World Sustainability Series

Walter Leal Filho
Arnolds Úbelis
Dina Bērziņa *Editors*

Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies

Springer

World Sustainability Series

Series editor

Walter Leal Filho, Hamburg, Germany

More information about this series at http://www.springer.com/series/13384

Walter Leal Filho · Arnolds Úbelis
Dina Bērziņa
Editors

Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies

Springer

Editors
Walter Leal Filho
Faculty of Environmental Science
HAW Hamburg
Hamburg
Germany

Arnolds Úbelis
Institute of Atomic Physics
and Spectroscopy
University of Latvia
Riga
Latvia

Dina Bērziņa
Institute of Atomic Physics
and Spectroscopy
University of Latvia
Riga
Latvia

ISSN 2199-7373 ISSN 2199-7381 (electronic)
World Sustainability Series
ISBN 978-3-319-14882-3 ISBN 978-3-319-14883-0 (eBook)
DOI 10.1007/978-3-319-14883-0

Library of Congress Control Number: 2015934681

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

Preface

The third International Conference on Integrative Approaches towards Sustainability, titled *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies* called "KNOWLEDGE" in short—was organised during 27–30 June 2012, in Jurmala, Latvia. It was among the early international attempts to contribute to the debate on how to link the "classical" issues of sustainable development and those about the development of a "knowledge society", currently growing in importance at the EU level including starting up the Horizon 2020 research agenda.

In 1987, the United Nations World Commission on Environment and Development (WCED) also known as the Brundtland Commission published its report *Our Common Future*. It introduced the concept of sustainable development to the political agenda with an overall substantial impact on the way we perceive the world and how political systems globally redirect themselves, since the report was published. Its substantial and deeply transforming implementation, however, has still to a large extent, to be established. The report led up to the three United Nations Conferences on Sustainable Development, starting in 1992 with the Rio de Janeiro conference on Environment and Development (UNCED also known as *the Earth Summit*) followed by the Johannesburg World Summit on Sustainable Development (WSSD) in 2002 and the 2012 world Conference on Sustainable Development, also in Rio and called *Rio+20*. All these events have had a substantial content of knowledge development in the fields being central to the concept of sustainable development. In 1992, the focus was on the "environment", in particular on climate and biodiversity. In Johannesburg, the focus of its "Plan of Implementation" was on research, education and technology. It led among other things to the 2005–2014 UN decade of Education for Sustainable Development. Finally at the 2012 Rio Summit, the focus was on the economy, in particular the so-called *Green Economy*, and the transition process to achieve a sustainable society was summarised in the document *The Future We Want*, the main conference report. It is in this context also worth mentioning that the Nobel Peace Prize was awarded in 2007 to the former US Vice-President Al Gore dealing with exactly these issues. Thus the Nobel Prize could also be regarded as a contemporary recognition of the importance of knowledge for world peace and sustainable development.

The key role of knowledge for development has a long background. Sociologist and management guru Peter Drucker identified knowledge (different from information) as a key economic resource in 1969, and in his 1993 short book entitled *Post-Capitalist Society*, he pointed at knowledge rather than capital, as a key resource for development. Despite the fact that the Internet was still in its pre-browser infancy in 1993, Drucker believed that the developed-world economies were entering a new *knowledge-based* era—a leap in civilisation as large as the one from the agrarian based to the industrial era.

This change was also recognised by the EU as it included the priority *Citizens and governance in a knowledge-based society* as a domain for research in the Sixth Framework Programme in 2002. A few years later, in 2005, the UNESCO-led Report *Towards Knowledge Societies* was published. The Report underlines the role a knowledge society will have to promote human rights and equity, and establishes the principles for forming an equitable knowledge society in which all people have equal, inclusive and universal access to knowledge.

Information and Communication Technologies (ICT) and Internet (World Wide Web) particularly have key roles to ensure that a knowledge society is functional. The speed at which data and analysis of data can be searched, produced and distributed has been dramatically increased. Data and the resulting knowledge are now available at the tip of our fingers in unforeseen quantities in all areas of science and social life. The role of universities, leaders and policymakers is to reduce the digital divide ensuring that everyone has access to the training and skills needed to access, use, manage and produce knowledge at any time actively.

It is obvious that this development is of great significance to our efforts to approach a sustainable society. Yet it is difficult to find any publications, documents or policy papers where the two concepts—knowledge society and sustainable development—are discussed, analysed and investigated together. A few recent policy documents from, e.g. the OECD points to this important crossover field. Nevertheless, a search on "Google" where both terms are used together gives only a few articles or editions of interest. During recent years, the UN University (UNU) has shown interest on this topic.

The present volume *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies* is meant to contribute to an analysis of the role of knowledge society to achieve sustainability. It is based on the above-mentioned conference with the same name. It includes conference papers and articles from conference speakers as well as a few articles from invited authors.

The title of the book highlights sustainable development, knowledge society and smart future manufacturing technologies together, and will hopefully serve as inspiration for further efforts to understand how the interception between sustainable development and knowledge society issues could lead to a better future.

The content of the book is only a small and modest contribution to the interplay between sustainable development and knowledge society. It is the last one in a series of three complementary conference books.[1]

The team of authors has a plan to upkeep the Forum *Sustainable Development and Knowledge Society* in Riga for the future.

Autumn 2014

Arnolds Úbelis
Lars Ryden
Uno Svedin
Walter Leal Filho

[1]Integrative Approaches Towards Sustainability in the Baltic Sea Region, Ed.: W. Leal, A. Úbelis, Peter Lang Europäischer Verlag der Wissenschaften 2004. 556 p.
Sustainable Development in the Baltic Sea Region and Beyond, Ed.: W. Leal, A. Úbelis, D. Berziņa, Peter Lang Europäischer Verlag der Wissenschaften 2006. 700 p.

Contents

Contributors

Janis Abolins Laboratory of Biomass Eco-Efficient Conversion, Latvian State Institute of Wood Chemistry, Riga, Latvia; Institute of Atomic Physics and Spectroscopy, University of Latvia, Riga, Latvia

Martins Andzs Laboratory of Biomass Eco-Efficient Conversion, Latvian State Institute of Wood Chemistry, Riga, Latvia; Forest Faculty, Latvia University of Agriculture, Jelgava, Latvia

Dusan G. Antonovic Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

Valdi Antons University of Latvia, Riga, Latvia

Dace Āriņa University of Agriculture of Latvia, Jelgava, Latvia

Marco Ascione Department of Science and Technology, University of Naples Parthenope, Naples, Italy

Ladislav Bakay Faculty of Horticulture and Landscape Engineering, Department of Planting Design and Maintenance, Slovak University of Agriculture, Nitra, Slovakia

Rūta Bendere Institute of Physical Energetics, Riga, Latvia

Dina Bērziņa Institute of Atomic Physics and Spectroscopy, University of Latvia, Riga, Latvia

Jānis Bērziņš National Defence Academy of Latvia, Centre for Security and Strategic Research, Riga, Latvia

A. Bianchin 5MBN, Vascon di Carbonera, Italy

Egils Bogans Laboratory of High-Resolution Spectroscopy and Light Source Technology, Institute of Atomic Physics and Spectroscopy, University of Latvia, Riga, Latvia

M. Cioffi D'Appolonia, Rome, Italy

Nina Drejerska Department of European Policy, Public Finance and Marketing, Faculty of Economic Sciences, Warsaw University of Life Sciences—SGGW, Warsaw, Poland

Raimonds Ernšteins University of Latvia, Riga, Latvia

Zanda Gavare Laboratory of High-Resolution Spectroscopy and Light Source Technology, Institute of Atomic Physics and Spectroscopy, University of Latvia, Riga, Latvia

D. Gonzalez PRODINTEC, Gijon, Spain

Janis Gravitis Laboratory of Biomass Eco-Efficient Conversion, Latvian State Institute of Wood Chemistry, Riga, Latvia

Daiva Jakutyte-Walangitang Austrian Institute of Technology, Vienna, Austria

Linas Kliucininkas Department of Environmental Technology, Kaunas University of Technology, Kaunas, Lithuania

Arnis Kokorevics Laboratory of Biomass Eco-Efficient Conversion, Latvian State Institute of Wood Chemistry, Riga, Latvia

Edvinas Krugly Department of Environmental Technology, Kaunas University of Technology, Kaunas, Lithuania

Silvija Kukle Institute of Textile Materials Technologies and Design, Riga Technical University, Riga, Latvia; Department of Design and Material Technologies, Riga Technical University, Riga, Latvia

Walter Leal Filho Research and Transfer Centre "Applications of Life Sciences", Faculty of Life Sciences, Hamburg University of Applied Sciences, Hamburg, Germany

Paula Lindroos Baltic University Programme, Uppsala University, Uppsala, Sweden; Centre for Lifelong Learning, Åbo Akademi University, Turku, Finland

Anita Lontone University of Latvia, Riga, Latvia

Māra Lubuze University of Latvia, Riga, Latvia

P. Matteazzi Vascon di Carbonera, Italy

Jonas Matulevicius Department of Environmental Technology, Kaunas University of Technology, Kaunas, Lithuania

Salvatore Mellino Department of Science and Technology, Centro Direzionale—Isola C4, Parthenope University of Naples, Naples, Italy

Ursula Mollay Austrian Institute for Regional Studies and Spatial Planning, Vienna, Austria

Aleksandra R. Nesic Institute for Nuclear Science, University of Belgrade, Belgrade, Serbia

Antonije Onjia Institute for Nuclear Science, University of Belgrade, Belgrade, Serbia

Valery Ozols-Kalnins Laboratory of Biomass Eco-Efficient Conversion, Latvian State Institute of Wood Chemistry, Riga, Latvia

Jessen Page University of Applied Sciences and Arts Western, Sion, Switzerland

Anastasia Pavlova Department of Industrial Ecology, University ITMO, Institute of Refrigeration and Biotechnologies, Saint Petersburg, Russia

Olivier Pol ATP Architekten und Ingenieure, Innsbruck, Austria

Anna Putnina Laboratory of Biomass Eco-Efficient Conversion, Latvian State Institute of Wood Chemistry, Riga, Latvia; Institute of Textile Materials Technologies and Design, Riga Technical University, Riga, Latvia

P. Queipo PRODINTEC, Gijon, Spain

A. Reinhardt microTEC, Bad Durkheim, Germany

Maddalena Ripa Department of Science and Technology, University of Naples Parthenope, Naples, Italy

Lars Rydén Centre for Sustainable Development, Uppsala University, Uppsala, Sweden

Ralf-Roman Schmidt Austrian Institute of Technology, Vienna, Austria

Janis Skudra Laboratory of High-Resolution Spectroscopy and Light Source Technology, Institute of Atomic Physics and Spectroscopy, University of Latvia, Riga, Latvia

Anda Svagere Laboratory of High-Resolution Spectroscopy and Light Source Technology, Institute of Atomic Physics and Spectroscopy, University of Latvia, Riga, Latvia

Uno Svedin Department of Computer and Systems Sciences (DSV), The Stockholm Resilience Center (SRC), Stockholm University, Stockholm, Sweden

Ināra Teibe University of Latvia, Riga, Latvia

Ramunas Tupciauskas Laboratory of Biomass Eco-Efficient Conversion, Latvian State Institute of Wood Chemistry, Riga, Latvia; Forest Faculty, Latvia University of Agriculture, Jelgava, Latvia

Arnolds Úbelis Institute of Atomic Physics and Spectroscopy, University of Latvia, Riga, Latvia

Sergio Ulgiati Department of Science and Technology, Centro Direzionale–Isola C4, Parthenope University of Naples, Naples, Italy

Sava J. Velickovic Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

Andris Veveris Laboratory of Biomass Eco-Efficient Conversion, Latvian State Institute of Wood Chemistry, Riga, Latvia

Silvio Viglia Department of Sciences and Technology, University of Naples Parthenope, Naples, Italy

T. Zadrozny NANOfutures aslb, Brussels, Belgium

Amalia Zucaro Department of Science and Technology, University of Naples Parthenope, Naples, Italy

