped with: diffuse external horizontal light shelf with more than 0.5 m depth (reflectance 0.8). The solar device is encapsulated in the horizontal shading device

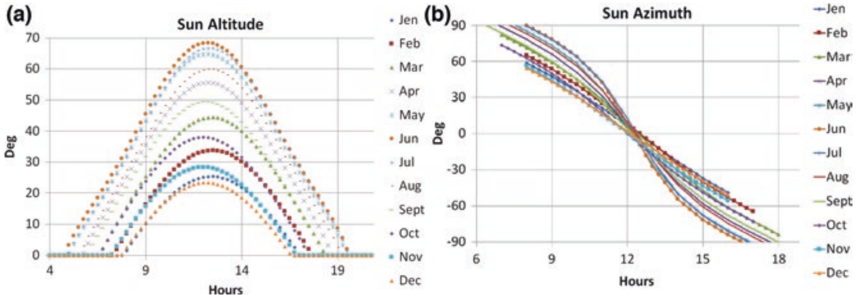

Fig. 32.7 (**a**) Sun altitude angles and (**b**) Sun azimuth angles in Florence, Italy

Table 32.1 Energy production vs. orientation, for a 2-m long device

	Horizontal (sun altitude)
Orientation	Energy production [%]
East	56
South-east	80
South-west	80
West	56

the same amount of electrical energy needed by the solar concentrator is now 9 m^2, on the same surface also 5000 kWh thermal energy is generated. Moreover, fluid outcoming the solar concentrator is operated at a higher temperature than hybrid flat PV/ST panels and, therefore, the thermal power is better used [9].

These results are referred for south wall installation and Table 32.1 reports the available production with respect to the other main direction. The values are the per cent respect of the south case.

Conclusion

Light shelves have been discussed in numerous studies as suitable solutions for controlling daylight inside lit spaces, but never integrated with a parabolic solar concentrator.

This study defines significant drawing to evaluate the performance result and appropriate specifications for light shelf and horizontal shading device studied as one component and according to various physical shapes and sizes for indoor space lighting.

The improvement of uniformity factor through test bed will be verified for the research development; at the moment, the component is studied for an internal light shelf at the summer solstice; other verifications need to be carried out by more variables in the further study.

The proposed light shelf integrated with external horizontal shading device and connected with the solar concentrator, attached to the upper window glass, the study results in a nearly 2% reduction of lighting energy consumption and improves the glare and uniformity when compared to a conventional light shelf.

The concentrated solar technology can be an interesting solution for building an autogenerated power and, therefore, it supports the zero energy philosophy [1].

Future work will consider the replacement of the monocrystalline cells with triple junction cells. Such a solution would nearly double the PV efficiency and, therefore, the average electric energy yearly generated can be significantly increased.

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Chapter 33
A Development of System Control Strategy Applied to PV Pumping System

Sarah Adoulraziq and Med Amine Abdourraziq

Introduction

The solar energy is a clean renewable energy used in the isolated sectors and rural areas to produce the needed electrical energy. The PV cell converts solar energy into electrical energy by a process called "photovoltaic effect" [1].

The use of photovoltaic (PV) energy as source to pumping water is considered one of the promising fields of PV application. Water can be pumped during the day and stored in tanks. With the increased use of this technology, greater attention has been paid to their design and their optimal use [2, 3]. Various studies have been done to define the optimal drive system, the choice of motor (DC motor or AC motor) [4] and pumps (centrifugal or volumetric), and other ways to control and optimize the water pumping system.

In this paper, the PV pumping system consists of PV panel, DC–DC boost converter, and DC motor pump, with the maximum power point tracking (MPPT) as online technique to track the maximum power point of the PV generator, which improves the efficiency of the system. Thus, several MPPT algorithms has been presented and implemented in the literature. The techniques vary in complexity, robustness, convergence speed, eases of implementation, and in other aspects. The most MPPT techniques used are: the P&O method [5, 6], Hill climbing [7], incremental conductance, and artificial intelligence-based algorithms [8]. However, in the recent publications, those techniques are developed to improve the accuracy of tracking, and the response speed time, including a novel variable step size incremental conductance [9], and combination of two techniques [10].

In this paper, we present a developed slide mode control strategy to track the maximum power point (MPP) of the PV generator, which improves the performance of

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the PV water pumping system. This technique presents the advantages of robustness, good accuracy, high stability, and efficiency. The developed method was tested in MATLAB/SIMULINK environment. The obtained results indicate the feasibility and improved functionality of the photovoltaic pumping system.

In the Modeling of Photovoltaic Pumping System section we present a modeling of PV pumping system. Slide Mode Control section brings out an explication about the proposed approach. Simulation Results section deals with the simulation results with a comparison between the developed method and the classical P&O method. Conclusion section presents critical observations and discussion followed by conclusion.

Modeling of Photovoltaic Pumping System

The general block diagram of the photovoltaic pumping system is shown in Fig. 33.1. The whole system is composed of a PV panel, a power DC–DC adapter, and PMDC motor driving a centrifugal pump.

PV Cell Model

The PV cell is a component that converts directly the solar energy into electrical power. Several papers have presented the modeling of PV cells, with one diode [9] and two diodes [10]. In order to provide the optimum power, we use the PV panel which is composed of many strings of solar cells in series, connected in parallel. Figure 33.2 shows the equivalent circuit of the PV cell.

The behavior of the PV array may be described by the following equations:

$$I = I_{ph} - I_d - I_p \tag{33.1}$$

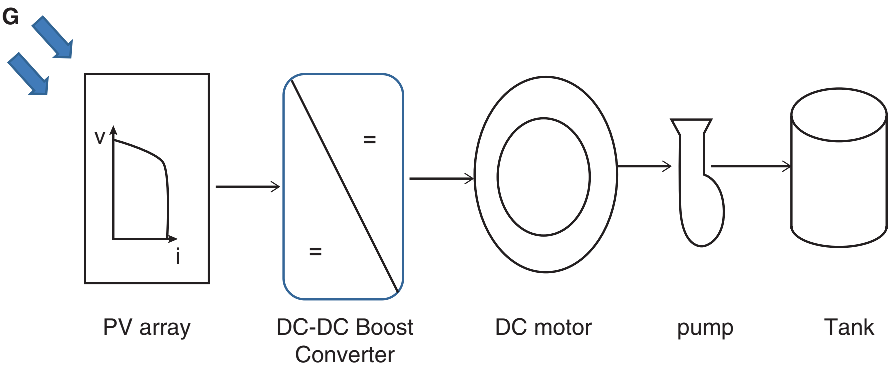

Fig. 33.1 General configuration of a photovoltaic pumping system

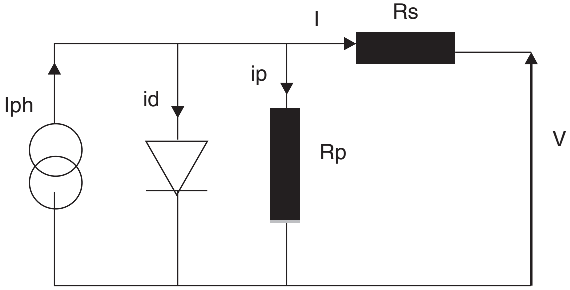

Fig. 33.2 Equivalent circuit of PV cell

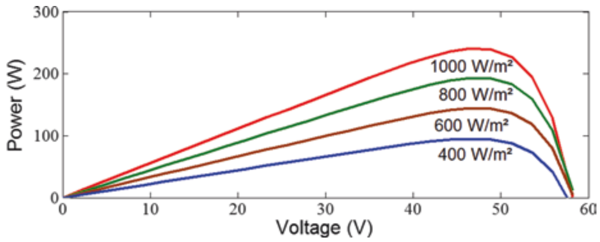

Fig. 33.3 Power versus Voltage at different Solar Intensity level

with

$$I_{\mathrm{d}} = I_0\left(\exp\left(\frac{V_j \cdot q}{K_0 \cdot T}\right)\right) - 1) \tag{33.2}$$

and

$$I_{\mathrm{p}} = \frac{V + R_{\mathrm{s}} \cdot I}{R_{\mathrm{p}}} \tag{33.3}$$

$$I = I_{\mathrm{ph}} - I_0\left(\exp\left(\frac{V_j q}{K_0 T}\right) - 1\right) - \frac{V + R_{\mathrm{s}} \cdot I}{R_{\mathrm{p}}} \tag{33.4}$$

where V = PV output voltage, I = PV output current, I_{ph} = photocurrent, and I_0 = saturation current.

The output characteristics of voltage-power and voltage-current of PV panel, under different values of radiation, are presented in Fig. 33.3.

The equation of the output voltage can be expressed as:

$$V_{\mathrm{o}} = \frac{1}{1-\alpha} V_{\mathrm{pv}} \tag{33.5}$$

where V_o and V_{pv} are, respectively, the DC–DC converter output and input voltages.

DC Motor Model

The choice of motor depends on many factors: the requirements of the size, efficiency, price, reliability, and availability. Among the different kinds of DC motors existing, the permanent magnet motors (PMDC) are most commonly used in PV pumping systems. They provide a high torque at startup.

The mathematical relationships that describe the model of a DC motor are expressed as follows:

Terminal voltage of the armature:

$$U = RI + E \tag{33.6}$$

Electromotive force:

$$E = K \cdot \omega \tag{33.7}$$

Electromagnetic torque:

$$\Gamma_e = K' \cdot I \tag{33.8}$$

The mathematical equation:

$$E = U\left(K_m \cdot \Phi\right) \tag{33.9}$$

K_m, the constant of the construction motor, depends on the number of pairs of poles and the number of conductors per section.

Centrifugal Pump Model

For solar pump, the centrifugal pumps and the volumetric pumps are the most used [3]. The centrifugal pump applies a torque proportional to the square of the rotational speed of the motor [4]:

$$\Gamma_r = K_c \cdot \omega^2 \tag{33.10}$$

where K_c is the proportionality constant [$(\mathrm{Nm/rad.s^{-1}})^2$] and ω is the rotational speed of the motor ($\mathrm{rad.s^{-1}}$).

Any pump is characterized by its output power, which is given by:

$$P = \frac{P_u}{\eta} \tag{33.11}$$

with:

$$P_u = \rho \cdot g \cdot H \cdot Q \tag{33.12}$$

Slide Mode Control

Several papers developed the sliding mode control method [1, 2] to track the MPP of the PV generator. It presents the advantages of simplicity and good performance. The control circuit adjusts the duty cycle of the switch with the different variation of radiation and temperature to track the MPP of the PV panel.

Depending on the position of the switch *S*, the equations can be written as follows:

$$\frac{dV_{pv}}{dt} = \frac{1}{C}\left(I_{pv} - I_l\right) \tag{33.13}$$

$$\frac{dI_l}{dt} = \frac{1}{L}\left(V_{pv} - (1 - D) \times V_o\right) \tag{33.14}$$

With the use of the concept of the approaching control [5], the sliding surface is selected as:

$$\frac{dP_{pv}}{dV_{pv}} = 0 \tag{33.15}$$

$$\frac{dP_{pv}}{dV_{pv}} = \frac{d\left(V_{pv} \times I_{pv}\right)}{dV_{pv}} \tag{33.16}$$

$$\frac{dP_{pv}}{dV_{pv}} = I_{pv} + V_{pv}\frac{dI_{pv}}{dV_{pv}} \tag{33.17}$$

So, from the precedent equations, the sliding surface (σ) can be written as follows:

$$\sigma = I_{pv} + V_{pv}\frac{dI_{pv}}{dV_{pv}} \tag{33.18}$$

The duty cycle *D* can be controlled by the following equations:

$$D = D + \Delta D \text{if} \quad \sigma > 0 \tag{33.19}$$

$$D = D - \Delta D \text{if} \quad \sigma < 0 \tag{33.20}$$

Eq. 33.17 can be written in general form of the nonlinear time invariant system [10].

$$\dot{\sigma} = \left[\frac{d\sigma}{dx}\right]^T \times \dot{X} = 0 \quad (33.21)$$

$$\dot{\sigma} = \left[\frac{d\sigma}{dx}\right]^{\mathrm{T}} \times \left(f(X) + g(X) \times D'\right) = 0 \quad (33.22)$$

The equivalent control D' obtained is [10]:

$$D' = \frac{\left[\frac{d\sigma}{dx}\right]^{\mathrm{T}} \times f(x)}{\left[\frac{d\sigma}{dx}\right]^{\mathrm{T}} \times g(x)} = 1 - \frac{V_{\mathrm{pv}}}{V_{\mathrm{o}}} \quad (33.23)$$

The equivalent duty cycle D' must vary between $0 < D' < 1$, and the real duty cycle control D is proposed as [10]:

$$D = 1 \quad \text{if} \quad D' + K\sigma \geq 1 \quad (33.24)$$

$$D = D' + k\sigma \quad \text{if} \quad 0 < D' + k\sigma < 1$$

$$D = 0 \quad \text{if} \quad D' + k\sigma \leq 0$$

To improve the accuracy of tracking of MPP and convergence time, the choice of the right surface of searching is very important. Figure 33.4 shows the proposed surfaces chosen to track the MPP.

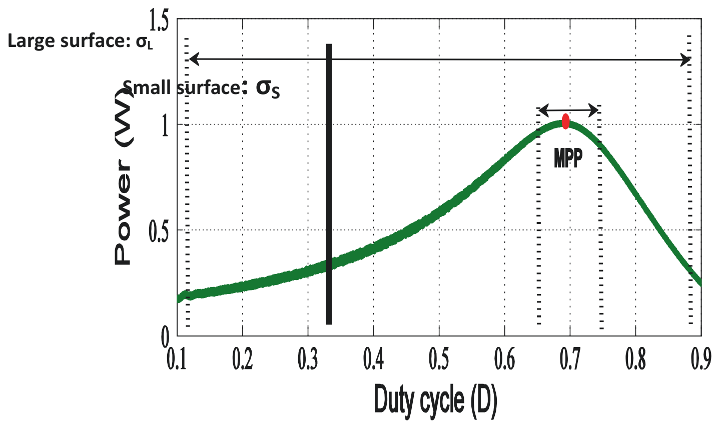

Fig. 33.4 The proposed surfaces of the proposed SMC to track the MPP of PV array

The principle of search of the MPP is based on dividing the position surface into two surfaces. One is near (small surface, σ_S) and the other is far (large surface, σ_l) from MPP. In our method, we insert a switch between these two surfaces by exploiting the variable $\frac{|\Delta P|}{|\Delta V|}$. If the obtained value is far from the MPP, the searching is done on the large surface $\sigma_{s,}$ which improves the efficiency of tracking and the response speed time. Else, if we are near to MPP of the PV panel, the surface of tracking is the small surface, to minimize the oscillations around the MPP, and reach it quickly. The equations of the novel duty cycle with the proposed technique become:

The equivalent duty cycle must varies between $0.1 < D' < 0.9$. The real controls signal D is proposed as:

$$D - 0.9 \quad \text{if} \quad D' + k\sigma \geq 0.9 \tag{33.25}$$

$$D = D' + k\sigma \quad \text{if} \quad 0.1 < D' + k\sigma < 0.9 \tag{33.26}$$

$$D = 0.1 \quad \text{if} \quad D' + k\sigma \geq 0.1 \tag{33.27}$$

The equivalent duty cycle varies as $0.6 < D' < 0.8$. The real controls signal D is proposed as:

$$D = 0.8 \quad \text{if} \quad D' + k\sigma \geq 0.8 \tag{33.28}$$

$$D = D' + k\sigma \quad \text{if} \quad 0.6 < D' + k\sigma < 0.8 \tag{33.29}$$

$$D = 0.6 \quad \text{if} \quad D' + k\sigma \leq 0.6 \tag{33.30}$$

The proposed equation of the reference power allows calculating the novel power simultaneously with variation of insolation and temperature. It determines the position of the power at each moment, which facilities the task of tracking MPP.

The simulation results of the proposed SMC technique are presented in the next section; they show clearly the efficiency of the method.

Simulation Results

In order to verify the efficiency of the proposed sliding mode control method, and its influence in the performance of the PV water pumping system driven by DC motor coupled to a centrifugal pump, a simulation is done using MATAB/SIMULINK environment. The PV generator source used is SES96M; it has the characteristics recorded in Table 33.1. Also, the parameters of the DC–DC boost converter employed have been noted in Table 33.2.

To show the effectiveness of the developed sliding mode control method, we compare it with the classical P&O method.

Table 33.1 Electrical parameters of SES96M

Maximum power (Pmpp)	240 W
Voltage at MPP (Vmpp)	48.5 V
Current at MPP (Impp)	4.95 A
Open circuit voltage (Voc)	58.2 V
Short circuit current (Isc)	5.55 A

Table 33.2 Electrical characteristics of DC–DC boost converter

C1	2 mF
C2	800 uF
L	10 mH
R	100 Ω

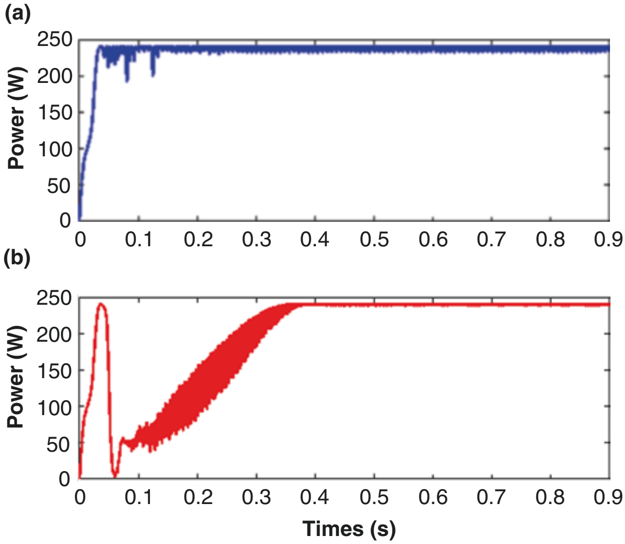

Fig. 33.5 Output power of the PV panel (**a**) proposed SMC, (**b**) classical P&O

Figures 33.5 and 33.6 present the output power, and output voltage of the PV panel with proposed SMC method and classical P&O technique, respectively, at $T = 25$ °C and $E = 1000$ W/m^2. It proves the utility of the developed method, in fact a considerable minimization of oscillations, and a clear improvement of response speed. Figure 33.7 shows the behavior of the output speed motor of the PV pumping system.

The output motor speed of the PV pumping system with the proposed sliding mode control and the classical P&O method as presented in Fig. 33.7 shows clearly the influence of the proposed SMC in this element of the system; it improves the accuracy and the speed of response time. The speed is stabilized from 0.15 s. However, with the use of P&O method, the speed begins to stabilize till 0.5 s. To demonstrate the feasibility of the proposed method with variation of radiation, we test it in MATLAB/SIMULINK at different values of radiation (Figs. 33.8 and 33.9).

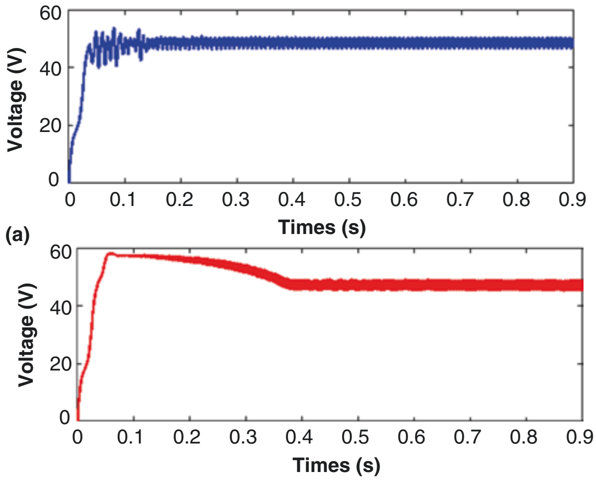

Fig. 33.6 Output voltage of the PV panel (**a**) proposed SMC, (**b**) classical P&O

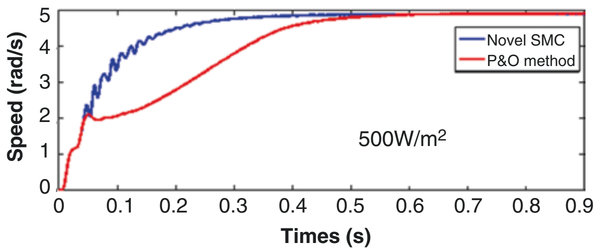

Fig. 33.7 Output characteristics of the motor speed with novel SMC and P&O method

Conclusion

In this paper, an online novel strategy of sliding mode control is developed to optimize the functioning of the global PV water pumping system driven by DC motor and coupled to a centrifugal pump. The main concluding remarks are summarized as follows:

- The obtained simulation results have shown the good performance of the proposed controller in terms of accuracy of output power of the PV generator
- It has also shown the improvement of the stability of the output motor speed, which influences the efficiency of the pump
- Furthermore, the expected insensitivity of the proposed SMC commands against variation of radiation and temperature.

The proposed sliding mode control provides a highly online accurate tracking of the optimal point of the PV pumping systems driven by conventional electrical components, and can become a standard regulator for optimizing such systems.

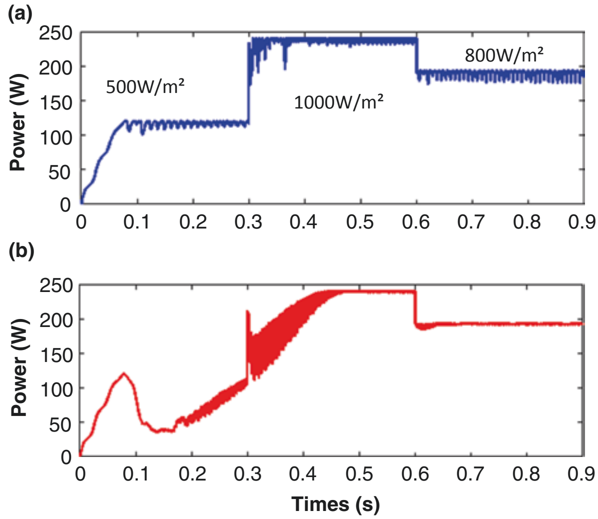

Fig. 33.8 Output power of PV panel at different value of radiation. (a) Proposed SMC, (b) P&O method

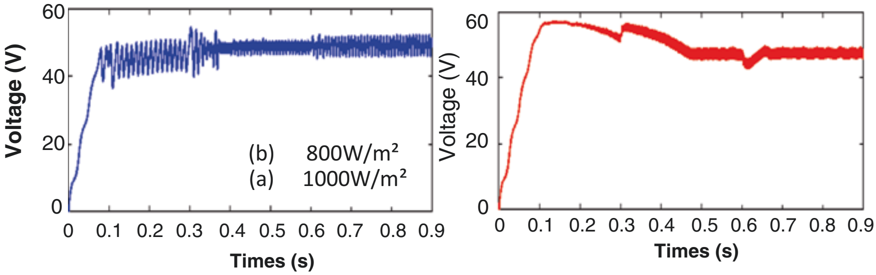

Fig. 33.9 Output power of PV panel at different value of time

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Chapter 34
Analysis of Wind Energy Potential Inside a Tunnel Located on the Highway

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Introduction

With increasing environmental concern, and approaching limits to fossil fuel consumption, wind energy (WE) has regained interest as a renewable energy (RE) source, where wind turbines (WT) produce electric power and are used for various applications. Discontinuous availability of WE makes a limitation on its utilization. One way to conserve (or harnessing) wind energy (WE) is by using a generator system that's powered by WT in highways/expressways/tunnels, where they remain busy day and night, or by locating WT in an urban or suburban environment (built environment). These small-scale WE cover small WT which are generally intended to supply electricity to buildings [1]. Wind turbulence created by the vehicles on the road can help us to improve the generated electrical energy (EE) yield [2, 3]. If the wind is properly directed towards the WT blades, optimum electricity may be generated. Wind has a lot of potential and if properly harnessed then it can help solve the energy crises in the world [3]. The desired direction of wind is obtained by a means for channeling wind, in the direction of the WT. Channeling of wind in a desired direction may be obtained by at least one truncated cone or pyramid-shaped housing or a pair of planar surface converging towards the blades of the wind turbine [4].

As the population increases year by year, the demand of energy sources also increases. In Iraq, which is situated in the Mediterranean Region, still there is a huge gap between the demand and supply of electricity in the main sectors: electricity generation sector, the sustainable building sector, the transport sector, etc. For example, electricity annual demand loads and supplied loads for Duhok, Iraq,

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during the period 2004–2018 are given in Fig. 34.1 [5]. It is clear that there is no sufficient supplied load in any year over all periods.

The gap between the demand and supply of electricity has to be bridged in order to sustain or maintain the economic growth of country. So, one has to search for the alternative sources of energy. The RE sources (which are green energy) do have the potential to provide significant amount of energy to meet the requirement of increasing demand. Wind is an environment-friendly source of energy that has got huge potential to satisfy energy needs of people and to mitigate the climate change due to greenhouse gasses emitted by the burning of fossil fuels.

A lots of advanced research work has already been done or going on the harnessing of natural wind energy (WE). Some work has been done previously to generate EE from highways. Several authors of the WE textbooks and publications try to base the success of any wind generation system on generalized wind speed data charts. They also base their data on whether the site is on a valley, hill, the capacity of the rotor used, wind speed, etc. [6]. The integration of WT into building is becoming a new possibility of energy efficiency and has begun to be studied in many Universities Research Centers for wind energy [7]. According to the experimental investigation in India [8], it was found that, the maximum value of Impact WE available on highways was at a height of 1.20 m. In 2014, an investigation into potential WE technologies (such as WT systems in Highway Maintenance Facilities) was completed for the state of Ohio, USA, by Elzarka and Andrews [9]. Zarkesh and Heidari [10] have given a model having a concrete frame at center which includes two small WT placed adjacent to each other. Each turbine working for only one direction of vehicles has low efficiency. In 2011, Georges and Slaoui [11] carried out a study of hybrid wind-solar power systems for street lighting. Hybrid wind turbine has been designed and developed by Devi and Singh [12] for highway side applications. It is a combination of two conventional vertical axis wind turbines (VAWTs). Also Darrieus and Savonius wind turbines are used as a combined model

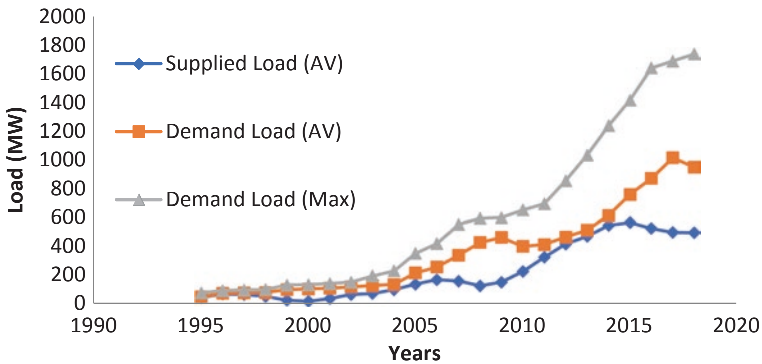

Fig. 34.1 Electricity annual demand loads and supplied loads for Duhok, Iraq, during the period 2004–2018

for highway side wind turbine (HSWT) [13]. Experimental comparison and investigations were carried out by Ali [14] to study the performance and to make a comparison between two and three blades Savonius wind turbine. Today, the most commonly used wind turbine is the horizontal axis wind turbine (HAWT), where the axis of rotation is parallel to the ground. However, there exist other types of wind turbines, one of which is the vertical axis wind turbine (VAWT). These devices can operate in flows coming from any direction, and take up much less space than a traditional HAWT [15]. For various reasons, interest is growing for VAWT over HAWT for power generation in built-up areas [1, 16]. Attentions have been paid to the research on straight-bladed VAWT. And many methods have been proposed for improving the aerodynamic performance [17, 18]. Investigation was carried out by Abohela et al. [19] to see the effect of roof shape, wind direction, building height, and urban configuration on the energy yield and positioning of roof mounted WT.

In the present study, we tried to find out the way of harnessing WE available when the automobiles moves inside a tunnel (Gali-Zakho Tunnel in Duhok, Iraq), located on the highway, since there is a creation of pressure. Therefore, lots of impact wind energy is generated due to the wind pressure difference. The wind pressure thrust depends on many factors such as the intensity of the traffic, the size of the automobile (i.e., bus, car, truck), and the speed of the automobiles. This WE can be converted into mechanical energy with the help of small turbines by placing them just nearby the tunnel or highway sides. Therefore, these small turbines will rotate. This rotational energy of turbine can be converted into EE with the help of a generating device, which can store the EE for temporary basis. The generated EE can be used for different applications. This system can be used to produce electricity for the following applications: lighting the tunnel, pumping water and develop a well-maintained irrigation system to nearby area, communications equipment, etc. Also this generated EE can be transferred to nearby villages and make them prosperous, or national park.

Briefly, this paper investigated the feasibility study for electricity generation inside a Gali-Zakho Tunnel in Duhok, Iraq from WE produced by fast moving vehicle and ventilation system.

Materials and Methods

Study Area

The study was conducted in Gali-Zakho (GZ) Tunnel, Duhok, located in the northwest part of Iraq (see Fig. 34.2), at latitude 36°55′20″ N and longitude 42°55′ E′. The GZ Tunnel is designed and constructed of a dual carriageway road with two lanes on each carriageway on the route linking Duhok to Zakho. The total length of the tunnel is 3604 m, and the diameter of each tunnel is 12.4 m.

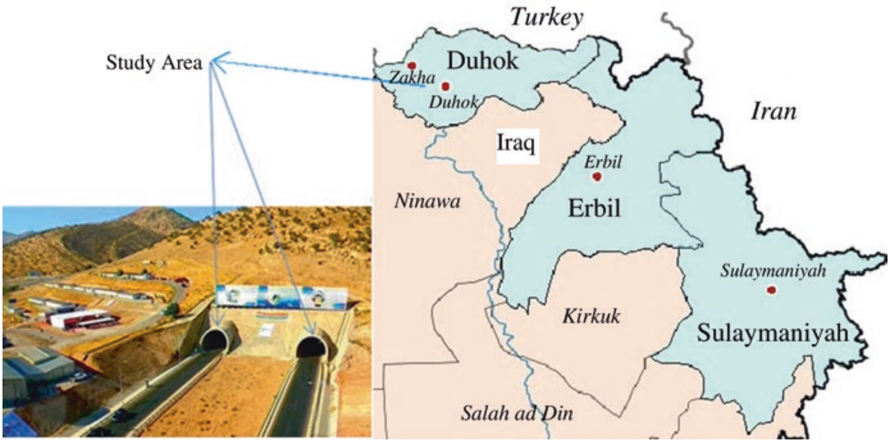

Fig. 34.2 Map showing location of the study area [Gali-Zakho (GZ) Tunnel]

Climate of the Area

Climate of the Kurdistan Region of Iraq [KRI] is classified as interior Mediterranean, mild to cold winter, dry and hot summer. In hot season, the area is under the influence of Mediterranean anticyclones and subtropical high pressure zone. In winter, the area is dominated by Mediterranean cyclones moving from E to NE. These winds that blow, in addition to Arabian Sea cyclones moving toward N with high rate of moisture content that cause precipitation. The area is characterized by semiarid climate with dry, hot summers and cold winters. It is also influenced by very cold polar air mass. The mean wind speed is varying seasonally ranging from 2 to 3 m/s from summer to winter correspondingly. Also the direction of prevailing wind is varying from SW, S, W, and SE [20].

Experimental Investigation

Extensive research work on wind flow patterns is required to find the method that how this Tunnel can be used for generating EE, and to investigate optimum places of generating EE by harnessing the available WE in a better efficient way inside this Tunnel.

An anemometer (type-Vortex wind sensor and VAM361) was used to conduct the experiment and collect data for velocity of the impact wind at different orientation (changing angle of impact from $\Theta = 15°$ to 90°) and different heights.

In order to test the proposed project in real outdoor environments, 15 locations (positions) had been selected in both sides from Duhok to Zakho way (PDZ1–PDZ15), and another 15 positions had been selected in both sides from Zakho to

Duhok way (PZD1–PZD15), to complete the study at GZ Tunnel. Both the manual and equipment-enabled traffic data collection carried out over the site study. Building a rich data set for traffic activity onsite was necessary to adapt the WE harvesting system design and to more accurately forecast potential WE generation. A number of traffic metrics were tracked over the course of the study, including: (1) total traffic count, and other metrics reported by hour, by day, etc., (2) average vehicle speed, and (3) average vehicle classification (e.g., estimated average vehicle weight).

Results and Discussions

Data displays hourly totals for average weekday activity for vehicular traffic volume at GZ Tunnel is shown in Table 34.1. Visual representation of average weekday activity for vehicular traffic at GZ Tunnel, broken down by hourly totals for all types of vehicles is given in Fig. 34.3. Visual representations clearly illustrate the consistency through the day (maximum no. of vehicles = 819 at 11–12 a.m.), and then drop off through the night (minimum no. of vehicles = 22 at 23–24 p.m. or 00–1 a.m.).

There are three sources of WE available during wind flowing through the GZ Tunnel: (1) natural wind energy, (2) impact wind energy, and (3) wind flow due to the ventilation system. So pressure difference is created by turbines installed at the roof of buildings (i.e., Tunnel). As soon as the ventilation system starts to spin, it vacuums air out of the attic. The faster it spins, the more air it exhausts (i.e., wind flow). A major hindrance in the growth of WE is fluctuation in the sources of wind energy. This problem of variability cannot be omitted as it is happening naturally. With concern to this, we have tried to investigate the pattern of impact wind energy available on GZ Tunnel.

Table 34.1 Data displays hourly totals for average weekday activity for vehicular traffic at GZ Tunnel

Time	No. of vehicles	Time	No. of vehicles
00–1	22	12–13	637
1–2	14	13–14	600
2–3	36	14–15	676
3–4	72	15–16	544
4–5	19	16–17	440
5–6	593	17–18	356
6–7	436	18–19	333
7–8	468	19–20	286
8–9	486	20–21	207
9–10	517	21–22	107
10–11	695	22–23	53
11–12	819	23–24	22

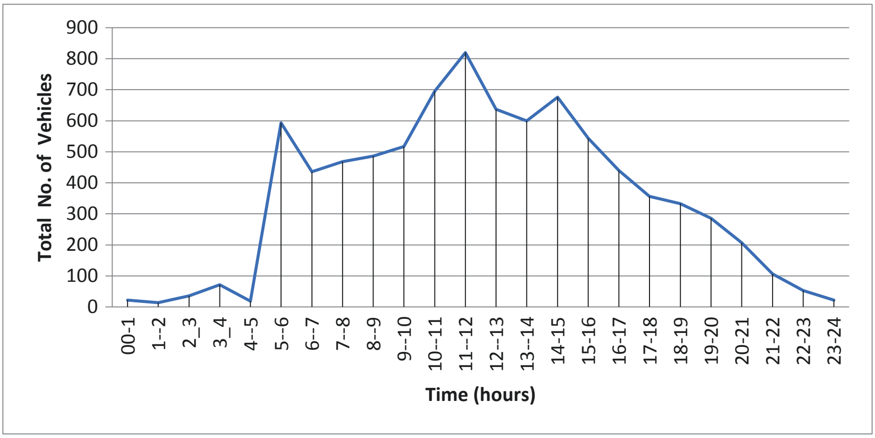

Fig. 34.3 Average weekday activity for vehicular traffic at GZ Tunnel, broken down by hourly totals for all types of vehicles

We have done experiment on GZ Tunnel to predict the height of maximum velocity of impact WE from the road level on GZ Tunnel. We have started to take data from 50 cm. As we go above, we are getting greater value of impact WE velocity. But after 200 cm, velocity decreases. It means that, at a height of 200 cm, we are getting highest value of impact WE velocity. Hence, we have to design the harnessing system (vertical axis wind turbine) according to the above experimental data in order to maximize the efficiency of harnessing system, that is to be implemented on the GZ Tunnel. We have not taken the data below 45 cm, because in the vehicles there is an air gap of 40–45 cm and pressure distribution (high pressure and low pressure) throughout the whole height of vehicles. It means that, we will get very low velocity of impact WE that is negligible or that of no use.

To test the effect of angle of impact on impact pressure thrust, we had changed angle of impact from $\Theta = 15°$ to $90°$. Figure 34.4 shows average values of velocity of impact WE vs. height of anemometer at two different angles ($\Theta = 30°$ and $\Theta = 45°$). It was found that velocity of impact WE was higher for $\Theta = 45°$. This is due to resultant of natural WE, Impact WE, and wind flow due to the ventilation system. Data in Fig. 34.4 represents average values for 15 positions of recording wind speed data from Duhok to Zakho way. However, we got higher wind speed when anemometer was in other positions. For example, the wind speed was 6.5 m/s at position PZD12.

A moving vehicle (bus, car, truck, etc.) in GZ Tunnel compresses the air in the front of it and pushes the air to its sides, thereby creating a vacuum at its rear and its sides as it moves forward. To fill up this vacuum a mass of airflow (wind) rushes into the sides and the rear. The kinetic energy of this wind movement thus created is used to generate electricity. According to the experimental investigation, we found that at a height of 2 m, getting the maximum value of Impact WE available on GZ Tunnel. And at higher height, the recording wind speed starts to drop. To test the effect of

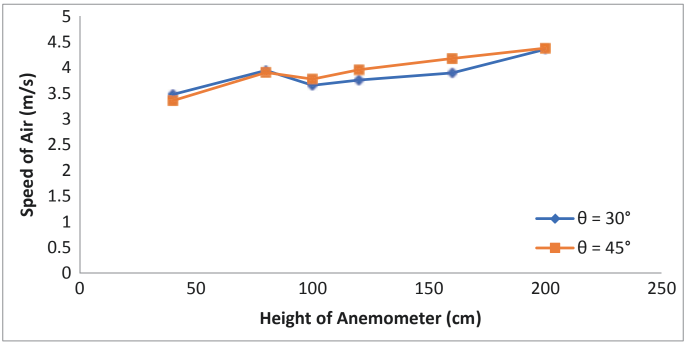

Fig. 34.4 Average values of velocity of impact WE vs. height of anemometer at GZ Tunnel

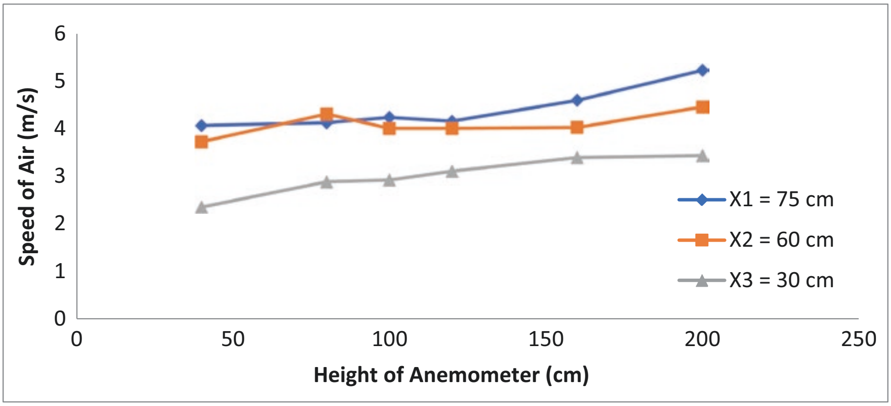

Fig. 34.5 Average values of velocity of impact WE vs. height of anemometer at different distances between anemometer and vehicles at GZ Tunnel

factor of distance between the harnessing system and vehicles on impact pressure thrust, we had changed the position of anemometer (i.e., distance between anemometer and vehicles). Figure 34.5 shows the velocity of impact WE vs. height of anemometer at different distances between anemometer and vehicles, $x = 30–75$ cm. It was found that the velocity of impact WE was higher when the distance between anemometer and vehicles (x) = 75 cm. Maximum value of impact WE available on GZ Tunnel was at a height of 2 m. Data in Fig. 34.5 represents the average values for 15 positions of recording wind speed data from Duhok to Zakho way. However, we got higher wind speed when anemometer was in other positions. For example, when the speed of small automobile was 65 km/h, the wind speed was 6 m/s at position PZD14. According to the result of this study, we can suggest a system for generating electricity from WE by using an efficient wind turbine to serve specifically in GZ Tunnel lightning system. A prototype wind turbine [tunnel side wind turbine (TSWT)] should be designed and fabricated (see below). This system can be used to facilitate many houses and homes. Wind turbine for this specific application must be designed in such a way that it can utilize the wind turbulence from every direction. Darrieus and Savonius wind turbines could be used for tunnel side wind turbine (TSWT). However, it will be similar to highway side wind turbine (HSWT) [21–24].

In order to get the optimum efficiency, a charge controller circuit should be designed and used. It provides charge monitor and flow control within the whole circuitry with the help of microcontroller. Battery bank system should be used to store the charge generated by the HSWT. Block diagram for proposed model is given in Fig. 34.6. This system can be very handy for implementation.

It would be useful to do further studies in this field, e.g., investigations need to be considered on the computational fluid dynamics (CFD) analysis/model on the design of the proposed wind turbines (WTs) and the locations (positions) of WTs in GZ Tunnel.

Conclusions

There is an urgent need for transition from nonrenewable energy to one based on renewable resources to decrease reliance on depleting reserves of fossil fuels, and to contribute to the cause of cleaner environment as it helps to reduce carbon emissions and also assists the government in saving fuel. This it would be possible to attract foreign investments to herald a Green Energy Revolution in Iraq. This paper attempts to illustrate the potential for success of wind turbine systems at these facilities and show the importance of site-specific considerations, such as the available wind speed and the use of detailed project assessments. It is concluded that the Impact pressure thrust depends on different factors such as: (a) the intensity/frequency of the vehicles traffic, (b) the speed of the vehicles, (c) the size of the vehicles, (d) velocity of natural wind, (e) angle of Impact, and (f) distance between the harnessing system and vehicles. Power generation on GZ Tunnel by using vertical axis wind turbine can be used to produce electricity for the many applications, such as lighting the tunnel, pumping water for irrigation system to nearby area, and

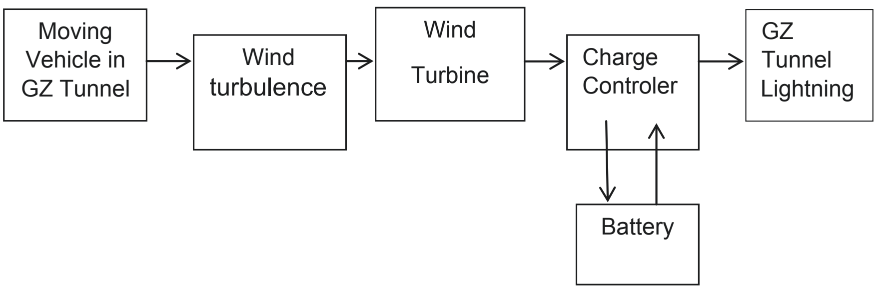

Fig. 34.6 Block diagram for proposed model at GZ Tunnel

communications equipment. Also this system can be used to facilitate many houses and home and will be very handy for implementation. This technology is expected to contribute to cleaner environment as it helps to reduce carbon emissions.

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Chapter 35
The Potential of Solar Thermal in Europe

Marta Szabo

Introduction

Despite the various treaties which were established by the European Council, the treaties of Paris (1951) and Rome (1957), we still did not achieve EU targets regarding the reduction of carbon emission and the use of renewable energy in a massive scale. In 2008, yet another target was set by the EU which stated: "The EU is committed to reducing its overall emissions to at least 20% below 1990 levels by 2020, and is prepared to scale up this reduction to as much as 30% under a new global climate change agreement if other developed countries make comparable efforts." [1].

In 2006, the global solar thermal installed capacity was 127.8 GWth (182.5 million square meters). Of this, 102.1 GWth were accounted for by flat-plate and evacuated tube collectors and 24.5 GWth for unglazed plastic collectors. Installed air collector capacity was 1.2 GWth [1], while China was leading the world, by having 65.1 GWth. In comparison, Europe had 14.173 GWth. The expectation at that time and the prediction was fully illustrated in Table 35.1 [1].

The steady increase in the use of renewable energy makes it one of the major sources of energy and gradually overtaken the fossil fuel in providing heating, cooling, and electricity to many countries around the world. We found that the term corporate sourcing of renewable energy sources have been adopted not only by the USA and Europe but also by Burkina Faso, Chile, China, Egypt, Ghana, India, Japan, Mexico, Namibia, and Thailand [2]. Regarding the power generation from solar thermal, concentrating solar thermal power (CSP) increased by 100 MW of capacity in 2017. The global capacity in 2018 was around 4.9 GW.

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Table 35.1 Total investment needed for the installation of solar thermal systems according to the RDP scenario

Year	Installed capacity (GWth)	Collector area 10^6 m^2	System cost excl. VAT (€/m^2)	Total investment until (billion €)
2006	16	23	650	15
2020	272	388	585	214
2030	1018	1454	470	663
2050	2716	3880	399	1540

Installed capacity collector area system cost excl. VAT

The USA has 1.75 GW, Spain has 2.25 GW, and rest of the world has 1.9 GW. Several projects that were due to enter operation during the year were delayed until 2018 and later. Although global capacity increased by just over 2% in 2017, the CSP industry was active, with a pipeline of about 2 GW of projects under construction around the world, particularly in China and in the Middle East and North Africa (MENA) region. It was for the second running year, South Africa led the market in new additions in 2017, being the only country to bring new CSP capacity online. Additionally for the second consecutive year, new capacity was confined to emerging markets, with no new capacity commissioned in the traditional markets of Spain and the United States. This latter trend is set to continue because all commercial CSP capacity under construction by the end of 2017 was located outside of Spain and the United States. Also 13 GWth of thermal energy storage (TES), based almost entirely on molten salts, was operational in conjunction with CSP plants across five continents by the end of 2017. The vast majority of CSP plants still under construction will incorporate some form of TES, which continues. Solar heating and cooling at the end of 2017 reached 472 GWth [2].

Country Reports

Europe started to pay more attention to the energy from solar thermal and several important reports are now available related to domestic cooling and heating and industrial processes [3].

Germany

Although Germany now has 40% of its electricity produced from renewable energy, they are mostly from onshore winds. They are planning by 2050 they will be carbon free [4]. Carbon emission reduction in 2020 will be 40%, and in 2035 it will be 55%. The area of collectors which were installed by the end of 2016 has reached 19.1 million square meters (see Fig. 35.1).

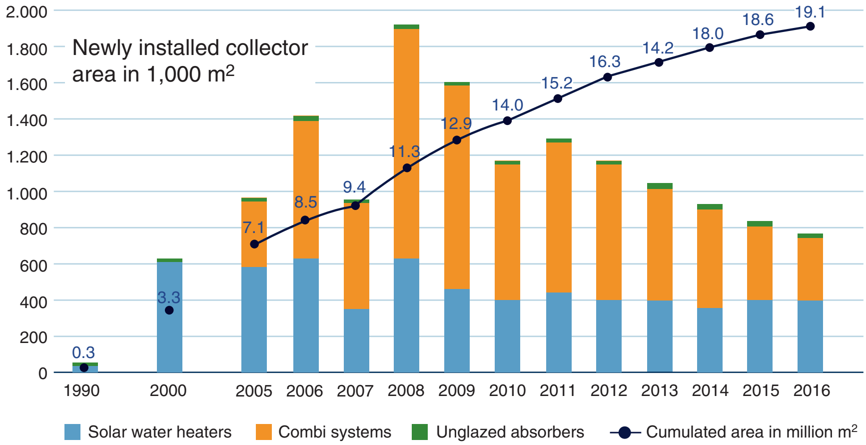


Fig. 35.1 Installed collectors in Germany by the end of 2016

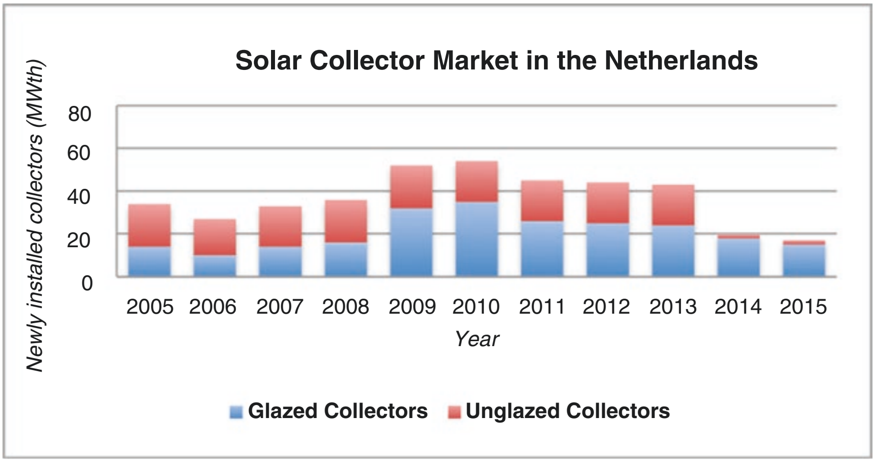


Fig. 35.2 Collector production in the Netherlands

Netherlands

In the Netherlands several manufacturers of hot water collectors are operating with about 500 people involved. As a comparison, China had in 1995 more than 3000 water heater manufacturers. Few district heating and cooling exist in some towns in the country. Figure 35.2 shows the production of collectors up to 2015 [5].

United Kingdom Land

"For over 30 years the Solar Trade Association has been the leading voice for solar in the UK. Established in 1978 as a not-for-profit trade association we represent a diverse membership across the solar power and solar heating industry." [5]. The UK has one of the largest evacuated tube collector company, Thermomax, which has two major factories, one in northern Island and the other in Wales.

Denmark

Denmark has several manufacturers in evacuated tube collectors as well as in glazed flat-plate collectors.

Conclusions

All 27 countries of the EU have some application in domestic heating and cooling systems.

In a report from Strathclyde University, the setting requirement, efficiency and other important criteria – for those who would like to install water heaters in their home – are the following [6]:

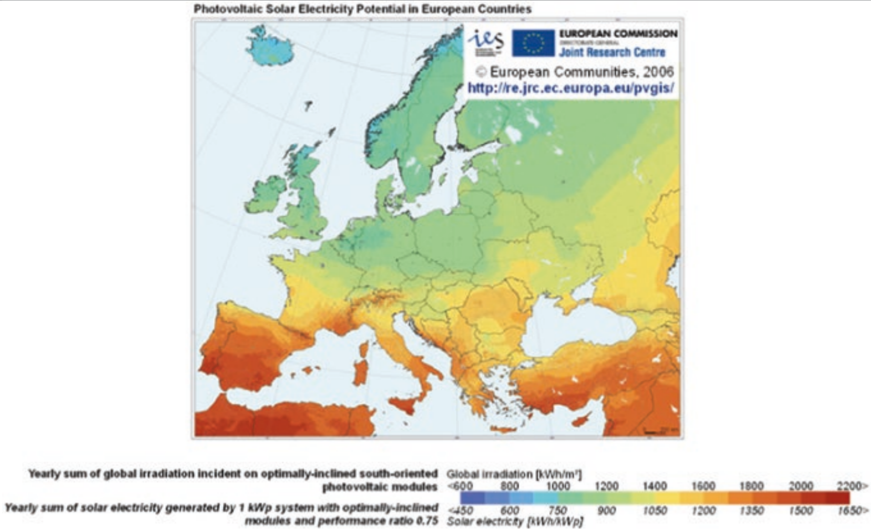
"Energy consumption for domestic hot water of a three-person family"	

Appliance/use	DHW load consumption kWh/day

Bath/shower	1.1
Wash hand basin	1.4
Dish washing	2.3
Clothes washing 50%	2.0
Clothes washing 50%	2.2

Output temperature (°C); T_{in} the water input temperature (10 °C)	

These would add up to 9 kWh/day for a three-person home or an average of 3300 kWh/year
Climatic Data As local climatic conditions are important in calculating the solar gains and: ambient temperature influences significantly heat losses. According the study the collectors must be oriented south (northern hemisphere) and be set at the optimum inclination angle. Solar irradiation on such an inclined surface is roughly 950 kWh/m^2 per year in North UK (Scotland) to about 1950 kWh/m^2 in Palermo. Optimum inclination solar radiation values per m^2 surface area optimally inclined are based on the following map: • 1000 kWh/year Scotland → 2.5 kWh/day • 1950 kWh/year Southern Italy → 5 kWh/day



As a thumb rule a panel size of 3–4 m^2 should be adequate for a four-person home varying in relation to the use of different types of panels (flat solar collectors require usually bigger roof area than evacuated tubes).

Tank is an improtant element of the system. Cylinders connected to solar panels are suggested as 20–30% bigger model. The quantity of water warmed in the cylinder shall be less than that of a conventionally heated cylinder. Oversizing the cylinder again would result to lower than required average cylinder temperatures.
Tank stratification can be taken into accoount in order to optimize efficiency:
High thermal stratification can increase performance due to the lower return to the panel meaning efficiency increase.

Assuming a linear relation between average solar radiation values and panel efficiencies, estimations included for northern and southern Europe were added in the following table based on literature:

[5]

Solar thermal systems daily energy generation. Evacuated tube systems considered have 20 tubes					
Panel type	Flat plate	Flat plate	Flat plate	Evacuated tube	Evacuated tube
Configuration	Direct active	Thermosiphon	Indirect active	Indirect active	Direct active
Total area (m^2)	2.49	1.98	1.87	2.85	2.97
Absorber area (m^2)	2.21	1.98	1.72	2.85	2.96
Maximum efficiency	0.68	0.74	0.61	0.57	0.46
Energy generation (kWh/day):					
Insolation 2.5 kWh/day (north Europe)	4.0	2.9	2.5	3.7	3.1
Insolation 3.2 kWh/day (mainland Europe)	5.3	3.9	3.3	4.8	4.0
Insolation 5 kWh/day (south Europe)	8.5	6.3	5.4	7.5	6.3
Insolation 6.5 kWh/day (tropic regions)	11.2	8.8	7.1	9.9	8.4

The utilization factor “UF” is the percentage of available solar energy actually consumed regarding DSWHS efficiency and daily-seasonal hot water dekmand patterns. According to numerous consumer profiles and solar radiation combinations, the assessed “UF” basically varies from 25% to 40%.

Costs—payback time

In the UK solar thermal systems cost vary from £2000 to £6000 depending on:

- Size of dwelling.
- Occupancy.
- Scaffolding.
- Grants.
- Cylinder type.
- Solar system type.

Grants currently in the UK are £400, and from 2011 there shall be a yearly grant introduced. Average life-span of installations after 1996 are up to 20 years (6). Companies provide 25 year cylinder guarantees and 10 year guarantees on collectors mentioning life spans of over 30 years.

As a Sustainability consideration

it is possible to save roughly half a tonne carbon dioxide emissions.

Relevant European standards:

- EN 806: General installation specifications.
- EN 1717: Protection against pollution of potable water device requirements concerning pollution by backflow.
- EN 60335: Safety specifications regarding household and relative electrical appliances.
- EN 94002.

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Part VIII
Urban Farming and Green Infrastructure

Chapter 36
Urban Regeneration with Rooftop Farming Pilot Projects

Lucia Ceccherini Nelli

Introduction

Urban agriculture is gaining attention and relevance among urban planners, landscape architects, policy makers, and researchers of many countries. As in many other cities worldwide, Germany, the United States, Spain, etc., urban farming has been progressively expanding also in the Italian cities as Milan, Turin, and Florence in the last few years. The urban agricultural solutions, such as family-home gardens, restaurant garden, school gardens, and garden plots, are "new forms" of urban farming that are realized with new design technique of farming. These new solutions of urban food producers focus on activities that take place around urban contests, improve green in cities, and reduce the hot island effect. Rooftop gardens and rooftop greenhouses have been set up by nonprofit associations, private initiatives, or business entrepreneurs for social activities, not always with a commercial purpose but also with social scopes.

Urban Agriculture as a Strategy for Temporary Redevelopment and Reuse

Urban agriculture has become very important in the recent years as the convergence motivation related to food health and to the development of the social community, particularly for the social aggregation. However, urban agriculture to be sustainable as a resilience strategy requires decision-support tools that allow planners, stockholders, and associations to jointly develop strategies and assess potential

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initiatives within urban food [1]. The social inclusion can be obtained with urban gardens and farms, with special politics and planning that can make them crucial, for activities to do in open green spaces. Forms of urban agriculture integrated with architecture are increasingly present in contemporary metropolises. Rooftop greenhouses, rooftop farms, and vertical farms are mostly described as smart solutions for green building, sustainable food production, and ethical consumption contributing to social inclusion and urban regeneration. Urban agriculture can play an important role with social cohesion perspective, can also support and mainstream a strategy of enhancing for resilience and sustainability of urban areas and citizens.

The case studies analyze urban agriculture as a process of social innovation in order to integrate the participatory mechanisms into decision-making processes, increase the social inclusion of vulnerable and marginalized groups, and stimulate the livability of cities, more specifically the development and the implementation of interesting case studies with public participation through solutions of rooftop urban agriculture.

Methodology and Objectives

The study is referred to a comparative analysis among some case studies of rooftop urban agriculture, finalized to the social urban environment. The methodology adopted takes into consideration the rooftop farming as a social innovation practice in order to design and implement processes aimed to combine several social needs and to generate social benefits at a larger scale. The analysis given by a research study [5] about the OrtiAlti project is that by designing a collaborative methodology for implementation, which consists of engaging communities of urban inhabitants in the design and management phases of the rooftop gardens, integrating private sector and nonprofit organizations or social cooperatives as funders and operative partners, and facilitating supporting networks of food distribution and educational activities, rooftop farming could work as an innovative solution of community place-making and urban resilience. The following case studies are used as a practical experiment for innovative practice in the Italian context.

Case Studies of Sustainable Urban Foods Exemplify Practices

Case Study: Community Garden of via Gandusio—Bologna, Italy

Via Gandusio is a community rooftop garden that is implemented by the municipality of Bologna, in collaboration with the University and the association BiodiverCity to foster the community building of the residents.

Via Gandusio was a social housing complex in the North district of Bologna (Italy) that was originally built to host workers that migrate from the South of Italy in the 1960s. Via Gandusio hosted two different communities: advanced-age Italians (former migrants in the 1960s) and current international immigrants from Africa and Asia. The difference in age and nationality creates some conflicts and limits in the relationships among the community Figs. 36.1, 36.2, 36.3. The sustainability of Gandusio project was an experiment of urban food system with reference to the three dimensions: environment, society and economy.

The community garden is designed by the Municipality of Bologna with the association BiodiverCity and the RESCUE-AB Laboratory of the University of Bologna, with the aim of setting a meeting point for the community where food production is the link between neighbors, to exchange knowledge, culture, and experiences. The roof garden (250 m^2) was realized in 2011, became the first rooftop garden with a social and educational scope in the city of Bologna and in Italy.

Fig. 36.1 Via Gandusio—Bologna, Italy. Copyright—Francesco Orsini (UNIBO). (**a**) Gandusio roof garden in Bologna, has represented an experiment of urban agriculture using rooftops of city centres, available areas in the suburbs or unused spaces on and between buildings. (**b**) These urban food systems are commonly associated with environmental, social and economic benefits with the scope to develop an interdisciplinary methodological framework to assess their sustainability. (**c**) The final goal of the initiative was to provide tools and data for supporting policies and decisions towards local and green economies with the diffusion of green roofs

Fig. 36.2 Piazza Ghiberti installation, Florence, Italy, Ur.CA prototype

Fig. 36.3 OrtiAlti as urban regeneration project

Ur.C.A. Project in Florence, Italy

The Ur.C.A Urban Temporary Agriculture project developed by the Department of Architecture of the University of Florence and funded by the Tuscany Region is led by the architects Chiara Casazza and Leonardo Boganini [2]. The project contributes at the construction of an innovative system for the redevelopment of empty areas or rooftops in the city of Florence; urban agriculture is the engine for the refunctionalization of spaces and for social cohesion. The experimental system is dedicated to temporary agriculture system and the design is based on the requirements of temporariness, reversibility, lightness, sustainability, autonomy, usability, well-being, flexibility, safety, quality, and architectural and environmental integration [3]. The system consists of the following elements: social vegetable garden and greenhouse production for a commercial purpose. The urban greenhouse uses hydroponic cultivation technology and allows a protected, sustainable cultivation, completely disconnected from the land and reversible, of vegetables, overcoming the constraints planning. This structure can be inserted in many places without altering the state of the places and without the need for works of any kind.

The temporary greenhouse is a good space of socialization and for sharing education, with the potential for agriculture production and social inclusion in the local micro economy. A multifunctional attractor center that revolves around the theme of sustainable km 0 agricultural aimed at education and dissemination.

Ur.C.A. is greenhouse, a pilot project for urban agriculture, a low-tech vegetable garden social/family, a community green space for educational activities. Ur.C.A. is also replicable in other urban contexts of green productive infrastructure. The temporary system, suitable for rooftops, has flexible characteristics and suitable for the institutionalization of urban agriculture and its involvement in the urban affairs in Italy [4]. For the insertion and planning of urban gardens, both temporary and itinerant, a 360° management and planning approach is required, at different levels: spaces for urban agriculture, water and energy infrastructure, services and new opportunities for work, market, transport, social relations, and activities.

OrtiAlti Project in Turin, Italy

The *OrtiAlti*[1] case study is an action-research project realized in Turin, set up to revitalize abandoned or underutilized urban buildings through rooftop community gardens. The research is aimed at understanding the extent to which rooftop farming can contribute to urban regeneration processes if framed as a social innovation practice of place-making and urban resilience, a multidimensional space that includes new economic and social actors as subjects able to produce values of collective interest for the community [5]. An experience of rooftop farming is implementation as a solution for the resilient city. The research question behind the OrtiAlti study was whether rooftop community farming, as a resilient practice, is able to improve the urban environment and empower local inhabitants in taking care of the urban common good. This action-research project was started in Turin in 2015 (Figs. 36.4, 36.5, and 36.6).

The "Ortoalto Le Fonderie Ozanam" is one hundred and fifty square meters of urban space dedicated to the cultivation of 29 types of vegetables.

[1] *OrtiAlti as urban regeneration devices: an action-research study on rooftop farming in Turin*. Retrieved from https://www.researchgate.net/publication/318092126_OrtiAlti_as_urban_regeneration_devices_An_action-research_study_on_rooftop_farming_in_Turin.

Fig. 36.4 Detail of paths and flowerbeds

Fig. 36.5 General view of Fonderie Ozanam in Turin, example of urban regeneration

Under the vegetable garden, there is a cooking school and the restaurant with the same name ("Le Fonderie Ozanam," managed by the social cooperative Meeting Service) which produces dishes made with natural products at "zero km." For the gardens are used a variety of textile and plastic materials that are laid on flat roofs, making them waterproof but allowing the water to be retained and to easily flow. Above this layer, it only takes 10–15 cm of a special, lightweight, and easy-to-use soil to start growing plants at a high altitude .

Casa Ozanam is a complex consists of several buildings with courtyards arranged in a triangular space, the house is a former printing house owned by the City of Turin and used as a guest worker's quarters. The building was designed by a Bulgarian architect, Nicolaj Diulgheroff, an interesting example of the architecture of the second Italian Futurism, unique in Turin. The building is preserved, treated, and regenerated. On the top of one of these buildings is realized the *Orti Alti* research project that shows how the rooftop garden can work as an urban regeneration and social aggregation community. Giulio Vesprini, a graphic designer, created

Fig. 36.6 Rooftop BOTANY by Giulio Vesprini in Turin, Italy

BOTANY; his art is mainly based on the study of the relationship between space and architecture, questioning on the dialog between urban spaces and habitants. In his continuous graphic research, he has always found new shapes to create designs that can be adapted to the surrounding architecture. He arrange walls like flowers, a suggestive choice to create a visual blossoming with natural and urban elements present in the neighborhood, by combining architecture and graphic in a poetic dialog, well contextualized in the city area (Fig. 36.7).

The **Piuarch** architects[2] has designed a model reproducible garden, inspired by the international urban farming movement; they have created a roof reconversion project that includes a reduction in the cost of cooling in summer, a decrease in waste water flow due to rainwater absorption, a reduction in temperature from 2 to

[2] ***Kinetic garden.*** *Retail design blog on 2016-05-29.*

Fig. 36.7 The Via Palermo vegetable garden in Milan, rooftop in Brera district, Copyright Daniele Cavadini

5 degrees inside, and an improvement in the quality of the environment regarding the climate and energy, as well as from an economic and social point of view [6]. The system is realised with modular pallet, an easy structure, easy to assemble, with two paths for walking, small planted areas for growing fruit, vegetables, and aromatic plant species, and places for relaxing and sunbathing while admiring the view from above; the garden is made for welcome guests and for landscape lessons or work meetings.

This experience aims not at being unique but rather a system that is repeatable on a large scale for redeveloping rooftops in urban areas that are not generally used. The pallets become floor and upside-down, as containers for soil. In this way, a single modular element is used to create all garden [7].

The project was developed together by the landscape designer **Cornelius Gavril** and with the collaboration of ***VerdeVivo* association**. This place is designed for schools for the education of children to assist in growing fruits and vegetables.

The rooftop garden is a complete ecosystem, which starts from the seeds, when seeds are germinated, provide food, decoration, medicinal plants, and at the end compost to fertilize a new season of plants. The open-air pharmacy involves the planting of medicinal plants with the aim of rediscovering the medicinal and therapeutic properties of plants used for centuries for pharmaceutical purposes. The garden hosts also medicinal plants, a relaxing area where history, work, and nature are reconciled (Fig. 36.8).

The Via Palermo vegetable garden[3] is not the only one of its kind in the center of Milan. On the seventh floor, next to Duomo square, there is the **Hotel Milano Scala**'s garden in Via dell'Orso 7. Here, aromatic herbs, flowers, seasonal fruit, and vegetables are grown, which are directly used in the hotel kitchen.

From Milan to Turin, hotel gardens are a growing trend. In the historic seventeenth-century palazzo, the rooftop terrace at the **NH Collection Piazza Carlina** in Turin contains a garden, where ingredients for the Carlina restaurant on the ground floor are grown (Fig. 36.9).

[3] Retrieved from https://ifdm.design/2017/06/22/urban-farming-in-milan-and-turin/?lang=en.

Fig. 36.8 Piuarch architects in Turin

Fig. 36.9 NH Collection Piazza Carlina, https://www.nh-collection.com

Conclusion

The paper emphasizes the strengths of urban agriculture in individual intervention, especially on the rooftop, for the possibility of contributing and defining a network, a local food system offer, resource management, and finally to generate new types of urban spaces, socially attractive. The districts of Turin will turn green thanks to

Fig. 36.10 Edenworks, New York startup by Eng. **Jason Verde**. An example of rooftop garden greenhouse with hydroponic farming. Copyright http://www.foodmakers.it/

the ***OrtiAlti*** research project, set up by architects **Elena Carmagnani** and **Emanuela Saporito**, with the sustainable rooftop garden designed as urban regeneration. A future development of the Ur.C.A. prototype and its strength lie especially in the possibility of creating a network of "itinerant" urban agriculture poles, which could in this way cover a part of demand for agricultural products by creating an urban km 0 market, on the other be part of the network of school or university canteens, hospital canteens, or become teaching spaces serving local schools, therapy areas serving other facilities, or entering the sustainable waste and urban water management network.

In conclusion, the general public can be affected by negative impacts and barriers from the implementation of urban agriculture projects, which can be handled by normative schemes. To overcome such barriers, pilot projects and the dissemination of current knowledge and practices are fundamental in improving the current understanding of local food systems among the multiple stakeholders. Furthermore, urban agriculture may focus on sustainable technologies (e.g., local resources, energy efficiency), integrating social aspects (e.g., education) and establishing new market structures (e.g., short supply-chains) to ensure a socially accepted development of this new form of urban agriculture (Fig. 36.10).

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Chapter 37
The Imitation Game: The Urban Sustainability Game as an Experience of Participation, Knowledge, Evaluation, and Project Sharing

Alessandro Rogora, Paolo Carli, and Michele Morganti

Introduction

Why should we design a role play on sustainability? What is the sense of playing a game involving students and citizens? And what is the relationship that connects this game with architecture and sustainability?

Our work addresses these questions introducing *The Imitation Game*, an innovative serious gaming, aiming at experiencing and sharing sustainable lifestyles. In particular, this paper focuses on describing the most relevant features of the game, defining some of the general rules, playing field features, player characteristics, etc.

In the last 20 years—but even more in some countries [1]—a phenomenon named *Cosplay* (1) was developed. At first, it happened in the role plays (in the table games, but not only), later in the manga (2) and videogames. Recently, we had the opportunity to visit some electronics fair in which one or more pavilions were specifically dedicated to role plays and manga cartoons. It was curious to discover in the stands people impersonating comic book figures, middle-aged men dressed as Marvel heroes, with the same haircut and beard but, moreover, the same behavior, or young ladies dressed up like Japanese cartoons.

In the same period, in the countryside near Milan, it was possible to meet people that organized a sort of middle age role play with arms and armors. In this case, it is reasonable to suppose that more than a few could have cost several thousand Euros, as well as several weeks of work. Even people never interested in such activities are fascinated by the participation of the people to these performances. After the play, the people are dirty and tired, but happy for the experience that was both dreamlike and real at the same time. And fascinating was the use of the first person to describe the experience lived by each "hero."

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At the end of the performance, almost all the actors have a discussion on the next coming experience that could have been better played changing, adding, or modifying something that the previous play taught the players.

To answer the original question: Why should we design a role play on sustainability? We can also refer to the UNESCO Report 2010 "*Tomorrow Today,*" in which it is clearly underlined that in order to achieve sustainable conditions in human settlements conventional actions alone are not enough: "*Reaching sustainability will require more than legal frameworks, financial resources and green technologies, it also needs us to change the way we think—change that can best be obtained through education.*" That is why we believe that new methods for the technical–scientific dissemination of the issues of sustainability and environmental protection are required.

Referring to the Roman motto we can write "*ludendo docere,*" which means teaching through play is effective …, a trick that every experienced teacher knows well.

Even if we consider the so-called "*serious games*" as part of the digital experience, these strategic games of simulation and war have been originally played since the first half of the twentieth century. The original scope was playful but also oriented to create an effective and enjoyable training experience.

Anyway the world of "serious and training games" is quite complex and structure as reported in Fig. 37.1. *The Imitation Game* can be considered part of the serious gaming because it causes a transformation in the real world through concrete actions played in a simplified, real context.

In 2011, a collaborative, web portal—originally developed by the University of Toulouse [2]—was developed to classify and diffuse the knowledge of serious games: table, online, and role play/LARP (live action role play).

The typology of game, as well as the support and the players, are different in each serious game and it is sometimes difficult to find a clear difference between these and the conventional, playful games because the training experience strongly depends on the way in which the game is played.

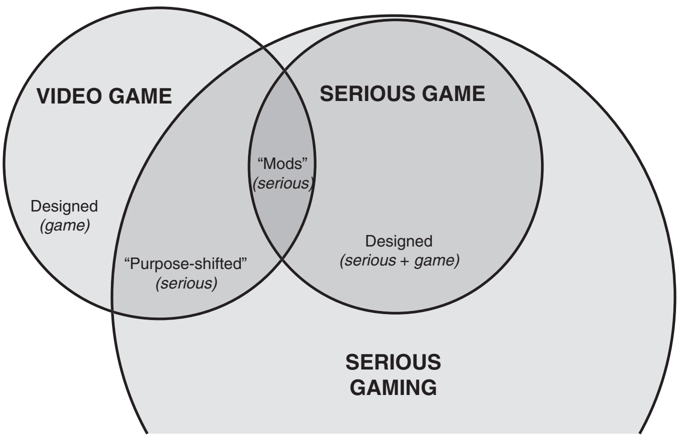

Fig. 37.1 The relationship between video games, serious games, and serious gaming [2]

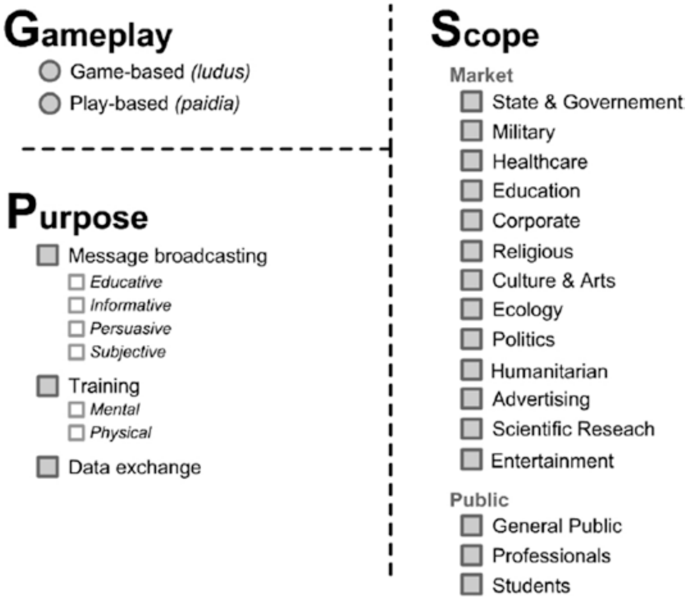

Fig. 37.2 A "printable page" representation of the game/purpose/scope model [2]

For example, an interactive, virtual simulation can be considered a serious game, because it is able to develop skills and abilities that the player can use in a real context (Figs. 37.2 and 37.3).

With reference to urban design and architecture, different uses of gaming have been explored in the past: from pure simulation, e.g., Sim City, to scenario making games Regionmaker Climatizer Spacefighter and Block Maker (games developed by the Dutch architecture firm MVRDV), and ArchSim by MIT, up to pervasive games, i.e., TIMNIT, REXplorer [4–6].

Among the serious gaming, just a few focuses on local sustainability of a community and more efforts are required in order to obtain an effective modification of human habits and to create environment-sensitive communities. *The Imitation Game* aims at bridging this gap tacking the urgent question of urban sustainability, using the accessible environment of games (free from any real-life jargon) engaging players (inhabitants) and stakeholders each other and facilitating collaborative knowledge and outcomes.

A Game to Practice Urban Sustainability

The Imitation Game is an ongoing research and it has been funded by the Department DASTU—Politecnico di Milano University. In the first stage, during these months, the research group is working on defining game rules and the data set organization. The first plays are scheduled to start within next autumn. *The Imitation Game* tries

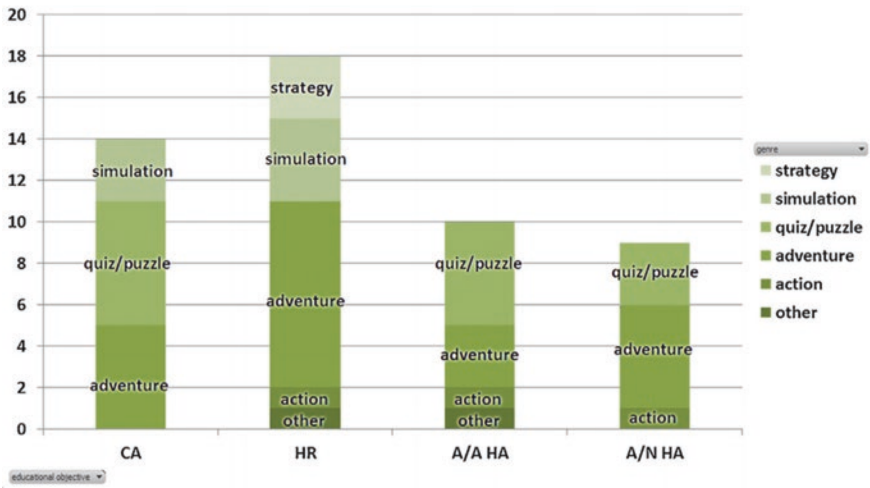

Fig. 37.3 Chart of the reviewed serious games (SGs) for cultural heritage according to the primary learning objective and the game genre, where *CA* cultural awareness, *HR* historical reconstruction, *A/A HA* artistic/archaeological heritage awareness, and *A/N HA* architectural/natural heritage awareness [3]

something similar to a role play. We are looking for actors and heroes of the play. The final objective is to transform lazy office workers and annoyed students into positive humans, ready to face a better future that is in their hands. A future, in which everyone can, becomes the hero of the day.

To start playing everyone needs a bit of strategy, a continuous application, tenacity, constancy, ingenuity, and little craziness. It is not possible to imagine a play sitting on the sofa or lying in bed listening to soft background music; the game must be participated and all the players must be active to be effective in the play. As most of the role plays, *The Imitation Game* lays between a real experience and a virtual simulation, making the lived experience more significant and projecting the experience outside the narrow spatial border of the playground and the temporal limits of the play. The final objective of the game is to find out sustainable behaviors at the local scale in order to "*meet the needs of the present without compromising the ability of future generations to meet their own needs*".[1] The solutions proposed and played in the game should be environmentally sustainable, economically viable, as well as socially acceptable, which means to satisfy both every single user and all the users at the same time.

In *The Imitation Game* the main objective is not the victory of a single player, but to make possible to experience and to share different scenarios through the adoption of sustainable/alternative behaviors and technological choices.

[1] The Brundtland Report "Our Common Future," 1987 [7].

Indirect purpose/aim of the games is to modify citizens' behavior, to transform the existing architectures, to be part of the urban transformation, to take action on mobility choices, to change consumer goals (and as a consequence to orient the industrial production), deeply to transform the behaviors and values of our society that is not as different as to save the princess, or to defeat a dragon or a handful of orcs that threaten our parents and our village!

The playground is a properly simplified real context with georeferred data related to the locally available resources (energy, money, productive land, etc.).

The preparation of the virtual playing field is delegated to the *Magister Ludi*.[2] This work defines the way in which the data are structured, organized, and made available to the players. These elements strongly affect the quality of the play and somehow, in a way, also the final result.

No maximum number of players is defined, but to a higher number of participants makes possible to have a more detailed description of the society. Each player represents a specific group of people in the society (e.g., single, couple without children, large family), and the associated consumptions of energy and goods. The player behavior during the game, as well as the technical choices adopted, will affect the final result. Each player has a given amount of available resources (money, time, etc.) due to the specific part of the society impersonated in the play. The game defines two possible modifications: the first is related to the reorganization of resource use (e.g., to use some money to buy solar panels—and these options will be simulated), and the second to the changing of user behavior. To be effective in the game the user behavior must be changed in the real world for the period of the play. The hypothesis to reduce the CO_2 emission moving from a carnivorous diet to a vegan one, for example, must be experienced for the entire period of the play by the players who chose this option; in the same way the proposal for light mobility (foot or bicycle) requires to abandon (or reduce) the use of private car for the period of the play.

During the play it is also possible to involve not playing people that can be convinced to experience the behaviors as proposed by players. Such persons are defined passive players and are very important because they give the chance to test the response of real persons (in terms of age, physical ability, use of the time, etc.) with an approach that is far beyond the virtual simulation.

The ability to involve passive players has been defined as "evangelization" and its purpose is to promote and disseminate the effect of the game and the citizens' awareness of the environmental consequences of personal choices.

The former plays will be used to verify the ability to imitate the real situation. The first round of play will be managed by our research group and played by students of the Politecnico di Milano University, in order to properly define both playing rules and playground; the first real rounds will be played in a Municipality that wants to experience the game. It does not mean that former plays will be used only to test the simulation model; in fact, it is expected that the experience lived directly by the students may produce positive and lasting effects on their behavior.

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[2] The term Magister Ludi comes from the book "The Glass Bead Game" by Herman Hesse [8].

The rules of the game concern the ways in which it is possible to modify the availability of some resources (time, food, materials, energy, water, land) to be as close as possible to local sustainability. Therefore, each single action and behavior differently affects all these resources. The description of the playground is made using georeferenced data available in public database coming from a field survey. Higher accuracy in the playground description as well as in modelling of the mutual relations will produce a more accurate result. We should remember that we are playing a game and it is nonsense to arrive at extreme complexity if we have to reduce playability. One of the main critical elements is the user interface that is considered more important than the quality of the algorithms that will be extremely simplified (at least in the first phase of the research).

As with many table games, you can get bonuses for specific activities or special events. It is possible to get bonuses reading books on sustainability, as well as participating in conferences on local sustainability, attending courses on the topic (also online), as well as promoting local activities focused on sustainability.

The game is structured in six sections plus one:

- Nutrition: Food
- Move: Transportation
- Reside: House
- Clothing: Clothes
- Communicate: Sociality
- Wellness: Wellbeing, culture hobby, and sport

The added section is related to the common services, at the moment computed as a percentage of the global consumptions (Figs. 37.4 and 37.5).