Līga Zvirbule University of Latvia, Riga, Latvia

Part I
Plenary Lectures and Invited Contributions: Sustainable Development, Knowledge Society and Knowledge-based Economy—Policy of Education, Research, and Technological Development

Challenges for Planetary Stewardship at the Entry of the Period of the Anthropocene

Uno Svedin

Abstract

In the long human history from the period of the use of stone ax tools and the agricultural revolution to the various phases of the industrial revolution from the 18th century and onwards all sorts of innovative approaches have been applied by humans for the sake of survival and prosperity. In earlier days the environmental impacts due to these solutions were limited—although not always locally or even regionally negligible as the example of hunting of big animals illustrates. Closer to our times the character of the solutions, their systemic connections and the global width of application has drastically changed the situation. Today it is not only the "classical" industrial manufacture of products that have environmental repercussions, but the entire support system for daily life which includes a global connectivity of food provisions and new kinds of energy solutions as examples. These illustrate the integrated cross sectorial nature of the challenge due to their character, intensity and global embrace. Indeed, humans have during the latest generation taken over as the prime driving force with regard to global environmental impacts. And the character of the transformation is accelerating. Thus we are quickly moving into a new historical era—sometimes called the Anthropocene. This confronts us with issues about the relation between actions at different scales—including challenges regarding the material base for society and its natural environmental embedding. This has been referred to—in risk handling terms at global level—to a concern for living

U. Svedin (✉)
Department of Computer and Systems Sciences (DSV), Stockholm University, Stockholm, Sweden
e-mail: uno.svedin@gmail.com

U. Svedin
The Stockholm Resilience Centre (SRC), Stockholm University, Stockholm 10691, Sweden

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_1

within a safe space set by "planetary boundaries". The interplay between the global macro level and other levels, not least with regard to governance and responsibility considerations, i.e. "stewardship", is at the core of our current societal situation. Systems and resilience considerations are now coming into the forefront when approaching this key "grand challenge". But also the societal distributional aspects increase in importance. The basis of our knowledge production and handling in connection to the expressed and used value systems are here of central importance when we have to face what stewardship at different scale levels from micro to macro might entail.

Keywords
Anthropocene · Complexity · Culture · European outlook · Future outlook · Global development · Industrial revolution · Innovations · Knowledge production · Long term history · Manufacture · Perspectives · Regions · Resilience · Scale · Solutions · Sustainability · Systems · Uncertainty

1 Humans Acting in the Environment—From Stone Ax to the Industrial Revolution

Humans have for tens of thousands of years deliberately manipulated environment to survive and prosper. This can be seen through findings of the early Stone Age tool technology items such as stone axes of various kinds—some of early remnants have been found in caves in parts of Africa, and similar tools of later origins have been found in the European region and elsewhere. These tools technologically are often very smart in design, e.g. in terms of the choice of the material or the design of the cutting performance. Later in history the types of tool functions (knives, axes, swords, etc.) were—as we know—produced using other types of materials as expression of the advancement of technology and handling of a wider range of natural resources (e.g., various metals as tin and copper and their alloys, iron and its alloys with other materials—all the compositions designed to improve the functions).

With the onset of the agricultural revolution in the Middle East and later in parts of Europe—an outflow of domesticated species (plants and animals) and practices from the Anatolian high plateau in present Turkey gradually stretched out. We, the humans, got a more stable provision of food, materials and functions than what was available through hunter and gatherer practices. The talk is not only about technology of the tools, but also about the ways they were used—including the kinds of activities related to hunting, fishing, agricultural (including forestry) and mining practices.

This means that the growing technical and organisational capacity associated with the accumulated knowledge has been of central importance. Not only did creation of the knowledge matter, but also its general geographical dissemination and transfer to future generations. Under a variety of environmental landscape, resources, and climate, the knowledge has started on the local and regional basis. (For further elaboration of the knowledge theme with regard to agricultural practices—and its relevance to the future see, e.g., Barthel et al. 2013).

But as time went by and connections widened through trade and warfare, the knowledge structure combined the regional capacities with a more general understanding and procedural capacities as we can see in the spread of agricultural processes and also in the sequence of uses of different materials for prestigious and other, more practical everyday items made e.g. of bronze in ancient times (found in such geographically disparate areas as the Baltic region and regions in the South of China as in Sichuan—see Bagley 2001) and by iron-based technologies to plastics and high-tech “nano”-technologies in our times.

The first association with the word “manufacture” in semi-modern times that might come to mind is the kind of industrial production that relates to the industrial revolution in the 18th century expanding from its centre in the UK and continental Europe. Sectors that might be associated with that development—and, in this context—over the last few centuries, are the energy-intensive iron and other metal products (at various levels of intensity and composition depending on the historical period we are talking about) providing industrial machinery such as engines, vehicles, and transport devices (as railways, railway engines, and other related devises, ships of steel, later cars and airplanes) and infrastructural products (as steel bridges promoting the transport of goods and mobility of people), high-rising building structures etc. (improving the centralisation of control from urban centres).

A symbolic manifestation of these types of actions—and capacities—by humans that easily come in mind is the Eiffel Tower built from 1887 to 1889—i.e., the year France celebrated 100 years from the beginning of the French Revolution and hosted the world exhibition in Paris. Thus, the Eiffel Tower was built as a symbolic exclamation mark to demonstrate what was now made possible under the skies by (then) “modern” technology.

In a similar way—and about the same time—the largest railway bridge at the time (with a lengths of as much as 2.5 km) was built in the UK 1883–90 over the wide water strait the Firth of Forth in Scotland. The bridge kept its world primacy for over 40 years (according to Wikipedia) and has today even been suggested to be on the UNESCO world heritage list. Again we see an example of the breakthrough of “modern times” when the human innovative capacity connected with “modern science-based technology” arose to make earlier impossible creations possible.

In the USA the construction of the Brooklyn Bridge in New York connecting Manhattan (with its emerging potential) with Brooklyn (i.e. one of the leading industrial towns in the late 19th century) could similarly be seen as a symbolic expression of material connectivity made possible in the “new modern Era” of the late 19th century. And the Golden Gate Bridge in San Francisco could be seen as an expression of how the industrial “manufacture” capacities drove westward in the USA. Not only bridges but also the tall buildings are children of the same type of capacities and their symbolic expressions—not only in Manhattan or Chicago, but also in a vast variety of cities—i.e. providing a vivid scenery which today is presented by the modern parts of Paris, Beijing, Singapore, or Rio de Janeiro.

During the 19th century we also see development of tools and machinery for industrial production of various sorts. Production towns such as Manchester, Detroit, Berlin, Hamburg, Mumbai and Shanghai might provide an image of a wide range of these types of activities over the centuries.

Of special importance were the new (19th century) innovative devices for agricultural use (such as iron ploughs and other agricultural-support items—and later tractors) that emerged around the 1850s. We also take note of the connecting technology to the industrial upgrading of agricultural products e.g. for the use of processing of grown fibres such as cotton for textile production at larger and larger scale—increasingly involving global trade, e.g., cotton import from India to Europe was made available. In this context the manufacture of industrially produced chemicals for agricultural use (such as artificial nitrogen fertilisers—but later also pesticides and insecticides of various sorts) are of importance, with its early initiatives in Germany as a starting point at the turn of the century around 1900.

Thus, the word "manufacture" alludes to the production of industrial capacities of the modern world, its urban skylines and the connection between the urban centres by land, by sea or later by air and, in our days, into space as far as to the moon and (still without humans) to the planets in our solar system. But it also alludes to the production of support for the agricultural practices that produce food for global markets. In this way the word manufacture also alludes to the full range of the system of "modern" production and consumption of products and services, including the international trade—of global reach—distributing the products and services according to the expressed demands from the global markets.

In earlier phases of the human history the trade routes also extended over vast distances (e.g. the silk route connecting the Mediterranean parts of the world with East and South-East Asia and vice versa), e.g. with one of its peaks during the Tang dynasty in China—more than a millennium ago. But it is not until the period of our very close to generations of the 19th century that the material magnitude of these flows reached such an enormous and expanding size—especially in the period after the Second World War—which Will Steffen and others (see e.g. Steffen et al. 2011 and references in that article) have named the period of the "Great Acceleration".

2 From the Onset of Sustainability into the Period of the Anthropocene

During the last few decades—especially after the UN Stockholm Conference on the Environment in 1972 and its follow-up at the UN Conference on the Environment and Development in Rio 1992—a growing concern has been voiced regarding the needs to highlight sustainability features of the manifestations of "manufacture", i.e. to develop new rules for the production and use of the well-known industrial products and associated infrastructural expressions—in terms of tools, constructions, vehicles, buildings, and other material manifestations and processes. In short:

it is high time to drastically upgrade the constraints (ecological, economic and social) connected to the production and also the use of the items of the “manufacturing” world. Likewise the same concerns relate to the impact of “modern agriculture” and other forms of land-use. These important sustainability features were in the Brundtland Commission thought frame (1987) outlined to be considered within the three-dimensional space of connected ecological, economic and social dimensions of the development—and with a long-term multi-generational perspective—and all being seen as a systemically combined set of criteria of central concern. This holds true both with regard to “urban” as well as “rural” expressions and the combination of both.

We are in fact already expanding such ideas—although the implementation is still too weak in relation to the tasks ahead. To some extent we are touching what, in a broader sense, could stand for “actions by humans in order deliberately to influence his/her environment” to improve the practices from the earlier preindustrial and industrial connotations facing our contemporary sustainability challenges. When we reflect upon a longer historical time perspective it seems that we are now moving into a rapidly changing environmental situation that may threaten to move humankind outside the earlier environmental conditions of long-term stability (corresponding roughly to the last ten thousand years i.e., the period sometimes called the Holocene, during which stability conditions, e.g., provided a frame for developing agriculture).

As there are recent and strong signs that suggest that we are uncomfortably and speedily heading into a situation where we might be moving out of the period of stable conditions, we should—even for the close future—distinctly start working to prepare to match the challenges of the possible emerging of the period of Anthropocene.

The characteristics of this emerging period during the last few years have been discussed (Crutzen and Stoermer 2000, 2002; Steffen et al. 2004, 2007, 2011; Richardson et al. 2009; Svedin 2009) especially in terms of being the period in the history of this planet in which humankind has grown in its influence and impact to be equal or even dominant in comparison with the size of the natural processes that always have been the dominant forces in earlier history (Vitousek et al. 1997).

Here we e.g. refer to the human influence on agriculture and food related material cycles as those of nitrogen and phosphorus, or the energy-related carbon cycle (of key importance for the climate change processes through the net flow into the atmosphere of carbon dioxide and other “greenhouse gases”). In a very long time horizon the “agricultural revolution” since around 8000 B.C. could be seen as a growing global impact of human intervention in planetary cycles, modest before “our modern times”, not disregarding the serious earlier regional disturbances, e.g., in empires such as Mesopotamian (in current Iraq and Syria) due to what now could be identified as agricultural malpractice at that time. The human endeavour has thus during the last ten thousand years constantly explored the possibilities embodied in various environments for survival and sometimes even expansion, i.e. for the intentional instrumental use by humans.

In this expanded perception of what the “manufacture” type of production could be seen to be—i.e. indicating human production of material conditions and “commodities” for a constantly growing world population and with increasing per capita demand—the importance of sustainability conditions is quickly increasing. This especially holds true since humans, due to the growing size of interference in the planetary material cycles, become more and more responsible for the health of the planet and for life on it. The combination of production and consumption will have to find new forms. This means that attention will have to be increasingly paid to how “production” is structured, organised and ethically pursued. These concerns also have to include a wider strategic consideration about how a “stewardship of the planet” in the period of the Anthropocene should be conceived and operationalised.

3 From Rural to Urban Futures—and Back

Thus, during the entire history of humankind a basically rural existence, with towns being an exemption, have been transformed into a heavily urbanised world of today. Still the seemingly two worlds—the rural and the urban—are not to be observed in isolation but as a connected systemic whole. A didactical expression of that is found today in the dense forests of Yucatan in Mexico where the ancient Mayan monuments hiding in the jungle are shown to the tourists. These old monuments are reminders of a glorious Mayan civilisation and making visible the urban nodal points of times gone half a thousand years ago (and, as we know, of a civilisation being crushed by European invaders). If we follow the recent findings of vast ancient systems of waterways below the land surface created—“manufactured”—in old times to provide drinking water and probably also irrigation for agriculture, we get a vivid expression of an ancient rural-urban system—the strong touch of humans—once and for all seemingly gone forever. However, if we in addition to just watching the visual appearance of the jungle landscape also listen to the local experts on Mayan botany, they tell us that we still today can see the organising human touch from the composition of plant species and through other indications in the basically unmanaged forest over the half a thousand years. For those who have eyes to see and the knowledge that 500 years gone have not demolished the signs of structural features of the rural and urban systems of a past civilisation connected in a combined and very deliberate way.

Similarly, we have to consider the strong systemic connectivity between the rural and urban worlds (Svedin 2011a) of our time. This is especially true in a situation of the still continuing growth of the world population—and of the fraction of the urbanised population expected to rise from around 50 % today to somewhere around 70–80 % in the next half century. This will indeed put pressure on the whole system, but it does not mean a decreasing importance of the rural system that will have to support the increasing urban population. The increased load will rather demand responsibilities of the rulers of the urban world for sustainable solutions to be expanded across the vast “hinterlands” of the rural support to the urban life

(Seitzinger et al. 2012). This connectivity—of systems solutions and the governance responsibility—will have to find its embodiments at all kinds of levels of the geographic scale from the global (in terms of collaborative measures between the major mega-cities) down to regional and semi-local integrated approaches.

It also means that the urban space will have to take a share of the production of local food in new ways. By development of computer networks and new facilities to operate societal functions regardless of geographical locus, i.e. through new processes in the work life earlier distinctly attributed to urban activities—e.g., regarding knowledge production—will spread geographically into new patterns of labour in earlier distinctly "rural" societies, i.e. based on rural practices. This will be a challenge also for Europe with its specific geographical, historical, cultural, political, infrastructural and economic conditions.

The keywords for the future relate to "understanding complexity" and implementation of connected management, multi-level micro-meso-macro connectivity (Liljenström and Svedin 2005), sustainability solutions, and interwoven systemic collaborative urban-rural arrangements. In this perspective, the rural development is more than sustainable agricultural development. As the rural and urban issues are strongly linked, the social aspects have to be considered distinctly when reflecting on handling the environmental constraints at all levels in broader sustainability connotations. Recent studies of the role and features of the future of agriculture—especially in relation to food security and the related structure of the demand for such commodities—strongly point to both the environmental and the social considerations in the rural-urban nexus (IAASTD 2009; Bengtsson et al. 2010; The 3rd EU SCAR Foresight 2011; UK Government Office for Science 2011; FAO 2011; Svedin 2012).

4 The Challenges of the Global Environmental Conditions

The social and structural changes alluded to above will have to be disposed to a drastically and quickly changing environment, not least in terms of climate conditions but also with regard to other often related changes of different sorts. The impact of the human enterprise on the planetary conditions is already raising concerns. Earlier in the 20th century it was relevant to reflect and take actions on *local* sustainability conditions (even before the word "sustainability" was in use) of the local and regional realities. But—as expressed symbolically by the focus of the Stockholm UN 1972 conference on the Environment through its international emphasis—there is a new historical need to watch closely what has been called "a safe operating space for humanity" at the planetary level (Rockström et al. 2009a, b). In such an analysis—exemplified by nine selected domains of challenges—the degree to which humankind already has reached, or is about to reach, that could be considered as serious "boarders" or "thresholds" that should not be transgressed under a further pressure of continued or increasing human activity. Especially

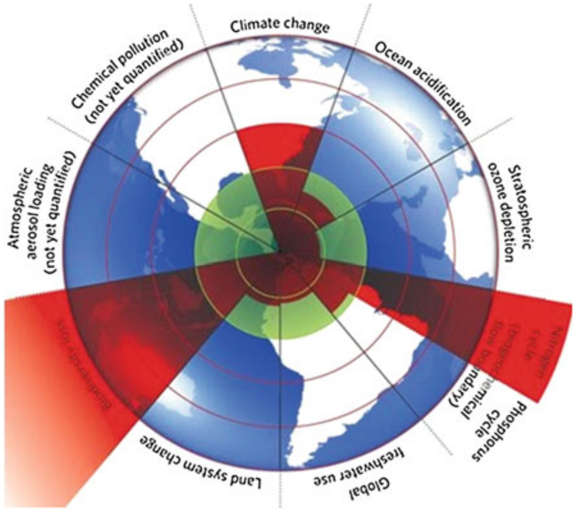


Fig. 1 Degrees of selected planetary risks (according to Rockström et al. 2009a, b)

critical issues in a broader historical perspective are the climate, the erosion of biodiversity and the nitrogen cycle. The chart in Fig. 1 provides an image of the state of the nine chosen categories. The degree of shading for the respective sector (from the centre out to the "risk periphery" represents the degree of human planetary involvement and related "risk") (Rockström et al. 2009a, b).

As emphasised in this analysis, the chosen issues are related not only to climate change, e.g. in terms of the overall change of the carbon cycle (with its close links to whatever happens in agriculture and forestry), but also to other cycles. In addition to the increasing importance of water conditions (in either "green", "blue" or other forms) (Falkenmark et al. 2009; Rockström et al. 2014), the nitrogen and phosphorous cycles have an integral relationship to agriculture—as does biodiversity (see e.g. Chapin et al. 2000).

With regard to the specific threats connected to climate change the IPCC report of 2007 (IPCC 2007) (enforced by the positions taken later in the IPCC reports presented 2013–14) provided an illuminative chart of a sequence of impact sectors (Fig. 2). The risk pattern of a specific "sector" is indicated through a multi-coloured vertical bar. At the bottom of the "bar" the risk is low and very high at the top. The interesting issue is how the risk panorama depends on the (vertically represented) state of global warming. In the lower part of the diagram the mean temperature is not considered to rise very much (+1 °C on global average) while the rise could be as high as 5°–7° at the vertical top level. The figure illustrates that problems quickly expand in almost all "sectors of impact" (top of the vertical bars) at a rise beyond 2°. One reason is an unpredictable increase of systemic risks when the rise of the global mean temperature exceeds 2°. The mean temperature increase is very sensitive to the degree of the possible emission reductions to the atmosphere that could be mobilised in form of deliberate countermeasures to the current rate of Green House Gas emissions. It is these potential reductions—especially with regard to the

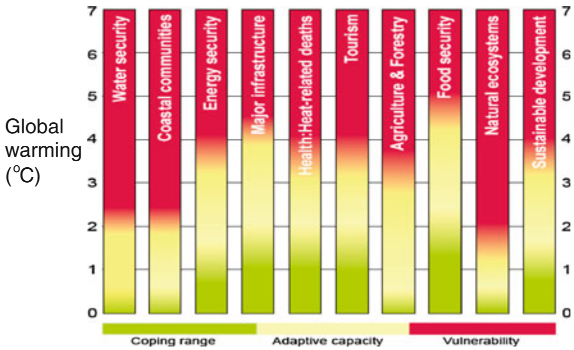


Fig. 2 The IPCC (2007) assessment of the risk panorama for global temperature increase distributed over a set of "sectors"

carbon dioxide emissions with the origin in fossil fuel use globally—that have to be implemented. This need was further empasized in the new update of the IPCC risk assessment in 2013–14, especially if the global mean temperature is expected to rise above the +2° level (for a set of scenarios) within the next half century, i.e. if the pace of the predicted change is faster than the tempo of implementing the current counter-measures.

Since the rate of growth of the global temperature depends on the counter-measures taken by humanity, the world policies—and their implementations—are of great importance. This holds true not least for already defined EU policies and their future implementation—striving for a low or zero net carbon outlet to the atmosphere by 2050—aiming to stabilise the global rise at the 2 °C level. Here efforts have to be mobilised to monitor the development, and to create model systems for transformation of the European societies by the policies and design of the political processes associated with these changes (COMPLEX 2012).

5 Regional Aspects in the Northern Europe—The Baltic Sea Region

The general issues alluded to above also have distinctly regional characteristics. With regard to the future potential climate situation in the northern region of Europe it is expected to be distinctly warmer and probably also characterised by more humid conditions. As with most of all future climate changes in general, more intense forms of weather driven phenomena are expected: storms and hurricanes, flooding—and also drought. Northern Europe will probably be characterised more by humid than dry conditions. This emerging general Northern European natural panorama combines with more specific features related to the Baltic Sea. One of these features is that of the eutrophication—mostly driven by the agricultural activities around the Sea. In addition, the outlets from sewage systems in most countries around the Sea also contribute to the water conditions. Fishing activities of varying intensity strikes the biodiversity situation in the aquatic ecosystem. This also holds true for industrial, especially the toxic, outlets of a number of sectors.

The kinds of outlets vary from legal to illegal kinds with a grey zone in between, such as outlets from marine vessels, from mining activities, and general types of urban outlets. Since the connection of the Baltic Sea to the North Sea and the Atlantic is fairly narrow, the conditions of the Baltic also depend on the streams and winds in the geographical interface areas, with considerable impact on the flows in and out of the Baltic Sea (Fig. 3).

Considering some of the flows already discussed above in the "planetary concern section", phosphorus (P) is a finite fossil mineral, which is mined for human use, and its use leads to increased amounts of P leaking into soils and from there into waterways, eventually causing pollution of the Baltic Sea. A major concern—highlighted in the article "Planetary Boundaries"—is the growing interaction, through human interference, of the nitrogen (N) and the P cycles. This interaction intensifies eutrophication (notably algae blooms) in rivers and coastal areas, as well as anoxia (severe reductions of oxygen levels in water eradicating aquatic life). Such challenges are well known in the Baltic (Zillén et al. 2008) and have been the object of considerable efforts at international negotiations and institutional platform designs, in an attempt to combat the problems during the last few decades.

Fig. 3 The watershed area around the Baltic Sea (Ref. The Beijer Institute at the Royal Swedish Academy of Sciences, Sweden). (For an overview of GIS information about the Baltic Sea Drainage Basin see e.g. Sweitzer et al. 1996)

How does this relate to the future of the Anthropocene with probably even stronger human impacts than the intense activities affecting the Sea today? The answer might be framed in terms of the balances of forces. On the one side the urban, industrial, sea transport, and agricultural activities might be even stronger than today. The demographic pressure of migration in the region could be stronger (due to various reasons of immigration: economical, political and environmental)—and the intensity of impacts might not slow down if the counter-measures are too weak. The political, economic and cultural connectivity however might become stronger in the future if a joint rational and wise governance effort is mobilised. The connectivity of all the EU states around the Baltic is already a sign of hope, although much more in terms of environmental protection and long-term collaborative actions to serve sustainability purposes is definitely required. But the emerging frame is there—and for the EU states the gradual step-by-step enforcement of common EU legislation and associated processes is under development, exemplified by the current implementation of the EU water directives.

A sense of common sustainability mission within the countries (including Russia) surrounding the Baltic to create common policy instruments, enhanced common institutions, and a broad cultural and economic understanding about the importance of common actions by the population around the Baltic Sea are needed. In a certain way the prospects here in this part of the world are much better than in others. There already exists a legal interstate framework and a high level of education in the involved countries. To some extent there is also a common history to be alluded to and a common economic interest not to ruin the biospheric basis by sloppy or illegal practices. Whilst the degree of future complications should not be underestimated, there exists a real need but also possibility for early and urgent action.

6 Challenges in the Period of the Anthropocene

6.1 On Complexity and Uncertainty

There are several major challenges entering the historical period of the anthropocene. The first deals with *the uncertainties connected with the nonlinear features* of the current socio-economical-cultural ecological system. The increased connectedness in that system provides all sorts of feedbacks and feed forwards opening drastic surprises. The uncertainties are of several kinds as has at an early stage been remarked e.g. by the late IPCC founder Bert Bolin. He considered three types of uncertainties that in different ways all relate to decision making. *The first* is due to present *insufficient knowledge* of various relevant systems that, in principle, could be addressed by further research. *The second type* is of a more complicated nature, but *although the detailed prognostic capacity is absent*, *there might be possibilities to make statements about a future "ensamble" of features of the system* in a probabilistic approach.