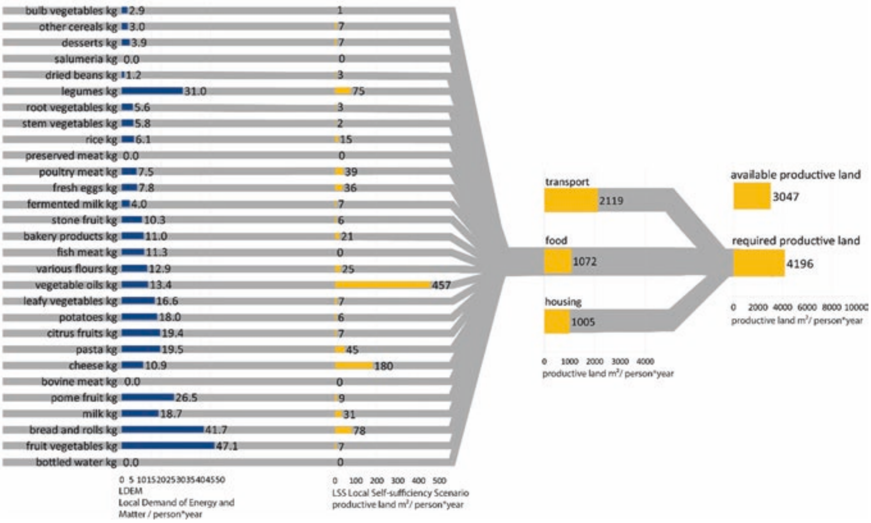

Fig. 37.4 Annual food consumption per person and the relative amount of productive land associated with the category of feeding [9]. A possible scenario for the play field of *The Imitation game*

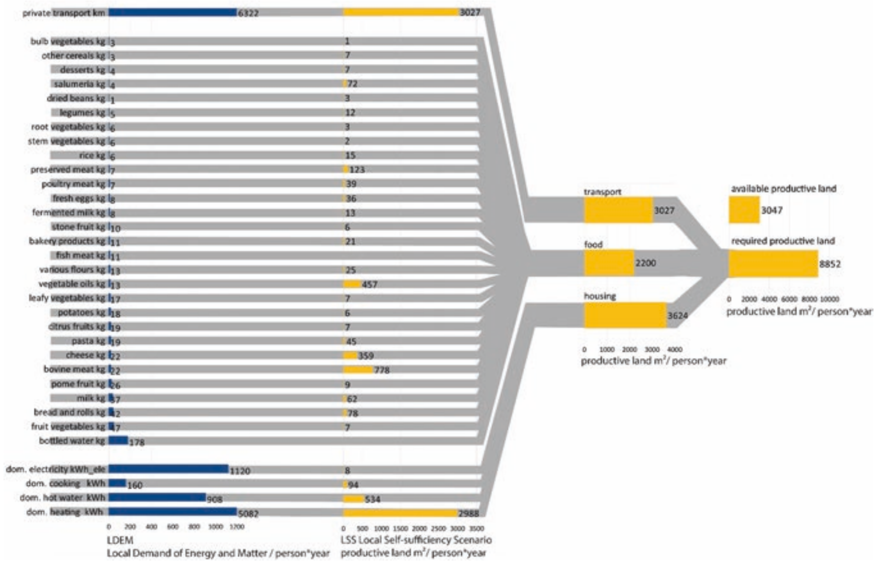

Fig. 37.5 Extension of productive land per person (in orange. On the right values are aggregated by consumption category: transport, food, and housing) [9]. A possible scenario for the play field of *The Imitation game*

Expected Results

Every play can last from 1 week to a few months; the longer the play and the higher the number of players, the more the results will be plausible and the conflicts and ways of solving them will be more evident.

During the round it will be possible to play solutions that could be really effective in terms of sustainability, but not practicable in terms of social consensus without a deep transformation of the local conditions. The use of bicycles is one clear example: very effective in terms of sustainability, but difficult to adopt without urban cycle paths that offer security. In this case, the involvement of the local administration could permit to experience temporary solution in terms of modification of road conditions, construction of protected cycle lanes, facilities, etc.

The result of the game is both formative and quantitative. On the one hand, we have the citizens-players who actively participate in the experimentation and experience the applied sustainability. On the other hand, we have the involvement of the administration that can quantitatively verify the results of the simulation and orient urban transformations towards solutions with greater sustainability and higher consensus.

Notes

1. The word *Cosplay* comes from the merging of two English words: costume and play and it indicates the identification of a Cosplayer with his/her favor fantasy hero (cartoon, manga, movies, or videogames), imitating gestures, behaviors, and, above all, aesthetic aspects through refined costumes accompanied by the same accessories (weapons, rings, scepters, etc.).
2. Manga are the typical Japanese comics, with characterizing differences compared to other types of comics (comic strips, graphic novel, etc.).
3. The Brundtland Report "Our Common Future," 1987.
4. The term *Magister Ludi* comes from the book "The Glass Bead Game" by Herman Hesse.

In our game the Magister Ludi is not necessarily a physical person, but it is the group of people who prepare the playing field for the game by organizing the data, making these data available and defining the relationship and the general and specific rules to be used in the game, etc.

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Chapter 38
Efficient Energy Conversion Contribution in Urban Area Transition Towards Smart Cities

Andrea Rocchetti and Filippo Nocentini

Introduction

The impacts of the greenhouse gas emissions on Earth's climate due to human activities are the big deal of this century. Climate changes and reduction of greenhouses effects are most relevant challenges. Solution attempts should involve all degree of society and governments all over the world. The attainment of societal sustainable environment goals is an issue that collects consensus and stimulates consciousness on public opinion and moreover will have great economic and social impact all around the world. It is generally believed that renewable energy sources use can help us to achieve the goal of protecting environment. Indeed, conversion of energetic systems towards a near-zero-emission green solution must be the main target that should be pursued. At present, most part of urban areas all around the world are so far from a "smart city" model and it is necessary to improve ecological and environmental footprint step by step. First step is starting from local resources and infrastructures, adopting smart behaviours, in order to meet environmental goals, which in many cases means also to mitigate local hazardous and polluted environmental conditions. Energy efficiency conversion and consumption reduction of most polluting fossil fuels are kickoff actions that can be widely applied in most part of the continents. It is specially an actual and particularly serious problem in developing countries such as China and India [1]. With this in mind, natural gas can represent transition from flammable fossil energy to zero-emission renewable energy [2]. In addition, natural gas is unique amongst fossil fuels with regards to benefits of complementing renewable resource integration [3]. As an energy source, natural gas will not only reduce emissions of standard pollutants and greenhouse gases, but it also has potential for transition to 100% renewable fuel (biogas, renewable hydrogen) [3].

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Natural gas consumption is expected to continuously grow significantly in coming decades due to its relatively low environmental impact and reduced appeal of nuclear energy after the Fukushima disaster. Oil was the primary fuel source of the twentieth century; natural gas most likely will be for much of the twenty-first century [4]. In recent years, natural gas pipelines networks (NGPN) received great attention due to relevant role represent in energy policy and, in general, on political relations between states involved in gas-based energy market. They also cover a strategic service in urban areas [4–7]. About reliability of the NGPN, many, though not all, gas supply crises result from equipment both infrastructure failures and extreme weather in urban areas. This sentence means NGPN is not able to withstand strains due to greater user's request during extreme winter weather conditions. The most important threats to gas security will be a decreasing ability to meet peak demand [8]. Improving the reliability of the NGPN means lowering this peak demand by introducing energy conversion systems that are able to better exploit the deliverable natural gas flow rate of NGPN. Similar considerations can be done for reliability of electric grid supply, stressed during summer season due to electric cooling systems peak request.

Aim of This Work

The use of renewable sources could represent ultimate goal towards smart city target and environmental sustainability, but, at present, it is necessary to be aware that coverage rate of thermal and cooling energy needs of urban utilities is largely satisfied by natural gas network and electric grid. In Italy, for example, distribution networks of energy carriers are fully loaded and unable to tolerate and manage peaks of demand for thermal and cooling power. Peak requests happen in severe seasonal external condition and climate changes are making increasingly extreme. Moreover, in most of Italian cities, several restrictions need to be considered when restoration interventions are planned, due to historical heritage protection. Therefore, this study considers the way to augment exploitation of an existing NGNP through efficient energy conversion systems able to manage energy needs in winter heating and summer cooling seasons. This paper explores feasibility and energy performance of an enhanced plant layout suitable to be inserted as upgrading of a heating and cooling system of large buildings in urban context. Based on a gas-fired cogeneration system, proposed conversion system efficiently uses simultaneous production of mechanical (or electrical) and thermal energy to power reversible vapour compression cycle heat pump and reversible heat-fed heat pumps, respectively. A geothermal source is considered as external source of heat pumps/chillers in order to improve system efficiency and reduce visual, acoustic and thermal impact on the local environment of the urban area. A numerical simulation on TRNSYS [9] was performed to investigate performance of system, comparing some different configurations in terms of primary energy consumptions.

Analysis Method and System Description

The substitution of energy system with another newest and more efficient is a key issue in energy refurbishment of buildings. Reducing primary energy consumption, using thermodynamic cycles working with natural refrigerants, and differentiating exploitation of energy carriers in all seasons can represent important tasks that could be pursued. An innovative solution of central heating cooling plant is considered in this study and a yearly energy analysis is applied to investigate its performance. Considering an urban area, a suitable test case is considered in order to evaluate a performance comparison by numerical simulation. In fact, in this work it is considered a typical large office building located in Firenze, 30,000 m^2 area, with a traditional heating and cooling plant equipment. Energy performance of this base-case is numerically calculated and used as reference. New heating and cooling generation system is modelled and applied to building plant to compare energy performances.

Base-Case

The buildings considered as case study is an office building, spaced 30,000 m^2 in Firenze. It can represent a typical large office building representative of existing building heritage. Building envelopes with minimum single transmittance accepted from Italian norms (DM 26.06.2015) is considered. 30% of window-to-wall ratio fixed to guarantee good natural lighting needed in an office building. Simple boundary conditions are posed to the energy building analysis to meet reasonable simulating times. Occupancy and gain load schedules are imposed for working days, from 8 a.m. to 8 p.m., from Monday to Friday. Mechanical fresh air ventilation (1 ach average) is provided by HVAC system equipped with heat recovery (effectiveness 50%). Heating and cooling loads are locally managed by fancoils. Indoor temperature setpoints at 20 and 26 °C for winter and summer season are set for heating and cooling load calculations.

Actual heating and cooling plants consist in natural gas-fired boilers supplied by the local NGPN and air-cooled chillers electrically powered by the grid. Total heating power is 1200 kW and total cooling capacity is 950 kW. Thermal plant provides heated water at 50 °C and cooled at 7 °C for the heating and cooling services of the building. In both cases, constant water flow rates are considered. Mean values for efficiency are used for primary energy calculation, presented in Table 38.1. No loads of auxiliary are considered.

Table 38.1 Mean values for devices efficiencies of actual plant and energy conversion factors

Mean gas boiler efficiency	$\eta = 0.9$
Mean air-cooled chillers electrically powered energy efficiency ratio	EER = 2.85

New Energy Systems

The new energy system proposed combines heat and power system (CHP) with reversible electric powered heat pump (EHP) and reversible heat-fed heat pump (THP). There is relevant literature treat about CHP combined with EHP, a review is provided in [10]. Called as gas engine driven heat pumps (GEHP), these devices produce heat for heating service (HS) and domestic hot water (DHW) using both hot temperature source of heat pump and thermal power coming from exhaust gas and cooling water of engine jacket. In cooling service (CS) mode, low temperature source of heat pump is devoted to produce cooling power and thermal power at hot temperature source of heat pump and that coming from CHP can by recovered to supply possible thermal loads or discharged. In our proposal a reversible THP, supplied by thermal power coming from CHP, produces useful thermal capacity as in heating and cooling modes. The general scheme is presented in Fig. 38.1.

THP technology is generally based on absorption cycle devices, but other solutions are facing up as ejector refrigeration cycles. Both are well oriented to natural refrigerants use [11, 12]. There is extensive literature in those technologies when CS is considered [13, 14], fewer when heat pump configuration is requested [15]. Some of these point up some arguments: an enhanced performance is gained when suitable heat source is used, as ground [16], and for this reason, in our solution, source like this is selected for THP. Following the natural refrigerant criteria, a CO_2 heat pump for EHP is selected and wide literature is already available [17]. Due to the size of the system, a CHP system based on a gas fire alternative engine is considered. For the sake of simplicity, we refer to an electrical efficiency of the CHP and an electrical powered reversible heat pump, stressing that a direct coupling of these two devices can be adopted.

Nominal parameters of new heating and cooling plant are presented in Table 38.2.

η_e and η_t are, respectively, ratio between nominal electric power or recovered heat and nominal primary energy of the CHP; EER_{EHP} is the ratio between nominal

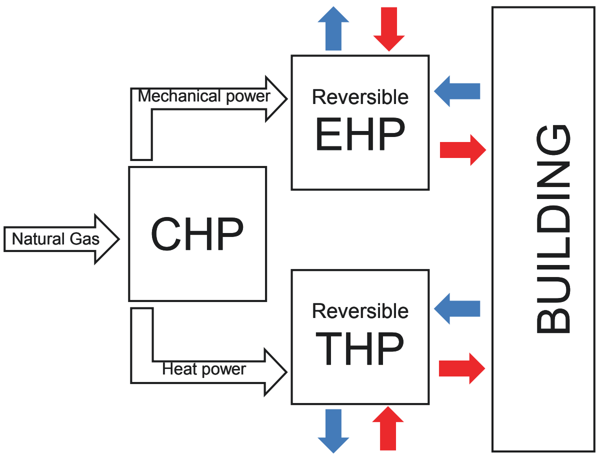

Fig. 38.1 Energy flow in HS (red arrows) and VS (blue arrows)

Table 38.2 Mean values for devices efficiencies of new plant and energy conversion factors

Mean electrical efficiency conversion of CHP	$\eta_e = 0.37$
Mean total thermal recovery efficiency of CHP	$\eta_t = 0.57$
Mean air-cooled CO_2 EHP energy efficiency ratio	$EER_{EHP} = 3.0$
Mean air-heated CO_2 EHP coefficient of performance	$COP_{EHP} = 3.4$
Mean ground cooled THP energy efficiency ratio	$EER_{THP} = 0.5$
Mean ground heated THP coefficient of performance	$COP_{THP} = 1.5$

refrigeration capacity and nominal electric power supplied to EHP in CS; COP_{EHP} is the ratio between nominal heating capacity and nominal electric power supplied to the EHP in HS; EER_{THP} is the ratio between nominal refrigeration capacity and nominal thermal power supplied by CHP to THP in CS; COP_{THP} is the ratio between nominal heating capacity and nominal thermal power supplied by CHP to THP in HS.

The system proposed is able to match thermal levels request by energy services of building and can be inserted in parallel, priority use, with current generators that cover the exceeding building loads and they are also used as backup systems, in order also to make easier performance comparison.

Numerical Simulation

A numerical code has been created and run in TRNSYS. This software allows to recreate all plant components (generators, controllers, storage tanks, etc.) in one simulation environment. In TRNSYS each component is called "type". Each type is composed from an internal code and external input/output data.

In the same simulation environment, it is possible to create a "type" building which is linked with another software TRNBuild. TRNBuild allows to create besides building envelope also crew profile inside volumes, internal gains, fresh air needed and all thermal and cooling loads concerning with energy balance of a building. In this way it is recreated a complete load profile that had to be satisfied by heating and cooling plants. TRNSYS works by performing energy balance of whole buildings/plants system with time steps that can be imposed by the users, hourly or sub-hourly, in order to better catch correct time dependencies between capacity of plant modulation and energy load variation. With this configuration, plants and building in the same work setting, interactions between plants and building are really considered, especially in inertial topics. TRNSYS uses special elements to take external inputs, like climatic data, and provide outputs can be stored and used to obtain all energy balance terms.

We modelled different plant configurations starting from base-case system and introducing some new configurations based on combined CHP/EHP/THP devices. Three scenarios are composed with these solutions:

- Model 1
  - HS: three boilers in series.
  - CS: three air-cooled chillers in series.

- Model 2
  - HS: one CHP with direct heat recovery; two boilers in series.
  - CS: one CHP with heat-fed chiller cooled by cooling tower; two air-cooled chillers in series.
- Model 3
  - HS: one CHP with heat-fed geothermal heat pump; two boilers in series.
  - CS: one CHP with heat-fed geothermal chiller; two chillers in series.

Model 1 (Base-Case)

This model simulates base-case of this work. A typical heating/cooling plant is modelled. TRNSYS's schemes of heating and cooling energy system are shown in Figs. 38.2 and 38.3. There are shown all types and their connections by fluids circuits and control blocks. Boilers have each one capacity of 400 kW with 90% effectiveness. All three boilers work with three different setpoints on 10 m^3 tank storages serving heating/cooling plant. TRNSYS provides special types, to control this procedure that needs to be correctly tuned to perform right, as a real control system. Building energy exchanges with plant by tanks; hot water goes out from tanks, serve buildings and come back in tanks. Constant water flow rates are considered.

Chillers are air/water machine and they are powered by electric grid. Each chiller has 315 kW cooling capacity and EER equal to 2.85. All three chillers work with three different setpoints on 10 m^3 tank storages. They work in the same way than boilers.

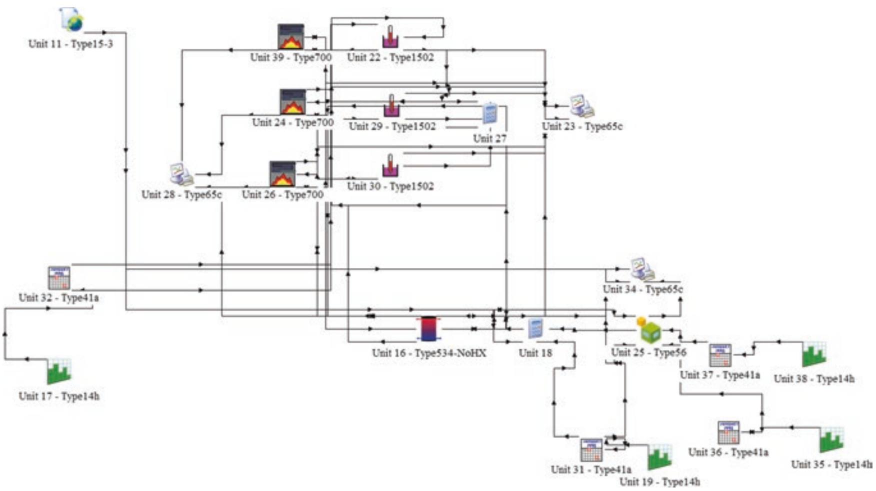

Fig. 38.2 TRNSYS model 1: heating mode

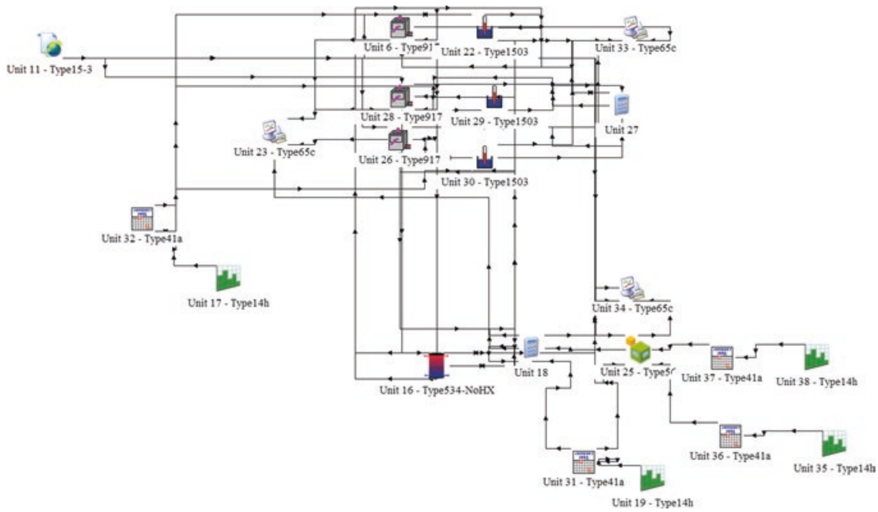

Fig. 38.3 TRNSYS model 1: cooling mode

Model 2 (Trigeneration)

In this model a new energy system is introduced in simulation. TRNSYS schemes of heating and cooling energy system are shown in Figs. 38.4 and 38.5. CHP is natural gas fired to produce combined electric and heat power. Nominal electric and heat recovery efficiencies are respectively 0.37 and 0.57, from manufacturer data sheet. In heat recovery, two principal inputs are considered: jacket water of engine goes through a water/water heat exchanger (JWHE) warming the heating plant circuit's water. This latter flows out JWHE and passes through an air/water exchanger where CHP exhausts flows in. After these two exchanges, hot water is delivered to tank storage during HS or to thermal chiller (reversed THP) during CS. This is common way the CHP heat recovery is used, called "trigeneration". THP condenses its exhaust heat in cooling towers. Electrical energy produced by CHP is sent to an electrical heat pump which produces heating or cooling energy. The combined CHP/EHP/reverse THP can be considered a black box that efficiently produces winter heating and summer cooling by using urban NGPN. In TRNSYS model, for the sake of simplicity, we consider operational mode of this energy system that had no modulation, just ON/OFF. Considering sizing criteria of this plant, we decided to limit heating and cooling power plant of combined trigeneration plant at near 20% of power requested by buildings. With this choice, considering high volume of storage tank, and calibrating right settings of temperature's control, it is possible to extend operating time of new efficient system. 50 kW is considered as nominal CHP electric energy production and supplies EHP able to produce 170 kW heating power or 150 kW cooling power. THP transform recovered heat energy in cooling energy

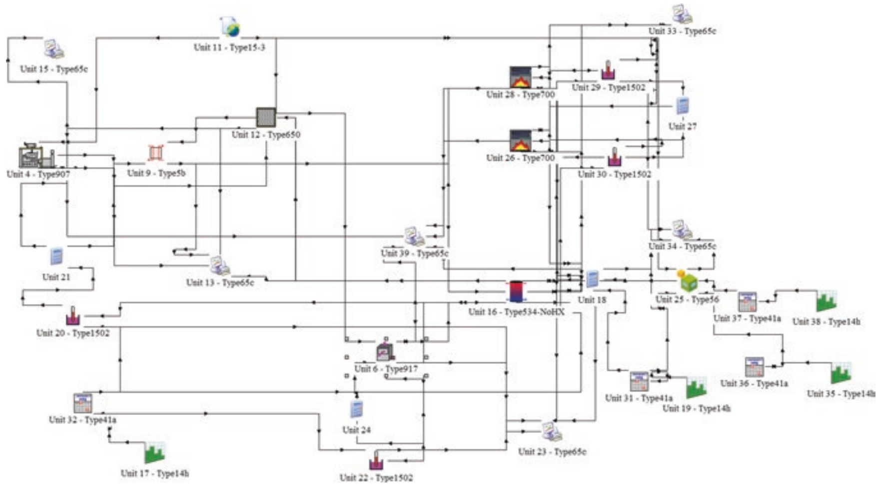

Fig. 38.4 TRNSYS model 2: heating mode

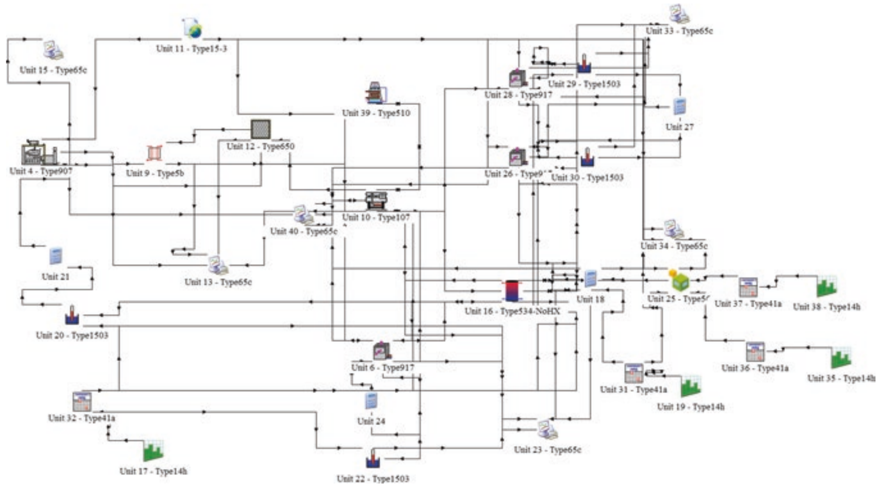

Fig. 38.5 TRNSYS model 2: cooling mode

with COP equal to 0.5. Two boilers and chillers as in model 1 are used to integrate the heating and cooling production of CHP/EHP/reverse THP when necessary. In this model it is very important making a good control strategy to make sure CHP has priority compared to “standard generators”. Furthermore, CHP signal has higher regulation dead band to limit on/off cycles. All heating or cooling generators exchange water with same storage tanks of model 1, equal to 10 m^3.

Model 3 (Enhanced Trigeneration)

This model, respect to model 2 (trigeneration) introduces possibility to use THP also during HS (then "enhanced" trigeneration). TRNSYS schemes of heating and cooling energy system are shown in Figs. 38.6 and 38.7. In fact, it is necessary to consider an external source with a quite constant temperature to prevent the risk of efficiency drops and other failures of this thermal heat pump. Both absorption and ejector heat pump work better with constant temperature levels at three heat

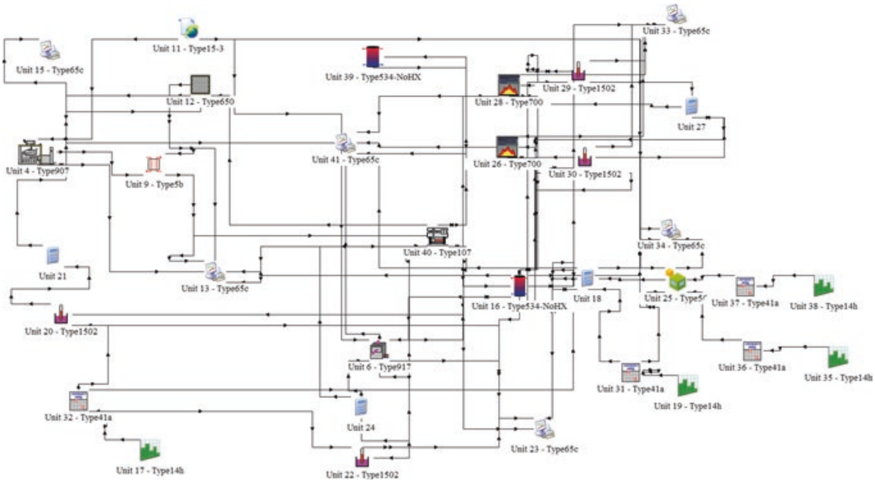

Fig. 38.6 TRNSYS model 3: heating mode

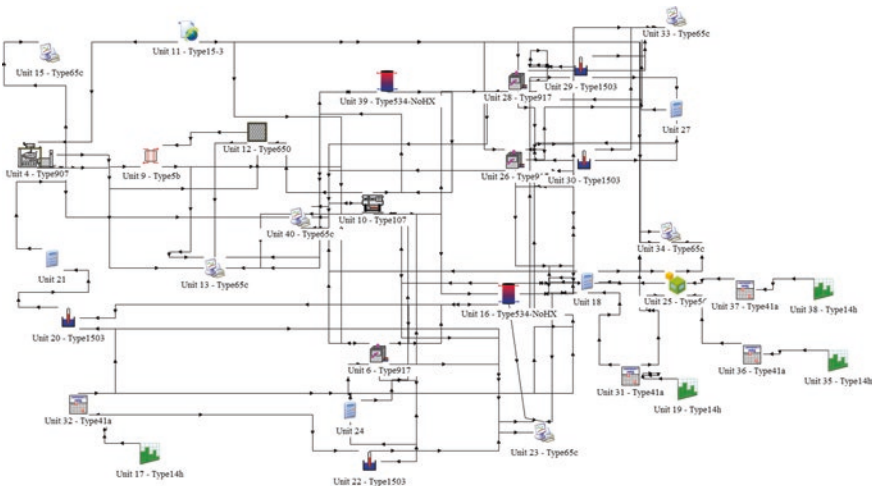

Fig. 38.7 TRNSYS model 3: cooling mode

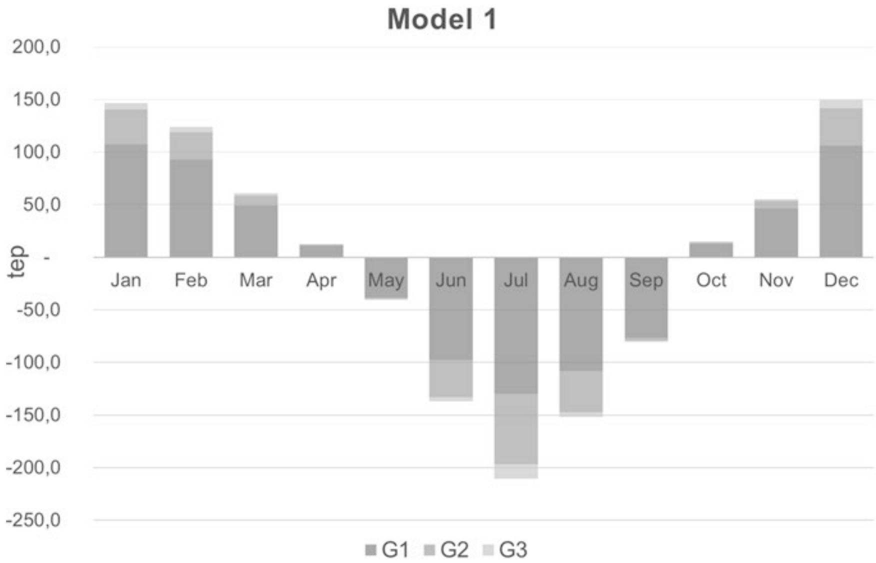

Fig. 38.8 Model 1: monthly energy balance

exchangers, then a geothermal external source is considered in this case with a constant temperature at 12 °C.

In this configuration a value of 1.5 is assumed for the COP_{THP} of the thermal heat pump. It is convenient to consider the ground source also for the thermal chiller in CS because the reinjection of heat during the summer period provides the necessary thermal compensation of the soil in annual scenario. In this case a better efficiency of the thermal chiller can be considered ($EER_{THP} = 0.5$).

All models presented above have same operating time schedule. Energy plants can work from 7 a.m. to 11 p.m. Occupation time is instead from 8 a.m. to 8 p.m. Extension of energy plant schedule is useful during the morning to bring air to internal setpoint temperature and at the end of the day to give possibility to leave storage tanks at their setpoint temperatures. This last condition is profitable especially when CHP accumulates energy with best efficiency.

Results and Discussion

In this paragraph simulation results are presented. As said previously, energy balance of primary energy consumption of base-case (model 1) is used as reference for comparisons. Energy analysis is presented in Fig. 38.8 in terms of primary energy consumed by each generator. In this case G1–G3 refer to respective boiler or chiller in the activation sequence. Primary energy is calculated in terms of "tonnellate equivalenti di petrolio, tep", considering the conversion factor values proposed by Italian "Ministero dello Sviluppo Economico—Circolare 14 Dicembre 2014":

- Natural gas: 1000 Nm^3 = 0.882 tep.
- Grid electric energy: 1 MWh = 0.187 tep.

Same data are shown in Figs. 38.9 and 38.10 for model 2 and model 3. In this case, CHP refers to the primary energy consumed by combined system CHP/EHP/THP, G2 and G3 to the back-up boilers and chillers.

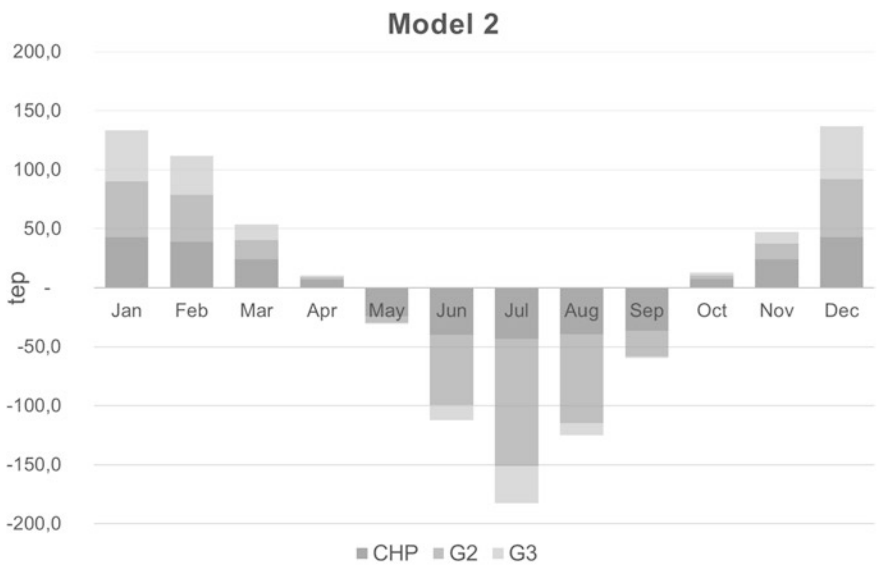

Fig. 38.9 Model 2: monthly energy balance

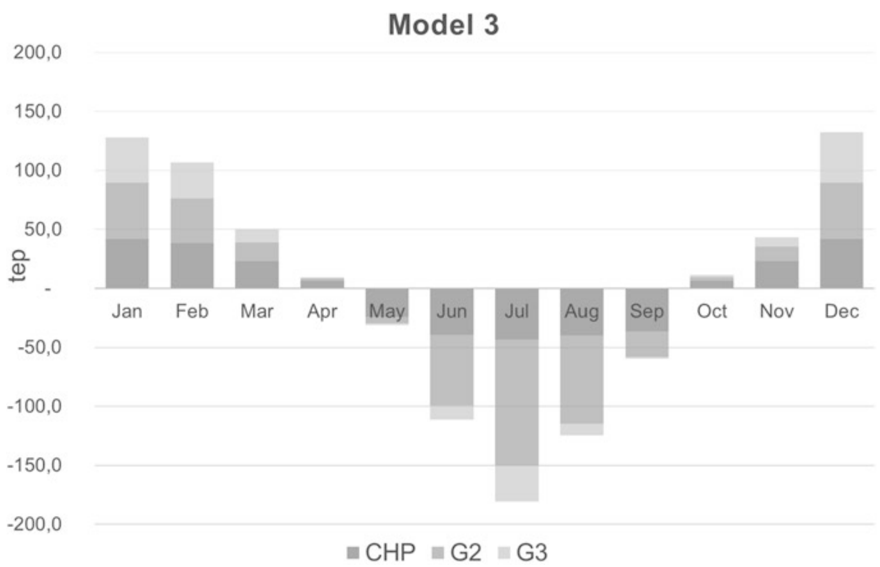

Fig. 38.10 Model 3: monthly energy balance

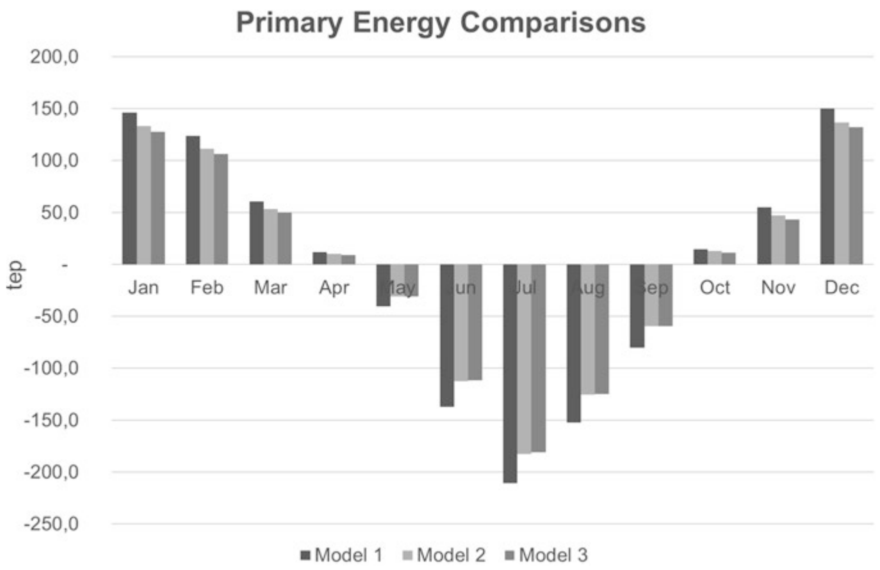

Fig. 38.11 Comparison of primary energy consumption for the three scenarios

Model 2 and model 3 present a sensible reduction in primary energy needs. It is interesting to notice the quite extensive exploitation of the combined CHP/EHP/THP system during both heating and cooling season. Models 2 and 3 performances sensibly differ in HS where the THP increases the energy conversion efficiency. During CS both models have same configuration except for presence of ground heat exchanger as cooling source of THP; this lead to a very small difference in energy consumption. Figure 38.11 presents the comparison of the global monthly primary energy consumption referred to the three analysed scenarios. An evident saving in primary yearly energy is obtained in model 3: 15% in HS and 18% in CS, corresponding about 16.5% per year, compared of reference model 1. Also model 2 shows energy saving attitude, almost same as model 3 in CS, reduced to 10% in HS.

Conclusion

In this paper energy performance of an innovative heating/cooling plant based on CHP, EHP and THP was analysed by a numerical simulation of a building's energy refurbishment with substitution of energy system. Based on cogeneration system, new plant uses natural gas from local urban NGPN to efficiently produce heat and cold for energy service of the building. The capacity of the new plant is set at 20% of building's power request and current generators are used in integration supply and as back-up system. Simulation uses TRNSYS code in sub-hourly step in order to catch the right dynamic of energy flows. Building and plant are both modelled and controlled using storage volumes and temperature controllers setting. Energy performance of actual and substituting plants is compared based on primary energy consumption (tep). New energy system presents a sensible primary energy saving (up to 18%) when a thermal heat pump is supplied by heat recovery of cogeneration system. These kind of devices have not a spread market but, in our plant configuration, is able to largely improve efficiency of the system. It also opens up to new perspectives in the use of solar cooling systems that find a way to enhance their winter performance.

The results of this study affirm proposed plant configuration and is able to efficiently provide winter heating and summer cooling by using natural gas from urban NPGN. It can reduces, furthermore, stress of this important infrastructure, especially during extreme cold weather season. It can also help to manage overload of the electric grid due to extensive use of electric powered chillers during severe hot summer weather.

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Chapter 39
Short Considerations on Urban Dynamics

Ruxandra Crutescu Gherasim

Introduction

After the next 50 years the earth will be a different place than it is now. Today, 54% of the world population lives in cities. Urban places now accommodate over half the world's population. In 2070, that percentage will be 80–85.

Any attempts to make the human population more sustainable in its use of resources will require the management of urban places to change radically and rapidly. Due to the forces of urban dynamics, cities and suburbs are changing.

Challenges for Future Cities

How the cities meet the challenges and decide their future? We chose three important challenges to be faced in the nearest future:

- The permanent battle for economic survival
- Accelerated climate change
- The rapidly growing aging population

In a recent research report of the NASA scientists—the computer simulation (Fig. 39.1) shows that if half of the carbon dioxide released from the burning of fossil fuels remains in the atmosphere and it is not absorbed by the existing vegetation and the oceans, the human-made carbon dioxide will continue to increase above levels not seen in hundreds of thousands of years [1].

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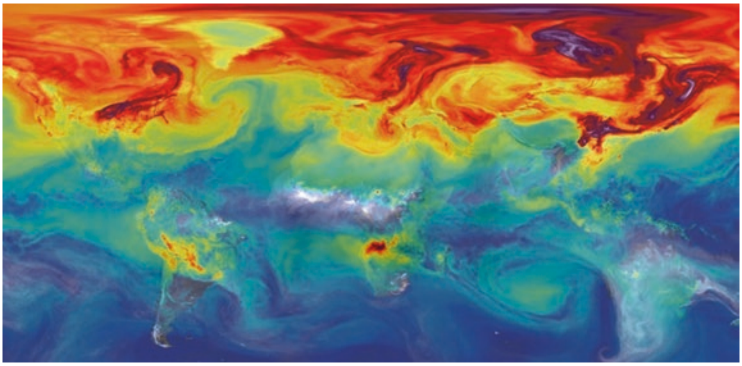

Fig. 39.1 CO_2 in Earth's atmosphere if half of global warming emissions are not absorbed. (NASA computer simulation). (Source: [2])

About 3.5 billion people now live in cities. We have two forces—urban heat islands and global warming—that are reinforcing each other and are going to create periodic, extreme conditions for more than half the world's population.

The challenge consists in how do we make cities more habitable in the future?

Environmental Effects

Temperatures in cities can rival the hottest desert. Using sensors installed at the Con Edison building in Queens, NY, scientists compare the surface temperature of black, white, and "green" (vegetated) roofs. The black roof can be up to 30 °C (54 °F) hotter than a green or white roof [2] (Fig. 39.2). Although installing a green, plant-covered roof is the ultimate technique to combat urban heat, even a simple step like painting black roofs white can reduce temperatures dramatically. Figure 39.3 shows the green roof and instrumentation on top of the Queens Con Edison building. (Source: Photograph ©2008 Con Edison of New York.)

The existence of urban heat islands has become a growing concern over the years. An urban heat island is formed when industrial and urban areas produce and retain heat. Much of the solar energy that reaches rural areas is consumed by evaporation of water from vegetation and soil. In cities, where there is less vegetation and exposed soil, most of the sun's energy is instead absorbed by buildings and asphalt, leading to higher surface temperatures. Vehicles, factories, and industrial and domestic heating and cooling units release even more heat [3]. As a result, cities are often 1–3 °C (1.8–5.4 °F) warmer than surrounding landscapes [4]. Impacts also include reducing soil moisture and a reduction in reabsorption of carbon dioxide emissions [5].

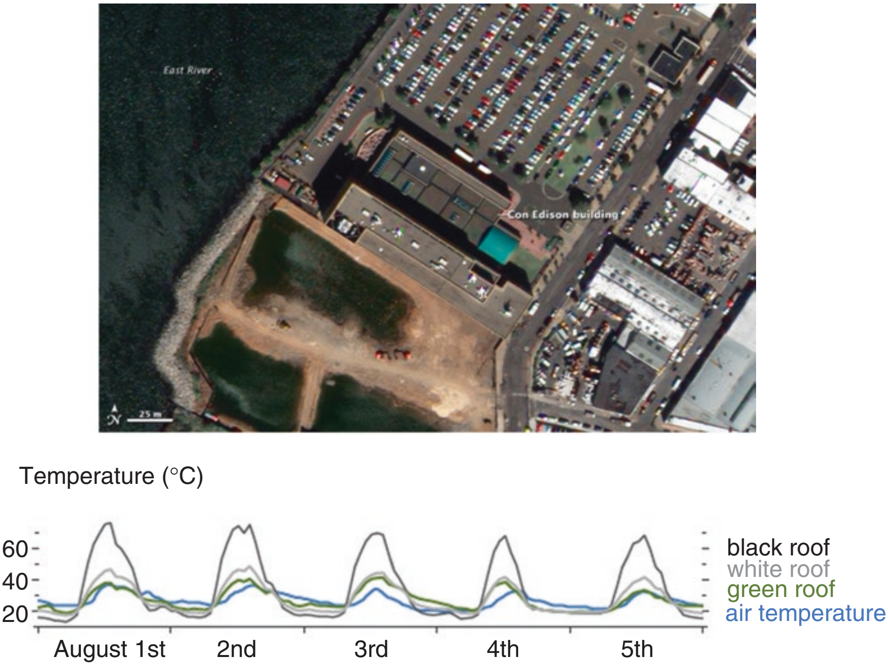

Fig. 39.2 Heat islands example. (Source: https://earthobservatory.nasa.gov/features/HottestSpot)

Fig. 39.3 Green roofs as a solution to reduce urban temperatures. (Source: [3, 4])

Europe: Urban and Rural Regions

Eurostat published a summary table with the populations of the EU-28's largest cities/urban areas (as of 1 January 2014), with the ranking based on data for functional urban areas (cities and their commuting zones). In the European Union, based on this typology, only London and Paris are true megacities, with more than 10 million inhabitants. London was the biggest with 12.5 million inhabitants, closely followed by Paris with 11.8 million inhabitants. (Source: Eurostat (urb_lpop1) (met_pjanaggr3) and (urb_cpop1).)

Just to give an idea of the size of these cities, they both had more inhabitants than the total populations of Belgium, the Czech Republic, or Portugal. Based on the same definition, Madrid (Spain) was the third largest functional urban area in the EU-28 with 6.5 million inhabitants, while the Ruhrgebiet and Berlin (both Germany) were the only other urban areas with more than 5 million inhabitants. As such, approximately 8 % of the EU-28 population was living in an urban area with more than 5 million inhabitants, which was considerably less than the corresponding share—approximately one-quarter—in the United States. The fragmented distribution of cities in the EU may be largely explained by the relatively small population size of most European Union member states (Fig. 39.4).

Between 1 January 2004 and 1 January 2014 the population living in predominantly urban regions of the EU-28 rose from 203.6 million to 215.7 million inhabitants, an overall increase of 6.0%. The most rapid expansion in population numbers was recorded for those living in predominantly urban regions with at least one million inhabitants, where there was a 12.3% increase in the number of inhabitants.

Between 1 January 2004 and 1 January 2014 the population living in predominantly urban regions of the EU-28 rose from 203.6 to 215.7 million inhabitants, an overall increase of 6.0%. The most rapid expansion in population numbers was

	Functional urban area	Metropolitan region	Greater city	City
London (UK)	12 496 800	14 031 830	8 477 600	–
Paris (FR) (2)	11 800 687	11 898 502	6 707 750	2 240 681
Madrid (ES)	6 529 700	6 378 297	:	3 165 235
Ruhrgebiet (DE)	5 045 784	5 045 784	:	–
Berlin (DE)	5 005 216	5 005 216	:	3 421 829
Barcelona (ES)	4 891 249	5 445 616	3 176 357	1 602 386
Roma (IT)	4 370 538	4 321 244	:	2 863 322
Milano (IT)	4 252 246	4 267 946	3 207 006	1 324 169
Napoli (IT)	3 627 021	3 127 390	3 176 107	989 111
Hamburg (DE)	3 173 871	3 173 871	:	1 746 342
Warszawa (PL) (3)	3 078 489	3 281 740	:	1 724 404
Budapest (HU) (3)	2 915 426	2 953 883	:	1 735 711
West Midlands (UK)	2 909 300	2 460 617	2 462 300	–
Manchester (UK)	2 815 100	2 723 479	2 723 900	517 300
Lisboa (PT) (4)	2 810 668	2 807 525	1 835 785	509 312
München (DE)	2 768 488	2 768 488	:	1 407 836
Stuttgart (DE)	2 668 439	2 668 439	:	604 297
Bruxelles/Brussel (BE)	2 607 961	2 967 513	:	1 183 841
Frankfurt am Main (DE)	2 573 745	2 573 745	:	701 350
Górnoslaski Zwiazek Metropolitalny/Katowice (PL) (3)	2 573 159	2 758 225	1 904 611	304 362

(1) Ranked on the number of inhabitants living in functional urban areas. Excluding Greece, Cyprus, Luxembourg and Malta. Data for the greater city has been created to ensure better comparability: the statistically comparable level is the greater city (when available) and cities (when no data are available for the greater city). Note that there is a discrepancy between the United Nations data used in the executive summary (based on national definitions) and the harmonised Eurostat data used here.
(2) 2012.
(3) 2013.
(4) 2015 except for metropolitan region (2014).

Fig. 39.4 Summary of 20 largest cities urban areas in the EU, 2014 (inhabitants). (Source: Eurostat (urb_lpop1) (met_pjanaggr3) and (urb_cpop1)) recorded for those living in predominantly urban regions with at least one million inhabitants, where there was a 12.3% increase in the number of inhabitants. Latvia, Lithuania, Greece, and Poland were the only four EU Member States where the size of the population living in predominantly urban regions declined in the period 1 January 2004 to 1 January 2014, situation explained by migratory patterns (Source: Eurostat (urb_lpop1) (met_pjanaggr3) and (urb_cpop1)). The reduction in the number of inhabitants in predominantly urban regions was reproduced in rural regions too, in Latvia, Lithuania, and Poland (to a lesser degree). A rapid rate of population growth was in the predominantly urban regions of Sweden, Ireland, the Czech Republic, Finland, and Spain, while high growth rates were also recorded in Norway, Iceland, and Switzerland. The largest disparities between population growth rates for predominantly urban regions and predominantly rural regions and therefore the fastest transformations towards a more urbanized society were recorded in Bulgaria, Romania, the three Baltic Member States, Finland, and Sweden (Source: Eurostat statistics Explained—Urban Europe—statistics on cities, towns, and suburbs—patterns of urban and city developments; data extracted in February–April 2016) (Source: Eurostat (urb_lpop1) (met_pjanaggr3) and (urb_cpop1)) [6] (Fig. 39.5).

Vertical Megacities

Megacities are urban places with populations of 10 million people or more. There are approximately 35 megacities globally, with 25 of these being located in the developing world. Over 40 cities will have to become megacities—the dense urban centers that have rapidly accommodated much of the population growth and rural-urban migration of the twentieth and early twenty-first century.

The Concept of FUTUROPOLIS: Case Study Singapore

While entering the second half of the century, a megacity like Singapore faces a population growth crisis that the vertical city will need to survive, so that future generations can also live their children and children for their children (Fig. 39.6).

If we are going to live in multi- story built like skyscrapers. Living high in the sky is the only solution for actual megacities as Singapore" as architects Alina Yeo and Schirin Taraz-Brienholt shared in the presentation of Singapore Futuropolis. It is a radical shift away from the traditional apartment block. But how high future buildings will go? The prototype will house 5 million people over 45 sq. km, with a density of approximately 100,000 peoples per square kilometer—this is ten times more than Singapore city center today. It will be a multilayer and a multifunctional megastructure and a massive concentration of humanity. The experts think that vertical cities can also be a community.

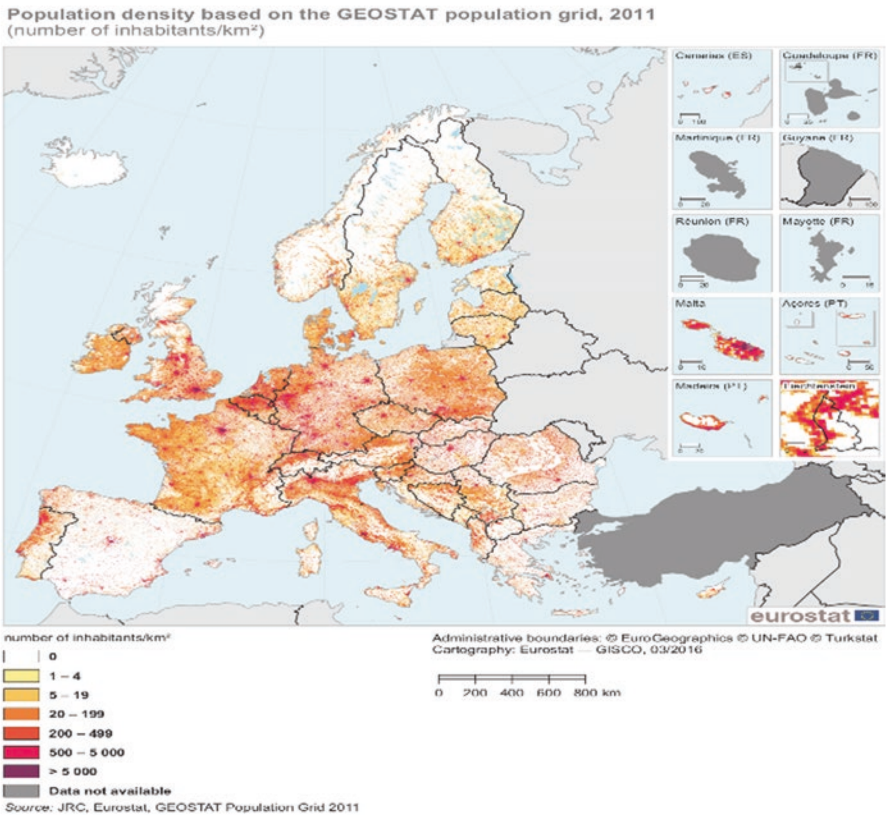

Fig. 39.5 Urban Europe. (Source: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Urban_Europe_%E2%80%94_statistics_on_cities,_towns_and_suburbs_%E2%80%94_patterns_of_urban_and_city_developments&oldid=302615#Patterns_of_urban_and_city_developments_in_the_EU)

Creating urban villages in the sky will require recreating the today's living spaces, hundreds of meters above the ground. It is critical we would better understand how we use and connect these new elevated neighborhoods. It is something never done before—an urban infrastructure some hundreds meters high. How will the residents like living in the sky? The vertical city must be a city to live and that is the biggest challenge for those who are designing the Singapore's future. Deep and powerful need to feel connected to the ground, the concept will attract residents to live into the sky. This will require a radical shift in thinking. For the first time, future planners will have to envision in 3D the entire neighborhoods relocated from the ground and elevate the current urban planning which is still 2D. But how will the residents react to this layered space? Reinventing the public space is the challenge. The architects will create new and interesting urban environments in the sky, vertical environment who will guarantee to the residents the same freedom to move

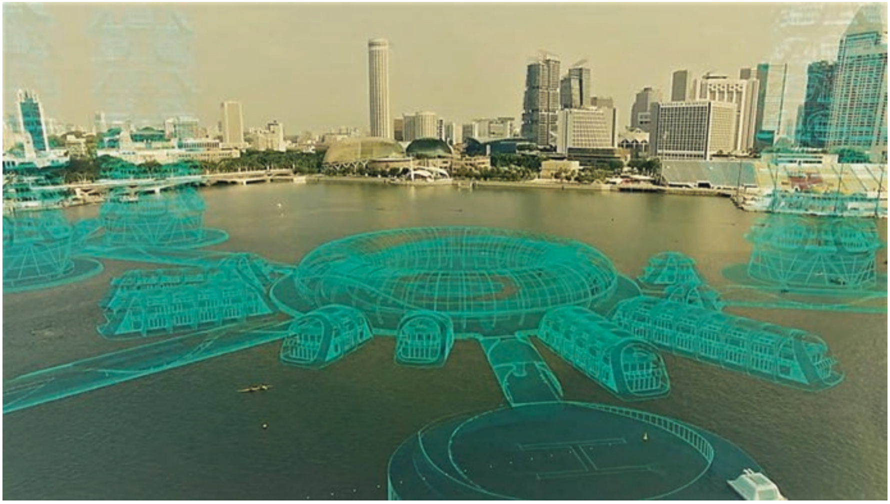

Fig. 39.6 Mapping the future of tomorrow https://www.google.com/search?q=futuropolis+mapping+the+city+of+tomorrow

that they would have on the ground. Communities who contain 80 homes, horizontally linking every 20 levels and provide public spaces and transportation normally find on the ground, and connectivity between different levels. But it is more than creating and linking space, it will mean understanding how human beings experience and move through their living space.

This can solve the problem of the population but can make another problem much worth, climate change.

As it becomes more urbanized, it will become hotter as well. The urban heat island will be present wile when you convert green forest into cities, you have buildings and more heat. One of the solutions to combat the urban heat islands is the greenery, who absorbs heat and provides shade. A future that could see nature not only be added to designs but driving design—a new form of smart climate sensitive architecture—greening the vertical city will cut down it's need for air conditioning, and making it a space to live, not making the city hotter.

In 2070, resources will be very precious. To be sustainable, vertical megacities will have to be smart. Smart sustainability will be the key to designing and building a successful vertical city and not just in managing resources consumption.

The vertical city will have to be intelligent. The Virtual Singapore project wants to build a 3D city map. The developers of the application develop their own tools. The photo shoots exactly positioned in the city.

By triangulating these photos with a computer, and with the help of the drones, it can add a third dimension to the model. It wants to bring all the 3D models of the city to the same place, and that platform can be used to create applications (Fig. 39.7).

Virtual Singapore applications will help architects and residents to prepare for the future by combining 3D maps.

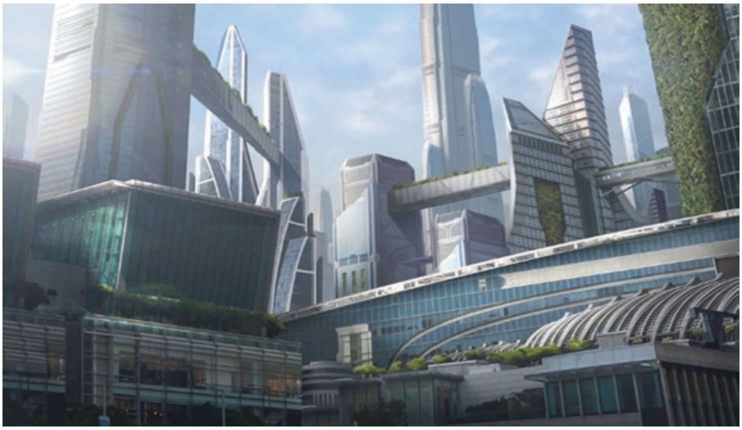

Fig. 39.7 The radical transformation of the city. (Source: https://ihavenotv.com/img/s3438.jpg)

Architects will be able to plan long-term strategies for the city, but also to deal with a more banal problem, such as designing bicycle tracks or street lighting.

Residents will be able to use the 3D application. Parents will be able to claim the safest route to school for their children, and architects could add a better facility.

When analyzed, the app will be a powerful tool that will help Singapore become a truly intelligent smart city.

There are divisions that take care of different aspects of the city, the sewer system, the energy supply, etc. Everyone is solving their task, but we need to have a more holistic approach to reach intelligent solutions. They will help Singapore to overcome the challenges it faces, the nation would be a spearhead for other megacities in the region until 2070.

But by 2020, climate change and urban overcrowding will threaten the entire world, and damages to cities will be hard to calculate.

Singapore will not just have to deal with its local problems. It will have to survive also to a changing world, and its future may be beyond the shore and beyond the clouds.

Conclusion

Today, almost all innovative architects and urban planners are working to find and create radical practical solutions that will transform the way we live [7]. Urban dynamics creates enormous social, economic, and environmental changes, which provide an opportunity for sustainability with the "potential to use resources more efficiently, to create more sustainable land use, and to protect the biodiversity of natural ecosystems." To assess the total current risks of climate change for human welfare, studies are suggesting the necessity to add to this global warming signal, that resulting from urbanization and other land use changes. As population continues to grow and urbanize at unprecedented rates, new urbanism and smart growth techniques are implemented to create a transition into developing environmentally, economically, and socially sustainable cities. Smart growth and new urbanism's principles include walkability, mixed-use development, comfortable high-density design, land conservation, social equity, and economic diversity. Mixed-use communities work to fight gentrification with affordable housing to promote social equity, decrease automobile dependency to lower use of fossil fuels, and promote a localized economy [8].

"You don't change the world as an architect, but you celebrate the change of the world." Source: https://www.archdaily.com/tag/vertical-cities Renzo Piano Talks Architecture and Discusses 'The Shard' with BBC News [9].

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Chapter 40
The Role of Urban Farming in Revitalizing Cities for Climate Change Adaptation and Attaining Sustainable Development: Case of the City of Conegliano, Italy

Haidy Mousa, May Elhadidi, Hadil Abdelhafez, Pietro Tonini, Lorenzo Fellin, Antonella Frongia, Virginia Castellucci, and Mohsen Aboulnaga

Introduction

Cities consume 60–80% of global total primary energy and emit between 60% and 70% of the world's total greenhouse gases mainly CO_2 [1–4] and are responsible for 75% of the natural resources [5]. The city of Conegliano in Italy is not far from these challenges, especially when it comes to urban regeneration and climate change impacts. After ten years of the evolution of Zoppas-Zanussi into the Electrolux group, the production center was moved away since 2003 and the ex-Zanussi factory was abandoned in the city as a 'black hole' with no economic and social values [6]. Several strategies for urban renewal were hypothesized includes urban green infrastructures. Urban agriculture is part of the urban ecological systems and it plays a vital role in the urban environmental management system [7–9]. Incorporating urban farms in cities can turn wastes into productive resources, especially in growing cities that produce large amount of wastewater and organic wastes [7, 10]. In China, 14 big cities produced more than 85% of fresh vegetable [10]. Hence, promoting urban farming and bringing about clean food in cities provide health benefits and improve air quality for inhabitants.

Urban farming utilizes innovative technologies based on innovative technologies, e.g., vertical hydroponic agriculture (ZipGrow) and circular production. The latter depends on three types of production: horticulture product, brewery production, and

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mushroom grow, to exhibit to the customer the complexity of the input transformation and the importance of the human capital. The new site also creates new jobs, contributes to economic growth of the city due to their proximity to consumers, circulates income and builds communities as well as enhances public health and above all, provides green spaces for citizens. Urban agriculture plays an increasingly important role in global food security. It provides a solution for growing needs of cities to expand without harming the ecological balance and producing clean food. Integrating urban farms into the city fabric has many economic, social, and environmental benefits. It offers clean food while improving air quality resulting from carbon emissions and air pollution mitigation. It also helps in creating solutions to wastewater and organic waste in megacities, contributes to creating jobs and supports the economic growth by increasing the GDP of the city of 34,891 inhabitants and acts as a "zero kilometers" self-sustained economy, healthy communities through providing organic food, in turn, green spot for the city [11]. Urban farms are beneficial in providing opportunities to residents' engagement in agricultural activities, beside the open spaces which could be used for disaster management and recreation as well. Urban farms have been widely used in many cities worldwide such as Tokyo, Japan [12, 13]; Seoul as an Agro-city, South Korea [14, 15]; Singapore [16]; and in Europe, particularly Berlin [17], Rome, and Milan [18]. In ACROS Fukuoka office building, 37,000 plants representing 76 species were planted and creating livable spaces for occupants plus clean food [19]. In Gyeonggi province, South Korea, 552,000 people were engaged in farming over 3.2 km^2 of land in 2017, but while farm size grew by 27.2% compared to 2014 the number of farmers surged by 83.8% [20]. Hence, indicates the importance of urban farming in cities. In South Korea, the majority of urban farming was executed on community spaces, e.g., weekend farms that account for 48%, whereas farming in parks is 33.4% followed by school farms 8.5% [20]. Also, urban farms were implemented in a smaller proportion as house gardens (0.4%), tall building rooftops at 0.8%, and seniors' centers at 5%. In addition, among urban farmers, 41.8% happened in community farms, while 20% raised crops in parks and 16.1% at school farms [20]. Figure 40.1 presents examples of urban farms in Japan, South Korea, Singapore, and Milan—Italy.

Objectives

The aim of this work is to redevelop the abandoned site of ex-Zanussi factory (Electrolux group) in the city of Conegliano and to improve livability in the city through innovation. The study focuses on the building and surrounding site by virtue of using urban farm incorporated on the building's walls and roof. It also addresses the project's economic sustainability, environmental sustainability, and social sustainability to meet sustainable development goals for a city of 34,891 inhabitants with about 41% workers as per 2016 [21]. Figure 40.2 shows the objective and sub-objectives of the study and Fig. 40.3 presents the demography of Conegliano.

Fig. 40.1 Examples of urban farming and green walls in different cities globally. (**a**) Flowers and fruits on Façades (Source: http://nigeldickinson.photoshelter.com). (**b**) Rice harvested three times yearly (Source: http://www.savingwater.co.za). (**c**) Tomato hanging from a meeting room's ceiling (Source: https://www.citylab.com/life/2016/09/the-tokyo-company-helping-to-solve-japans-farming-crisis/501410/). (**d**) Urban farming in a Park (Source: http://www.koreabizwire.com/urban-farming-growing-in-popularity/124483). (**e**) Blending farms in buildings (Source: https://www.3blmedia.com/News/Vertical-Farming-Offers-Solutions-Food-Scarcity-Singapore). (**f**) Bosco vertical forest, Milan (Source: https://www.pinterest.com/pin/491596115556386684/)

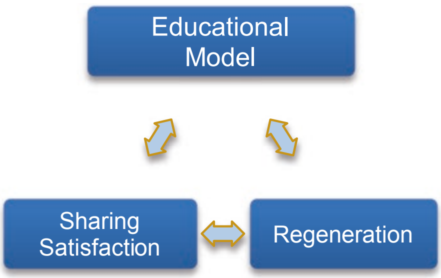

Fig. 40.2 Sub-objectives of the regenerative city

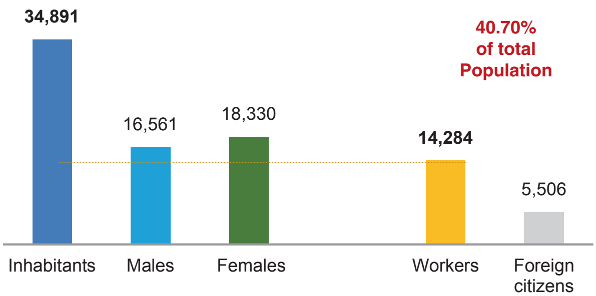

Fig. 40.3 Demography of Conegliano population

Issues and Challenges

During the last decades, cities rapidly have been turning into inhospitable place while global population constantly grows rapidly and resource run scarce. A transition is needed to make our cities more sustainable that taken in account these trends and fulfill the new requirements and needs of the present and future cities inhabitants. The site under study is located in the City of Conegliano, North of Venice, Italy at coordinates 45°53′27.6″N 12°17′34.8″E (Fig. 40.4).

There are many problems associated with the city of Conegliano and the site as follows:

- The site is a dumped one and the old building is abandoned (Fig. 40.4c, d).
- Citizens are viewing the black hole in the cities in their way to schools and back daily.
- Vegetable and fruits are coming from the surroundings farms using transport and fuels.
- Insufficient public and green areas.
- Inefficiency in the adaptive reuse policy of this abandoned site for more than 10 years.
- Site is huge, more than 165,000 m^2 in area.

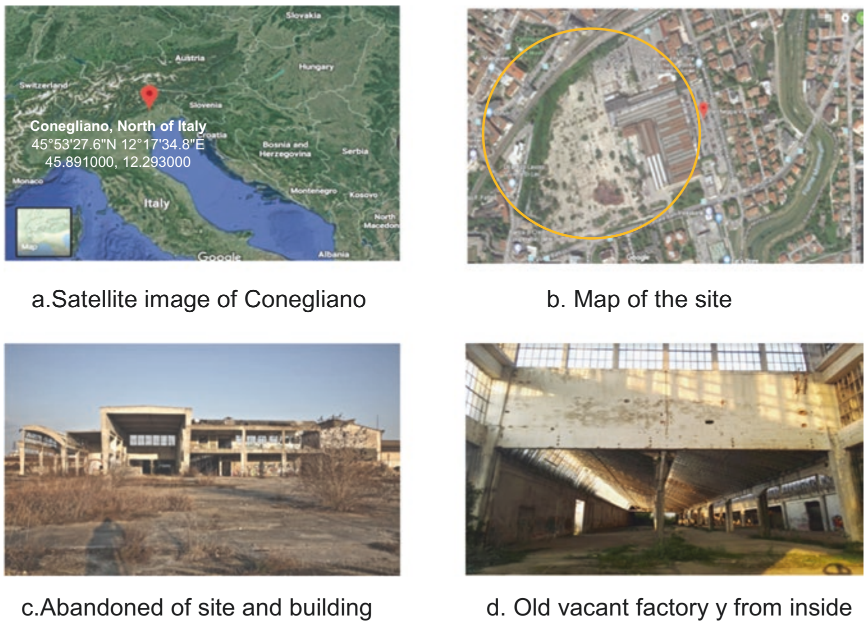

Fig. 40.4 The abandoned ex-Zanussi factory building and site, City of Conegliano, Italy. (**a**) Satellite image of Conegliano (Source: www.Google.com/map/). (**b**) The site's map (Source: www.Google.com/map/). (**c**) The abandoned site and factory. (**d**) The interior of vacant factory [6] (Source: https://site.unibo.it/urban-farm/en/location-2019/conegliano-zanussi-area)

Methodology

The study methodology depends on inductive and analytical approaches: the first part includes a review on the site and assessment. The work also analyzed different buildings design approaches implemented in this project using innovative architectural solutions and technologies. This work was part of 'The Wanderers' team in the UrbanFarm 2019 International Challenge [22].

SWOT Analysis

It was necessary to carry out a SWOT assessment of the project planning, so we can understand the project's strengths, weaknesses, opportunities, and threats (Fig. 40.5).

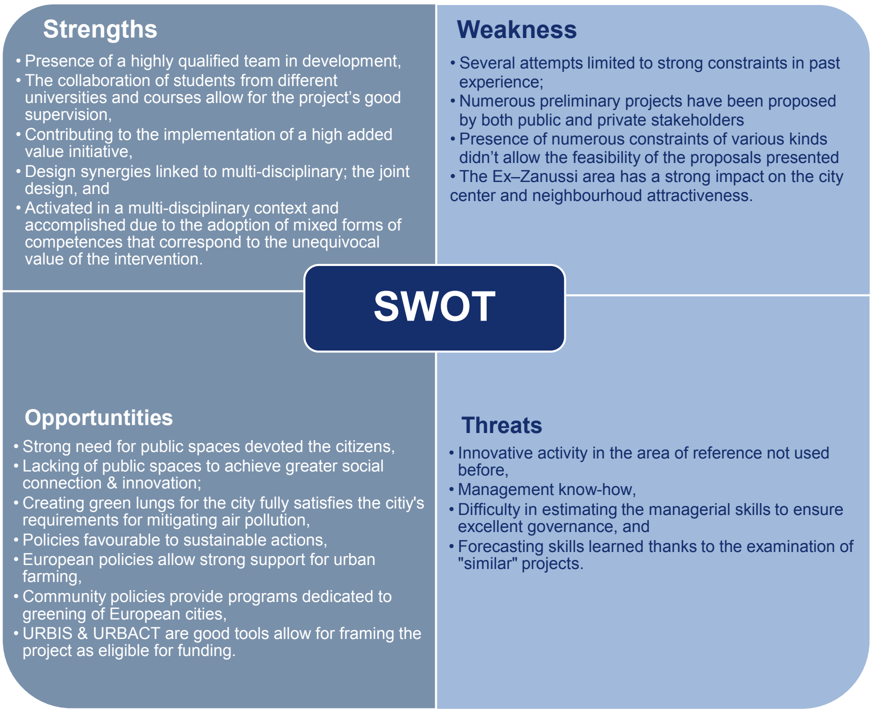

Fig. 40.5 The SWOT assessment results

Concept

The name of the project is taken from the famous epic poem of Gilgamesh. Human transformation from the wilderness occurs when it starts to turn raw material into a product—“such as oil from olives, bread from wheat, and beer from hop.” Within the project, this concept of transformation is used to underline human potential to transform the matter in different field such as agriculture, art, and architecture (Fig. 40.6).

Overview

The wide area of old factory will be divided to hold different functions while keeping the old building structure. It will host an integrated *art-agriculture training center* with spaces shared by artists, agronomists, and farmers to share their knowledge and experiences. The project aims at building an educational model through as a long journey, on contrast to the raising “food pornography” trend proposed in social media, where the food pleasure is reduced to the mere visual contemplation. We want to transmit the satisfaction of producing by linking the individual to the process instead of the client to the product. Agriculture activities will be performed in-door thanks to hydroponic vertical system called ZipGrow while the outdoor area will host a wide range of local fruit and flower varieties and a dedicated area for hop production. Following the Gilgamesh concept, a microbrewery will be established using a traditional brass age and local fruit and hop will contribute to the differentiation and amplification of the breweries products. The mushroom factories will utilize the by-product of this process for producing the Oyster mushrooms in an integrated process aimed to decrease the cost and limiting the waste.

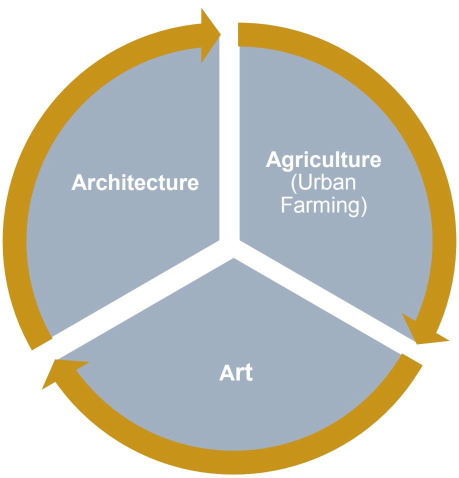

Fig. 40.6 The three main pillars of the project concept

Planting the Art

In order to enhance the social pillar of sustainable development, art and agriculture are blended in one public space of the site. These two components are mixed to provide an educational multi-approach, where agriculture can support the educational process of art and vice versa. Therefore, the artists and farmers work together and teach the youth new techniques to produce an artistic product from the plants. The educational process is established to create a cycle of training of trainer and capacity building as well as raising awareness of citizens.

Dome of Imagination

Ensuring daylighting provision, domes are designed for rentable studios for artists since they need spaces to be inspired, while they are working. The rooms are located below the ground level to keep the artists away from any source of noise and distraction. The rooms' ceilings are replaced with a dome for a wider view for the surrounding, and then light wells are inserted onto these spaces, to catch the inspiring nature of Conegliano. While moving the light well on a circular path on the dome, the artists have different views all the day as illustrated in Fig. 40.7.

Farming Tour Application

To arouse people's curiosity to grow crops using technology, an educational mobile game application will turn the process into an URBAN GAME. It is about a team work in levels where the application provides the team with the basic information they need and organize the process of plantation through tips and schedules for

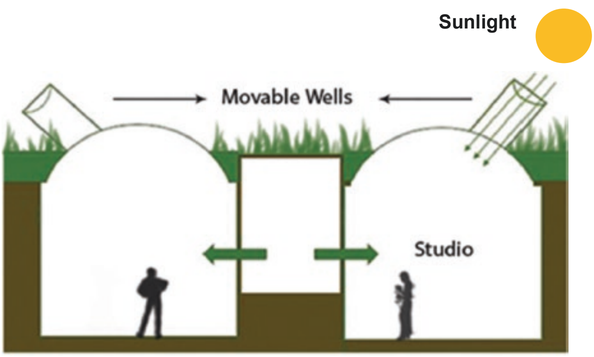

Fig. 40.7 The conceptual model for the dome of imagination

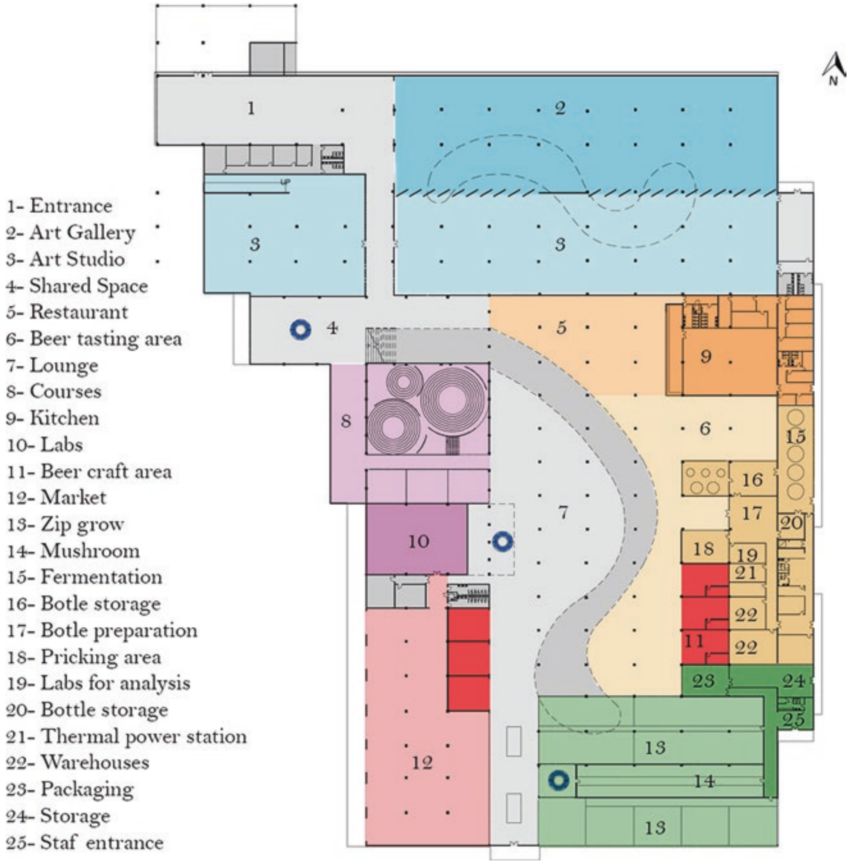

Fig. 40.8 Layout and architectural elements of the project

irrigation and fertilization. The place is open to visitors, which could also choose to be involved in the plant production more regularly and drive them into an input-education-output cycle. In this way, the user is also seen as the employer and vice-versa. The project layout is shown in Fig. 40.8.

Architectural Interventions and Innovation

The project has two main accesses from the north and south. The first entrance is for the art wing, which passes through the art gallery and the art center till it reaches the heart of the site where a shared space and a restaurant for all the users of the building with an educational center and labs overlooking that space integrating urban farming with users' activities. The southern entrance is defined by the greenhouse

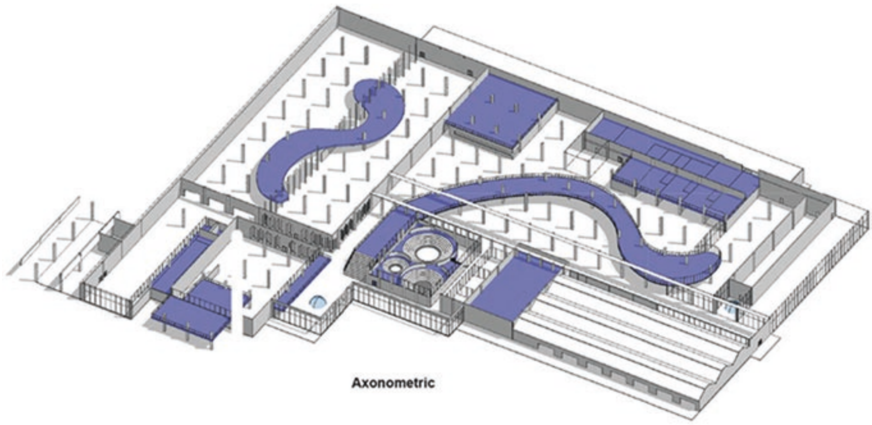

Fig. 40.9 Layout and zoning of the project

and an organic food market inside the building. This allows the users to pass through the farming wing to see and get the experience of all the farming process till they reach the brewery for observing the beer production and taste the freshly brewed beer as illustrated in Fig. 40.9.

Architectural Features

- *Art center and gallery:* they are huge spaces that holds different types of artworks; graffiti, planting the art, and painting. The center is connected to the gallery through movable walls.
- *Educational center:* it includes research labs, classes, and a hall for hosting courses and group discussions to provide courses for the artists and farmers as well as disadvantaged social categories as people with disabilities, ex-cons, and refuges. The interior design of the courses hall is mainly groups of concentric stages separated by temporary partitions that could be assembled by the users according to their needs.
- *Restaurant:* its position is central to serve all users and the services area is covered in an upper dining area to provide visual connection with the other uses in the building. Besides, an organic food market is located in the south near the site to serve the residential area.
- *Microbrewery:* the brewery design integrates the production area with the selling, tasting, and crafts area.
- *Indoor farming area:* in order to fulfill the requirements of ZipGrow greenhouse, the wooden roof is replaced with transparent material in the southern part to permit sunlight, and the brick wall is replaced with openable curtain walls to convert this area into an outdoor area when the climate is warm but crops that

require shading are located inside to provide a green view to users inside. On the contrary, the mushroom production area is in the center and covered with solid walls and roofs to prevent sunlight and provide humidity.

- *Shared space:* it is expected one universal space shared by all types of users and visitors and divided by a bridge crossing all functions starting with interaction space and ending over the zip-grow area.