The third and most difficult group contains all those uncertainties that *are not reachable for prognostic statements in principle*. It might not always be easy to distinguish from situation to situation which of these types are at hand in a particular case. What could be said though is that, with regard to decision making, the three types will have to be handled in different ways. For the first category obviously more research is called for and also greater investments in the production of analytical knowledge. Here, also the connection between the research world and the decision making structures is important at various levels—from global to local.

This also holds true for the second category of uncertainties where it is important to find transparent ways to tell something about the nature of the limits, to make certain prognostic statements as an input to the dialogue between researchers and decision-makers. For the third category (intrinsically unknowable) the advice has to emphasise the need for development of flexible instruments and policies that could be mobilised when facing unknown events. Importance of finding ways to handle the different types of uncertainties increases in the period of the anthropocene. Here the interface between the system generating knowledge and the decision making world is of increasing importance (Svedin 2011b).

6.2 Biosphere Services

There are several specific issues that emerge in the context of the anthropocene. One deals with *the concern that capacity of the biosphere to continue delivery of fundamental services for humankind and to the rest of the natural world might be "eroded" by human action—knowingly or without really being sufficiently contemplated*. With the increasing human load on the biospheric system, the resilience issues are coming more and more into focus. Of particularly high importance is when considering the resilience of the whole system means to address the relationship between the societal processes and the changing flows and sizes of the natural cycles.

6.3 Systems Concerns and Resilience

One way to illustrate such features is to consider a specific system in relationship to its environmental context as a "ball" rolling in a constantly changing "topological landscape". If the landscape is tilting towards "the geographical left" (see the front part of Fig. 4), the ball is also rolling towards the left as time goes by.

If the landscape is changing by tilting towards the right as is illustrated in the back of the figure, the ball is moving towards the right. But sometimes the landscape is not flat as a plane but has features of "hills and valleys". In such cases the "ball" might find a (semi-) stable point. When the landscape is changing (i.e. along the dimension "conditions" in the figure), stability might be eroded and the earlier fairly stable situation is changed. Suddenly the situation has changed to such an extent that the ball just totally rolls out of its previous (semi-) stable conditions (see

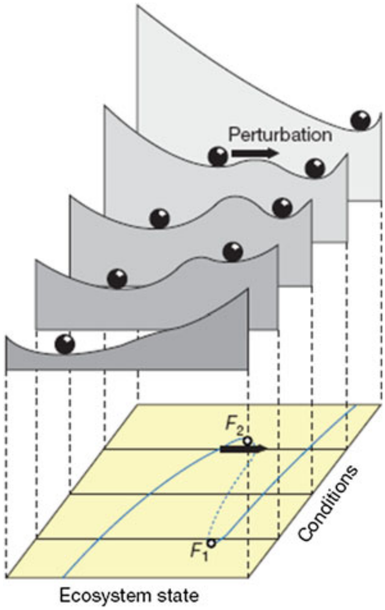


Fig. 4 Illustration of changes in the context of the "topological landscape" (see direction "conditions") and how they influence the features of stability conditions for a particular system (see distribution of the states—represented by "balls" in the "ecosystem state" dimension). (For an elaboration of changes in such a space see e.g. Folke et al. 2004). The figure can illustrate many different types of dynamic processes

Fig. 4). Here the resilience features depend on both the characteristics of the "ball" itself and on the surrounding contextual landscape—and their respective changes.

In the Anthropocene period onward, such "topological landscape changes" might be more frequent and potentially more drastic. The topological landscape of conditions in the Anthropocene might not be as smooth as earlier. The "ruggedness" of the topological landscape might be stronger—e.g., as an alpine mountain region differs from a landscape of smooth hills. This also means that when there will be changes in the new system of the Anthropocene i.e. when the "ball" starts rolling out of its earlier (semi-) stable position, it might fall quicker and steeper into the next valley—because the topological landscape looks more like a "mountainous landscape".

The increased load of global population (probably stabilising around 9–11 billion within a century) and its distribution over the earth might be seen as a facet of such a "changing landscape". The shift from a rural to urban population heading to 70–80 % of the global population dwelling in urban spaces is connected to the "topological landscape shift" (Seitzinger et al. 2012 and references in that paper). The shifts are going on in Europe, although the increase of the world population today takes place in other geographical parts. However, there are connections to the more general demographic panorama in terms of current and future migration into Europe and effects on the landscape of global production and consumption. Thus, global food security—affected by the climate change—will increasingly manifest itself in the European socio-ecological system.

6.4 New Management and Governance Features

In the world of new "topological conditions" the forms of actions must change. This calls for changing emphasis on perspectives in the knowledge-producing system. This new knowledge of the kind of systems has to match the demanded action in a better way (Svedin 2011b). The implementation capacity and momentum of policies must increase at all levels including the global. New forms of cooperation have to be initiated with long-term sustainability in mind. One example is the suggested collaboration about such issues between mega-cities of the world (Seitzinger et al. 2012). Such moves towards a planetary system of management embracing the world conditions need a much improved reflection on what such stewardship in terms of responsibility and ethics might mean.

6.5 New Balances

The needed emerging system is characterised by new balances. The high pressure for efficiency gains (not only in materials and energy but also in more general terms of "resources for function") is strongly required on the production side to join with the "slimming of consumption"; these aspects especially put pressure on the global environmental conditions, e.g., meat consumption. This will have to connect to a new set of standards aiming at "less is better", which in turn might relate to more pronounced reflections on issues started to be discussed already today, for example, in terms of the "happiness index" (exemplified by the "Bhutan" approach, or in other forms dealing with the need to reform the metric of value assignment and similar goal structures; that is, moving away from too limited and "simplistic" GDP types of measures not providing sufficient insight about hidden costs and benefits—especially in a cultural context).

Generally the systems approaches (including more "systems thinking") to the broad range of decision-making issues will have to be involved constantly. This necessity is being driven in particular by the increasingly complex nature of the behaviour of systems rooted in the growing number of linkages—mirrored by an expanding set of feedbacks and feed-forwards.

The challenges will need a corresponding educational "system emphasis", and attention being paid to research. The governance systems will have to be designed to allow the balancing considerations and finding natural platforms for dialogue and evaluation.

7 Summary

A summary of development directions for the period of the Anthropocene could thus improve the dialogue on the development of a new mind-set reflecting the emerging conditions. This involves:

- to be alert to social and demographic factors

- to boost new technological solutions in conjunction with social, economic and cultural sensitivities and the "degree of smartness" constraints
- to change the corresponding knowledge-producing system towards an understanding of systems thinking and its solutions
- to encourage an improved sensitivity towards the multilevel, multi-functional and multi-actor characteristics of the emerging system
- designing of new governance structures (connecting the local and the global) to match the grand challenges—and not continuing only within the historically given frames
- to be alert of issues of culture and rules in the move into a more integrated world system with common responsibilities for the planet in the period of the Anthropocene.

References

Bagley R (ed) (2001) Ancient Sichuan. Treasures from a lost civilization. The Seattle Arts Museum in Association with Princeton University Press, Princeton

Barthel S, Crumley C, Svedin U (2013) Bio cultural refugia—safeguarding diversity of practices for food security and biodiversity. Glob Environ Change 23(5):1142–1152

Bengtsson J et al (2010) Future agriculture—livestock, crops and land use. A strategic programme for research. Swedish University of Agricultural Sciences (SLU), Sweden

Chapin FS et al (2000) Consequences of changing biotic diversity. Nature 405:234–242

COMPLEX, EU-project (2012–2016). Knowledge Based Climate Mitigation Systems for a Low Carbon Economy. www.complex2050.eu

Crépin A-S (2007) Using fast and slow processes to manage resources with thresholds. Environ Resour Econ 36:191–213

Crutzen PJ (2002) Geology of mankind: the Anthropocene. Nature 415:23

Crutzen PJ, Stoermer EF (2000) The "Anthropocene". Glob Change Newsl 41:17–18

Falkenmark M, Rockström J, Karlberg L (2009) Present and future water requirements for feeding humanity. Food Secur 1:59–69

Folke C, Carpenter S, Walker B, Scheffer M, Elmqvist T, Gunderson L, Holling CS (2004) Regime shifts, resilience, and biodiversity in ecosystem management. Annu Rev Ecol Evol Syst 35:557–581

FAO (2011) FAO food price index. Downloaded from www.fao.org/worldfoodsituation/wfs-home/foodpricesindex/en/

IAASTD (2009) Agriculture at a crossroads, International Assessment of Agricultural Knowledge, Science and Technology for Development

IPCC (2007) Fourth Assessment Report (AR4), The United Nations Intergovernmental Panel on Climate Change

Liljenström H, Svedin U (eds) (2005) Micro, meso, makro. Addressing complex systems couplings. World Scientific, Singapore

Richardson K et al (2009) Synthesis report. Climate change: global risks, challenges and decisions. University of Copenhagen, Denmark

Rockström J, Steffen W, Noone K, Persson Å, Chapin FS, Lambin EF, Lenton TM, Scheffer M,Folke C, Schellnhuber HJ, Nykvist B, de Wit CA, Hughes T, van der Leeuw S, Rodhe H, Sörlin S, Snyder PK, Costanza R, Svedin U, Falkenmark M, Karlberg L, Corell RW, Fabry VJ, Hansen J, Walker B, Liverman D, Richardson K, Crutzen P, Foley J (2009a) Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14(2):32. www.ecologyandsociety.org/vol14/iss2/art32 (This is a more elaborated version at the same time andwith the same authors of the article referred to below, i.e. Rockström et al in Nature, 2009b)

Rockström J, Steffen W, Noone K, Persson Å, Chapin FS, Lambin EF, Lenton TM, Scheffer M, Folke C, Schellnhuber HJ, Nykvist B, de Wit CA, Hughes T, van der Leeuw S, Rodhe H, Sörlin S, Snyder PK, Costanza R, Svedin U, Falkenmark M, Karlberg L, Corell RW, Fabry VJ, Hansen J, Walker B, Liverman D, Richardson K, Crutzen P, Foley J (2009b) A safe operating space for humanity. Nature 461:472–475 (A more detailed presentation was published at the same time by the same authors (2009a) in Ecology and Society 14(2):32. www.ecologyandsociety.org/vol14/iss2/art32)

Rockström J, Falkenmark M, Allan T, Folke C, Jagerskog A, Kummu M, Lannerstad M, Meybeck M, Molden D, Postel S, Savenije HHG, Svedin U, Turton A, Varis O (2014) The unfolding water drama in the Antropocene: towards a resilience-based perspective on water for global sustainability, Ecohydrology 7(5):1249–1261

Seitzinger SP, Svedin U, Crumley C, Arif S, Alfsen C, Broadgate W, Biermann F, Bondre N, Dearing J, Deutsch L, Dhakal S, Farahbakhshazad N, Gaffney O, Haberl H, Lavorel S, Mbow C, McMichael AJ, Morais J, Olsson P, Pinho P, Seto K, Sinclair P, Stafford-Smith M, Steffen W, Sugar L (2012) Planetary stewardship in an urbanising world: beyond city limits. AMBIO 41 (8):787–794

Steffen W, Sanderson A, Tyson PD, Jäger J, Matson P, Moore B III, Oldfield F, Richardson K, Schellnhuber HJ, Turner BL, Wasson RJ (2004) Global Change and the Earth System: a planet under pressure, IGBP Global Change Series. Springer, Berlin

Steffen W, Crutzen PJ, McNeill JR (2007) The Anthropocene: are humans now overwhelming the great forces of nature. Ambio 36(8):614

Steffen W, Persson Å, Deutsch L, Zalasiewicz J, Williams M, Richardson K, Crumley C, Crutzen P, Folke C, Gordon L, Molina M, Ramanathan V, Rockström J, Scheffer M, Schellnhuber J, Svedin U (2011) The anthropocene: from global change to planetary stewardship. Contribution (background report Nr. 2) to the 3rd nobel laureate symposium on global sustainability, Stockholm, May 2011. Published in Ambio. http://dx.doi.org/10.1007/s.13280-011-0185-x

Svedin U (2009) Towards the gardening of the planet in the period of the Anthropocene: the world as socio-bio-space (SBS). Future options and challenges. Report to the EU foresight study "The world in 2025. Rising Asia and socio-ecological transition" published in summary by the European Commission, DG Research, EUR 23921, Brussels

Svedin U (2011a) Urban development and the environmental challenges—'green' systems considerations, European Commission, DG Regio, 2011. Thematic issue paper to the project "Cities of tomorrow—challenges, visions, ways forward". Ref. via the EU web link ec.europa.eu/regional_policy/conferences/citiesoftomorrow/index_en.cfm with specific reference to "urban environmental challenges"

Svedin U (2011b) Issues that need to be addressed—assessing experience. In: Kasperson RE, Berberian M (eds) Integrating science and policy—vulnerability and resilience in global environmental change. Science in society series (chapter 17). Earthscan, London

Svedin U (2012) Global conditions for the future of agriculture in the "anthropocen". In: Jacquet P, Pachauri RK, Tubiana L (eds) Development, the environment and food: towards agricultural change? (chapter 6). A planet for life 2012, French Development Agency (AFD), The Energy and Resources Institute (TERI) and The Institute for Sustainable Development and International relations (IDDRI), TERI Press, New Delhi (A French version was published simultaneously under the name "2012 Regards sur la Terre. Développement, alimentation, environnement: changer l´agriculture?")