Sustainable Technologies

In the project many sustainable technologies and solutions were exploited. These include:

- Ethylene tetrafluoroethylene (ETFE), which is a man-made fluoropolymer stands that is used for the roof and the domes of imagination. It is a single layer type for the roof and the double layer for the domes. The ETFE appearance is like a transparent sheeting material type that can be employed instead of glass and plastic that are hard in nature. It also possesses a nonsticky surface, which gives them a self-cleaning as well as recycling capacity. The ETFE material also helps in life cycle costing (LCC) by assuring lower maintenance costs; besides it is stretchable, so variation in size can be compromised. The ETFE is lightweight in nature and has a self-cleaning property, as they clean out dirt coming over it, because of the smooth surface it possesses. During rain, the dirt is washed out easily. In addition, ETFE is an excellent light transmission capability, highly durable, eco-friendly, and its material after use can be recycled and converted into useful industrial products. The lightweight nature of ETFE makes the use of it lesser fabrication, thus mitigating carbon dioxide (CO_2) emissions. Therefore, it provides adequate ventilation of the buildings' indoor; reducing the cost and energy of additional lighting requirements besides it is a fire resistant and self-venting building (Fig. 40.10).
- The ByFusion Blocker: it is a machine that transforms all types of plastic waste into high-tech building blocks (Fig. 40.11). It turns an environmental disaster into profit due to the fact that it turns plastic trash into the building blocks that can be sold to nearby building projects. The blocker takes any category of unsorted and

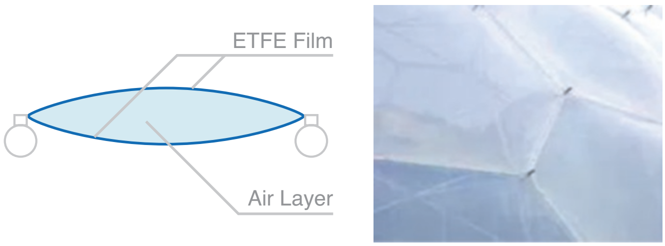

Fig. 40.10 Cross section and impression of ethylene tetrafluoroethylene (ETFE). (Source: https://www.area-info.net)

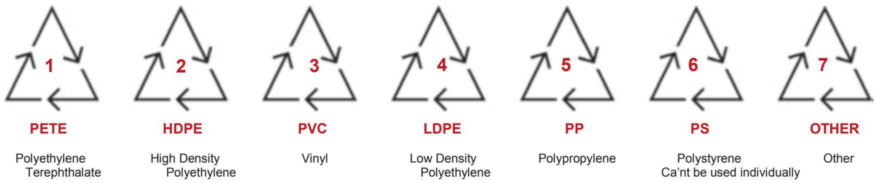

Fig. 40.11 Transformation of plastic waste used in the project. (Source: https://www.byfusion.com/the-blocker/)

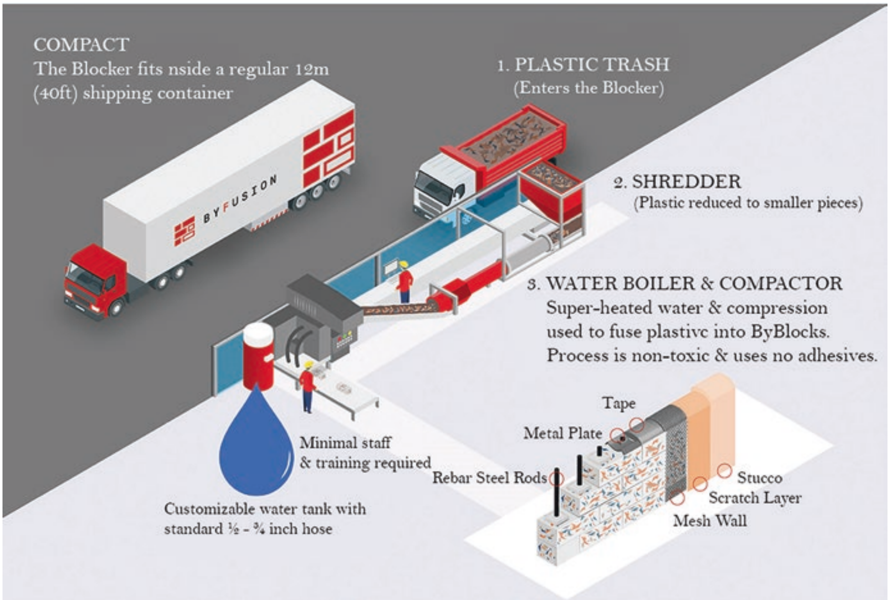

Fig. 40.12 The transformation process and requirements are demonstrated. (Source: https://www.byfusion.com)

unwashed plastic waste and turns it into an advanced building material which is better insulated than concrete and stronger than bricks. The transformation process and requirements is demonstrated as shown in Fig. 40.12 [23].

- Lucid pipe power system: it is a system that generates electricity from water pipes (Fig. 40.13) which has advantages in energy production using patented, spherical turbines that spin as water passes through them. Lucid pipe converts an otherwise untapped energy source the excess head pressure into electricity. Therefore, it creates clean carbon-free electricity with no negative impacts on water delivery or the environment [24].
- ES pipe: a pipe water wheel that turns water supply into a mini hydroelectric generator used to power the light bulbs to reduce energy consumption. Thus, the water pipes will be exposed and used in lighting as shown in Fig. 40.14 [25].

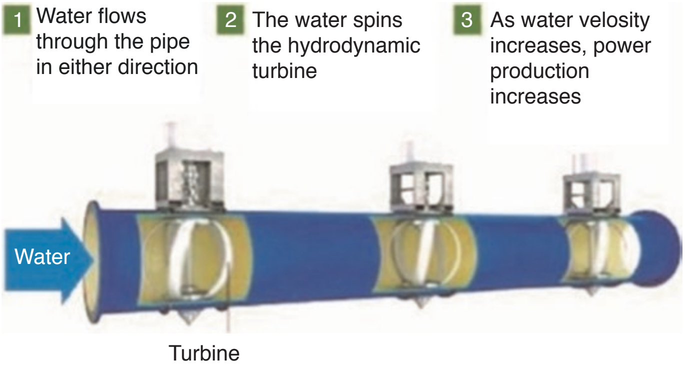

Fig. 40.13 Generation of electricity from water pipes. (Source: http://lucidenergy.com/how-it-works)

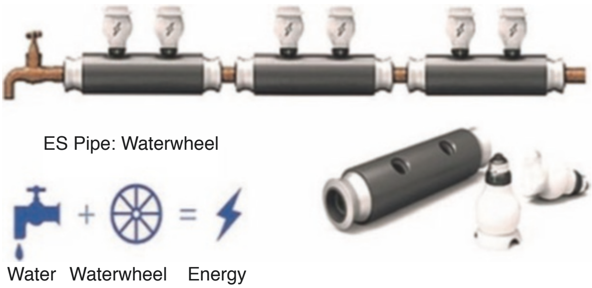

Fig. 40.14 ES pipe installation. (Source: https://thetechjournal.com/green-tech/es-pipe-water-wheel-turns-regular-water-supply-into-a-amini-hydroelectric-generator.xhtml)

- Rainwater harvesting: by using the potential of the building's facades as the biggest possible surface to collect rainwater as illustrated in Fig. 40.15 [26]. Through the rain facade, the collected water is carefully transferred from one module to the next in a down welling way. This playful view communicates the amount of water being collected to the pedestrians viewing the facade. It also can be collected through the landscape.
- Bioluminescent algae: phosphorescent algae can provide natural light during the night. It can grow almost anywhere on the planet and double in size within a day. It could improve air quality and reduce greenhouse gases because it absorbs carbon dioxide and converts it into oxygen. Also, it could be used to clean industrial wastewater and prevent harmful because it can even grow in polluted water.
- LED lighting: they are well known for their efficiency, which translates to energy savings for the consumer. LED lighting supports sustainability in several different ways, as it is a low energy consumption that uses less energy than other types of light bulbs and this saves the consumer money and places less demand on our energy grid and, ultimately, less demand on the natural resources used to power

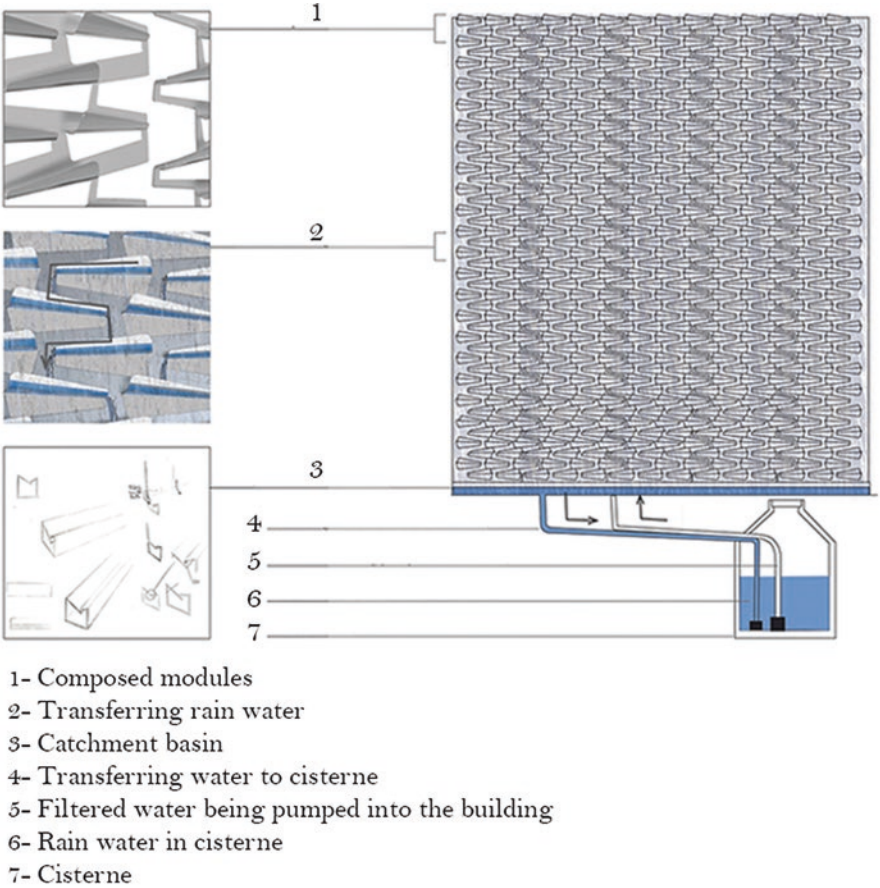

Fig. 40.15 Generation of electricity from water pipes. (Source: http://lucidenergy.com/how-it-works)

that grid. LEDs have no harmful materials used in construction and are made of recyclable materials. Although you cannot throw them out with the curbside recyclables, LEDs can be taken to special collection events or drop-off locations where they can be collected and sent off to be dismantled. Parts can then be reused, repurposed, or recycled.

- Green furniture: its concept makes sustainable seating and lighting for public interiors. It gives the flexibility to create configurations unique. The furniture elements are integrated in the natural cycle or in a technical cycle free of waste.
- The LINK: it is a freestanding, modular partitioning system, that link together to create free-standing mobile partitions and room dividers for different interior settings as presented in Fig. 40.16 [27]. It is quick to construct and quick to change. Units can be arranged to form undulating or straight walls and are 100% recyclable, toxin-free, emission-free, and allergy friendly. It is used to reduce the costs and save resources.

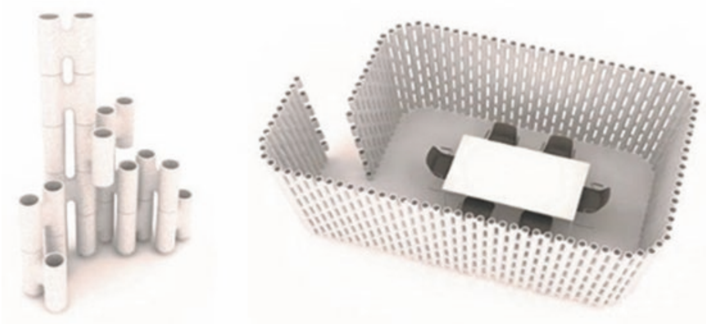

Fig. 40.16 The LINK's elements and partitions. (Source: https://movisi.com/en/pages/product-link-system)

Urban Farm Design

Surrounding Area

The outdoor area surrounding the industrial building is covered with concrete. However, wild trees and shrubs already started to colonize the numerous cracks that formed on the surface, expanding them. This project aims to take advantage of this fact and form uncovered raised beds areas where the concrete is already compromised, maintaining the rest as a walking path which allows visitors and staff to easily access the green beds. These green areas are shown in Fig. 40.16. The perimeter which is created will allow the possibility to raise ground level initially adding soil and further on adding the digested by-products of beer, mushroom, and vegetable production (Sustainable Technologies section). The outdoor design consists of three different areas. One dedicated to local fruit trees growth (orange colored in Fig. 40.17), one formed by many smaller beds dedicated to horticultural annual crops, aromatic and flower plants (green colored in Fig. 40.17), and a long pergola corridor dedicated to hop growth (yellow colored in Fig. 40.17).

Fruit Tree

The three species chosen to inhabit three major beds are apple, cherry and fig. Also three local varieties, traditionally grown on Treviso's hills have been selected to enhance and support the local biodiversity: Mela di Monfumo (Monfumo's apple), Ciliegia dei Colli Asolani (Asolani's hills cherry) and Figo Longhet di Tarzo (Long Tarzo's fig). Every fruit variety will be pruned differently taking into consideration the pre-extensive techniques which utilize low and medium plant density.

This approach not only favors natural plants growth thanks to the most appropriate cultivation method forms (Fig. 40.18), but also permits to create a useful and

Fig. 40.17 Green areas used for horticulture production resulting from the removal of compromising concrete

Fig. 40.18 Different training systems adopted for the three different tree species. Vase for cherry trees, central leader for apple trees, and eventually globular bush type for figs' trees

educational portray of different pruning methods. This will show to visitors how farmers, thanks to the scientific knowledge developed in century, are able to cooperate with nature to reach a productive goal (insights about plant growth and development, different fruit trees cycles, buds, chili requirement).

Fig. 40.19 Type of flowers that are commonly growing in the foothills of the Veneto Alps

Flower

Flowers have a multiple role within the garden design. First of all, they will support other plant growth, both perennials and annuals, increasing pollinator and attracting beneficial insects, such as ladybirds and lacewings. Also, they play a fundamental ornamental role in ensuring a great visual experience to visitors. In addition, the selected flower plants are commonly growing in the foothills of the Veneto Alps (pre-alps), offering an important educational purpose into spreading knowledge which have been rapidly lost in the urban context. Informational boards will provide info related to flower characteristics and traditional uses of the different plants' parts as illustrated in Fig. 40.19.

Pest Management

Choosing extremely local or traditional varieties is the first step to prevent the occurrence of major plant pathologies. Thanks to a long adaptation process and an accurate selection made by many farmers' generations, these plants are more resistant to phytopathology naturally occurring in this territory. For instance "Mele di Monfumo" such as the Ferro da Cesio variety, are resistant to hot and cold weather, and it gets hardly infected by plant diseases [28]. Particular care needs to be done to invasive insect species. For instance, all the planted fruit trees can be attacked by *Drosophila suzukii,* a well-known alien insect pest, a fruit fly, which is able to oviposit eggs within the fruit compromising fruit quality and promoting secondary infections. Apart from apples, which are less affected by this pest, figs and especially cherries can be severely compromised by attack [29, 30].

Pest control will be based on an IPM (integrated pest management) strategy, where cultural practices play a fundamental role for prevention [31, 32]. These practices will be adopted within the project and shared with local farmers and visitors to spread good agricultural practices, including:

- Reduce favorable insect pest habitat. Considering that *D. suzukii* adults favor humid and cooler area, pruning plays a fundamental role to prevent pest occurrence and reduce damage. Winter and summer pruning will be aimed at increasing wind flow and reducing shadow in the inner foliar.
- Reduced host plants in the surrounding environment. This process is made easier by the garden design, which is based on different beds separated by concrete pathways.
- Eradicate favorable pest insect condition thanks to appropriate harvest and fruit removal. This practice is particularly useful to reduce Drosophilae pest attack, and it is based on the removal of mature and rotten fruits from the tree, which could attract pests and be easily attacked [33].
- Monitor and capture insect pest. The pest population will be monitored using chromatic trap to manage control approaches including the use of attractive traps used for mass trapping, an efficient organic practice.

Indoor Farming

Within the ex-Zanussi area, three types of production were established: horticulture production (ZipGrow system), brewery production, and mushroom grow. Following the concept of Gilgamesh, these process is realized in order to show to the customer the complexity of the input transformation and the extremely importance of the human capital. The following sections will provide the specific methods and material selected for each process.

ZipGrow

This vertical hydroponic system is best suited to allow a continued production along the year which also permits to relocate it easily whenever necessary. At winter, the vegetable production will take place indoor, supported by an independent heating system backed up by the heat produced during beer production and a dedicated LED illumination. From spring to autumn, partial production will take place outside, with the main purpose to offer an educational journey through an evolving agriculture, based on a technological approach. Thematic such as urban agriculture, precision agriculture, and growth optimization is shared with the public in an easy and understandable way.

The ZipGrow design is intended to grow plants vertically by using a modular set up based on single phase towers. These metal towers have housing, where the

Fig. 40.20 Types of leafy vegetables cultivated in the project

substrate is inserted, and a 2–4 cm narrow aperture where plantlets can extrude and grow. Although resistant, these modular towers are light weighted and can be easily moved. Towers, thanks to metal hooks, can be hanged to a main structure and consequently plugged into the hydraulic system, which constantly supply nutrient solution though a dripper. Nutrient solution is then collected on the bottom to ensure a closed loop system and nutrient recycling. A fertirrigation system allows for monitoring nutrient solution quality and will be managed directly within the building. The hydraulic system, however, will extrude both indoor and outdoor, to easily connect the system when moved outside (in Fig. 40.17, the area dedicated to the outdoor hydroponic production is colored in gray). The crop selected which are better suited for this vertical farming are mainly green leafy vegetables and aromatic plants and have been selected also according to locally produced varieties [34] (Fig. 40.20). Although temperatures and light intensity can be controlled indoor, the production of species, which requires lower temperatures and light, has been scheduled in winter, to reduce energy consumptions and costs.

To stimulate the curiosity of visitors, spacing separating different groups of seedlings is set at 5 cm if not differently specified, allowing the tower to be almost completely covered. Harvest will be done through apical cutting or hand picking.

Microbrewery

The microbrewery is one of the business idea planned for the area ex-Zanussi in Conegliano, Treviso. The scenario where the project is proposed is positive in terms of demand: the beer sector today plays a preeminent role in national economy and export and beer has got more and more into the consumption habits of Italians and is an integral part of the Mediterranean diet. One of the most interesting parts of the sector is craft beer that bring thanks to consumers being ever more curious and better-educated regarding the product. The sector of craft beer recently had a real boom. Indeed, after the birth, all over the country, of new entrepreneurial businesses, mostly led by young people, today microbreweries are over 850, mostly concentrated in Lombardia (134), Piedmont (80), Veneto (74), and Tuscany (63). The market reveals: young, chaotic, and far away from his maturity [35]. The microbrewery aim is contributing to the sustainable regeneration and development of ex-Zanussi, through the endorsement of natural and human resources. As contextualized in the overall project of Gilgamesh, the microbrewery has a double-purpose: production and education. The main investments of the microbreweries are related to machinery acquisition for the production and packaging of beer. The system is characterized by high performance, ergonomic and equipped with easy and intuitive software that allows the control over all the production. The TANKER model provides a heat exchanger for rapidly decreasing of the temperature in the system through the use of water production. The hot water (more than 75 °C) obtained is recirculated in the system for a new process of beer production and thus decreasing the cost of production considerably. The short-term objective is achieving an operatively positive result of 60,000 euro through the optimal use of finance and human resource. The forecast of production is 1133 bottles in the first year, for a total amount of 408 hL and the recruitment of two employers, brew-master and one worker. The educational process will embrace the different stage of the process providing different course linked with beer production and tasting.

The aim of the educational process is giving an additional value to the location and product making easier the process of project diffusion in the city. To achieve these objectives, efficient communication strategies that enlighten the peculiarity of the product were developed; thus, securing customer loyalty in Conegliano city. The main objective for the middle and long term is consolidating the turnover to cover the fix cost and guarantee a living wage for the employer. These two objectives will be achieved by insuring an increment of revenues through amplification and diversification of products and services, that allow for a better positioning in the craft market in Conegliano as well as in the region of Veneto. The amplification of the production will be achieved through the system of "doppia cotta" leading to the increase of until 1224 hL in the fourth year. Barley wine, aged beer, and fruit beer, Lambic style beer refermented with the addition of local fruit varieties grow in the soilless thematic park, are the main strategies for diversification of the production in order to achieve higher price and achieve different target of the market.

Oyster Mushroom Production

The idea of the project is the establishment of learning and production center inside the ex-Zanussi area of 200 m^2. Mushroom is an exotic and nutritious source of vegetarian food. It is a major horticulture product all over the world and is also becoming popular in Italy. It contains many vitamins and minerals but very low on sugar and fat. It can be grown in a temperature between 20 and 30 °C and required relative humidity is 55–75%. Many examples of mushroom production within the city are available in Europe. RotterZwan [34], La Caverne [35], and Bunker comestible [36] are just few examples of successful stories on the production of mushroom in the urban and sub-urban area. As the project is inside Gilgamesh, two main activities will be delivered inside the area: production and learning activities. The learning actions will be carried out by the personal that works inside the project and will play a crucial role in the creation of the brand inside the city of Conegliano. At the beginning of the project, two main products will be provided: fresh mushroom and canned mushroom. These two products will ensure the minimum of waste of the production as fresh mushrooms have very limited shelf life but dried and packed mushrooms have considerable shelf life. The variety selected is the *Pleurotus ostreatus*, so-called oyster mushroom, a common edible mushroom. Oyster mushrooms are easy to cultivate and process and do not require huge investment. Hence, this note deals with cultivation and processing of oyster mushrooms. The objective of the first year is to achieve an income of 33,780 Euro and in the second year 42,767 Euro covering the fixing cost and the salaries of four people (1 skilled personal, 2 helpers, and 1 salesman) following the concept of living wage. The long-term objectives are based on the principle of differentiation and amplification of the production thanks to the experiences and the better knowledge of the market.

The production of mushroom will be added in the cycle of input and output established within the project Gilgamesh. Indeed, the by-product of the brewery process will be included inside the substrate for the mushroom production and the exhausted substrate will be used as natural fertilizer for the orchard in the thematic soilless park. For successful cultivation, careful attention has to be paid to three aspects, viz. good compost, reliable spawn, and right temperature, during growing period or else partial or complete failure of the crop may result. Natural compost is prepared from spent brewery grain (10%), wheat bran (20%), beech sawdust (68%), and calcium carbonate (2%).

According to Andrej Gregori et al. [37] this compost has been tested for the cultivation of *Pleurotus ostreatus* and as a result, the fastest mycelium growth substrate. On the other hand, a recent article from "L'Informatore agrario," important agriculture newspaper, reported the positive results of the application, previous pasteurization and sterilization, in the soil as mineral improvement [38]. The site before and after redevelopment is shown in Fig. 40.21a, b.

a. The site before development **b.**The site after urban farming development

Fig. 40.21 The site before and after urban farming development. (**a**) The site before development. (**b**) The site after urban farming development

Business Model and Feasibility

The project aims to achieve sustainability under the three different challenges: the social, the environmental, and the economical one. The economic analysis was obtained by evaluating the necessary restructuring costs and production costs and revenues for each type of area.

Redevelopment Costs

In order to redevelop the ex-Zanussi area, a synthesis of major costs is reported on the table. The total amount is equal to € 2,250,000 (Figs. 40.21, 40.22, and 40.23). It is divided in amortization's quotas of € 75,000,00 given an estimated duration of

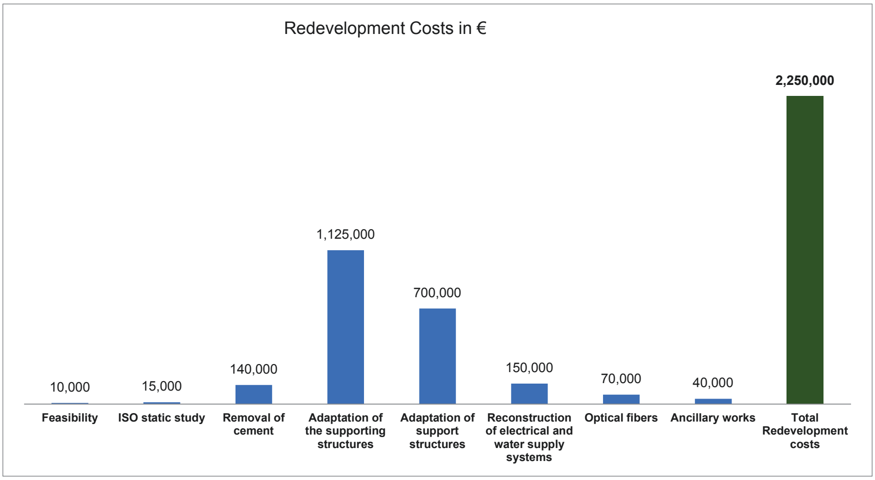

Fig. 40.22 Total costs and revenues of the project redevelopment

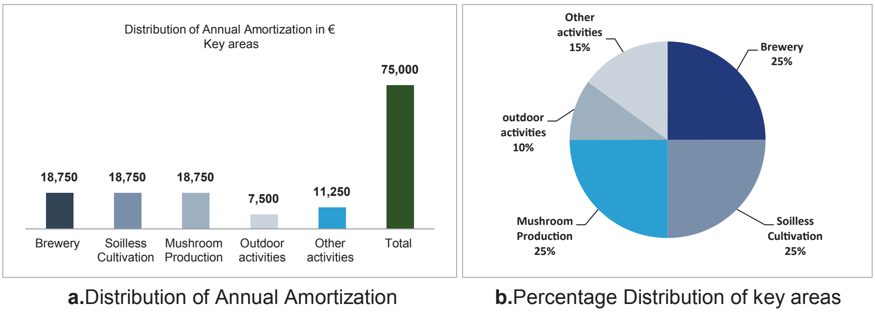

Fig. 40.23 Distribution of annual amortization of the key areas envisaged in the project. (**a**) Distribution of annual amortization. (**b**) Percentage distribution of key areas

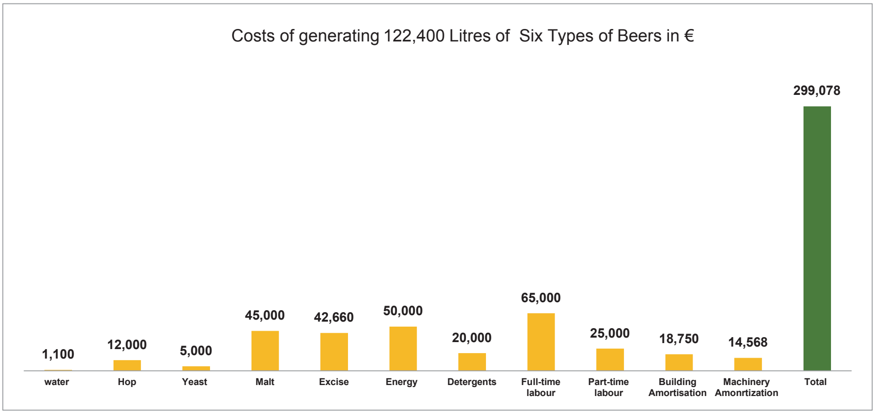

Fig. 40.24 Costs of brewery production

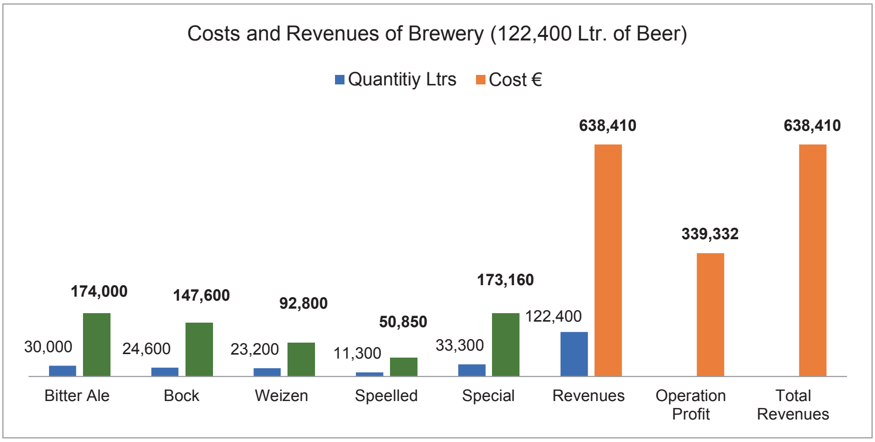

Fig. 40.25 Costs and revenues of brewery

30 years. Details of costs and revenues for the whole project are listed in the Appendix (Tables 40.2, 40.3, 40.4, 40.5, 40.6, and 40.7).

Brewery

The estimated cost for the brewery is around € 218,520,00, considering machinery and accessories' costs. Production is focused on five kinds of beer: Production is focused on five kinds of beer: Bitter Ale, Bock, Weizen, Spelt, and Special that are sold internally to the factory but also to local markets. The remuneration of the brewery is very high: the "cash cow" of the entire business plan as shown in Figs. 40.24 and 40.25 and Table 40.4 in Appendix.

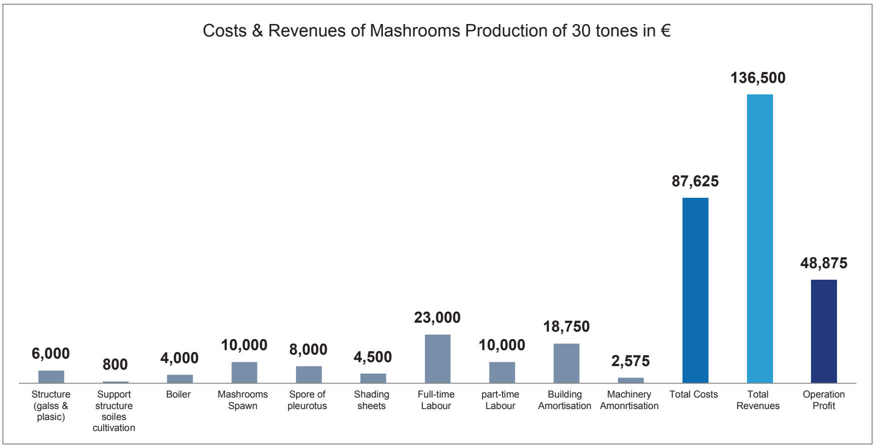

Fig. 40.26 Costs and revenues of production of mushrooms

Mushrooms

The estimated cost for the mushrooms' greenhouse is around € 12,875,00 considering machinery and accessories' costs. Experimentation activities will be foreseen to find substrates at no cost (Fig. 40.26). In order to optimize the operating profit and contribute to the circularity of the processes, the production cycle of mushroom lends itself well to the exploitation of waste: think, e.g., to the inoculation of the substrates composed of the mocha (Table 40.5, Appendix).

Soilless Cultivation

Soilless cultivation will be the main source of income and activity that will most involve the society in the execution of the project (Fig. 40.27). In line with the vision, numerous courses will be conducted to bring citizenship closer to protected cultivation: training and experimentation will accompany the entire life of the Gilgamesh project. Despite the high initial investment costs (€ 140,700,00), value of production is an optimal opportunity to gain the ROI (Table 40.6, Appendix).

Outdoor Cultivation

Around the plant, a green area will be built as an orchard, including types of herbs cultivated in the project as shown in Fig. 40.28. The high maintenance needs that will be required by the green will be completely absorbed by the associations of

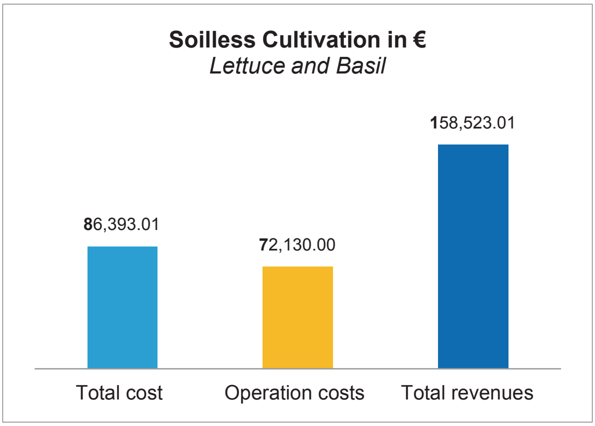

Fig. 40.27 Costs and revenues of soilless cultivation

Fig. 40.28 Types of herbs cultivated in outdoor. (Images source: (1) http://www.outsidepride.com; (2) https://www.johnnyseeds.com/herbs/basil; (3) http://www.FreeFoodPhotos.com; (4) https://livingseeds.co.za/red-rubin-basil.html; (5) https://www.angelplants.co.uk; (6) https://www.amazon.com/Parsley-Italian-Garden-Seed-Kingdom/dp/B00523M0WG; (7) https://www.hausa.premiumtimesng.com; (8) https://www.outsidepride.com; (9) https://www.ingegnoli.it)

"collective agriculture" that will be managed by the structure's representatives. In this way, therefore, the area will not only be used for production, but, above all, will have a sociocultural vocation in the urban context of reference. An App will make outdoor cultivation activities attractive, providing the challenge among the members of the Gilgamesh project. There will be challenges related to production, pruning speed and harvesting, as well as functions such as "Adopt your tree." There will be numerous bonuses, which can be spent in the company, to those who will take care of the collective areas outside the plant in addition to other activities (Fig. 40.29, Table 40.7, Appendix).

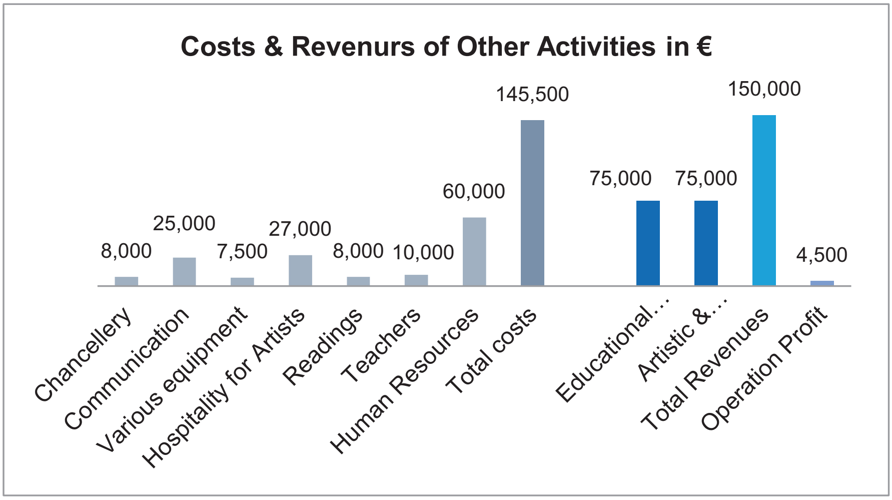

Fig. 40.29 Costs and revenues of other activities

Transversal Initiatives

The transversal activities will guarantee the assiduous participation of citizens in the Gilgamesh project. The collective fruition is based on numerous collective activities that will guarantee the frequency of the ex-Zanussi factory to all age groups: children, students, the elderly, people tired from the gray daily routine.

Results

The assessments of the project revealed the following results. Table 40.1 shows the interventions in the project and its impact on the three pillars of sustainability. Figures 40.30, 40.31, 40.32, 40.33, 40.34, 40.35, and 40.36 present all technologies and innovative solutions.

Conclusion

The Wonderers® is a regenerative project that achieved set objectives by integrating the urban farm with its surrounding urban context to create a living heart for the city of Conegliano. This project turns a black hole in the city Conegliano into a green, regenerative site. It also becomes a social and an economic hub for the city utilizing smart architectural and urban farm technologies and innovative solutions.

Table 40.1 Sustainable development pillars assessment of the project features

No.	Mission	Economic sustainability	Social sustainability	Environmental sustainability
1	Presence of various functions indoor and outdoor	√	√	NA
2	keeping the old building structure	√	NA	√
3	Host an integrated art-agriculture training center	√	√	NA
4	Blend Art and Agriculture in one space	NA	√	NA
5	Create an Art Center and Gallery	√	√	NA
6	Create a space for restaurant and organic food market	√	NA	NA
7	Integrate the production area of the microbrewery with the selling, tasting, and crafts area	√	NA	NA
8	Create one universal space shared by all types of users	NA	√	NA
9	Create an underground rentable studios for artists	√	√	√
10	Build an educational mobile game application will turn the process into an URBAN GAME	√	√	√
11	Architectural sustainable technologies	√	NA	√
12	Uncovered raised beds areas where the concrete is already compromised	√	NA	√
13	Planting three local varieties	NA	NA	√
14	Flower plants are commonly growing in the pre-alps, offering an educational purpose.	NA	√	√
15	Vertical hydroponic system (ZipGrow)	√	NA	√
16	Greenhouse for mushrooms	√	NA	√
17	Redevelopment of the building	√	√	NA
18	Courses for disadvantaged social categories as immigrants, people with disabilities and ex-cons.	NA	√	NA
19	Providing education in the field of plant production and managerial skills	√	√	√
	Total achieved	14/19	11/19	10/19

The project also covers all three pillars of sustainability; environmental, social, and economic aspects to achieve a self-sustained hub that creates new jobs in its' four phases. It also provides clean vegetables and productive hub for the city including many species. The project reduces the footprint of the city yet being an innovative model to be followed in other cities in Italy and worldwide. It is blending art, architecture with agriculture to create connectivity and social innovation through a variety of social spaces (Figs. 40.30, 40.31, 40.32, 40.33, 40.34, 40.35, and 40.36), beside the urban farm to attract citizens and students to the new site and hub. Moreover the project helps in creating livable, healthy, and sustainable urban environments in the city of Conegliano, north of Venice, Italy. The project redevelopment contributes to attaining sustainable development goals, particularly SDGs 7, 8, 11, 12, and 13.

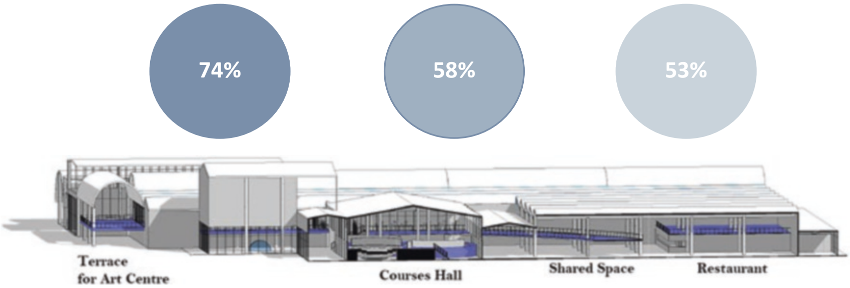

Fig. 40.30 3D of the redeveloped project in the City of Conegliano, Italy

Fig. 40.31 Developed site after incorporating all urban farming technologies

Fig. 40.32 Impression of the skylight and social connectivity

Fig. 40.33 Green wall in the restaurant

Fig. 40.34 Impression of interior interactive spaces

Fig. 40.35 Impression of the farm learning

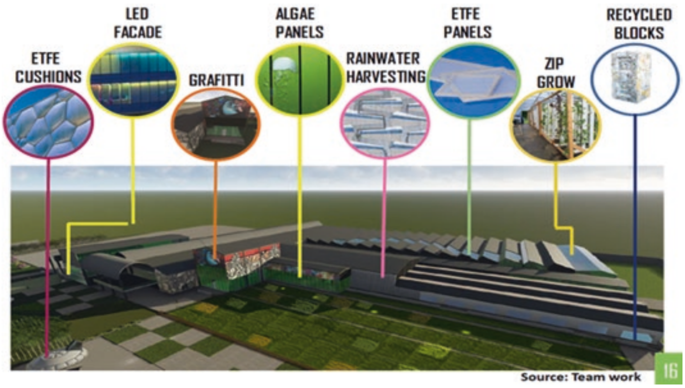

Fig. 40.36 3D depicting innovation and technologies

Appendix

Table 40.2 Redevelopment costs of the project

Redevelopment Costs	
1. Feasibility	€ 10,000.00
2. ISO static study	€ 15,000.00
3. Removal of cement	€ 140,000.00
4. Adaptation of the supporting structures	€ 1,125,000.00
5. Adaptation of support structures	€ 700,000.00
6. Reconstruction of electrical and water supply systems	€ 150,000.00
7. Optical fibers	€ 70,000.00
8. Ancillary works	€ 40,000.00
Total	€ 2,250,000.00

Table 40.3 Distribution costs of key areas

Distribution of annual amortization between the key areas envisaged by the project		
Key-area	% of attribution	Amount
Brewery	25%	€ 18,750.00
Soilless Cultivation	25%	€ 18,750.00
Mushroom Production	25%	€ 18,750.00
Outdoor activities	10%	€ 7,500.00
Other activities	15%	€ 11,250.00
Total	**100%**	**€ 75,000.00**

Table 40.4 Costs and revenues—brewery

Costs and revenues (122.400 Ltr. of beer)					
Costs		Revenues			
Water	€ 1,100.00	Typology	Quantity (L)	Price	Total
Hop	€ 12,000.00	Bitter Ale	€ 30,000.00	€ 5.80	€ 174,000.00
Yeast	€ 5,000.00	Bock	€ 24,600.00	€ 6.00	€ 147,600.00
Malt	€ 45,000.00	Weizen	€ 23,200.00	€ 4.00	€ 92,800.00
Excise	€ 42,660.00	Speelled	€ 11,300.00	€ 4.50	€ 50,850.00
Energy	€ 50,000.00	Special	€ 33,300.00	€ 5.20	€ 173,160.00
Detergents	€ 20,000.00	Revenues	€ 122,400.00		€ 638,410.00
Full-time labour	€ 65,000.00	Profit			
Part-time labour	€ 25,000.00				
Building Amortization	€ 18,750.00	Total Revenues			€ 638,410.00
Machinery Amortization	€ 14,568.00	Total Costs			€ 299,078.00
TOTAL	€ 299,078.00	Operation Profit			€ 339,332.00

Table 40.5 Costs and revenues—mushrooms

Costs and revenues (30 Tones of mushrooms)					
Costs		Revenues			
Structure (glass & plastic)	€ 6,000.00	Typology	Quantity (L)	Price	Total
Support structure soilless cultivation	€ 800.00	Pleurotus eryngii	€ 20,000.00	€ 5.00	€ 100,000.00
Boiler	€ 4,000.00	Champignons	€ 7,500.00	€ 3.50	€ 26,250.00
Mushrooms Spawn	€ 10,000.00	Shiitake	€ 2,500.00	€ 4.10	€ 10,250.00
Spore of pleurotus	€ 8,000.00	Total	€ 30,000.00		€ 136,500.00
Shading sheets	€ 4,500.00	Profit			
Full-time Labour	€ 23,000.00				
Part-time Labour	€ 10,000.00				
Building Amortization	€ 18,750.00	Total Revenues		€ 136,500.00	
Machinery Amortization	€ 2,575.00	Total Costs		€ 87,625.00	
TOTAL	€ 87,625.00	Operation Profit		€ 48,875.00	

Table 40.6 Costs and revenues—soilless cultivation

Cost and revenues (Soilless cultivation)					
Costs		Revenues			
Submersible water pump (800 GPH)	€ 50.00	Typology	Quantity (L)	Price	Total
Tubing syste	€ 200.00	Lettuce	€ 25,899.00	€ 2.00	€ 51,798.00
Leafy vegetable and aromatic seeds	€ 960.00	Basil	€ 21,345.00	€ 5.00	€ 106,725.00
Utilities (electricity)	€ 5,167.27	TOTAL	€ 47,244.00		€ 158,523.00
Utilities (water)	€ 125.74	Profit			
Labour full-time	€ 23,000.00				
Labour part-time	€ 10,000.00				
Building Amortization	€ 18,750.00	Total Revenues		€ 158,523.00	
Machinery Amortization	€ 28,140.00	Total costs		€ 86,393.01	
TOTAL	€ 86,393.01	Operation Profit		€ 72,130.00	

Table 40.7 Costs and revenues—other activities

Cost and revenues (other activities)			
Costs		Revenues	
Chancellery	€ 8,000.00	Educational Activities	€ 75,000.00
Communication	€ 25,000.00	Artistic & Recreational Activities	€ 75,000.00
Various equipment	€ 7,500.00	Total Revenues	€ 150,000.00
Hospitality for Artists	€ 27,000.00	Profit	
Readings	€ 8,000.00		
Teachers	€ 10,000.00	Total Revenues	€ 150,000.00
Human Resources	€ 60,000.00	Total costs	€ 145,500.00
TOTAL	€ 145,500.00	Operation Profit	€ 4,500.00

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Part IX
Policy, Education, Training and Finance

Chapter 41
Comfortable Places for Moving and Rest Along Cycle Paths

Valentina Dessi

Introduction

The paper is part of the framework of strategies for improving the use of pleasant, interesting places, but which are often not involved in the processes of management and development of the territory, despite having the requirements to be. One of the most incisive and less invasive methods that can be applied to a fragile territory is the realization of light infrastructures that help a slow fruition and a deep knowledge of the territory.

These are cycle–pedestrian routes, which do not fracture the territory-generating barriers and definitive caesuras, but on the contrary help mend the landscapes and allow a type of use that generates strong links between the territory and the user (otherwise impossible), and which remain in the memory [1]. They can be paths for pedestrian and cycle paths that consider existing paths, but which often require new interventions. In any case, they represent a mode of movement that allows to meet the heritage, physical and cultural, sustainable from all points of view.

To encourage the presence of people on cycle-pedestrian paths in both urban and rural contexts, especially in hot weather, it is advisable to provide systems that improve the microclimate and therefore the thermal comfort conditions, i.e., strategies that have the possibility to cool without interfering on the perception of places.

It is also true that these cycling routes often cross areas of historical and cultural interest of considerable interest. For this reason, it is important to analyze accurately the places in order to identify the right strategy that can be an opportunity to enhance these places, also in terms of microclimatic conditions.

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The Case Study: Vittorio Veneto Square in Brandizzo (To)

VENTO is a pedestrian cycle route project, a ridge that runs along the Po River, which will connect Turin with Venice, following the course of the river and crossing several cities, such as Milan, Pavia, Cremona, Mantova, Ferrara, and Chioggia.
The cycle track tries to use the existing routes and new connections and sections that intercept places of historical, architectural, and landscape interest. It is a journey that starts from Turin and arrives in Venice and offers the possibility of stopping along the route in areas that are not inhabited, or in urban centers. But it is also a landscape resuscitation project capable of proposing new employment and widespread economies for the sustainable development of the internal areas of the State [2].

The paper takes into consideration an area along the route of the VENTO, which is a square near the starting point of VENTO, Piazza Vittorio Veneto, a square of about 930 m^2, located in the Municipality of Brandizzo, in the province of Turin. It is an urban space, and therefore equipped with services. It is a stage on the VENTO route, but also a meeting place or stop for residents and visitors.

Looking from the top at Piazza Vittorio Veneto in Brandizzo, we can realize that the church of San Giacomo Apostolo is located in the middle of a rectangular space, elongated along the north–south axis. In fact, two spaces are generated, and only the one on the north side is public.

The church and its bell tower, therefore, represent the vertical limits that characterize the south side of Piazza Vittorio Veneto. The square, raised on the north side, has only one driveway along the north side, while the rest of the square, being raised, is pedestrian (it guarantees limited access through a ramp).

It is one of the stopping places that the VENTO cycle path intercepts, given the presence of the Po River not far from the city. The square is located in the historic center of the town, overlooking Via Torino, which hosts some commercial activities along its route, such as shops, food shops, bars, restaurants, a bank, and a pharmacy. The Baroque Church of San Giacomo Apostolo built around 1700, and the relative Bell Tower, represent the most recognizable elements of the square, bounded by historical buildings, in most cases, two stories high.

Some benches, a public fountain and two horse chestnut trees characterize the square, paved with "sanpietrini" (beveled stones of basalt) in two different colors, one on gray and one on red also used for pedestrian crossing. Piazza Vittorio Veneto can be reached by bus, or by the train that stops at the Brandizzo railway station, around 350 m from the square. Inside the square there are only two deciduous horse chestnut trees, with fastigiate/rounded habit. Generally used as ornamental trees mainly in parks, they have heights that can reach a maximum of 25 or 30 m (currently they are about 10 m high, with a crown diameter of about 6 m) (Fig. 41.1).

Fig. 41.1 View of the square (left) and characteristics of the trees (right)

Microclimatic Survey

The work aims to make a morphological, fruitive analysis and microclimatic conditions to evaluate in case of need, the possibility to improve the conditions of thermal comfort through the use of bioclimatic strategies, or to give some indication about location and devices to use.

The analysis covered several aspects:

- Urban materials, particularly flooring
- Vegetation on surfaces and trees
- The equipment and furniture of the urban space
- Public and private commercial activities present in the area (bars, restaurants, kiosks, etc.)
- A study of the shadows, in 3 h of the day in 3 days of the year (the two solstices and an equinox). Afterwards, the conditions of thermal comfort of some moments of the day have been calculated and mapped and thermal comfort values have been calculated represented in graphical form

The study of the physical behavior of the space is necessary to understand the daily and seasonal rhythms of a place, to understand its energy flows, and its potential [3]. For the study of radiant behavior and thermal comfort conditions simulations have been carried out with the OTC model software.

The evaluations of the thermal comfort conditions were calculated with the PET (physiological equivalent temperature) which considers the comfort zone between a temperature of 18 and 26 °C.

The results are represented as a map (the condition of only one moment in the whole area); in this case the hours of sunshine of a day, referred to one sunny point and a shaded point The climate data of the city of Turin for the square of Brandizzo were used, and in particular the values relating to the days of solstice and equinox. The data was used to calculate the PET.

Shadow Pattern in Vittoria Veneto Square in Brandizzo (To)

The church, inserted in the north side of the square, generates two niches, spaces of about 100 m^2 each, that flank the church. Excluding the two side bands to the east and west, and the driveway on the north side, the space available to people, is a rectangle of about 600 m^2 developed along the east–west axis. The church, which occupies the south side, helps to generate shade throughout the year (Fig. 41.2).

The analysis of the shadows was carried out on March 21st (9:00 a.m., 12:00 p.m., and 4:00 p.m.); June 21st (9:00 a.m., 2:00 p.m., and 5:00 p.m.); and December 21st (Winter Solstice) (9:00, 12:00, and 3:00 p.m.). In winter the square remains shaded throughout the day, although the surrounding buildings are not high; in spring, but especially in summer, the square is often under the sun, especially in the middle of the day.

The two horse chestnuts, during the hot season, apart from the central hours of the day, tend to cast their own shadow on the road located north of the square.

Time	March	June	December
Morning	 Time: 9 a.m	 Time: 9 a.m	 Time: 9 a.m
Lunch time	 Time: 12 p.m	 Time: 2 p.m	 Time: 12 p.m
afternoon	 Time: 4 p.m	 Time: 5 p.m	 Time: 3 p.m

Fig. 41.2 Shadow pattern of Vittorio Veneto square in Brandizzo (To). Three hours per day in 3 days of the year. (Elaboration by M. Menduni and L. Magni)

Radiant Behavior and Thermal Comfort Condition

Piazza Vittorio Veneto is a space that has the ability to intercept solar radiation throughout the year. Looking at the map of radiant behavior on March 21 and June 21 at 12:00 (the time when the sun is at the highest point on the horizon), it can be seen that radiation is present in almost all the space. In December, at the same time, the church casts its shadow for about half of the square.

The assessments carried out for March show thermal comfort values that are acceptable under the sun, as the PET always exceeds the threshold value of 18 °C in the central hours of the day and reaches even 26 °C; they are not acceptable in the shade of trees and buildings, where the value is around 13 °C.

If we analyze the radiant behavior map on June 21 (summer solstice) at 12:00, we can see that the solar radiation is present throughout the square.

The thermal comfort values are unsatisfactory both in the sunny area and in the shade of trees or buildings, as the PET reaches values around 42 °C in the central hours of the day in the sun, 34 °C in the shade, exceeding the comfort threshold by many degrees.

Finally, observing the graph of radiant behavior on December 21st (winter solstice) at 12:00, we can see that there is solar radiation in the northern and eastern part of the square, while the rest is in the shade. Thermal comfort values are acceptable in the sun, values around 20 °C can be found; in the shadow, on the other hand, the values are around 10 °C, i.e., far below the values corresponding to comfort (Fig. 41.3).

The difference between a sunny point and a shaded one can be near 8 °C in winter, in spring, close to 13 °C whereas in summer it can have differences up to 8 °C.

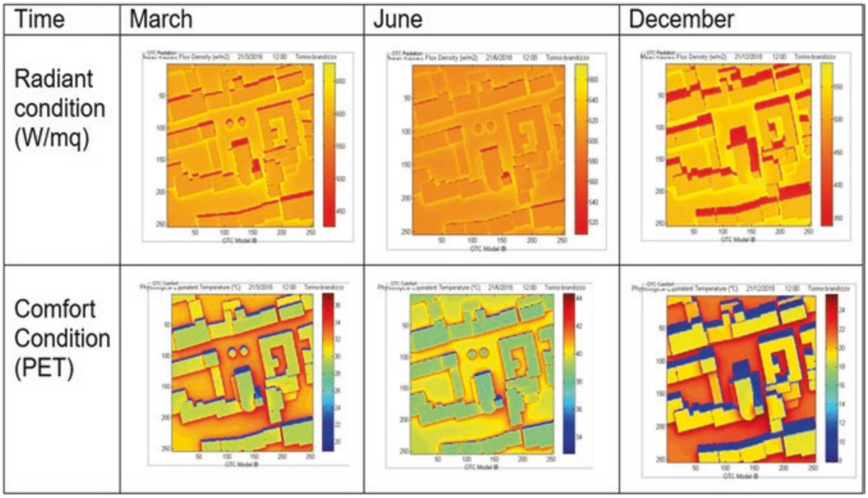

Fig. 41.3 Radiant patterns and comfort conditions at midday in spring, summer, and winter. (Elaboration by M. Menduni and L. Magni)

Some Hint for Reasoning

The improvement of the environmental performance of a space can include strong interventions, such as the replacement of flooring materials with materials with high albedo values, use of water and vegetation and shading devices in order to reduce surface temperatures and lower the air temperature values.

In this case, i.e., in a square of historical interest it is recommended to avoid burdensome intervention and work on removable equipment that does not definitively modify the configuration of the square.

Without arriving at the definition of a redevelopment project of an existing space, we can ask ourselves how an urban space can be made more hospitable for those who ride along a path and find themselves in a place, such as for example a square in a historical center of a small city, a place rich in history and cultural identities.

A stage along a cycle path must meet the requirements established by law, in particular, in Italy the decree of the Ministero dei Lavori Pubblici n.557. The art.4 in point 3(d), referring to the equipment, indicates as appropriate "… *the racks for the parking of the velocipedes and, especially on the tracks for tourist use, benches and preferably arboreal shaded areas, drinking water fountains every 5 km of track …* ." If the indications refer expressly to rest areas along extra-urban routes, intervening even within an urban structure can be an opportunity for the cycle tourist who comes into contact with interesting realm from the historical–cultural points of view, but it also becomes important for the resident citizen who can use equipment that otherwise would not exist when he moves on foot or by bicycle.

For example, in the analyzed square there are no racks, there is no fountain, there is only one linear bench located very close to the street. Some things can be proposed, especially to enhance the existing features. Piazza Vittorio Veneto of Brandizzo, as it is configured, offers the possibility of being in the sun and in the shade, even on the hottest and sunniest days. In the morning, both in March and June, the niche to the left of the church is in shadow, as well as the niche to the right of the church in the afternoon.

They are spaces where it is possible to provide racks. The month of June, in the central hours of the day, is the period that has the greatest lack of shade, if we exclude the little shade that the two trees on the square make, which is important and precious. It is appropriate to review the position of existing benches and possibly integrate some of them, which guarantee the possibility of stopping not only for cyclists, but also for residents, who today can sit, in addition to the only bench, in the stairs facing the street, or sit on the bar chairs that occupy part of the square.

Although there is already a bar, it is also worth considering a drinking water fountain. As far as the shadow is concerned, today there are temporary equipment belonging to the bar, it would be useful to provide, shading devices, removable in the winter season, along the sides of the square.

The objective of this type of analysis is therefore not a project but the definition of light strategies that can respond to the mix of elements present, such as compliance with regulations, improvement of thermal comfort conditions, and not least respect for a design of historic square in which the resident citizens recognize and identify themselves.

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Chapter 42
Energy Auditor and Building Certification: Three School Buildings Case Studies in Florence, Italy

Lucia Ceccherini Nelli and Alessandra Donato

Introduction

The educational buildings stock in Italy presents a very low energy performance. Most of the schools were built before 1976, with poor performing building envelopes without insulation, which incorporate single glazing windows with low thermal properties and low solar reflectance index, inefficient lighting and heating systems.

The Energy Efficiency Directive (EED, 2012/27/EU) states that since January 1st 2014, the 3% of the total floor area of conditioned buildings owned and occupied by the central government is recovered each year to meet at least the minimum energy performance requirements. In Italy, the EED has been transposed by the Legislative Decree 102/2014 that establishes a framework of measures for the energy efficiency improvement and enforces the refurbishment of the 3% of the central authorities public buildings conditioned area or the reduction of the energy consumption of 0.04 Mtoe in the period 2014–2020.

Considering that energy consumption in schools is the second highest expenditure of municipalities' total running costs, this sector has a high potential for energy optimization and offers potentially remarkable achievements in terms of energy efficiency and the integration of renewable energy sources (RES) and carbon footprint reduction [1].

The RAEE 2015 (Enea, 2015) report shows that in Italy there are 51,000 buildings for exclusive or prevalent educational use, covering a total surface of 73.2 million m^2 and a volume of 256.4 million m^3 [2, 3].

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Table 42.1 Potential reduction of energy consumption to 2020 across different type of civil buildings, 2014–2020 *(source: Energy Efficiency National Plan—PAE 2014)*

Tipologia edificio	Superficie soggetta annualmente ad intervento (m^2)	Risparmio energetico totale al 2020 (GWh/anno)	Risparmio energetico totale al 2020 (Mtep/anno)
Uffici Privati	2.880.000	2.858	0.25
Uffici Pubblici	2.640.000	3.881	0.33
Alberghi	1.425.000	1.167	0.10
Scuole Private	1.000.000	617	0.05
Scuole Pubbliche	4.950.000	5.821	0.50
Banche	782.811	726	0.06
Centri commerciali	2.289.163	2.159	0.19
Totale	15.966.974	17.229	1.49
Fonte: Piano d'Azione per I'Efficienza Energetica 2014			

The 2014 Energy Efficiency National Plan (PAE 2014) states that for Public Administrations the reduction of primary energy consumption until 2020 is estimated around 0.8 Mtoe, corresponding to 0.57 Mtoe of final energy consumption [4, 5]. In particular, with reference to public building stock with energy consumption 50% higher than the reference benchmark, Table 42.1 shows the potential for reducing consumption to 2020 across different type of civil buildings. Thus, taking into account different types of retrofit measures on building envelope and plats (thermal and electric), the expected energy saving potential for public schools is about 5.821 GWh/year, equivalent to about 0.5 Mtep/year.

In accordance with many international research projects (*Energy@School-Interreg 2016–2019, Teenergy Schools 2007–2013, School of the Future 2011–2016*) and national studies [6–9] on energy-efficient retrofitting in educational buildings, several methodologies for the energy audit of schools have been developed providing advice on energy-efficient retrofit measures, for use of government and local administration's decision makers.

Public buildings energy performance, should be assessed taking into account not only energy and environmental implications but also economic resources needed by municipalities to realized the retrofit measures [10].

The knowledge of the building energy performance through effective energy assessment methodologies requires strong efforts but is necessary to identify the building weaknesses and to provide a set of suitable retrofit solutions aimed at improving the building energy efficiency [11].

Energy Audit Procedure for School Buildings

As cases of study three energy audits are carried out on public buildings of the Municipality of Florence: two secondary schools, the Giosuè Carducci School, the Giuseppe Verdi School, and a small gym in the San Niccolò district. The University of Florence in collaboration with the Municipality of Florence, which provided all the technical documentation [12], coordinated the activity.

In accordance with Legislative Decree 102/2014, transposition of the European Directive 2012/27/EU, the Municipality of Florence, as Public Administration, has the obligation to play an exemplary role in containing and limiting energy consumption and waste through interventions by energy requalification [13–19].

The Municipality of Florence has made the audits with the following purpose:

- Measuring the overall energy and environmental performance of the building
- Increasing internal comfort for occupants
- Developing an investment plan in order to improve the energy class
- Reducing the costs of energy bills
- Providing access to various kinds of public funding and/or benefits (fiscal, financial, etc.)

Considering UNI EN 16247-4 and current legislation, the procedure of energy auditing started from the collection of real data on building technologies, operation, climate, and energy consumption. A tailored analysis of real energy consumption was performed to choose a set of feasible retrofit actions for energy efficiency based on benefits and costs evaluation, considering both the building envelope and the plants. The simulation software used was Energy Plus with Design Builder, which maximize the modeling data process to compare the energy consumption and comfort parameters of the buildings, the levels of natural and artificial daylighting, and the performance of the materials adopted.

Input data collected for energy audit concern:

- The site and climate data
- Building dimensions (floor area, volume, numbers of floors, etc.)
- Opaque and transparent building envelope information (type, characteristics, thermal properties, etc.)
- Operational data on occupancy (total number of occupants, daily operational hours)
- Electric equipment and lighting uses (type, number, days of use per week, etc.)
- Annual utility Consumption (electricity, gas, water)
- Heating, ventilation, and air conditioning systems information and technical data
- Availability of detailed information (e.g., projects, technical reports, specific analyses, and audit purpose)

The retrofit measures proposed for the three buildings focus on exterior walls renovation by thermal insulation application, glazing and thermal bridges improvement as the most effective way to prevent heat losses and to reduce energy consumption for heating and cooling. Other solutions concerned the temperature control by means of automation on the heating plant, new lighting system with LED technology and integrated RES.

Case Studies

Energy Audit of the Carducci Secondary School in Florence

Secondary School G. Carducci diagnosis is the evidence of the great wall and windows dispersion that give a lot of energy consumption.

After starting collecting data on actual consumption and related energy costs at normal use, inspections and surveys were conducted on the building and particular solutions for energy improvement were proposed. From the data analysis, it emerges how the energy is used, and what produce the biggest energy losses and which are the best solutions to solve the problem and get improvements.

A preliminary technical feasibility for energy retrofitting was carried out on the basis of the economic improvement in order to evaluate the cost-benefit analysis and the optimization for energy primary consumption [1].

The goal is not only to contain costs, but also to improve the student and occupants comfort conditions.

The audit carried out uses an energy model in compliance with UNI EN 16247-4 part legislation, whose validation is performed through appropriate adjustment factors: real climate data in comparison with the real use of the building. The audit report consists of a summary section of results and analysis carried out, calculations, and retail evaluations (Figs. 42.1 and 42.2).

The audit has produced the following documentation:

- Characterization of the asset of the building, according to its historical construction, dimensional and technical data
- Plan construction analysis and technological aspects of energy consumption
- Technical audits on the building asset in order to objectively verify the data acquired in the previous; phases data processing and validation
- Issues of the audit report and final meeting

Fig. 42.1 Carducci secondary school in Florence

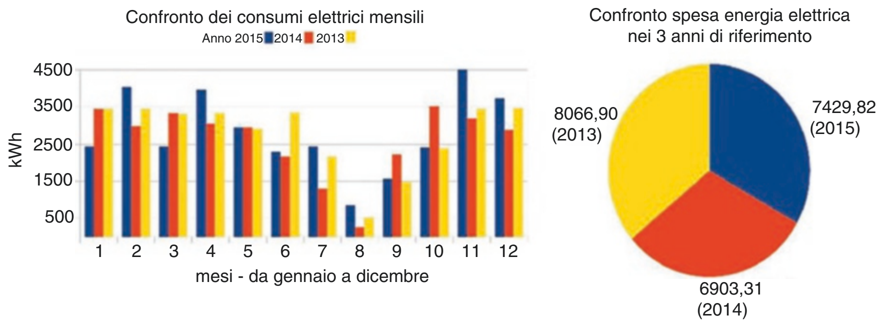


Fig. 42.2 Electric energy consumption analysis over 3 years (2013–2015)

The choice of interventions depends on the state of conservation of the building, on the energy saving that can be achieved, and above all on the economic availability and capacity to raise funds. As a result of daylight analysis, interventions on technological components and plant components have been proposed considering the following aspects:

- The type and prevalent position of the emission systems and the type of regulation
- For single heated volume, by area and for the whole building (presence of valves thermostats, climate control by zone, etc.)
- Check the type of distribution for heating (vertical and horizontal), and the presence or not the presence of insulation on pipes and their condition
- Check of the characteristics and data of the heat generator, as well as its status of conservation
- The operating mode of the plants (continuous, intermittent, or attenuated), with identification of the continuous one during the teaching activity time

To save energy during the winter season, for the heating system the energy audit suggests the introduction of thermostatic valves in order to keep the room temperature at a fixed value, avoiding unwanted thermal increases. The temperature is controlled room by room considering different exposures to benefit from solar gains during winter. By means of this solution it is possible to achieve an energy saving of 15%. An external temperature probe installed on the north wall of the building allows managing the heating system, so the heat generator turns on when the outdoor temperature drops below the set point.

Lighting has a particular impact on school energy consumption. The entire group of lighting equipment consists of neon tubes of various sizes installed on the ceiling. The greater use of artificial light is between 8.00 a.m. and 2.00 p.m. All the lighting sources have been replaced with LEDs using timers and moving sensors to automate the light switch in the bathrooms.

To reduce artificial lighting requirements and for PC workstations and IWB (interactive whiteboard) in all classrooms of the school building automatic switching and regulation of the luminous flux was used. The payback period for these solutions has been estimated at 6 years.

Energy Audit of the San Niccolò Gym in Florence

San Niccolò Gym is located in the central district of "San Niccolò" and is a property of the Municipality of Florence. This historical building was renovated only once in the 1990s and it consists of two floors above ground, including two housing units, one of which is a municipality office and the other is a double-height space used as a gym.

This audit is aimed at:

- Detecting the energy consumption of the building by analysis of bills and final costs
- Obtaining an energy consumption profile during a year (W/m^2)
- Identifying the heat losses through the building envelope
- Identifying energy losses due to the plant systems
- Identifying opportunities for energy saving considering both the building envelope and the plants
- Quantifying energy savings in terms of costs and benefits ratio

As in the previous work, first it was performed a climate analysis of the site, and then a detailed analysis of the building considering both architectural and technological aspects related to building envelope and plants, to propose alternative energy saving scenarios for budget compliance imposed by the Municipality of Florence.

The building envelope is 45 cm thick masonry not thermally insulated. On the outside, the front facing on street is covered with ashlar stone, while on the backside is covered with yellow plaster.

During the building inspection, it was noted that:

- In the office area, the radiators are positioned under the windows and the wall thickness is reduced.
- The roof is sloped and non-insulated.
- There are no shields or overhangs to reduce solar gains during summer.
- In the office area windows are 3 mm single glass with a wooden frame.
- In the gym there are some windows with single glass and iron frame and others with simple glass and wooden frame.
- Considering the occupancy profile, the gym is used daily from 7:00 a.m. to 11:00 p.m., Monday to Saturday.

The analysis of real consumption has been based on an accurate survey of the devices that consume thermal and electrical energy, considering the real use scheduled in the building. Consumption has therefore been calculated on the basis of time of presumed use of each of them, or at the time of use verified, as in the case of the heating system that has fixed and established times in both areas of the building envelope.

Once this calculation was made, the simulated data were compared with the actual consumption obtained from the bills for the last three years. As for the electrical system, analyzing the data detected, the hours of use by the user were first considered.

The estimated power relating to heating terminals is about 56 kW (48 kW belong to the gym, and only 8 kW to the offices). For this reason, the greater attention, in carrying out the energy analysis, has been placed right on the first element.

The daily use coefficient and the annual use coefficient allowed to define the consumption of each device considering the total hours of use per year. Also, the occupancy profile has been defined considering that the gym is open for 16 h a day, 276 days per year, while the offices are occupied for 7 h a day. The second phase of the study included a qualitative analysis of the results deriving from the survey of occupancy satisfaction in order to comfort indoor.

In addition, by means of infrared thermographic analysis, some critical issues have been shown, for example, the thermal losses due to the position of radiators under the windows, where the wall thickness is smaller than that of the exterior wall. Therefore, near these areas thermography shows great heat losses. As retrofit measures, in this case it has been suggested to install insulation panels of reflective material to limit thermal losses through the exterior wall. In addition, other measures suggested providing the heating plant of a regulation system by means of thermostatic valves (Fig. 42.3).

With reference to the actual costs for energy consumption per year derived, the energy saving from both these retrofit measures is 4% for insulation panels and 11% for thermostatic valves, respectively, despite payback time of 10 years; these solutions are however advisable to increase the comfort indoor.

For lighting, both inside and outside the gym (in the external courtyard), it has been suggested to replace all lighting devices with high efficiency LEDs. Through a cost-benefit analysis, this solution may produce an energy saving of almost 1000 euros per year with a payback time of fewer than 2 years.

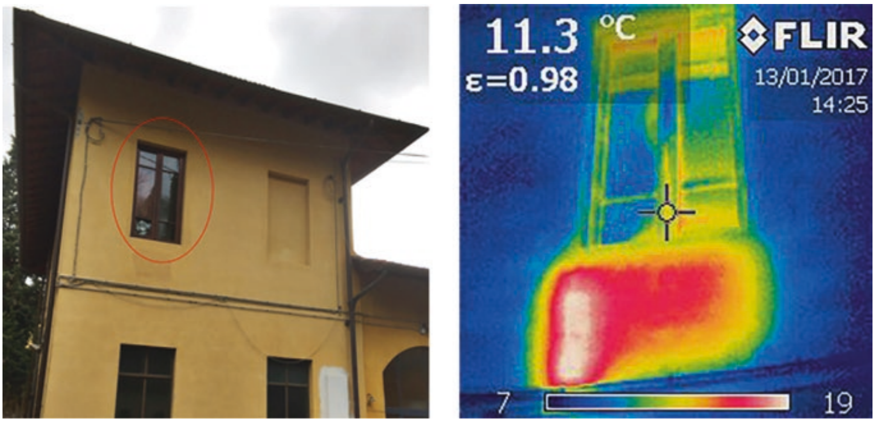


Fig. 42.3 Infrared thermography analysis shows the thermal losses due to the position of radiators under the window

Energy Audit of the Giuseppe Verdi Secondary School in Florence

The school building was built in the 1970s in the north of Florence surrounded by green areas and trees that avoid summer overheating. The different areas of the building are positioned around a central courtyard: the teaching room, classrooms, services, gym, and an auditorium are located at the ground floor, while on the first floor there are classrooms, laboratories for afternoon activities, services, and school offices. The building has also an unconditioned underground.

All data concerning the building construction and plant systems were derived from technical documents of the building and during surveys. The structure is in concrete, the building envelope is in brick walls with not insulated air cavity and single glazing windows with metal frame without solar shading devices.

A gas standard heat generator is installed in the building and the heat distribution consists of radiators, located on the walls facing outdoor of each room. The auditorium and the gym are equipped with two different mechanical ventilation systems. The building is not provided with cooling systems. The most used lighting devices are fluorescent lamps.

Hot water is provided from two boilers, one located in the underground and the other on the roof for hot water supply during summertime. Hourly occupancy weekly profiles were derived from surveys and documents providing information about the number of students and school staff, considering different activities for each room category.

The real consumption data of natural gas for space heating and electricity over 3 years (2015–2017) was derived from energy bills. In particular, the electricity and thermal total consumption, referring to the year 2015, amounted at around 50,000 euros (Fig. 42.4).

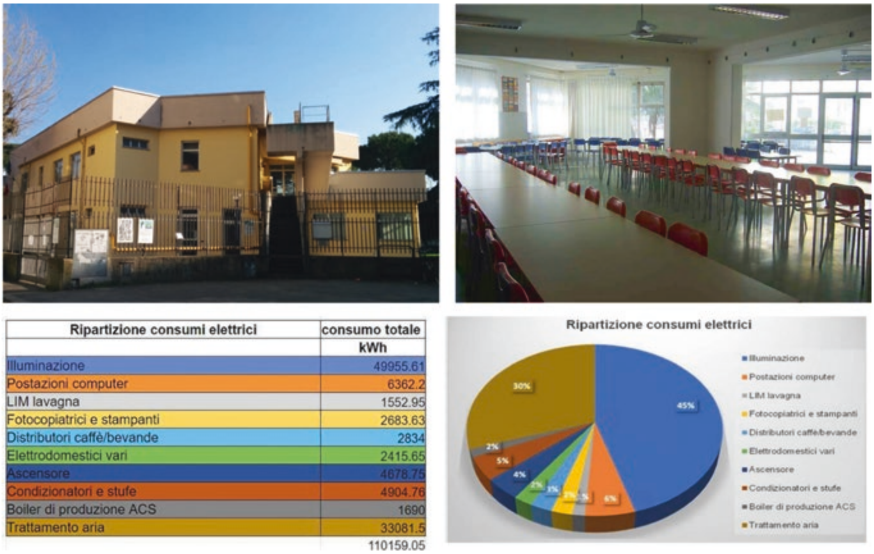
Detailed analysis of final use of energy has shown that the largest consumption is attributable to the lighting system (45%). It was proposed that the substitution of the lighting devices with high efficiency LED lamps obtains annual energy savings in terms of costs of about 5200 euro and a payback time of 4 years.

Another solution takes into account the use of thermostatic valves heat meters to regulate the indoor temperature depending on the real heating energy demand.

On the other hand, the heat meters allow the user to adjust the indoor temperature and to monitor the effective energy consumption in each zone.

In the specific case of this school, for example, the temperature probe was positioned in the entrance hall, so in the classrooms with different volumes and internal gains, the air temperature was always higher than the real needs with high energy consumption.

Considering the national financial incentives available for energy retrofit of public buildings of public administration entities—*Conto termico 2.0*—it was proposed to replace existing windows with double glazing windows and thermally insulated frame in all the classrooms and with a total cost of 27,000 euros, with payback times under 12–13 years.



Ripartizione consumi elettrici	consumo totale kWh
Illuminazione	49955.61
Postazioni computer	6362.2
LIM lavagna	1552.95
Fotocopiatrici e stampanti	2683.63
Distributori caffè/bevande	2834
Elettrodomestici vari	2415.65
Ascensore	4678.75
Condizionatori e stufe	4904.76
Boiler di produzione ACS	1690
Trattamento aria	33081.5
	110159.05

Fig. 42.4 Giuseppe Verdi secondary school in Florence (above); electric energy consumption divided by uses (below)

Conclusion

This work shows a simple approach to the energy audit based on a tailored analysis in order to set feasible retrofit actions for energy efficiency based on benefits and costs evaluation, considering both the building envelope and the plants. The aim is to propose a procedure that allows to meet the current law requirements on energy efficiency and to provide local authorities with new technical retrofit solutions, as well as to assess the economic feasibility. The innovative approach consists of developing a digital toolkit to support auditors to implement auditing activities on public buildings, with special reference to schools and to address retrofit actions to improve energy efficiency both of envelope and plants.

In particular, three public buildings with low energy performance were analyzed belonging to the Municipality of Florence, hosting educational activities.

All the studies have been carried out with reference to the standardized method reported in UNI CEI EN 16247-1:2012 in order to provide a correct building energy diagnosis.

Retrofit actions were detected after the collection of information on building and plants, infrared thermography analysis, while real consumptions were derived from energy bills and interviews and surveys to the occupants.

Among the cases analyzed, the proposed solutions focused on: (1) exterior walls renovation by thermal insulation application; (2) glazing and thermal bridges improvement; and (3) building automation system to control heating and/or lighting system.

A financial analysis was performed on different energy efficiency measures based on payback period comparison and their economic feasibility was evaluated considering benefits and costs ratio. The priority must be given to solutions that will reduce the consumption in buildings taking into account the technical and economic feasibility, considering national public financing program to increase the energy efficiency of the Italian building stock.

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Chapter 43
Fallacies and Misunderstandings About Global Warming

Don Swift-Hook

Introduction

Global warming is an emotive subject. Those who question its theoretical basis are accused of being "in denial" and there is of course no experimental basis. There are many fallacies abounding in the subject and this paper will point out a number of them.

The reports produced by the United Nations Intergovernmental Panel on Climate Change are the most authoritative summaries of the scientific work available. The most recent IPCC Report appeared in 2014 and the next major report by the IPCC is due in 2022. Many of the misunderstandings about global warming arise because the IPCC reports are misused or ignored.

The Cessation of Global Warming

Probably the most glaring fallacy concerns ongoing global warming itself. Ironically, the most recent IPCC Report in 2014 showed that global warming was not ongoing but had in fact ceased. The global temperature peaked in 1998, the year following the Kyoto Agreement (1997) and showed no signs of an increase after that, see Fig. 43.1. It was a fallacy to suggest that global warming was ongoing after Kyoto (Fallacy 1). This levelling off in temperature was referred to as a "hiatus" in the belief that global warming would continue at some time in the future but there is still no explanation of this stand-still phenomenon following the pre-Kyoto rise

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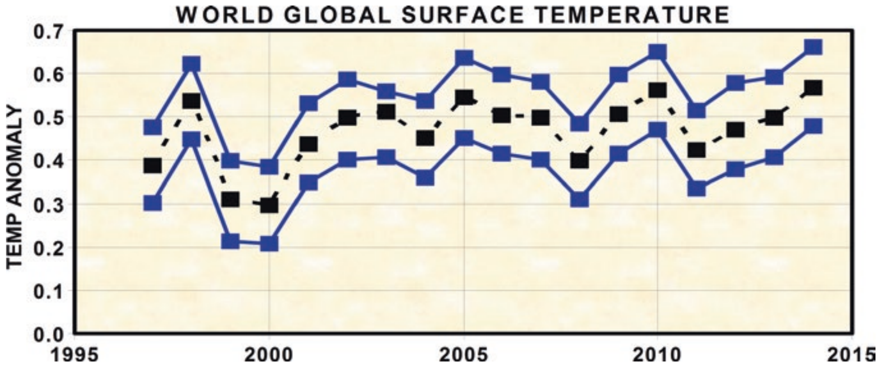

Fig. 43.1 There was a hiatus in the rise of global surface temperatures after Kyoto 1997

from 1980 to 1998. A hiatus is not predicted or explained by any of the models which are used to predict global warming.

It is interesting to note the response of the global warming community to this good news. The cessation of global warming should surely have been widely welcomed even if it proves to be only temporary. Instead, it has been widely ignored. However, the designation "climate change" is now used far more often than "global warming" and this is sensible because there isn't any.

In more recent years since 2014, some higher global temperatures have been recorded. These may well indicate a resumption of global warming but it is far too early to tell. The next major report by the IPCC is not due until 2022 and measurements since 2014 will need to be reviewed, confirmed and approved in that new report to achieve the same weight as those shown in the 2014 Report in Fig. 43.1, which are backed by the whole weight of the IPCC.

It should not be necessary (but it is) to say what global warming means. Global warming is an increase in the global temperature.

Some enthusiasts, when faced with this hiatus, assert that global warming is a process that was continuing steadily despite the fact that the global temperature was not changing significantly. Such doublespeak, altering the meanings of words, should have no place in sensible scientific discussions of the subject.

However, the global temperature needs to be clearly identified and there is no global thermometer that we can point to which measures the global temperature. There are many meteorological stations around the world, including satellites, whose data is collected by two principal organisations, NASA in the USA and the Meteorological Office in the United Kingdom. The Americans are regarded as the experts when it comes to satellite measurements of surface temperatures while the British have a history of collecting data from meteorological stations all round the globe, often in remote locations, dating back to the time when they had "an Empire upon which the sun never set".

The meteorological data is sent back to these two organisations who average it spatially (around the globe) and temporarily, i.e. time-wise (annually) to arrive at a single figure which is effectively jointly agreed and published. That is the only meaningful global temperature. Everybody has to use the same one and it is the one used by the IPCC.

Attempts are often made to use temperatures averaged over different regions or periods, for example, Arctic or desert areas. It cannot be emphasised too strongly that such alternative temperatures cannot be firmly relied upon and certainly such work cannot carry the same weight as that published by the IPCC.

Fossil Fuels Are Not Yet Running Out

During the lifetime of a fuel there is a long build-up period leading to peak production and then a fall off period when the fuel is running out. It makes little sense to suggest that a fuel is running out from the very beginning of its use; that would be as misleading as saying that a newborn baby with a life expectancy of 80 years is dying from the day it is born.

It is often asserted that fossil fuels are running out. This may or may not be true for oil but it is certainly not for coal or gas.

There is enough coal for 500 years or, to be more precise, the world's coal reserves are 500 times our annual consumption. There is enough gas for 300 years or, to be more precise, the frackable reserves of gas are 300 times our annual consumption (although, to be fair, what rocks are frackable are not so clearly defined).

There is some uncertainty about when oil will reach its peak production and will start to run out (if it has not already done so) but there is no doubt at all that coal and gas both have very long ways to go before they need reach their peaks and start running out. To suggest that they are already doing so is a fallacy (Fallacy 2).

To consider what 300 years of reserves imply it is helpful to think back 300 years in history to around the year 1700 and to imagine how useful and how accurate 300 year forward projections then of resources would have been. Quite evidently useless and inaccurate are.

Renewables Are to Save Fuel

It is often mistakenly said that renewable energy is necessary because fossil fuels are running out (Fallacy 3). That is obviously incorrect, since they are not. However, renewables are indeed to save and replace fuel. There may be plenty of fuel around the world but it is not uniformly distributed and those countries lacking their own indigenous sources of fuel welcome renewable energy when it is freely available. At the same time, the biggest fuel producers have the biggest interest in saving or replacing fuel by installing renewables when renewables are cheaper than fossil fuels.