Sweitzer J, Langaas S, Folke C (1996) Land cover and population density in the baltic sea drainage basin: a GIS database. Ambio 25(3):191–198

The 3rd EU SCAR Foresight Exercise (FEG3) (expert report) (2011) Sustainable food consumption and production in a resource-constrained world. ec.europa.eu/research/agriculture/scar/pdf/scar_feg3_final_report_report_01_02_2011.pdf

UK Government Office for Science (2011) The future of food and farming. Final report, London

Vitousek PM, Mooney HA, Lubchenco J, Melillo JM (1997) Human domination of Earth's ecosystems. Science 277:494–499

Zillén L, Conley DJ, Andrén T, Andren E, Björk S (2008) Past occurrences of hypoxia in the Baltic Sea and the role of climate variability, environmental change, and human impact. Earth-Sci Rev 91:77–92

Is Local Energy Supply a Main Road to Sustainability?

Lars Rydén

Abstract

The use of local energy production as a strategy to improve energy safety, control costs and mitigate climate change is reviewed. Local energy is in practice equivalent to renewable energy. There are a large number of different sources of local energy production. Some of them, including solar electricity, energy efficient building and biogas production, are in rapid technical development. The use of local energy is estimated to be around 50 % in Sweden. A number of cases, mostly from Sweden and Europe, where local energy has been a strong and important policy are described. Networks of municipalities which work for local energy autonomy are found all over the world and some of them are reviewed. Typically a strong policy for local energy production creates substantial numbers of job opportunities and thus contributes to the local economy, provides social and environmental benefits, improves energy security, and reduces emissions of greenhouse gases.

Keywords

Local energy · Sustainable development · Energy security · Energy safety · Renewable energy · Energy mapping · Distributed generation · Energy autonomy · Energy efficiency · Transition towns · Case studies

---

L. Rydén (✉)
Centre for Sustainable Development, Uppsala University,
Villavägen 16, 752 36 Uppsala, Sweden
e-mail: lars.ryden@csduppsala.uu.se

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_2

1 Background and Some Definitions

One of the largest difficulties for sustainable development today is the overwhelming dependence of most societies on non-renewable fossil energy supplies (Höök et al. 2010). The consequences of the enormous use of fossil carbon are twofold—first that supplies will come to an end; secondly that the end product builds up and causes environmental damage. For all non-renewable resources the effects of end products are typically felt before the source is emptied; the end product of the combustion of fossil carbon is foremost carbon dioxide causing climate change although there are also a number of other serious pollution problems appearing long before reaching the global peak oil. An additional dilemma is that for most societies the energy use has been tightly coupled with the economic growth throughout the history (Stern 2003) and dwindling energy resources is feared to cause economic decline.

So far the efforts to establish a carbon free economy, not dependent on fossil coal, oil and gas, have been mostly discussed as a global problem and in need to be solved as part of a global agenda. Here I will, on the contrary, ask to what extent it may instead be seen as a local problem and be solved locally. The questions to be addressed in this paper are:

1. To what extent have the possibilities to fulfil the local energy needs by local energy supplies been discussed as an option for policy or strategy?
2. What is the potential of local energy supplies?
3. To what extent has local energy supplies replaced previous external energy supplies?
4. What are the steps needed to achieve that?

Since very few countries, about ten, have large supplies of fossil carbon sources (Aleklett 2012), local supplies in most cases are equivalent to *renewable* energy sources. This does not make the issue of local supplies less valid. Research on renewable energy suggests that globally it is possible to replace all fossil energy with renewable alternatives—wind, water and sun—in a fairly short period (Delucchi and Jacobson 2011). Regardless of the possibility that in a few cases fossil carbon actually is available locally I will here refer to local energy supplies as renewables.

Renewable sources do not, however, need to be local in any advanced meaning. They may often be national, as for example large hydropower plants can even be used by several countries responsible for supplies as is assumed in the *Desertec* project now attracting huge investments for solar electricity in northern Africa, mostly Tunisia. Here, however, I will refer to local as mostly municipal, sometimes regional, or even smaller scale: energy-independent houses or households or neighbourhoods in cities will be considered part of the local energy supplies of local communities (municipalities).

2 Local Energy Supply as a Policy and/or Strategy Option

When searching the web and other documents for policy declarations on local energy they appear under a *variety of names*. Thus, communities which declare their intention to develop local energy supplies may work for Energy independence, Energy autonomy, Energy Self-Sufficiency, Energy self-reliance or to become Fossil fuel free.

As a *strategy* option in the literature on sustainable development it is most often referred to as Distributed generation or Distributed production. It is interesting to note that in the Baltic University Urban Forum project (Rydén 2006, 2008) the most common sustainability strategy option was *rescaling*. Both *upscaling* (e.g. from individual heating of houses to district heating) and *downscaling* (e.g. from district heating to heat pumps) are common strategies. Developing local energy supply may be seen as a down-scaling strategy going from international, import-dependent, energy provisions, to the strategy of managing energy needs on the local scale.

From many discussions with local politicians it seems that the declared *reasons* for developing local energy supplies are dominated by the communities' intention to increase their *energy safety* (World Energy Council 2011). In particular the approaching peak oil with an expected increased competition for fossil carbon based energy (especially oil) is feared. Often the cost of buying external energy, or a feared future sharp increase of costs, is also a reason for developing local energy sources, and a part of developing energy safety. For municipalities and regions (and nations) the climate argument is always or almost always there, but more as part of the initial discussion and not so visible in the actual planning of local resources. The exchange of fossil carbon for renewables is then seen as a mitigation step to combat climate change.

With the German post-Fukushima energy policy—*Energiwende*—this transition towards local supplies has become national policy (Respati 2012). It seems in the first place being caused by the determination to end the use of nuclear power. There are 21 nuclear power stations in Germany, more than decreasing the use of fossil sources of energy—the development of coal-based electricity production is still strong. But the effect is, nevertheless, dramatically increasing local energy supplies through solar cells, biogas stations, wind power, etc.

We also see some more principal discussions on the role of the local energy supply as promoted in the recent full-length movie "The fourth revolution—on energy autonomy" by Carl Fechner in Germany (Fechner 2010) reporting from societies in Denmark, Germany, Bangladesh and Zambia, all on the way to improve their life by using local energy sources. The web-based newsletter *Local Energy* (see localenergynews.com) declares that

> higher energy prices and uncertainty of supply are driving communities toward renewables, but the understanding of how to implement renewable energy such that local benefits are maximized is still in its infancy. Therefore Local Energy helps communities develop stronger, healthier economies based on local self-reliance in energy. There is a growing

awareness that continued reliance on energy supplies from outside of the local community – especially oil and gas – poses significant economic risks.

Several networks of municipalities and/or regions promote local energy initiatives all over the world. Examples illustrating this include the USA based Post carbon cities which advise cities how to tackle the problem (Lerch 2008). The sustainable cities and towns campaign, though ICLEI (local authorities for sustainability) and with support from the German Government, runs the Local Renewables Initiative which supports and strengthens local governments in promoting sustainable energy in the urban environment (See www.local-renewables.iclei.org). Activities exist in Europe, but are also important in India and Brazil. The Australian Government supports the Solar Cities network for a sustainable energy future with the aim of reducing greenhouse gas emissions, promoting energy efficiency, adapting to climate change impacts and helping to create a global solution (www.greenhouse.gov.au/solarcities/).

Several cities have independently declared their intention to become energy autonomous. Thus the French city of *Perpignan* proudly announces that "Perpignan has signed an agreement, in the presence of the Minister for Ecology and Sustainable Development, which will encourage a decrease in energy consumption along with the expansion of renewable sources of energy—wind power and photovoltaic solar power. It will allow Perpignan to produce more energy than it consumes." Similar declarations, but a little less pompous, are found, in Sweden by *Växjö* (one of the first) Mörbylånga on Öland Island, Gotland Island, and many others.

3 Local Energy Supply Today—The Case of Sweden

Clearly, the possibilities for a municipality to provide all energy needed for itself varies dramatically with the circumstances. For Sweden, energy autonomy is probably a comparatively realistic option due to the reasonably small population density, as compared to the more densely populated continental Europe. Sweden today has the largest share of renewable energy in the EU, close to 50 % (Fig. 1). Still there are a number of such projects in Germany, Austria, and the Netherlands. Here we will discuss separately heat, electricity, and fuels (e.g. for cars) and mostly stay within Sweden as an example.

3.1 Heating

In Sweden, the *heating sector* is becoming almost fossil-fuel free (Swedish Energy Authority 2011). Today very few buildings use coal, oil or gas for heating, since it has become quite expensive due to high carbon dioxide taxation. Most houses in the country today are heated by district heating, for which the power stations use biofuels. In the heating sector, thus, the vision of local energy supply is already

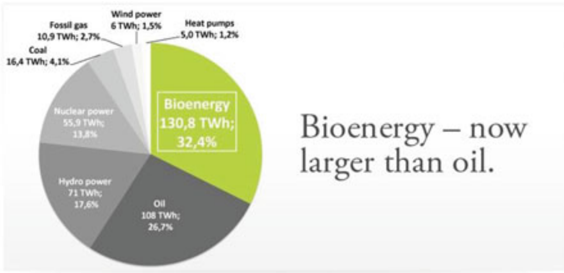


Fig. 1 Swedish energy budget 2011. *Source* Swedish Bioenergy Association (Svebio): www.svebio.se

close to reality. Many households—in 2010 estimated to be 800,000—use heat pumps. These need electricity but are 3–5 times more efficient than direct heating by electricity. Since the electricity in the country is practically fossil fuel free—about 50 % is hydro and 50 % nuclear—it does not contribute much to GHG emissions even if it is not local. Solar panels for solar heating exist, but are less common in Sweden than in southern Europe where they are found on almost every house. Finally, the use of wood chips or pellets for heating is also a growing market.

Energy efficiency measures are an important part of making local energy supply sufficient. Especially in the heating sector where the needed energy may be substantially reduced by energy efficiency projects. In Sweden 38 % of the national energy budget, 150 TWh of a total of 400 TWh, is the energy demand in the housing sector (IVL, Swedish Environmental Institute 2011). An estimated 20 % of that can be reduced by efficiency measures. The experiences from the project *Energy Performance Contracting* (EPC), a European Energy Service initiative, substantiates that. In Sweden (epc-sverige) there are more than 60 good examples (see www.epc-sverige.ivl).

For new houses, *low energy technology* is rapidly spreading, even if very few buildings so far meet a passive energy standard. The additional costs for building a low energy house is small, estimations vary between a few up to 10 %, compared to traditional buildings (Knivsta 2012), and the added costs are rapidly paid back by smaller energy bills.