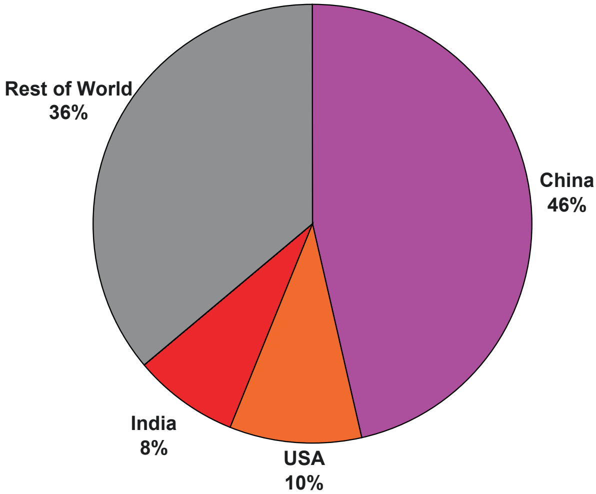

Fig. 43.2 The world's coal production 2017. China, the USA and India between them produce nearly two-thirds of the world's coal

It is no accident that the world's major coal producers are also the world's leading wind farmers. Figure 43.2 shows that China, the USA, and India between them produce nearly two-thirds of the world's coal while Fig. 43.3 shows that between them they have more than half of the world's wind capacity. The biggest coal producers have the biggest interest in saving or replacing coal by installing wind.

The Relentless Increase in Power Consumption Has Come to an End

Power generation is a major source of the greenhouse gases that are thought to cause global warming. Ever since power systems were invented, all countries have experienced a steady increase in their power consumption. This increase has seemed to be relentless and inexorable as civilisation expands. Indeed, power consumption has often been regarded as a surrogate for economic development and standard of living. It is with a great deal of surprise that many people discover that electrical power consumption and, indeed, the consumption of energy as a whole have been falling for many years in many countries.

In the UK, peak power consumption of 62 GW was reached in 2005 and it had fallen by 20% to 50.4 GW in January 2018. Primary energy consumption is also falling: it is down 10% since 2000 and is back below the level that it was half a century ago.

Clearly, the supposedly relentless increase in power consumption has come to an end and is no longer inexorable (Fallacy 4). One of the implications of this for

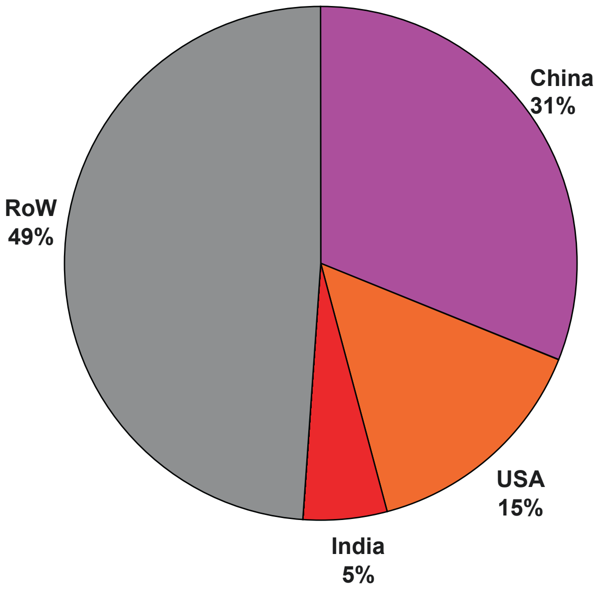

Fig. 43.3 The world's wind farmers 2017. China, the USA and India between them have more half of the world's wind capacity

global warming is that we can expect the causes, e.g. the emission of greenhouse gases, to be reduced correspondingly, quite apart from any more positive action that may be taken.

Subsidies Are Withdrawn When Wind and Solar Are the Cheapest

In recent years, the prices of wind turbines and photovoltaic panels have fallen dramatically. Solar prices have halved in the last two years. These two technologies are now the cheapest available in many countries, cheaper than gas turbines and coal-fired plant. There is more wind and solar capacity being installed today than any other type of power plant. This has led to many misunderstandings. For example, when wind and solar are the cheapest type of generation it is no longer necessary or appropriate to subsidise them in order to encourage their use. Governments therefore are widely withdrawing their subsidies. The media frequently misinterpret this and report that governments no longer favour wind or solar (Fallacy 5) when the reverse is true and governments are recognising that wind and solar are the cheapest methods of generation available and are economic in their own right without subsidies.

Fig. 43.4 A blade of the 12 MW Haliade-X wind turbine being built by GE

Most Solar Power Is Now on an Industrial Scale

Most wind power has always been on an industrial scale with wind farms comprising many wind turbines, which in turn have each always been sizeable and can now be described as gigantic. The latest 12 MW machine has blades 107 m in length, see Fig. 43.4.

In past years, the development of solar power has concentrated upon domestic installations, such as that shown in Fig. 43.5. A good deal of the technical discussion still focuses on the problems of installing solar panels on rooftops, even though there are no longer any feed-in tariff subsidies. This is misleading (Fallacy 7), when the vast majority of panels nowadays are being installed in solar farms on an industrial scale such as the 50 MW Shotwick Solar Park on Deeside in North Wales shown in Fig. 43.6.

PV Solar Power Cannot be Stored (Economically, on a Power System)

Most domestic electricity installations are mains connected. When PV solar power is not mains connected, storage is often provided in the form of a battery. Figure 43.7 shows a typical device, a garden light which can stand alone, with no mains connection, wherever sunlight is available. Other examples of devices that are in remote locations or mobile include repeaters across sparsely inhabited countryside, buoys tethered offshore and satellites, see Fig. 43.8. A mains connection would make storage unnecessary and uneconomic.

Fig. 43.5 A typical domestic solar installation

Fig. 43.6 The 50 MW Shotwick Solar Park

It is sometimes asserted that it would be valuable to install a battery alongside a PV solar domestic installation. There are even examples of electrical utilities encouraging their customers to do so. This is quite wrong (Fallacy 8).

To be economic, a store on a power system must buy electrical energy when it is cheap and sell it when it is dear. This means it must buy electricity at night and sell

Fig. 43.7 A stand-alone garden lantern with no mains connection needs battery storage

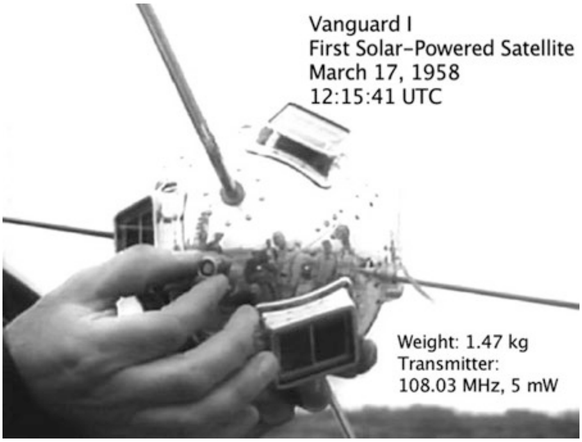

Fig. 43.8 A battery is needed when mains connection is not possible for a mobile device

it during the day. There is no sunshine at night—by definition—and so an economic store on a power system cannot buy solar power. This means that PV solar power cannot be stored—economically if it is mains connected.

Intermittent Wind

Wind is intermittent and it is often asserted that storage would be valuable to convert it to baseload, operating continuously. It would not (Fallacy 8). There are actually two fallacies here. At times of baseload, when the minimum amount of power needs to be generated, the largest amounts of plant are standing idle, waiting to be called upon. The value of providing more generation to stand idle at such a time is negligible.

Also the cost of storing wind power would be prohibitive. The wind frequently blows for up to 10 days at a time (and frequently ceases for up to 10 days) as a weather front passes. To provide storage capacity for such lengthy periods, a store would cost 20 times as much as current energy storage which is typically from night to day. This would make it hopelessly uneconomic.

So to convert wind power to baseload would cost too much for the store and the extra baseload is worthless (Fallacy 8).

Conclusions

These fallacies are false for the reasons given:

Fallacy 1	*Global warming was on-going after Kyoto.*
	It was not; there was a hiatus in temperature rise.
Fallacy 2	*Fossil fuels are running out.*
	Oil may be but there is enough coal for 500 years and gas for 300 years.
Fallacy 3	*Renewables are necessary because fossil fuels are running out.*
	Renewables are not necessary but they are the cheapest.
Fallacy 4	*The relentless increase in power consumption, e.g. in the UK is inexorable.*
	Maximum electricity demand in the UK has decreased 20% since 2005.
Fallacy 5	*Withdrawing subsidies mean that wind and solar are out of favour.*
	Far from it; withdrawing subsidies means they are the cheapest.
Fallacy 6	*Most solar panels are on domestic roof-tops.*
	No longer; most PV solar is now industrial scale.
Fallacy 7	*Battery storage is valuable for domestic solar power.*
	A commercial store must buy cheap power at night when there is no sun.
Fallacy 8	*Storage can convert intermittent wind to baseload.*
	Storing wind would cost too much and extra baseload is worthless.

Chapter 44
Building Beauty: A New Program Teaching Students to Help Heal the World

Yodan Rofè, Sergio Porta, Susan Ingham, Christopher R. Andrews, Or Ettlinger, Paolo Robazza, and Maggie Moore Alexander

> *What it would be like to live in a mental world where one's reasons for making something functionally, and one's reasons for making something a certain shape, or in a certain ornamental way are coming from precisely the same place in you. Precisely the same place.*
>
> Christopher Alexander [1]

Introduction

In order to be sustainable, buildings and places have to be cared for and loved over generations. Beautiful buildings and places are more likely to be loved, and they become more beautiful, and loved, through the attention given to them over time. Beauty is therefore, not a luxury, or an option, it is a necessary requirement for a truly sustainable culture.

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The Building Beauty Program of architecture was founded in 2017–2018. It is a program dedicated to teaching architects to be able once again to create life, beauty, and wholeness in the world, based on the theory and practice developed by Christopher Alexander. The fundamentals of this theory are the unity of geometry and function, and the importance of the act of making in the process of building beauty in the world.

The president of the program is Maggie Moore Alexander, and its international director is Sergio Porta, Professor of Architecture and Urban Design at Strathclyde University in Glasgow. The course director in Sant'Anna is the lead author of this paper. It has a faculty of over 15 professionals and academics from throughout the world, and includes support staff of local craftspeople that guide the students in construction and making. The program has attracted students from all over the world, women and men, young students, as well as experienced professionals. It is open to anyone who has a bachelor's degree in design disciplines or related fields, has completed three years of a 5 year program in architecture, or can demonstrate equivalent working/professional experience.

The program is located in the Sant'Anna Institute in Sorrento, Italy. A former convent and school, the institute is dedicated to Italian language and culture education for students abroad, and language teaching to local people of all ages. It also hosts, for the past 10 years, a study abroad semester of the architecture program at Alfred State College in the US. The Sant'Anna Institute, and its garden in particular, is the main learning site of the program. The aim of Building Beauty is to transform the garden over the years into a place of beauty and repose—and a resource to the learning community of the institute.

This paper describes the founding principles and curriculum of the program, the process of learning that takes the students from the beauty of small objects and learning about self to larger ensembles, and the engagement with community. It briefly describes the planning process for the garden, and the projects built by the students to date. It concludes with a summary of achievements so far and the challenges awaiting the program, and with a call to join us in reforming architectural education for our time.

Founding Principles and Curriculum

Building Beauty is based on 13 principles, encapsulating Alexander's teachings, theory, and practice while developing and adapting them to today's challenges. The curriculum is based on three main activities: designing and building in the

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real world, self and community and their embodiment in space, and seminars extending both theoretical underpinnings of practice and learning and mastering new tools for practice.

1. Beauty—The Building Beauty program is based on a belief that there exists in the natural, cultural, and physical world a class of phenomena that are beautiful. This beauty is essentially a part of our everyday material and spiritual life. The aim of the program is to understand what characterizes these phenomena, how they occur and change, and, as makers, how to be able to help bring them into this world.
2. Cosmology—The context in which we approach problems and develop solutions embraces complexity, uncertainty, and rapid change that are ever more prevalent in our world. We explore a nonconventional agenda in education and research which poses making beauty and its generative process center stage.
3. Ordinary, minute functionalism—We acknowledge that life takes place by continuously adapting the surrounding environment in an uninterrupted everyday process of adaptation. We intend making as an adaptive process of change that predominantly occurs in the dimension of the ordinary.
4. Objective nature of beauty—Beautiful ordinary spaces have a quality whose value, once explored appropriately, belongs to all human beings, and is good for everyone. Because that quality exists, makers can, at each step in the process of making, add to and expand—rather than detract and reduce—the original quality.
5. Holistic nature of space—Space is essentially grounded in our individual and collective self, where functionality, ornament, and beauty are just different names for the same thing. We explore our individual and collective self in space as a fundamental way to understanding how to make things and changes in space itself.
6. Quality of space before function—Beauty emerges, in the physical world, as an inner order that is spatial in nature. Functionality, and the sense of belonging and wellness, are both by-products of the same order. We focus on ordering space as it occurs in the phenomena of beauty: what is it made of? And how can we help it to emerge and expand over time?
7. Testing the quality—The quality of space can be tested through understanding the authentic feelings that connect us to place and to others in a profound way. We pursue the ability to recognize, trust, and develop our own feelings as a reliable measure for testing the quality of space.
8. Making with exquisite care—The quality of spaces does not come from design. It can only emerge during the process of making. We experience beauty in space when we perceive that everything around us has risen from careful choice based on consideration of both the place and our own self. We are interested in the process of fine-tuning that creates a place, both in the making of a small-scale object or project, and in the evolution of settlements and monuments.
9. The unfolding nature of beauty generation—Making beauty is essentially a process of adaptive transformation which happens in steps whereby each step

expands the preexistent beauty, and in itself, is complete and makes full sense. We test and explore this unfolding nature both in the process of making, and in teaching how to make.

10. Making beauty is healing—Reunifying what was previously separated is central to the process—in space, in communities, and in ourselves as citizens and makers. Conventional separations (between actors, places, and times of decision) are overcome and unified at each step in a fully integrated healed whole. We explore how to reunify self and community, design and construction at each step of the process of making.
11. The reality of the land and in ourselves—Making has to do with understanding the order of space existing on the land, and the order in what we wish to make (existent in ourselves), and then with unifying the two in one coherent whole. We investigate the means to make such orders explicit and knowable, and find ways to reinforce each other.
12. Mocking up—In a conventional building process the means for creating separations are drawings. People make decisions, separately, by looking at drawings. We use drawings as an integral part of making which is a physical, on-site, trial and error process based on using scale models of various sorts and full-scale physical mock-ups. We practice and teach full-scale mocking up as the core way for decision making in the building process.
13. Integrated design and construction—Direct hands-on building is essential to making. That is where and when everything happens. The building yard and the actual act of construction are the place and the moment where the healing reunification of space can occur. We practice and teach direct construction as the all-encompassing environment of making.

Curriculum

The curriculum incorporates these principles in three main areas of study. The first one is design, construction, and cultivation, where the main focus is on the actual making of beauty in the world at all scales, with the goal of healing the earth. It includes both a planning and design studio, and learning actual making and building. The second area of studies is learning about self, community, and space through land exploration, feeling maps [2], exploring the visions of oneself and others, and developing pattern and project languages—word pictures that combine the understanding of the land with the wishes and desires of people connected with the project. The third area of study are theoretical and practical seminars designed to give students the theoretical understanding and tools necessary to carry out the above two tasks.

The integrated approach to design and construction pervades the two major courses in the program: the Design and Construction Studio, and the Construction Skills class. In these two classes the students learn the necessary skills to do construction and detail work, and appreciate the minute organization of space necessary to create deep feeling. They also confront practical problems of spatial organization. The course concludes with a ten day summer school dedicated to learn and practice a traditional or low-energy technology building technique.

The self, community, and space aspect of the program is intensively explored through the first phase of the Design and Construction Studio, when students concentrate on designing and making personal objects. It is also explored in exercises accompanying the Nature of Order seminar (see below), in the mapping of centers and feelings, as well as in the visions of members of the community with regards to the garden. Gradually, students understand that learning to notice their own feelings, and how they react to space, are the most important tools at their disposal in making decisions, while progressing in a design or during the development of details of construction.

Accompanying the learning process is the major theoretical subject in the program—a reading seminar of Alexander's The Nature of Order series of books [3]. The readings, and exercises done to enhance and practice the concepts learned, are intended to introduce to the students a different way of looking at space, and the world. They act as both a guide to, and a commentary on, the work they are doing in the design studio and in making and building. In the first semester, the students take turns introducing the chapters, and a discussion or short exercises are done to practice and get acquainted with the concepts learned: wholeness, life, centers, the 15 properties of the field of centers, deep feeling, the mirror of the self, the importance of an unfolding process as a means to create life, structure preserving transformations, and how feeling guides the process. In the second semester, former students of Alexander, as well as other practitioners, lecture on their own experiences and ways of implementing these ideas through their work, and on the cosmological, emotional and intellectual meaning of Alexander's work. This allows the students an opportunity to see how these ideas can actually influence practice in different contexts, and the plurality of approaches to their interpretation. This year, we opened the seminar as a webinar, and we've had about 15 people from throughout the world joining us in the discussions.

The students also take part in three courses given by high level academics and professionals from around the world. The course on analysis and design of places and settlements is intended to give the students basic tools in analyzing urban space, in order to understand better the urban context of Sorrento, as well as to gain some tools of analysis and application of complex order in the urban environment. It includes modules on observation, documentation, and analysis of streets and urban places [4]; an introduction to urban morphology [5]; basics of network analysis of urban space [6]; the codes, patterns, and rules that are at the basis of the urban environment in the Mediterranean basin [7]; and a class on ecology, resilience and urban form [8].

The second course is complexity and order in the built environment. This course is intended to give students a broader understanding on complexity and order in other sciences and how these concepts are applied to the study of the built environment. It includes modules on the systems view of life [9], complex networks, space and centrality [10], the new science of cities [11, 12] and complexity in architectural theory [13].

The third course discusses practice and ethics. It includes several modules intended to broaden the students' horizons and discuss either the application of similar principles in other fields, or issues relevant to the ethics and practice of architecture when building beauty is its overriding aim. The course includes modules on working with communities [14], Building Beauty in digital space [15], developing ethical architects, and designing cognitive spaces [16].

Process of Learning

The learning process follows two paths of growth during the year: from the design and making of an ornament to intervening in larger spaces such as a garden or the city, and from understanding of self to the exploration of community.

Ornament: The Design of Objects

The year starts with the design and making of ornaments—objects whose only function is to be beautiful and to please their makers and the people who observe them. The students work on ceramic vessels and tiles, and learn about and design replicas of Anatolian carpets. The objective is to make something beautiful that comes from their soul, and is pleasing to them. In creating a tile panel, they also begin the work of merging together their own selves with those of others (Fig. 44.1). In designing carpets based on ancient Anatolian designs, they learn to understand the geometrical designs and centers on the basis of which Alexander began developing his theory of order [17–19]. They also take part in an ongoing project which intends to replace the original carpets found today in Transylvanian Lutheran Churches with replicas produced by similar methods, so as to enable the conservation of the originals in a museum.

Fig. 44.1 Ceramic panels produced by the students with Master craftsman Pasquale Liguori 2017 (left) and 2018 (right)

Home: A Personal Building

The second project done by the students is the design of their own homes on a particular site. In this project they are called upon to define 5–7 "jewels," which are particularly strong centers that define their home, and which give it its emotional power. The process of design is carried out mostly on-site, by locating the centers and staking them out. On the basis of this stakeout plan, the students create their plan, and develop it in several physical models and simulations. They make a small-scale 1:200 model or images of the context in order to examine their homes in their context, and a larger 1:50 model to start thinking about the building's structure, and how it orders, solidifies, and further defines the "jewels." The whole project is still deeply personal—but the students have to consider space also from a practical and functional point of view. From this project an understanding should emerge that, in the end, the geometry of the building defines both its beauty as well as its functionality. This project was also used as the basis for the Home Event led by Arch. Duo Dickinson, in which students from four schools of architecture participated and received feedback on their initial design from a large panel of advisors. This culminated in a webinar where all the projects were presented, and prizes were given to the best designs.

The Garden: A Learning Community

The major learning context of the Building Beauty program is the garden of Sant'Anna Institute (Fig. 44.2). This is the place where programming and visioning, site analysis, design, and building come together. The garden, tended and cultivated

Fig. 44.2 Sant'Anna Institute and its Garden

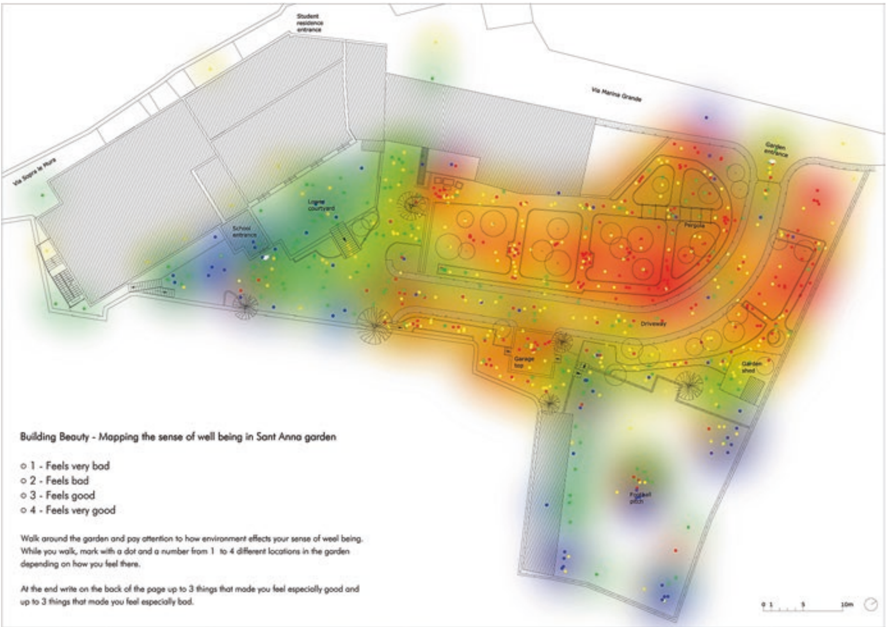

Fig. 44.3 Integrated feeling map of the garden (2018). Red and yellow dots represent very good and good feelings, respectively, green and blue dots represent bad and very bad feelings

but rather underused by staff and students, is the focus of each year's work. Our vision is to gradually transform it over several years of the program, and, in cooperation with the Sant'Anna Institute, make it into an integral part of the learning community that inhabits the institute: the staff, the students of Italian language and culture who come and go, the local students of English and other languages, the students from study abroad programs, and our own little community of architecture students, faculty, and staff.

In the first year of the program we took a holistic view of the problem, examined the garden and the community's aspirations and frustrations with regard to it. Our students mapped centers and feelings throughout the garden, identifying those places that felt better and those that felt worse, or were deemed to be in need of repair (Fig. 44.3). They carried out interviews with the institute's staff, other students in the institute and each other, to understand their visions of an ideal garden, and learn what are the recurring themes in the different visions. At a later stage in the process, they surveyed the students and staff to learn which concrete ideas for the garden were most attractive. On the basis of both of these analyses a project language was developed for the garden (see below). In parallel, study of other gardens in the Sorrento area resulted in a form language to use in developing the projects in the garden. Finally, an overall design for the garden was developed on a large-scale working model, and several projects were suggested by our students for building.

After consultation with the institute's president and director, and the local architect in charge of the school's maintenance and development, the first year project was decided upon: a large bench at the edge of the entrance courtyard, connecting it to the North Garden. This project was designed, mocked-up, and built by the end of the first year.

In the second year, the students concentrated their work on the North Garden only. Exploration of visions and feelings was done again, but this time only for the North Garden. Various places in need of repair were found, some of them already identified in the previous year, and some of them more clearly understood looking at the North Garden in further detail. Project ideas were brought forth and discussed. While the major project to be carried out was the replacing of the pergola, which was in great need of repair, its detailed design, and the design of the bench at the Northern edge of the garden were reexamined completely anew.

Thus, while the overall vision of the garden was developed by the first year's students and documented in the project language document and in a model of the garden—each year students will reexamine the detailed projects to be carried out. Some may yet emerge as the garden develops further and integrates with the learning community. The project and form languages form the basis for the continued development of the garden, but do not predetermine it. The model is but a record of intentions and a way to examine them within the wholeness of the garden. It is not a plan to be mechanically executed.

Form Language for Sorrento Gardens

In parallel with studying people's visions for the garden, and the site with its problems and opportunities, the first year students embarked on a thorough study of institutional and private gardens in the Sorrento area. This is a significant part of local culture, and we felt it was important to understand the form language [20] used in building those gardens, so that we could employ it in our work. The form language contains nine sections, starting from the general organization of the gardens and going down to minute details of plants and their organization, and typical building details. It provides a palette of forms the students could work with as they were developing their overall design of the garden, and the specific projects to be built within it [21].

Project Language and Plan for the Sant'Anna Garden

The project language is like a pattern language in that it forms the qualitative and quantitative "program" for the project. It encapsulates the perceived problems, and the envisioned solutions that are an outcome of work with the community of users and understanding the site and its conditions. It includes 17 patterns ranging in hierarchy from three major patterns that are needed to overcome the disconnection of the garden from the active spaces in the building, and therefore its relative underuse. This is to be overcome by creating learning activities in the garden, that will draw the students into it, and by creating a variety of places to stay in groups of various size and individually. The full document is available on Building Beauty's website [22].

Fig. 44.4 The large bench built in 2018 (left); the pergola built in 2019 the second bench could be seen at the end of the path

Built Projects: Bench at Entrance, Pergola, and Small Bench

Carrying out a project from the first visions to real building on-site is one of the fundamental principles of Building Beauty. The students of the first year built a large bench at the edge of the entrance courtyard (Fig. 44.4, left), incorporating a small pool. This bench was meant to replace one parking place, and transform it into a nice place to sit outside that is still close to the entrance and could therefore be used on short breaks or for meetings. The second year's students rebuilt and enlarged the falling down pergola in the North Garden They also transformed the edge of the garden from a somewhat abandoned place, to a place where one can sit and enjoy one of the garden's only glimpses of the nearby sea (Fig. 44.4, right). The process is a continuous design, mocking up and building process through which the built work gets its final shape and details.

Achievements, Challenges, and Further Development

Overall, the students had a very positive experience. They were able to learn through a fully integrated design and construction process from start (visions, pattern language) to finish (completed bench project). The second year's students had the realistic experience of continuing an ongoing project, and the challenge of having to find ways to integrate their designs into it, rather than starting afresh. The hands-on workshops and construction guidance from local craftspeople were a highlight and instrumental to the success of the program. Teaching all four volumes of The Nature of Order over the course of the year worked very well in creating an intellectual backbone for the practical work. Including several guest speakers as part of the course allowed students to learn how this material is being practiced today. Adding to it, people participating in a webinar from all over the world enriched the experience of the students, and raised the level of the discussion.

The main challenge at this point is the lack of official accreditation of the Building Beauty program. We have secured an agreement with Hartford University, who will send us students as a study abroad program with full credits. We are currently working on and seeking agreements with other universities to gain accreditation through them. The lack of accreditation makes reaching and attracting students more difficult. For the program to continue, we need more students than the 6–7 students we have had in the last couple of years. A group of 12–15 students per year would enable us to do much more.

In the light of this we are now working together with Greha Association in India on developing a different model for teaching Building Beauty. This is a four year course of architecture, which will be given in different universities throughout the world, but under the same governing principles described above. The pilot is now being elaborated and we will be sharing it soon with interested universities.

Conclusions

There is no contradiction between a more humane and a more sustainable architecture. For long-term sustainability, buildings and places have to be loved by people and touch their hearts. They have to be cared for over generations. They have to make the world more whole, and more alive. They have to be beautiful.

The Building Beauty program has been running at the Sant'Anna Institute for the last 2 years. It is an ambitious undertaking that aims to provide a different model of architectural education based on a full cognizance of the complexity of the order that supports life, and that the way to achieve it is through an unfolding process that integrates design and construction.

The program combines the theoretical and practical knowledge of a committed and dedicated group of faculty from around the world, and is built on the basis of Alexander's theory, practice, and teaching methods. It seeks to extend the reach of his teachings, and find meeting ground with other programs of architecture throughout the world that are seeking ways to heal the earth. If you are in any way in sympathy with our goals and aims we call on you to join us.

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Chapter 45
Extreme Design: Preparing for a Different Future

Susan Roaf, Joao Pinelo Silva, and Manuel Correia Guedes

Introduction: Rationale

A critical pathway to a safer future in the built environment must now encompass the reality that society has to grapple with the challenge of building and refurbishing structures and infrastructures to a standard that can withstand ever greater climate challenges. Weather records around the world are being broken, often on an annual basis. The recent International Panel on Climate Change report [1] on limiting global temperature rises to 1.5 °C claims that adaptation and mitigation actions are already occurring. However, the fact that they are ineffective is highlighted in the recent International Energy Agency report [2] on the latest trends in global energy use and CO_2 emissions states:

> *Driven by higher energy demand in 2018, global energy-related CO_2 emissions rose 1.7% to a historic high of 33.1 Gt CO_2*

A 2019 IPCC report shows clearly the range of climate dangers we face in the built environment including those resulting from more extreme weather events and heat-related morbidity and mortality. A critical pathway to a safer future in buildings and cities is to build and refurbish structures and infrastructures that can withstand ever greater climate challenges. Many buildings, in which people and populations can

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bounce forwards [5] to remain safe and resilient in the face of ever worse weather and climate trends and events, will need to be upgraded in their performance. In the 1990s the idea of robust and climate-ready design was experimented with, for instance in the Oxford Ecohouse [6] for which a wide range of adaptive features were designed in, and have subsequently been proven to work well in the most extreme climate events experienced to date. When the scale of the increasingly extreme climate events was beginning to become apparent, Roaf [7] pioneered with publications on how to systematically adapt buildings and cities for climate change, and also how to transform markets to ensure that both mitigation and adaptation could occur to make necessary changes happen [8]. However, in the face of ever more extreme climate and weather events and impacts, the need for ever more *resilient design* has become increasingly apparent over the past decade [9].

In the face of the scale of the predicted escalation of climate extremes, as shown in Fig. 45.1, high profile movements such as Extinction Rebellion, whose leading proponent is Greta Thunberg, must be sympathised with, as she said of the threats posed by our heating world [10]:

"I want you to panic.. I want you to act as if our House is on Fire. Because it is".

Architects appear to be almost ignorant of the scale of the related challenges we face in the built environment, not least in their causing of the extensive overheating problems that characterise so many modern buildings [11, 12]. In the last two decades, building performance has worsened, exacerbated by the systemic flaws in many 'modern' designs that promote over-glazed, lightweight, poorly ventilated, unshaded, buildings of a type already that were a huge problem by the 1960s [13].

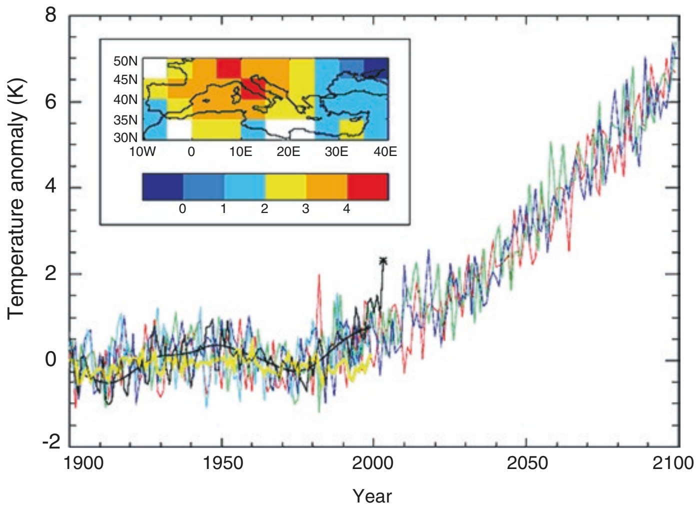


Fig. 45.1 The black temperature outlier marked x is the extreme European heatwave of 2003 in a graph showing that according to this prediction published in Nature, by 2050 this extreme summer will be considered a cool one [3]. Some 52,000 across Europe died during this event, many in buildings [4] (Source: Stott et al., 2004)

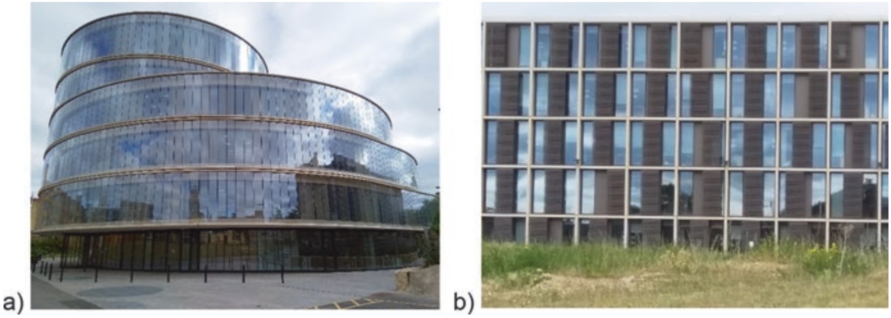


Fig. 45.2 Two flawed envelope approaches in new buildings in Oxford, UK, clearly demonstrate the problem. (**a**) All occupant needs are considered subservient to the desire to ‘wow’ with a ‘novel’ sculptural form in a research centre with 100% glazed outer walls. (**b**) Typical mistake made in student residences, poorly designed floor to ceiling glazing leads to lack of privacy, blinds down, lights and always on causing sub-optimal internal lighting conditions for desktop study, coupled with no natural ventilation. Both projects are flanked by greenfield sites

Designers and developers still produce ‘business as usual’ (BaU) solutions, reflecting those over-glazed, fixed-window, tight-skinned, market archetypes they have convinced themselves are still acceptable models for twenty-first century design. Many examples are even peddled as ’green buildings’. Figure 45.2 shows two architecturally fashionable building types in Oxford, UK, run completely on mechanical heating, cooling and ventilation systems, flanked by greenfield sites. No wonder emissions from UK buildings continued to rise in 2018 [14]. After nearly 30 years of *energy efficiency* thinking that promotes mechanical solutions through regulations [15], and rating systems [16], there is a shift forwards to ideas of designing for *energy sufficient* [17], reducing the need for using energy at all. An EU concept paper on Energy Sufficiency [18] defines it as a “*state in which people’s basic needs for energy services are met equitably and ecological limits are respected*”.

Even the performance of energy sufficient buildings is reported in building indicators such as kWh/m^2 for energy use or CO_2/m^2 for emissions. Genuinely low-energy buildings can be achieved by simply turning off mechanical systems altogether, but they can run the risk of then being deeply uncomfortable. Genuinely low emissions, resilient buildings can be sensibly run for as much of the day and year as possible on local natural energy from sun and wind using sensible opening window designs and shading, etc. [19], whilst still maintaining thermally safe and acceptably comfortable conditions within the building. This property of resilient buildings can only be measured by their thermal performance, without HVAC systems running. The urgency of producing ‘thermally safe’ buildings is clear, but designers appear to be stuck in twentieth century design thinking in a rapidly changing world (Fig. 45.3).

In the twenty-first century, as temperature records are broken globally, there is a growing onus on all building creators to come up with better, low carbon, ways of protecting occupants passively from extreme heat and cold, even when grid power supplies fail.

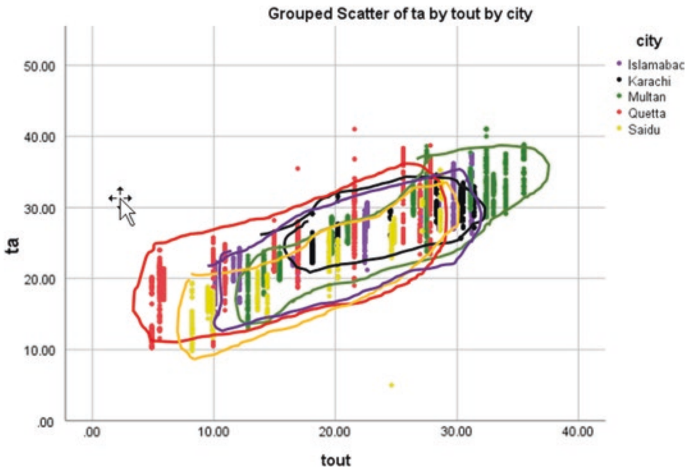


Fig. 45.3 Temperature clouds for five different cities in Pakistan [20]. Every different geographical location has a different outdoor climate that is reflected in the rough cloud for each city. Note that the hottest city (Multan) (green) includes the highest temperatures and the coolest city (Quetta) the lowest temperatures. Karachi has the smallest range of both outdoor and indoor temperatures (Source: Nicol, 2017)

We now know that local populations across the globe are traditionally adapted to those customary temperatures they normally occupy, with people in warmer climates being comfortable at higher temperatures in naturally ventilated buildings [21]. Fergus Nicol, famed for his work on Adaptive Thermal Comfort, has recently published examples of *Comfort Clouds,* built from robust data, that show the temperatures locally adapted populations actually live and work in, around the world. The data shows that people find indoor temperatures acceptable, ranging between 10 and 35 °C in their homes [22, 23]. This applies to temperatures customarily occupied, and beyond these limits, the ability to physiologically adapt becomes limited, and the structures people occupy must increasingly play a greater role in withstanding the onslaught of extreme weather trends and events.

The Extreme Lodge Project

To explore and test design strategies under extreme conditions we devised a project to educate ourselves, and others, on the steps that need to be taken to reinforce structures, both structurally and thermally again extremes of climate. The extreme design project focussed on building two temporary shelters, one in one of the coldest. and the other in on of the hottest, climates in the world. The first was built in Antarctica, the Polar Lodge, and it is that we are reporting on here [24, 25].

The aim of designing the Polar Lodge was to create a project to help push us beyond our (albeit deeply passive) design comfort zones by testing our skills in the extreme cold. We had to rethink the performance of a range of materials, structures and forms with a view to providing a thermally and structurally safe shelter for −30 °C and 140 km/h winds. The result was a robust and effective, off-grid shelter capable of providing acceptable levels of protection in extreme cold environments that is also easy to transport and assemble, for occupation by three non-experts with minimum tools.

Whilst not compromising on performance, the project explored different ways of achieving the design aims whilst minimising the waste streams, and environmental impacts generated by the structure, within affordable cost limits, for early adopters. These may include people in refugee camps, temporary workers or researchers in remote areas, eco-camping organisations, desert hunters and travellers, utility companies for infra-structural repair teams, etc. The final structure was called the Polar Lodge and was erected in Antarctica in February 2019. Used by researchers into the effects of climate change, it is now being tested for structural stability, unoccupied over the winter, and will be revisited in January 2020 to garner lessons for future versions.

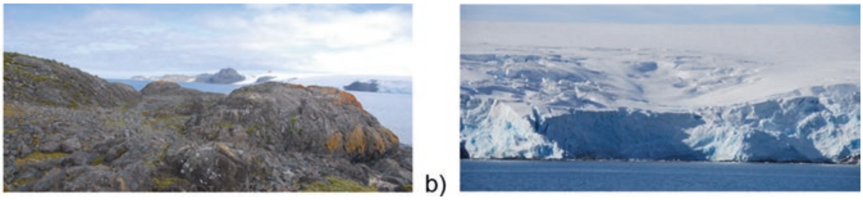
Extreme Design Process

A key lesson learnt in this project is that at the extremes, as designers seeking to create a successful shelter for the Antarctic climate, we were working not only beyond the limits of our knowledge, but also beyond the limits of our imagination. Over the months leading up to, and during, the site work we developed a clear process for the robust, step by step, testing of ideas. This project has highlighted that simulation alone offers limited insights and opportunities for the design and construction of safe structures in extreme climates. It highlighted the usefulness of empirical learning and of bench and field testing in the development of the necessary understanding of the design challenges involved, to produce safe and comfortable structures at the extremes. To enable extreme design to happen, replicably and efficiently, a clear *Extreme Design Process* was identified covering the whole term of the project [26].

The list in Table 45.1 might provide a usable process for a student design project as well as a live design. What is important here is that the structure/shelter/building

Table 45.1 The extreme design process: a simple staged process for exploring, developing, testing and building an extreme design

	The extreme design process
1	Study the site and its environs in great depth
2	Source and study appropriate vernacular archetypes for inspiration
3	Simulate improvements to the traditional structure for the proposed site
4	Explore innovative material solutions building on advice from product experts
5	Bench and Field Test structures and materials in an appropriate local facility
6	Finalise structural and envelope design with tent makers
7	Transport and build final design on site
8	Continually measure conditions on site and refine structure for local conditions
9	Monitor structure for a year for strengths and weaknesses to inform next design



a) b)

Fig. 45.4 Images (**a**) of the site and (**b**) from the site (Source: Roaf)

should be designed and built for, and in, an extreme environment, in current or future climates, to push the limits of a designer's understanding to new heights. Once realised, such a project will ensure that its designer will never again think in the same way about the climatic design of any building today. Hopefully they will henceforth build using a new assemblage of (extreme) tools and methods in their everyday working practice. The step-by-step process proposed is outlined below in relation to the Polar Lodge Project.