3.2 Electricity

In Sweden, the electricity produced nationally is about 50 % hydro and 50 % nuclear and thus independent on imported fossils, a situation sharply different from Continental Europe where coal-based power stations dominate. Local electricity production is still in its infancy in Sweden, since the national supply is mostly safe and sufficient. Still, for many reasons, perhaps mostly discontent with the changes in prices, a number of individuals and local municipalities have developed their own local generation of electricity.

There is a long tradition in *small-scale hydropower*. Several thousand small stations have been in operation, some for up to 100 years, in many municipalities. However, production from these stations is not at all sufficient for the municipalities and often varies much over the year. 4.6 TWh is produced by the 1615 Small Hydropower Stations of the country; that is, those with an installed capacity of maximum 10 MW. Whether the larger national hydropower stations should be counted as local is a matter of definition.

Most important is probably *cogenerated electricity* from district heating power stations. Additional sources include *wind power* stations, owned by municipalities or individuals or groups of individuals. *Solar electricity* from photovoltaic cells on individual buildings, or fields of cells owned by local energy companies (e.g. Sala Heby Energy Company north of Uppsala) is today increasing very rapidly. For the energy independent (see below) local communities by far the most important source today seems to be wind energy.

3.3 Fuel for Transport

Probably the most difficult issue for local energy is fuel for transport. Today imported fossil fuel by far dominates the market. Examples of a different situation today include city buses using locally produced *biogas*. Thus, many municipalities in Sweden use their own biogas, produced from food residues and similar sources. In some areas we see regional buses using locally produced *biodiesel*, from oil seeds to make RME (Rapeseed Methyl Ester) or in FAME (Fatty Acid Methyl Ester). This is not a big share of all fuel in the public transport sector. Bioethanol, partly produced locally, is mostly used for cars. Biodiesel from forest sector's black liquor is rapidly increasing although not as local, but national projects. The share of electric cars and hybrid cars is slowly increasing and so is the energy efficiency of cars in general. A large-scale change to such technologies is still waited for.

3.4 How Much Energy Is Produced Locally?

Estimations of the extent of locally produced energy for Swedish municipalities today are close to guesswork. It is, however, obvious that it is not very low. Knowing that heating in the housing sector accounts for 38 % of the energy need of the country today and is mostly provided from local sources, and that the other two energy sectors—electricity and fuel for transport—is marginally taken care of locally we may make an informed guess. If these are estimated to be 5 % each we will still arrive at a total of 50 % local energy supply in the country. This is in sharp contrast to continental Europe where electricity production is dominated by coal fired power plants, district heating is not the rule as in Sweden, and transport is based on fossils; we have a clear advantage to explore the potential of local energy supply as a means of increased sustainability.

Municipalities which announce themselves as fossil-fuel free have all made their heating system free of fossils, and, as local electricity production is less complete, it may in fact boil down to fossil-free heating. It should be noted that household waste generation is not fully fossil-fuel free. In 2013, the fossil content of the waste incineration plant in Uppsala, one of the largest in the country, was 13 %, mostly due to plastic waste.

3.5 The Policy Steps to Promote Local Energy

Local-scale energy companies may be private, public or the public-private partnerships. Quite often we see municipal energy companies in which the city has a majority in the company board, while the daily business is run as in a private company. Typically, it is the smaller regionally or locally active companies, not the big international energy companies, which promote local renewable energy production (STUNS 2011).

The projects and investments of the local companies often rely on support from the local municipalities. Thus, the local energy supply typically requires a strong political support. Conditions for a strong local energy policy and steps taken to achieve that, were studied by the IIIEE at Lund University (Vega 2010). The cases reported by her included Växjö, Enköping and Kristianstad municipalities. There are several others, which have at least an equally strong local energy policy. Some 30 of them take part in the project *Klimatkommunerna* (Climate Municipalities), and others in *Omställning Sverige* (Transition towns, Sweden).

4 Some Cases of Communities with Strong Local Energy Policies

4.1 Continental Europe—Austria and Germany

It seems that the small Austrian town of Güssing (see webpages) close to the Hungarian and Slovenian borders, is an extraordinary case. From 1992 within eleven years, Güssing became self-sufficient with regard to electricity, heating, and transportation. It was all the result of building a modern CHP plant which also produces biodiesel based on gasification of woodchips. Thus, heat (and an added district heating network) and electricity were produced locally, as was the fuel for transport. In the process, more than 60 new companies and over 1500 new "Green Jobs" were created and the share of commuters to other regions fell from 80 to 40 %. The value added to the region by sale of "surplus" energy products is over $28 million per year. Finally, green-house gas emissions were reduced by over 80 %.

This development was initiated and supported by a new mayor elected in 1992, and a Viennese scientist who developed the technology of wood chip gasification. Energy efficiency in the buildings in the town was also drastically improved, by almost 50 %. The approach spread and there are today 27 decentralised power plants within the Güssing County. In Austria as a whole more than 15 regions are, and a further 66 region work to become, energy independent with regard to electricity, heating and/or transportation. This covers 1.7 million inhabitants or 21 % of Austria's population (from www.blogs.worldwatch.org).

Also in Germany one may find extraordinary cases. The neighbourhoods of Vauban and Rieselfeld in Freiburg on the border with France and Switzerland have become, in the process of being rebuilt from a former military base into a residential area, almost energy independent. The area is very energy efficient; new regulations require that new houses use no more than 40 kWh/m^2 per year. About 50 % of electricity is produced by co-generation power stations which deliver heat to the district heating. There are about 90 small CHP units. 12.3 MW of solar PV panels, found on almost every house, produces 10 million kWh, and 5 medium sized wind turbines produce 14 million kWh annually.

Freiburg has developed a green image with political will and citizen involvement already over decades. It has fostered not only a very special "green culture" but also economic development. The initiatives have attracted about 1500 green businesses with some 10,000 employees; of these 1500 are in the solar energy sector. Austria and Germany appear to be in the frontline of developing fossil independence in Continental Europe.

4.2 Sweden

The Swedish town of *Växjö* decided in 1996 to become "fossil fuel free". Växjö has since built two biomass plants and use for the municipality only green electricity. In 2000 the municipality developed the "local initiatives award" and in 2007 became the winner of the "Sustainable Energy Europe Award". Växjö is also a frontrunner in low energy buildings. It is clear that there is a political consensus on the fossil-fuel free policy in Växjö; the members of the city council several times have participated in energy projects run by the municipality.

Many smaller towns and municipalities have a considerable energy independence mostly built on biomass. Thus, Enköping power station has its own energy forest (short rotation Salix plantation) and uses only forest biomass. Several farmers in the area use oilseeds to produce biodiesel. Heby municipality, with support from the inhabitants, has started to build fields of solar cells, an investment which continues and becomes more profitable as the investment costs for installations decrease. Several small neighbouring municipalities joined the initiative.

On the larger scale, one should mention *Stockholm Royal Seaport* (Djurgårdsstaden), one of Europe's largest urban development projects launched in May 2009. Stockholm Royal Seaport is planned to house 12,000 new dwellings, 35,000 work spaces and a modern port for ferries and passenger traffic. An intelligent electricity grid—smart grid—will reduce annual energy consumption to a maximum of 55 KWh per square metre annually. The fully automated system, currently being developed, will fine-tune heating and ventilation systems to run when electricity prices—and energy consumption—are lowest. The construction work started in May 2011. In 2012 the first inhabitants moved in.

4.3 Islands

On the island *Samsø* in Denmark with 114 km^2 the 4000 inhabitants changed their daily lives for greater energy efficiency. 21 wind turbines generating 28,000 MWh annually have been built to meet the community's electricity demands and public transportation system; the surplus to sell is 10 %. Farmers have adapted their tractors and other vehicles to use ethanol or other fuels distilled from locally grown plants, like canola. The community experiments with electric cars as distances are very short, less than 50 km.

Samsø may become the first truly energy independent island in the world. However, they compete with *El Hierro* in the Canary Islands for this position. But as El Hierro is important for tourism they receive a substantial support from outside. A 54 million Euro 11 megawatt wind farm and two hydroelectric projects were created by the local Gorona del Viento El Hierro consortium with financial aid from the European Union. It will supply electricity for approximately 11,000 residents, an additional number of tourists, and three water desalination facilities. A hybrid wind/pumped hydro storage system will store surplus wind power by pumping water up 700 m to fill the crater of an extinct volcano to store electrical power. The closed-loop hybrid wind/hydro system was scheduled to be tested by the end of 2011, but was still not complete in early 2013.

5 Some Comments on Technical and Economic Developments for Local Energy Production

5.1 Energy Mapping

The conditions which make it economically and technically viable to produce energy in the smaller and local scale is rapidly developing. There are a large number of possible energy sources on the local level. In a small energy mapping effort in Uppsala County we reached 18 different sources without being comprehensive. Some of them are listed:

- Electricity: CHP using various solid fuels including energy forest, forest waste, solar cells, wind power, hydro power, streaming water power, wave power.

- Heat: Solar panels individual or larger scale, heat pumps, incineration using wood chips, pellets, solid waste; biogas from manure, food residues, wetland plants
- Transport: biodiesel from different substrates, bio ethanol from different substrates, biogas, electricity.

This mapping activity maybe the first proper step when deciding on which technologies to develop for local energy supplies. A few interesting developments are commented on below.

5.2 Solar Electricity

The use of and installation of solar electricity is increasing rapidly, by up to 20 % annually in many areas. It seems as if photovoltaic (PV) has an advantage over concentrated solar power (CSP). The cost of installed MWh has decreased almost 4 times in 2 years, mostly due to massive production in China. Today the investment cost of installation of PV on the rooftop of a house in southern and mid Sweden is paid back in 7–9 years assuming energy costs of 1 SEK per kWh. The installation is then expected to produce electricity for another 20 years, or more. The absence of mechanical parts in a solar cell makes it less sensitive to wear. Research on solar electricity is very intense and it is reasonable to expect new types of cells and lower prices as technology develops and the scale of production increases.

The biggest dilemma with locally produced electricity is the difficulties to store electricity. Only for very limited use may an ordinary battery be sufficient, as we see e.g. in developing countries where the possibilities to use electric lights in the evening when they have a 1 m^2 PV on the roof has been a blessing in many families. New batteries will come, but in Sweden the most realistic option today is to sell excess electricity to the national grid and get electricity back during the dark hours. In practice, the large hydropower plants provide the storing capacity needed.

5.3 Heating

For heating, by far the best option is to build low energy houses and upgrade existing houses. Solar heating using panels should be profitable but so far have not been increasing much in northern Europe, although it is standard in the south. There are however some exceptions. In Kungsbacka 48 one-family-houses cover 70 % of its annual consumption of hot water from 900 m^2 of solar panel field, one of the largest installations in the world. The heating capacity in Sweden is not a large problem for most municipalities to provide locally.

5.4 Biogas

Biogas production is rapidly increasing in all of northern Europe even if it seems as if Germany and Sweden have the lead in this development. The investments needed in both countries are supported by state subsidies. In the agricultural sector biogas is used for both heating and electricity in CHP facilities. In the cities in Sweden it is upgraded to vehicle gas and much is used for public transport. In Germany this is less often the case and much biogas is fed into the national natural gas network.

5.5 Transport

Providing transport with energy sources other than fossil oil is the most difficult of the challenges of local energy supply. According to the Swedish Royal Academy of Sciences, the future of sustainable transport will rely on electricity. It is well motivated for the simple reason that electricity is much better for mechanical work than fuel (about 4 times less energy is needed than in a combustion engine). The development of batteries promises that storing electricity rather than the very energy dense oil will be practically possible. At present, the hybrid vehicle is the most energy-efficient alternative.

For combustion engines, biogas is now rapidly expanding. A recent prognosis is that all buses in the country may be run on biogas. Likewise, biodiesel production is rapidly increasing using forest products or oil seeds. A future possibility is to use forest products for the so-called second-generation biofuels, in particular methanol, or turn it into biodiesel.

Among the non-technical developments is a more efficient public transport network to decrease the use of the private car and thus the need for transport fuels in general. This is a development seen in larger cities. To this should be added the increased use of bicycles. This development requires better biking paths in urban areas and better parking options. It is a development going on in many cities at least in northern and partly in Eastern Europe.

6 Research Questions

The question of dependence on locally produced energy is an important one when global efforts to reduce coal, oil, and gas to mitigate GHG emissions look pessimistic. Still the interest from the research community is small. A few of the central questions include:

1. How many local authorities are interested in this option? What are the main reasons for those interested? Today it appears that energy security, i.e. safe supplies, high prices and environmental concerns, in particular for climate change, dominate.

2. What are the best policy instruments on the state level to support the local energy option? So far the German feed-in tariffs (guaranteed energy prices for locally produced energy) have been recognised as very efficient. It was also proposed at the COP 15 in Copenhagen by the UN CSD as the best option for a policy to combat climate change. Many states have also used subsidies to promote transition from fossil-dependent to renewable energy alternatives, including Sweden. Larger subsidies scheme include the Swedish KLIMP project (4 BSEK) concluded in 2012 in which close to 200 municipalities provide 75 % of the funding and the KLIMP 25 % in about 2000 projects. Another even more efficient scheme was the Program for energy efficiency in energy intensive industry (PFE) run by the Swedish Energy Authority since 2004 and now concluded. In this program 110 large companies invested 708 MSEK to reduce energy costs by 400 MSEK (1.45 TWh) annually to avoid tax costs by 150 MSEK.
3. Which is the balance between the actions taken by individuals and the municipality for energy projects? Today much of local energy production is made by households. This refers in particular to solar hot water panels and PV cells on the roofs. But also many households install boilers using wood pellets or heat pumps to reduce energy from outside. One may also mention increased bicycling reducing energy consumption for transport.
4. What is the role of small and local energy companies? Today we see that the large energy providers—Vattenfall, EoN, Fortum etc.—do not support local energy projects in contrary to many of the small companies, e.g. Sala Heby Energy AB (SHE) or Enköping Energy AB (ENEA) etc. STUNS, in which Uppsala University, Municipality, and the County work together, is presently running a project on the role of the small energy companies.
5. To what extent does local energy provision support local economic development? There are many examples of how this happens.
6. Local energy production is just one case of local resource provision. Is there a general lesson to be learned here that localisation of the energy and resource provision is a main strategy for creation of a sustainable future? (In contrast to globalisation and free trade, e.g. in the EU).

References

Aleklett K (2012) Peeking at peak oil. Springer, Berlin

Biogas in Sweden and North Europe. www.balticuniv.uu.se/index.php/component/content/article/271-reports/846-biogas-production-in-belarus-and-sweden

Delucchi MA, Jacobson MZ (2011) Providing all global energy with wind, water, and solar power. Part I: technologies, energy resources, quantities and areas of infrastructure, and materials. Part II: reliability, system and transmission costs, and policies. Energy Policy 39:1170–1190. www.stanford.edu/group/efmh/jacobson/Articles/I/DJEnPolicyPt2.pdf

Energy Performance Contracting (EPC) Sweden (2011) A project coordinated by Swedish Environmental Institute, IVL. www.epc-sverige.ivl.se

European Energy Service Initiative—EESI. www.european-energy-service-initiative.net/swedish/eu/project.html
Fechner C (2010) The fourth revolution—on energy autonomy, a film. http://energyautonomy.org/index.php?article_id=21&clang=1
Freiburg Energy. www.youtube.com/watch?v=IMnB6V5yG1I
Güssing Energy. www.gussingrenewable.com/htcms/en/company/history.html
Güssing, Austria. www.guessing.co.at/
Höök M, Sivertsson A, Aleklett K (2010) Validity of the fossil fuel production outlooks in the IPCC Emission Scenarios. Nat Resour Res 19(2):63–81, , doi:10.1007/s11053-010-9113-1
http://blogs.worldwatch.org/the-model-region-of-gussing-%E2%80%93-an-example-of-the-austrian-grassroots-strategy-for-energy-independence/
http://postcarboncities.net/node/2680
Klimatkommunerna (climate communities). www.klimatkommunerna.se/
Knivsta (2012) Personal communication at the passive energy house seminar at Knivsta municipality, Sweden
Lerch D (2008) Post carbon cities: planning for energy and climate uncertainty. http://postcarboncities.net/
Local Energy News. Energy self-reliance in action. www.localenergynews.org/
Local Renewables Initiative ICLEI. http://local-renewables.iclei.org/
Respati J (2012) German's "Energiwende" and Energy Security Respects July 26, 2012. www.respectsmagazine.net/206/
Rydén L (2008) Tools for integrated sustainability management in cities and towns. Baltic University Press, Uppsala. (http://www.balticuniv.uu.se/index.php/boll-online-library/858). See also BUUF (Baltic University Urban Forum). www.balticuniv.uu.se/buuf
Rydén L (2006) Urban sustainability strategies—is there a common structure? In: Filho WL, Ubelis A, Berzina D (eds) Sustainable development in the Baltic and beyond. Peter Lang, Frankfurt am Main, Germany, pp 177–193
Sala Heby Energy Company. www.sheab.se, http://vmisenergy.com/tag/solar-electricity/
Samsø, Denmark. www.visitsamsoe.dk/en/oplevelser/vedvarende-energi-o/
Solar Cities Network Australia. www.sustainablecitiesnet.com/research/movement-network-solar-cities-australia/
Stern DI (2003) Energy and economic growth. www.sterndavidi.com/Publications/Growth.pdf
STUNS (2011) Stuns Activity Report 2011, p 13–14 (in Swedish).http://www.stuns.se/media/1004/verksamhetsberattelse_2011.pdf
Swedish Energy Consumption (2011) www.svebio.se/english/bioenergy-facts
Swedish Hydropower Association. www.svenskvattenkraft.se/default.asp?L=EN
Transition Sweden (Omställning Sverige). http://transitionsweden.ning.com/
Växjö as fossil fuel free city. www.vaxjo.se/Other-languages/Other-languages/Engelska–English1/Sustainable-development/Fossil-Fuel-Free-Vaxjo/
Vega DC (2010) Renewable energy systems at the local level—transferability of Swedish experiences to Poland. Master thesis, IIIEE Lund University Report 2010, p 4. ISBN: 978-91-88902-65-8
World Energy Council (2011) Policies for the future. 2011 Assessment of country energy and climate policies, p 9. http://www.worldenergy.org/wp-content/uploads/2012/10/PUB_wec_2011_assessment_of_energy_and_climate_policies_2011_WEC.pdf

Introducing Education for Sustainable Development—Challenges for Students and Teachers

Paula Lindroos

Abstract

Networking and internationalisation among institutions of higher education can improve the opportunities and critical mass for partnerships in projects, and so provide a platform to widen the educational offer and develop new areas such as sustainable development. Dedicated university networks also offer their partners activities such as common seminars and courses, competence development and institutional change. In addition, networks can function as platforms for individual contacts at all levels, including students and teachers. One example from our region is the Baltic University Programme network which supports universities in their work to integrate sustainability in education, research, and management, and where researchers, teachers, and students cooperate at a macro-regional level. The BUP is a strategic partner of the Council of Baltic Sea States, and a Flagship project under the EU Strategy for the Baltic Sea Region to support enhanced university cooperation in the region. Current challenges for higher education include lifelong learning, diversified student groups, partnerships and internationalisation. Regarding sustainable development the challenges for education and research point at certain critical points, such as multidisciplinarity, systems thinking and the involvement of uncertainty and risk. Institutions of higher education are also important actors and role models in

P. Lindroos (✉)
Baltic University Programme, Uppsala University, Uppsala, Sweden
e-mail: paula.lindroos@csduppsala.uu.se

Present Address:
P. Lindroos
Centre for Lifelong Learning, Åbo Akademi University, Turku, Finland
e-mail: paula.lindroos@abo.fi

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_3

their societies. Much has been achieved, but still the work for sustainable development seems like a patchwork, and at all levels much remains to be done.

Keywords
Higher education · Sustainable development · Whole-of-institution-approach

1 Introduction

Networking and internationalisation can improve the opportunities and critical mass for partnerships in projects, and also widen the educational offer and development of new areas such as sustainable development. University networks can provide their partners with opportunities for activities such as common seminars and courses, competence development and institutional change. Networks can also function as platforms for individual contacts at all levels, including students and teachers. One current example is the Baltic University Programme (BUP) network, which has supported introduction of sustainability in education, research, and management, and where researchers, teachers, and students cooperate at a macro-regional level. Internationalisation, research and development of education for sustainable development have been the guiding principles of the BUP network. The BUP network has more than 200 member institutions of higher education, and it cooperates in projects with cities and other stakeholders in the Baltic Sea Region. The Baltic University Programme is a Flagship project under the EU Strategy for the Baltic Sea Region to support enhanced university cooperation in the region.

The common projects of the BUP network started in 1991 during 20 years have covered the whole region on topics such as sustainability, water management, the Baltic Sea environment, the cultures and societies in the region, urban development, environmental management systems, and sustainable agriculture. Locally at the universities or together, more than 1500 researchers and about 120,000 students have participated in common projects, courses, seminars, and conferences. The Baltic Sea regional approach and the introduced teaching and learning methods were identified at an early stage as being unifying components. Sustainability being a new and challenging topic in university education also brought up the need for competence development among university teachers in the region. The courses on sustainable development usually demand both a multi-disciplinary and an international approach and, consequently, the use of learning methods supporting both learning for and learning about sustainability.

2 Current Challenges in Higher Education

At present, there are several trends in higher education on the horizon. In the coming years, the agenda of the multidimensional change would include, among other things, lifelong learning, a diversified student population, partnerships in support of education, and internationalisation.

Lifelong learning is often defined as a set of activities provided outside the mainstream education. However, the situation is changing and in the future university level lifelong learning should rather be seen as an integrated part of university education. With external pressures, such as unemployment, needs of upgrading skills, and broadening participation, lifelong learning is moving higher up on strategic agendas of IHE.

Diversified student groups. Due to internationalisation in universities and demographic changes, universities find themselves in a situation where they are in competition for attracting students and researchers. The multinational and mixed-age student populations will need new ways of support in study counselling, learning provisions, and learning methods. At the same time, the need for widened access to education also calls for support from physical planning and flexible learning.

Partnerships in support of education. These partnerships traditionally involve research and researchers, but, in the future, education will be increasingly involved. Students also need to create their partnerships and networks, and cooperation with industry can already begin at the undergraduate level. The partnerships open up for varied teaching methods and contents and so they support many of the aspects of education for sustainable development.

One challenge to universities is shaped by the often specific market needs and the management of such tailored education in parallel with traditional mass education, which will create new study paths at the university. Work-based learning and accreditation of prior learning (even recognition of the equivalence to a full degree) as elements of higher education are two examples of models used already being a possible way to access higher education.

Internationalisation. In the European University Association Report Trends 2010, university leaders consider internationalisation, quality assurance and the Bologna process as the most important developments in the coming five years. The international partnerships are supposed to improve the critical mass in research, widen the educational offer and enhance the institutional reputation. As a consequence, there is a shift from the traditional individual contacts towards strategic institutional partnerships, and internationalisation should be a concern for all: the students, researchers, teachers, and the administration.

3 Higher Education and Sustainable Development

The UN Decade of Education for Sustainable Development (DESD) was declared for 2005–2014. The aim is to integrate sustainable development at all levels of education, the focus in its first years being on implementation of the ESD strategies and policies at national levels. The second part is focused on sharing good practices and developing a scheme of competences for teachers at all educational levels.

There are several roles for higher education in sustainable development. The first—the students as the "products" entering the labour market to meet the daily demands of the society. Are the students equipped for the sustainability issues that they will meet in their professional life? This question is relevant across all academic disciplines, but even if the idea that students need the competence in a particular kind of knowledge and action seems to be accepted, it is less clear how it is implemented.

The second is the research performed at universities. There will be increased opportunities for research on sustainability as long as the need is growing among businesses and organisations funding the research. However, one problem remains—the multi- and inter-disciplinary nature of sustainability research is still found in the shadow of the traditional disciplinary studies.