Study the Site and Its Environs in Great Depth: The Collin's Bay Site

The site is located beside a remote research outpost around five nautical miles away by Zodiac boat from Escudero, the main Chilean research station of King George Island. PL2 was designed as a sleeping and work base for using that facility, so people had to be able to walk inside it. Polar Lodge 2 (PL2) was erected on a rather exposed promontory at the foot of the Collins Glacier, on which an earlier version of the tent (PL1) failed catastrophically in 2016 for various reasons [27]. The site was chosen to support an adjacent Chilean research pod and the early structural modelling was done using a generalised site map. On arriving at the site for the second season it was necessary to intimately walk, evaluate, map and model the site to ensure the right decisions on positioning and door siting were made [28] (Fig. 45.4).

Source and Study Appropriate Vernacular Archetypes for Inspiration

PL1 was inspired by examples of Mongolian yurts, circular tents in which the traditional dwellers of the intensely cold Siberia and Mongolia have for centuries endured the hardships of extreme winters. Figure 45.5 shows that, in reality, the occupied forms of acclimatised Siberian tent dwellers of eastern Russia bear little resemblance to the westernised ideal of such structures as was built for PL2 with its higher pitched roof.

Fig. 45.5 (**a**) The original PL1 built in the site in 2016 (Source: Bruno Cantuária) with a very different profile to (**b**) the low Siberian tent anchored down with rock filled bags (Source: Wouter van Marken Lichtenbelt)

Simulate Improvements to the Traditional Structure for the Proposed Site

The failure of PL1 provided salutary lessons about the need to optimise the structural stability of the PL2 structure to last at all on this site. This exercise was undertaken with a range of modelling tools, a process that continued until the project was on site, when not only the thermal performance of the tent was improved, [29] but also the additions of various extra strengthening features were added to assess if the structure could withstand the 200 km winds that had apparently been recorded previously at the site.

The structural studies are outlined in Guedes et al., 2019 [30]. The idea that vernacular solutions are optimal ones has been shown not to be the case also for extremely hot desert climates. Meir and Roaf were able to take many of the very sensible design features of hot desert dwellers homes in the Negev desert and significantly improve them with a range of simulated upgrades that provided solutions inspired by vernacular structures, and also benefitting from modern design tools [31] (Fig. 45.6).

Explore Innovative Material Solutions Building on Advice from Product Experts

PL1 failed badly in terms of its envelope material, for a number of reasons: The felt, when wet, became heavy and difficult to dry; the canvass outer envelope was in two pieces, walls and roof that were poorly joined leading to flapping and failure in the

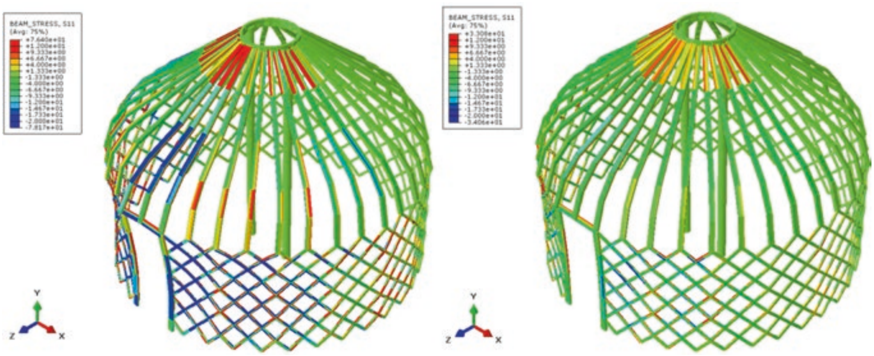


Fig. 45.6 Longitudinal stresses on the Lodge beams in a wind speed of 200 km/h. Left: without rock wall; right: with protective wind facing rock wall (Source: Guedes, Duarte et al., 2019)

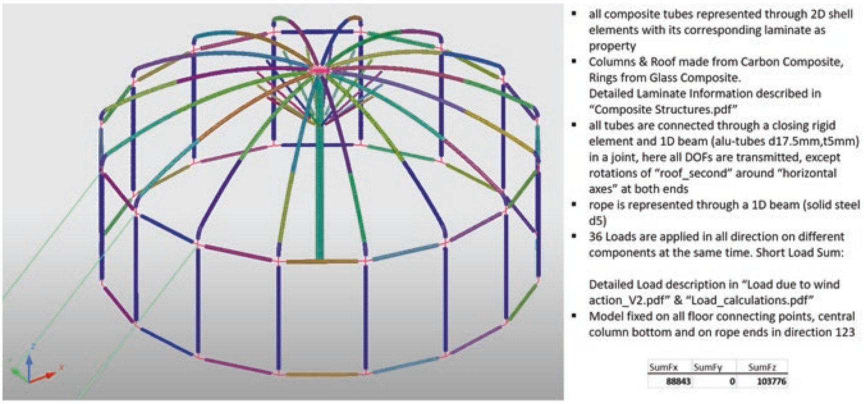


Fig. 45.7 Bio-composite structure was modelled to look at detailed loading on individual elements, and parts of them, to inform the casting of the structure (Roaf et al., 2019)

wind; the two external envelopes attached to the timber structure led to significant cold bridging visible in the thermal images. The result was a tent that was not only structurally unsound, but also thermally poor.

In order to strengthen the structure, modelling was undertaken by Martin Oughton of Mode Ltd., Oxford to create the structure out of a bio-composite material similar to that used for the hulls of racing yachts. During very detailed modelling this structure performed very well. Unfortunately, the proposed cost of c. 40,000 euros to build the tent structure in this material proved beyond the finances of the project.

The PL2 team were determined to avoid the PL1 failures again, and attention then concentrated on the design of an innovative design for a triple-skinned envelope with two leaves outside the structure being an external lightweight skin able to take the guy strain and keep out wind and rain and a second skin inside that but over

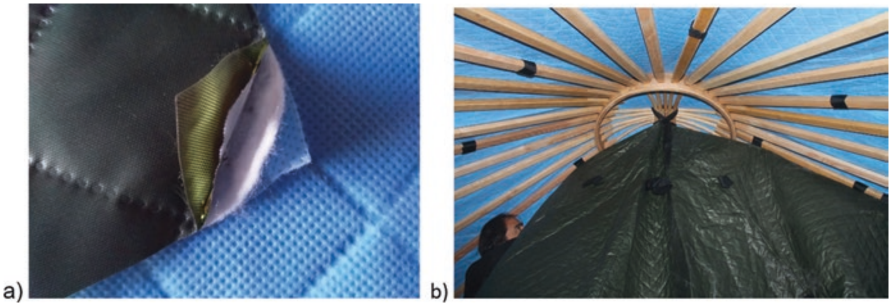


Fig. 45.8 (**a**) Four layers in ORV8, each unique and (**b**) suspending the inner lining to the structure

the structure to provide thermal insulation. A third internal lining was suspended within the traditional timber yurt structure to eliminate cold bridging as far as possible (Fig. 45.7).

After considerable research a new material was identified: ORV8 a quadruple layer extremely light weight material made by ORVEC in Hull in the UK (http://www.orvec.com). Light, strong, thermally excellent, and fire-resistant. A choice to use it was made, but the manufacturers were unwilling to supply the large quantities of the material needed for an experimental tent without further testing being done to provide confidence in its suitability for the project. Hence the prototype experiments (Fig. 45.8).

Field Test Structures and Materials in an Appropriate Local Test Facility

A pop-up tent with two skins of ORV8 was made up, with one external and one internal to the structure skin and the envelope structures were field tested in a cold store facility in Hull. Working with Tony Codd at ORVEC, the pop up structure and the envelope were supplied by Stainton Reid at Sheerspeed of Honiton, and the tests done by Professors Adrian Pitts from Huddersfield University and Susan Roaf of Heriot Watt University [32]. Important lessons were learnt on the effectiveness of the double envelope in eliminating cold bridging, the importance of understanding the potentials of harvesting heat from the thermal stratification within the occupied tent, and the importance of the floor in the internal temperatures in the tent. Tests showed cold bridging was also almost eliminated by using the envelopes internal and external to the structure. It also highlighted the key role of the floor in shaping the thermal landscape in the tent. The prototype tests provided the confidence to go ahead with the tent manufacture despite the fact the ORV8 had never been used for such exposed structural functions before. The outer layer was made up of the material Dyneema cut from a racing yacht sail donated by Fiona Bruce at North Sails, the

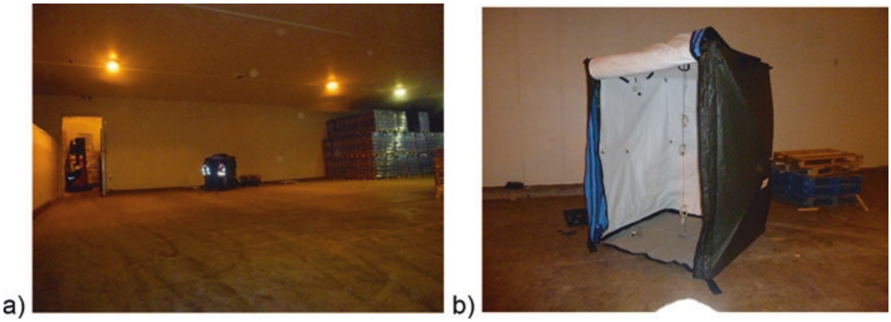


Fig. 45.9 Prototype testing took place (**a**) in a frozen Haddock storage facility in Hull in August 2018 and (**b**) tests gave sufficient confidence to go ahead with construction

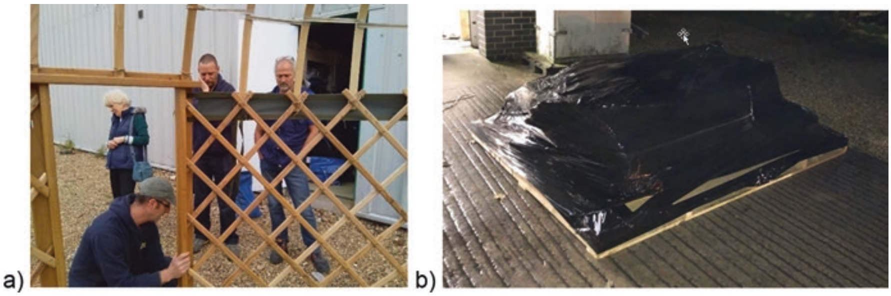


Fig. 45.10 Design deliberations continue as (**a**) the structure is put up with Henry, kneeling, and Stainton, right, and team wonder how best to make up the triple envelope. (**b**) The whole tent is packed in plastic on a 2500 × 1800 heat-treated pallet for shipping by road and sea

premier global yacht sails company (www.northsails.com). It is, for its weight one of the strongest materials in the world, and in its external location would provide useful protection from the extreme site winds (Fig. 45.9).

Finalise Structural and Envelope Design with Tent Makers

Based on four different sources of knowledge the final design for the PL2 tent went ahead. These were (a) the extreme knowledge, experience and skills of the ORVEC, the Sheerspeed and the Yurt Maker staff without whom the tent would never have been built; (b) the modelling of the structure undertaken to demonstrate that the tent could theoretically withstand the extreme 200 km/h winds on the site; (c) the prototype testing and what was learnt from them and (d) the experiences of living and working in similar tents of two of the team who could envision how the structure would work in practice. Based on these insights, the final tent design was arrived at and built, with the structure by Henry Dowell at Yurtmaker (www.yurtmaker.co.uk) and the envelope by Sheerspeed (www.sheerspeed.com) (Fig. 45.10).

Transport and Build Final Design on Site

One of the core design features of the Polar Lodge was the need to minimise packaging and waste taken back from the site. It was packed onto a 2500 × 1800 mm palette in Devon, then transported by road to Cartagena in Spain, and then shipped to King George Island to await the team. All the plastic packaging and wrapping materials were placed onto the lower ground sheet as insulation beneath a carpet underlay made from recycled bottles by Weaver Green [33], beneath the upper ground sheet, on top of which was then placed more underlay covered by Weaver Green tribal rugs.

The time taken to build on site was around 1.5 h for the structure, lower ground sheet and outer two skins, 1.5 h for the inner lining, insulation and upper groundsheet and twin structural columns, 5 h for the guying in difficult ground conditions and 5 h for building the rock windbreak wall. A further 2 hours were needed to put the tent to bed finally and all of this in c.−5 to +12 °C in good wind and solar conditions (Fig. 45.11).

Continually Measure Site Conditions and Refine Structure for Local Conditions

As the tent was being erected and in the 2 weeks the team were there a number of really important problems were faced, and solutions arrived at, using both locally inspired, and hotly debated decisions, backed up by simultaneous simulations being done remotely in both Lisbon and Bahrain by the extended team members. These we termed 'extreme design features', outlined in more detail in a previous paper [34] (Fig. 45.12).

Extreme design features*: developed to ensure the integrity of the structure in situ and the safety of its occupants in extreme climate locations and events, including:*

Tent form: as built profile of the yurt—critical for wind resistance—needs to be lower?

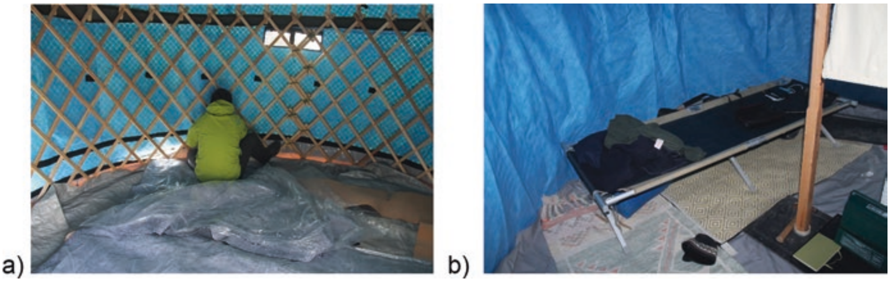


Fig. 45.11 (**a**) All the transport packaging was then used between the lower and upper groundsheets to insulated the floor, (**b**) over which the tribal rugs and underlay were placed

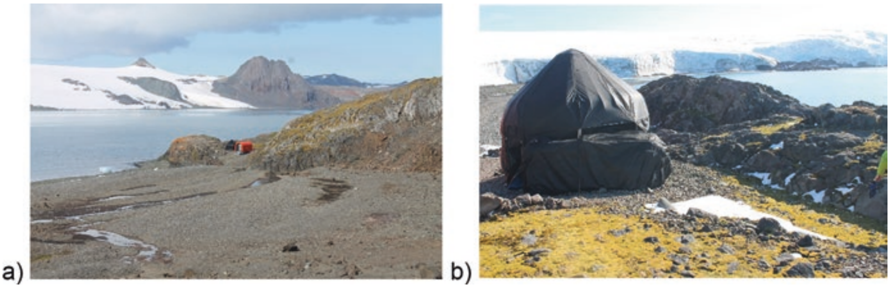


Fig. 45.12 View of the Polar Lodge looking (**a**) South East showing adjacent research pod and (**b**) North East towards the Collins Bay glacier showing the external reinforcing rock wall built against the strong prevailing wind.

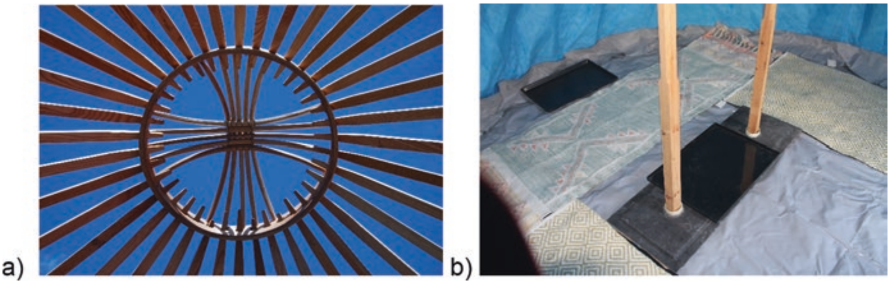


Fig. 45.13 Small details can make the difference between success of failure like (**a**) the extension of the rafters well into the timber crown structure critical and (**b**) the anchoring of two crown support columns into bio-composite shoes to prevent displacement

Door orientation: needed to take into account wind and snow ingress and impacts.

Timber roof crown: holding the rafters and structure together. A key element.

Crown support columns: timber columns bases anchored in bio-composite shoes (Fig. 45.13).

Cold bridging design: cold bridges almost eliminated in the triple envelope.

Guying: this proved contentious—vertical or lateral guys? Rocks are useful too.

Flue design: expelling carbon monoxide from gas fire of the tent critical, not resolved.

Heating: solar heating with passive window and also batteries now being explored.

Windows: current tent only light by solar lamps but summer sun strong so rethinking.

Flooring: the current floor is not the source of most cold for occupants when in use.

Window locations: outer and inner windows opposite door. Middle above door.

Windbreak rock wall: garden waste bags used to build rock wind wall. Will it work?

The number of decisions that needed to be refined and revised on site was illuminating as site conditions overcame preconcieved, 'scientifically correct solutions' in some cases, and the importance of on-site evidence and 'feel' was often the deciding factor.

Monitor Structure for a Year for Strengths and Weaknesses to Inform Next Tent

This will be done on a return visit in early 2020 when the team hopes to revisit the site and assess the extent of the damage to it from an Antarctic winter where wind speeds may get up to 200 km/h. A number of improvements will be weighed up and the tent reinforced, and floor re-insulated, to see if it can also survive a second winter on site.

The work of our team has been made possible by the Portuguese ProPolar organisation who is working extensively in Antarctica on a range of climate monitoring projects (http://www.propolar.org). The lessons learned then will not only be used to improve the remote research tent already there, but also be incorporated into the construction of further tents for other uses in extremely cold locations for research, humanitarian and commercial projects.

Conclusions

The 2019 Polar Lodge team were all already experienced designers of buildings for very hot, and cold, climates. The experiences of designing a tent for the *extremely* cold conditions of Antarctica made us profoundly revise our thinking about the underlying design processes they had used to date. In *extreme* design they found that:

> *"We were working not only beyond the limits of our knowledge,*
> *but also beyond the limits of our imagination."*

None of us have a clear idea of the climates we will occupy anywhere in the world in 10, 20 or even 50 years' time. The extreme lodge project enabled the authors to move beyond their own climatic design limits, and create an extreme tent structure by rethinking design, relying more heavily on empirical knowledge, advice and expertise, by bench testing structures, and learning by doing during construction.

Architects and engineers must wake up and now take responsibility for the climate-readiness of their designs. How can they, viscerally and intellectually, understand the scale of the challenge, and also comprehend it be vital for humanity that they do so?

We propose that extreme design projects are taught widely during the education of young architects and engineers to enable them to envisage what they don't yet know, and grow sufficiently in design skills and imagination to be prepared to be competent designers for the more extreme climates and events we will soon, all, be occupying (Fig. 45.14).

Fig. 45.14 Sunset over Collins Glacier and Antarctica. What you cannot hear, reading this, is the regular splash of the calving glacier. Great chunks broke away from its face, crashing into the sea, providing background sounds to our hard working days. Occasionally, we heard a crash so loud we rushed to see where the cliffs had exploded into clouds of snow and ice, driving iceberg riddled ripples across the Bay. Great breaks left our beach littered with such icebergs, the greater the break, the larger they were

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Chapter 46
Energy and Ecology Efficiency as a Chance for Cultural Heritage

Alessandra Battisti

Introduction

The urgency to mitigate the harmful impacts that buildings and urban spaces have on the environment and the requirement to promote adaptation and resilience to climate change scenarios are placing significant demands on practitioners of the built environment [1], as the cost for the demanded transition is really high in terms of political and legislation improvements, but also technical renovation of the building stock and general redevelopment of urban management of energy and resources [2]. These requirements and the subsequent potential strategies and practices demand a new generation of practitioners, capable of blending advanced multidisciplinary technical abilities with the broader set of creative skills brought to bear on finding creative solutions to design problems [3]. As a result, researchers, academics, and stakeholders are confronted with the significant challenge of negotiating a clear path that embraces robust, pluralist, contextually sensitive conceptions of sustainability [4].

The small settlements' cultural heritage assets are permanently exposed to natural and anthropogenic hazards and the risk analysis are the most important tools needed for decision making in process of regeneration, management, and maintenance of their urban environment.

This means that all operators in the building sector must be cooperative and have a more appropriate way of interacting in order to attain innovation and compete on the domestic and foreign markets, and to complete the difficult path that allows the transformation of an invention into an innovative idea and subsequently into a resilient urban environment [5]. The topic of cooperation among the actors in the production

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chain thus provides an interesting, as well as urgent, scenario of reference [6]. In other words, a culture of resilience cultural heritage is being outlined—a culture that makes it possible to envisage forms of economic, social, and spatial organization focusing on collective intelligence and the enhancement of the human being in all his variety [7]. An intelligence distributed everywhere, continuously enhanced, coordinated in real-time, which leads to an extensive mobilization of resources, definitively exorcising all sterile reductions of the complex problems for which we are called upon to provide answers, and which becomes the background, the fertile substrate of a resilient city based on a cycle of listening that—as asserted by the Pierre Lévy—not only listens to the surrounding environment, but also to itself and to its intimate truth: a kind of listening that brings to the surface, making them visible or audible, myriad ideas, facts, assessments, inventions, and relationships that make up the social fabric, the whole social sphere, and its darkest depths [8].

In 2008, for the first time in history, more than half the world's population was living in cities and metropolises. According to the "2019 State of the World Population Report," this figure is expected to grow by 2030, to a total of 5 billion inhabitants concentrated in the major built-up urban areas [9]. It is a mind-boggling growth in which the urban system is a centralizing force that is revolutionizing consumption models in terms of both quality and quantity, where our cities—consolidated places of community living, one of the highest expressions of human society, with their wealth of knowledge, creativity, and capacity for innovation capacity—are among the main causes of territorial consumption, pollution, and, ultimately, climate change. Cities are thus reinterpreted as energy-consuming ecological monsters, consuming a massive amount of raw materials and land, producing a shortage of farmlands and resulting food crisis, and producing a huge quantity of polluting substances.

The challenge awaiting us is a radical change of course, for a rearrangement of balances, a reconvergence between internal rural area and city; we are the single factor that most affects the changes in climate and the earth's surface. There is no turning back. But we can study the transformation process taking place, learn to control it, and attempt to manage it [10].

In this sense the concept of a city resilient to climate change, comprises two main aspects or actions: mitigation and adaptation strategies. While mitigation tries to reduce the impact that can lead to higher energy consumption and emissions [11], adaptation aims to decrease the other harmful effects of climate change and to prepare the built environment to climate emergency [12].

Resilient Historic Assets

In the last decades, in the Italian internal areas—characterized with small historical centers, it is undertaking a fight against the basic social, economic, and environmental challenges of rural poverty: low rate of demographic growth; threats to ecology and agriculture sustainability; inefficient energy solutions and underuse of local energy potential; lack of education and technical training; poor mechanization and quality of working techniques and tools; weak mobility systems and difficulty for exchanges and communications; insecurity of living conditions; migration and loss of labor force [13].

In such circumstances, historic heritage, energy efficiency improvements and ecological innovation do not contradict each other; instead, by salvaging a place's historic architectural culture, they are seen in a new light, as the result of a long process of continual innovation that, step by step, proposed specific solutions that were suited to particular local problems [14]. Many of the solutions that are currently part of environmentally sustainable construction techniques lay, perhaps subconsciously, at the heart of traditional methods, due to a culture of materials that imposed an open-ended dialog between the interior microenvironment and the exterior macroenvironment, in the search for interaction and synergy, as a natural extension of the historic, geographic, and cultural context.

The real challenge for the future will be urban historic environments ecologically sustainable, yet capable to generate sustenance and income, assure healthy and comfortable living condition and the possibility for further development of the communities [14]. The strategies of small internal settlements regeneration, through the analysis made with a consolidated approach, seek to understand whether enhance community connections and redesign of public buildings and space can trigger social dynamics, environmental conservation, and economic engine to foster a resilient and sustainable society against the disadvantage of internal realities and natural risks. In this regeneration process, the first design step is to identify the potential risks for heritage asset under observation and then the capacity of asset to resist the potential harmful impacts. In this way the sustainable protection of cultural heritage asset consists also in collecting of as much as possible complete set of data with a large use of contemporary and emerging ICT tools [15].

In *Retrofitting Historic Buildings for Sustainability* the Westminster City Council outlines as: "Conservation of historic buildings is part of sustainable development—it minimizes the use of new natural resources; prevents the wastage of existing resources; provides economic value through tourism revenue; and contributes a range of social values important to our health, well-being and education" [16]. Appropriate regeneration of cultural heritage is a crucial part of his conservation to ensure it has a sustainable future. Improving the environmental performance of buildings and protection of the historic built environment are therefore complementary objectives. Planning policies for both heritage conservation and sustainable, resilient design have a crucial role to play [17].

Adaptive Design

Faced with the limits of the classic ecological energy approach that regulates the problem of resources and pollution afterwards, a new conception of urban regeneration is emerging such as to conceive productive activities as ecosystems, composed of flows of matter, of energy and information, capable of self-healing, tackling the development of new power infrastructure based on a distributed energy resource system [18].

Starting from the knowledge on the functioning of ecosystems, it proposes the reorganization of a dynamic distributed generation system towards an operating model of energy-producing made by a vast range of renewable technologies that is able to produce energy on the site where the community lives [19].

In his interview for the exhibition "Design with the other 90%," Edgar Pieterse points out four indivisible key principles, that he calls "Ethical Touchstones," to pursue simultaneously sustainable infrastructure, the inclusive economy and efficient special form (or land-use), glued by processes of democratic political decision-making [20].

He talks about resource efficiency through more efficient and waste-free means of increasing economic output while decreasing the rate and the intensity of nonrenewable sources extraction and consumption.

The second principle is inclusivity, meaning providing every resident with a fundamental set of rights to healthcare, education, land, and social space to exercise 'cultural freedoms' [21]. Then it comes what Pieterse calls "human flourishing," a safe and nurturing context to come into one's cultural fullness—the magic vitality that makes all cities and places unique and connected. Mostly alongside with the role played by education and social networks, it is usual to find the concept of participation, intended as 'taking part in' the social/architectural processes. According to Paul Jenkins and Leslie Forsyth, widening social participation, or community design, has an essential value in the process, people being in control of decision-making process related to their communities, and there is an urgency to reassess the relationship between architects and other stakeholders (weather users or wider society), as architecture has an important social function often ignored in the profession [22]. As Nina-Marie Lister claims, "adaptive design emerges from a deliberative—approach to planning, design, and management. The adaptive context is one where learning is a collaborative and conscious activity, derived from empirically or experimental acquired information, which in turn is transformed into knowledge through adaptive behaviour" [23].

Finally, the last touchstone shows us how communities represent an economic opportunity, pursuing more inclusive and fulfilling forms of economic development and growth.

Case of Study

The Project Rail Ripensa Agisci Innova Lepini (Rethink, Act, Innovate Lepini) is setted in Carpineto Romano an Italian town of 4396 inhabitants in the Lazio Region, located between the heights of the Lepini mountains which for centuries represented the only escape from the malaria that infested the territory. From the beginning of the twentieth century, the village of Carpineto was slowly depopulated as were the other villages of the internal Lazio region of the Monti Lepini community. The regeneration project consists in the construction of a Monti Lepini territorial web with the other small historical centers and the regeneration of the territories and the creation of a Civic Centre hub located in Carpineto Romano aims at the promotion of socioeconomic development and enhancement of the condition of disadvantage of the Monti Lepini community. Through educational activities, vocational workshops, the specialization of farming and small craft businesses, it is possible to provide the community with specific development tools that can restore and enhance the local culture. At the same time this project aims to develop an intelligent decision support system (i-DSS) to enable public and private bodies to proactively manage climatic-risks and energy and resource consumption of cultural heritage. This was achieved through an interdisciplinary approach of combining both urbanistic, architectural, ecological engineering aspects and socioeconomic impacts. The architecture of the project presented consists of a smart screening tool employed as a 'fast-scanning' method and combines critical engineering parameters coupled with social and cultural value of cultural heritage, properly communicated to end-users. The obtained information will enable stakeholders to plan adaptation strategies and proactively manage and maintain their territories and cultural heritage.

Following this lead, we formulate the hypothesis that operative public space can act as key player in the regeneration of these disadvantaged contexts in internal areas (Figs. 46.1, 46.2, 46.3, 46.4).

It is a premise to the growth and resilience of rural communities:

1. If the design strategies that integrate education and training to production, meet in an environment that fosters trades and social interaction the community becomes self-sustaining.
2. If the resource management is based on public interest and solidarity through cooperative production and storage the inhabitants gain a secure source for basic needs.
3. If the architectural project involves the community at all stages of the process—design, construction, management—promoting participation and inclusive development.
4. If it encourages the use of appropriate architectural, ecological and energy technologies and devices, which should be efficient, affordable, and foster community participation.

In an effort to increase the living standard, the aim of the research is the revitalization of the rural economic system, through the introduction of new sources of income and the creation of a surplus of production that allows the active participation in trades with neighboring communities; through improved efficiency in the use of traditional technologies and in the exploitation of local energy sources within environmental conservation and ecological balance, for the satisfaction of inhabitants.

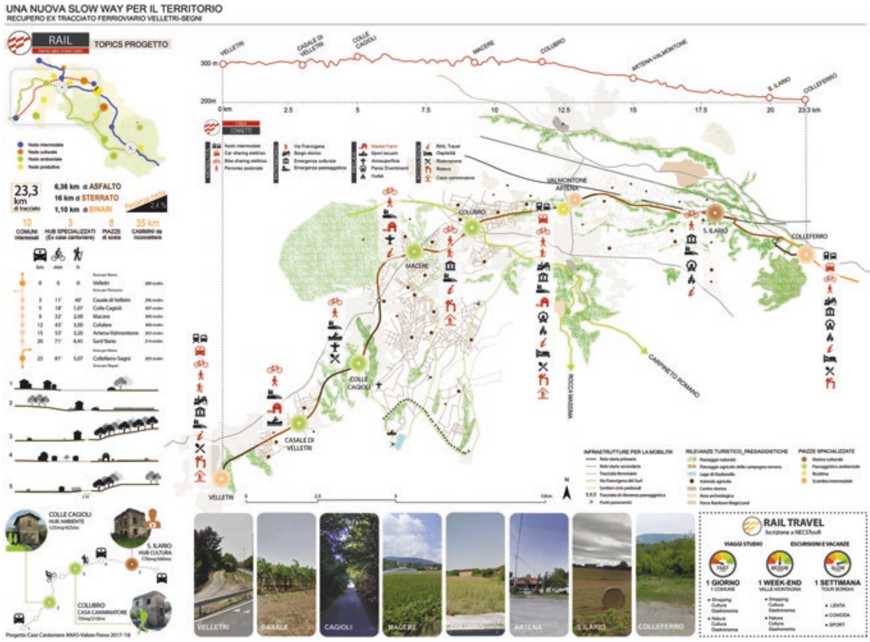

Fig. 46.1 Project RAIL Ripensa Agisci Innova Lepini (Rethink, Act, Innovate Lepini) is setted in Carpineto. The research was carried out by G. Laprocina, M.M. Pani within the second level Master of Sapienza in Valorisation and enhancement of small historical centers. Environment Culture Territory integrated actions. Directed by A. Battisti

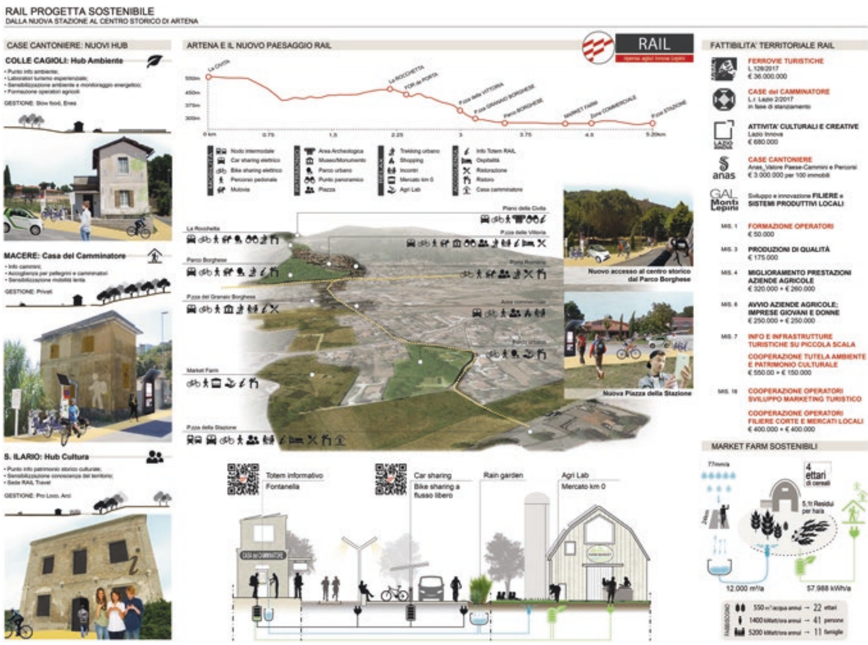

Fig. 46.2 Project RAIL Ripensa Agisci Innova Lepini (Rethink, Act, Innovate Lepini) is setted in Carpineto. The research was carried out by G. Laprocina, M.M. Pani within the second level Master of Sapienza in Valorisation and enhancement of small historical centers. Environment Culture Territory integrated actions. Directed by A. Battisti

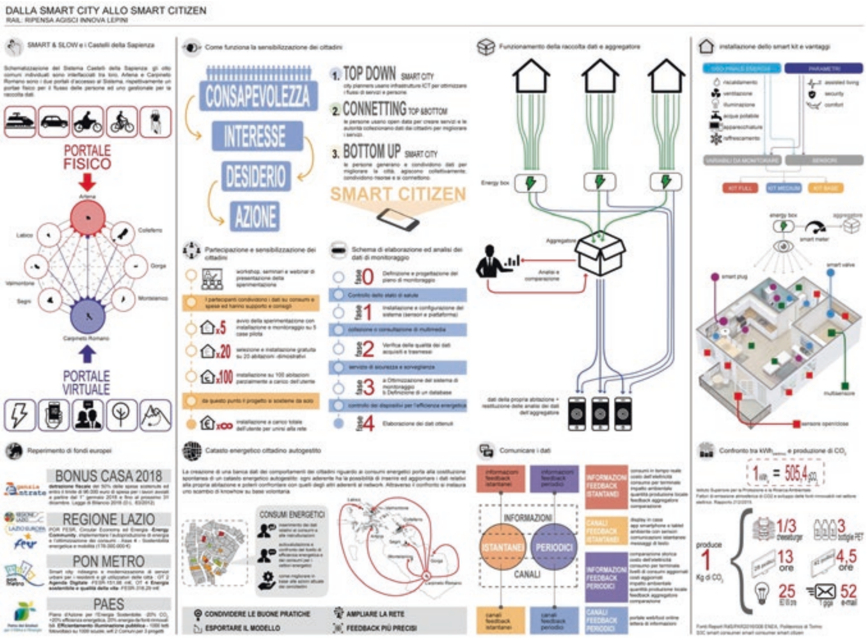

Fig. 46.3 Project RAIL Ripensa Agisci Innova Lepini (Rethink, Act, Innovate Lepini) is setted in Carpineto. The research was carried out by G. Laprocina, M.M. Pani within the second level Master of Sapienza in Valorisation and enhancement of small historical centers. Environment Culture Territory integrated actions. Directed by A. Battisti

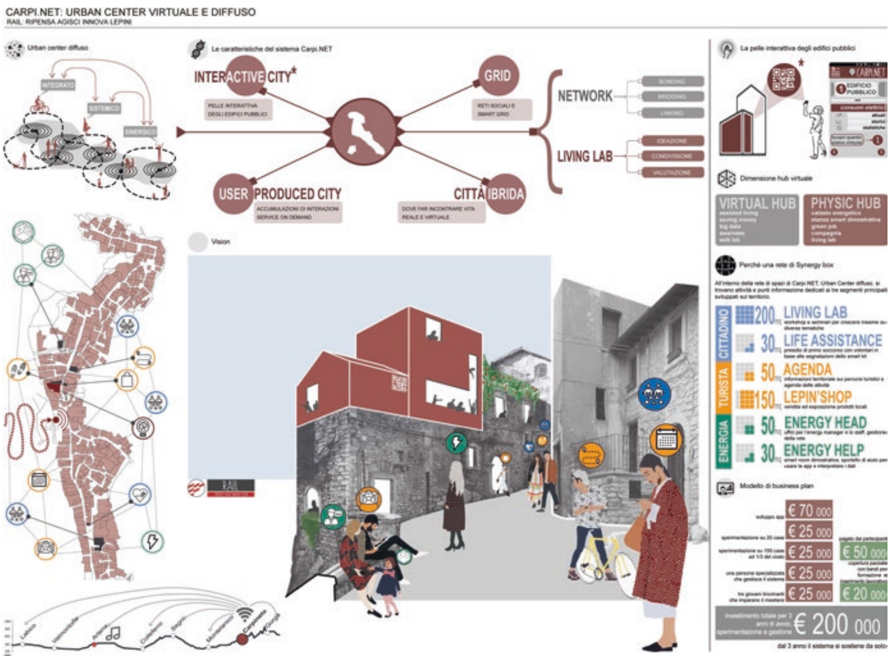

Fig. 46.4 Project RAIL Ripensa Agisci Innova Lepini (Rethink, Act, Innovate Lepini) is setted in Carpineto. The research was carried out by G. Laprocina, M.M. Pani within the second level Master of Sapienza in Valorisation and enhancement of small historical centers. Environment Culture Territory integrated actions. Directed by A. Battisti

Conclusion

The local redevelopment of the historical heritage is configured as an internal concentration of history and evolution of the settlement and its inhabitants, places of culture understood as the presence/value of the built environment and as a result of the human and immaterial resources that this history contributed to write. These are situations where it clearly emerges that it is not enough to recover single buildings within areas that are gradually becoming depopulated, but it is necessary to intervene on fractions and widespread nuclei on the public and private assets to engage connections with other sector policies such as tourism, agriculture and crafts. This attitude requires integrated actions aimed at creating a critical mass from the supply point of view, also able to direct some specific segments of the tertiary, receptive and residential market, setting in motion a mechanism of complex proposals for external users, which involving the local population, they produce good levels of quality of life, enhancement of the landscape, architecture and the environment, operating an energetic redevelopment of the physical heritage and creating employment and services.

The potential for positive impact, linked to the redevelopment and enhancement of the villages on local economies, will be effectively activated only if the operators in the building sector in the area will be able to respond to the needs and demands arising from the listening cycle. The capacity and effectiveness of such a response also depends on the skills of the companies themselves, in particular the building and artisan businesses that are directly involved in the renovation of the buildings. It is therefore of crucial importance that operators in the construction and plant engineering sectors, from small businesses to professionals, understand the potential of the long-term vision of the environmental challenge, that vision that Walter Stahel, a Swiss scholar of production cycles, portrays well in the story of the three stonecutters who are asked what they are doing. The first answers that he is passing eight hours of work, the second says he is cutting limestone blocks, and the third replies that he is building a cathedral[1] [24].

Regenerate and reconsider small settlements in the global discourse of sustainable development means suggesting and realizing ways of enhancing traditional buildings capable of setting up the requisites linked to the territory's vocation, environmental planning, energy saving, well-being, and quality of life with the precious architectural characteristics of the historic buildings, giving due importance to the cultural heritage, and giving proper emphasis to the territorial enhancement and to that "cathedral" to which we all aspire in our vision of a sustainable future.

[1] I read the story in the beautiful essay by Gianfranco Bologna *Servono due pianeti. Dagli anni ottanta consumiamo una terra e mezzo ogni anno. E acceleriamo*, pagg. 193–204, in *Calendario della fine del mondo* (edited by) Pacillo A., Pizzo A., Sullo P., Edizioni Intra Moenia, Roma 2011.

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Correction to: Evaluation of Multifunctional Aspects of a Green Roof in Mitigating the Negative Effects of Urbanization in Mediterranean Environment

Martina Pratesi, Fabrizio Cinelli, and Giovanni Santi

Correction to:
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The original version of this chapter was inadvertently published with incorrect given name and family name of the authors.

The given and family names for authors must be interchanged. The author's name has now been updated as listed below:

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