The third role is within the third mission, where universities cooperate and communicate with their societies and industry, through dissemination of research results and through dialogues for opening of new connections. In the learning societies these are arenas for innovation where information and knowledge travels in both directions. Both innovation and sustainability have a domain of uncertainty in common providing a tension between stability and change. Today we are faced with a situation in which students will not have the same permanent jobs during their whole career, and the students should be able to handle presently unknown circumstances that may occur. The tension between the known and unknown in university teaching, as a result, being just as strong as it is in research.

4 Learning Outcomes and Competences for Sustainability—Students

What should the student know about sustainability? Learning outcomes are usually expressed at course and programme levels. One example of an effort for commonly agreed learning outcomes for all programmes is Portland State University. Eight such campus-wide learning outcomes were produced and one of them is about sustainability, and it says: *Students will identify, act on, and evaluate their professional and personal actions with the knowledge and appreciation of interconnections among economic, environmental and social perspectives in order to create a more sustainable future* (www.pdx.edu/institutional-assessment-council/campus-wide-learning-outcomes). In the rationale it says that "understanding sustainability is essential to join the international discourse and work cooperatively in the closely interconnected world of the new millennium". The role of the university is to "… inform and lead students and communities in creating a sustainable future and can provide a place for students who have this inclination to get an education". Students at this university will be able to describe the environmental integrity, economic vitality and social equity aspects of sustainability and give examples of how they are interrelated. They will also be able to explain how sustainability relates to their lives as citizens, workers and individuals and how their actions impact sustainability. They will learn how to apply concepts of sustainability locally, regionally and globally by engaging in the challenges and solutions of sustainability in a broader context.

Quality criteria can refer both to education for sustainable development and about sustainable development. The UNESCO has developed quality criteria for education for sustainable development which include a common value base for sustainable development and interdisciplinary and holistic approaches, where learning *for* sustainable development is integrated in the whole curriculum and not only as an independent discipline. The recommendations also include development of critical thinking and the use of several teaching and learning methods in education. Additional quality criteria are presented in the OECD's list of competences focusing more on knowledge *about* sustainable development, such as subject competencies, methodological competencies, societal competencies and personal competencies.

5 Competences for Education for and About Sustainable Development—Teachers

The challenges for teachers to handle the new educational scenarios are manifold. They should be open for new roles being more as coaches and team leaders, at the same time having to revise their knowledge of the subject into a more holistic and systemic setting with the student groups not as homogeneous as before. It is also said that in countries where environmental education has traditionally been strong it has been more difficult to introduce all aspects in education for sustainable development, and, consequently, the social and economic aspects have remained relatively weak.

The UN Economic Commission for Europe Strategy for Education for Sustainable Development has published the report *Learning for the Future. Competences in Education for Sustainable Development* (2011). The four competences presented are comprehensive and reflect a wide range of learning experiences: Learning to know, learning to do, Learning to live and learning to be (www.unece.org/fileadmin/DAM/env/esd/ESD_Publications/Competences_Publication.pdf).

The UNESCO DESD is oriented to promoting education for sustainable development at all levels, which includes broad changes in teaching and learning approaches to ensure sustainable lifestyles. Four competencies mentioned above (OECD) for students also have their bearing on teachers, and still rather general:

Subject competencies—knowledge, facts, definitions, concepts; Systems; methodological competencies—skills, fact-finding, analysis; Problem-solving; Social competencies—communicating, working interactively, active citizenship and Personal competencies—attitudes, values, ethics.

The CSCT project (Curriculum, Sustainable Development, Teacher training, www.csct-project.org, http://ensi.org/Projects/Former_Projects/Teacher_Education/) has, in addition to the above mentioned competences, emphasised competences related to action. The role of the teacher to empower students and show them how they can influence and work with sustainability issues is seen as one important aspect of education for sustainable development.

There are more aspects which need to be taken into consideration when talking about research and education in relation to sustainable development and which are really challenging for traditional academic education. The tension between the known and the unknown is underlined by the need for communication of uncertainty and risk, in contrast to the traditional evolution of knowledge which aims at minimising uncertainty. The challenges also include competencies related to resource management and to demand management, and competences to handle conflicting interests. At the same time we know that sustainable development is an evolving concept which changes over time and focus is different in different parts of the globe.

Methodological recommendations include the integration of the local, regional and global aspects in courses, and a participatory decision-making where students participate in decisions regarding their learning. And the multi- and interdisciplinary nature of education for sustainable development calls for cooperation over the traditional disciplinary borders. In summary, the challenges and requirements for change are many, but much is already applied in education, although not always recognised.

	Courses	Concepts	Systems	Measurement	Practices
Primary school	Single pillars taught broadly in general lessons	Economic environment Social	Markets ecosystems Society	Wealth eco-footprints Voters	Fundraising eco-schools Citizenship
Secondary school	Integration of two (or mote) pillars taught in existing courses, (e.g. social studies)	–Economic/ environment –Economic/social –Social-environment	–Carbon trading –Human capital –Transport	–Costs of climate inaction –Income distribution –Measures of well-being	–Green entrepreneurs –Poverty reduction –Fairtrade
Tertiary level	Integration of three pillars taught in stand-alone	–Economic/ environment and social	–SD strategies (NSDS) –Sust. consumption	–Capital-based indicators –Sustainability indices	–Sustainable production –Sustainable consumption

(continued)

(continued)

	Courses	Concepts	Systems	Measurement	Practices
	units (SD studies)	– Intergenerational concerns –Participatory processes	and production strategies (SCP) –ESD strategies	–Sustainability impact assessments	–Corporate responsibility

The table above presents an example of integrating sustainable development in education at primary, secondary and tertiary levels (Source anonymous).

6 Do We Live as We Preach?

In addition to being institutions of higher education and research, universities are also critical social multipliers in achieving sustainable production and consumption patterns, and they are important actors in communities as employers, purchasers and service users. Universities are also enterprises where the proper use of resources saves money, and safeguards reputation.

But how do the universities practice what they preach? There are many good examples, where universities are certified according to international environmental and sustainability standards. The certification is made for the whole institution or parts of the institution, such as a faculty or department. Many institutions use modified quality assurance systems according to their needs. Additionally there are many declarations on sustainable development signed by university leaders. One such example is the Copernicus Charter for Sustainable Development from 1994, and its follower, the Copernicus Campus, which have been signed by more than 300 institutions of higher education in Europe. All in all there are many different ways of working towards a more sustainable education and institution. But still the overall results look more like a patchwork, and in order to have more profound changes there is room for much more to be done. One way forward could be to bring together cities and universities in education and research for sustainability, and these meetings could serve as catalysts for the integration of green innovations in the daily functions of both universities and cities and, additionally, to show the benefits from having a university campus within the city borders. Education could be brought closer to the real life, through project- and problem-based learning, through the involvement of expertise outside the campus and through internationalisation of education by cooperating in networks.

Innovation and Development in Latvia

Jānis Bērziņš

Abstract

The process of economic development is increasingly dependent on new technologies. Because of patents and copyrights, countries innovating poorly assume a subordinate position in the international economic system, reproducing a situation that can be describes as "development of underdevelopment". Although Latvia has joined the European Union and adopted the Euro, it is still struggling for development. A fair question regards the state of innovation of the Latvian economy. This paper discuses the relationship between innovation and development, making a critical assessment of Latvia's innovation performance, in comparison with other European Countries. The results show that Latvia is one of the least innovative countries in Europe. This was aggravated by Latvia's own economic structure, which is trapped into non-dynamic sectors. As a result, it has the same structural problems it had just before the 2008 crisis. The author suggests that, although it is necessary to implement structural policies promoting innovation, Lavia's own economic and political structure might impede it.

Keywords

Innovation · Economic development · Knowledge society · Latvia

J. Bērziņš (✉)
National Defence Academy of Latvia, Centre for Security and Strategic Research,
Riga, Latvia
e-mail: janis.berzins01@mil.lv

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_4

1 Economic Growth, Development and Underdevelopment in the Knowledge Society

Development is one of the most sensitive questions in Economics. Although there are many concurrent definitions of the concept of "development", all of them have in common the notion that development is the consequence of economic improvement, which necessarily results in better social and living standards. However, the economic growth may not result in higher living standards. This is an idea characteristic to the capitalist system, as every historic period has its own notion of development, determined by perceptions of qualitative change in some aspect(s), in both individual and social perspectives.

In an individual perspective it is the result of a subjective idea of the world shaped by personal views about the reality. The interaction of every person with the reality is unique, being determined by individual views and experiences resulting in a particular assumption of the real, defined by personal idiosyncrasies. These personal idiosyncrasies are the outcome of the relationship between the psychological subjective and the concrete, as a result of the process of human construction. By the other side, in a social/collective perspective, there is a limit to the natural variation of the individual opinions and views, which is imposed by the society itself. This results from the standards established by the social dynamics, which are influenced by the individuals but not determined by them and are determined by the relationship of the process of historical evolution with the reproduction of the material life.

In this way, different historical periods in different places always have had different concepts not only of morality, religion, culture, and politics but also of development. The notion of development of the Chinese society at the beginning of the Ming Dynasty was different from the one of the medieval Germany. The notion of social development as an intrinsic result of the process of economic growth established itself after the renaissance. Since future was not a part of the medieval mentality, the economic development and social progress were not objectives to be foreseen during medieval times, although the society was not completely immobile. Only with the establishment of the nation-states after the fifteenth century did the notion of social development become attached to economic growth in the rhetoric of the rulers and dependent of state intervention to occur.[1] At the same time, with the establishment of the capitalist system, since the XIX century there is a wide acceptance of a causal relation that economic growth is equal to social development at the global level.

---

[1]Although in the last 30 years the religious notion of the market as a demiurge responsible for solving all the problems of mankind has been imposed and repeated in a monotone way as a dogma, the History shows that without the intervention of the State to protect the system of Capitalism from itself, most probably it would have disappeared by now. Not only the great slump of the 1930s, but also the crisis the world is facing are good examples. Without support of the state the capitalist system most probably would consume itself and disappear, so that development is completely dependent on the State.

Although there are discordances in the literature about the most adequate definition of the term "development" in economics, most schools agree that economic development is a direct function of the process of economic growth, while others argue that economic growth and economic development are different and independent processes. To go through the discussion, going back to the classics determining the subject of Economics as a discipline is first necessary. In 1767, 10 years before Smith's Wealth of Nations, Sir James Steuart in his "An Inquiry into the Principles of Political Economy" defined the object of Economics as follows:

> Economy, in general, is the art of providing for all wants of a family, with frugality. If any thing necessary or useful be found wanting, if any thing provided be lost or misapplied, if any servant, any animal, be supernumerary or useless, if any one sick or infirm be neglected, we immediately perceive a want of oeconomy. The object of it, in a private family, is therefore to provide for the nourishment, the other wants, and the employment of every individual.
>
> (…)
>
> The principal object of this science is to secure a certain fund of subsistence for all the inhabitants, to obviate every circumstance which may render it precarious; to provide every thing necessary for supplying the wants of the society, and to employ the inhabitants (supposing them to be free-men) in such a manner as naturally to create reciprocal relations and dependencies between them, so as to make their several interests lead them to supply one another with their reciprocal wants (Steuart 1767).

At the same time, Adam Smith's definition of the subject of the Economy may be found in the Introduction and Plan of Work of the Wealth of Nations. Although Smith did not make it as explicit as Steuart, it is completely clear that to him the subject of the Economy is the national economy and the improvement of the productive powers of the labour (Smith 1994). In other words, that the action of private agents promoting economic improvement would result in an increase of the wealth of the nation in question, at its time resulting in an increase of the living standards of the population. With the exemption of the Marxist schools defending the idea that economic growth in the capitalist system results in the impoverishment of the working class as result of the social relations of (re)production of the material life and of the Schumpeterian approaches, this is the most accepted idea: the economic growth is equal to social development. This rhetoric has been used to such an extent that the expression economic growth has assumed the meaning of socioeconomic development.

Although simplistic, as merely economic growth may not result in social development because of problems in distribution such as concentration of wealth, the economic and social sciences' mainstream theories often rely on this presupposition. Naturally, it has been partially reflecting the reality; otherwise it would not be accepted by so many scholars. However, since the 1970s the capitalist system is reproducing itself in a different way. This decade represents a structural change in the way the capitalist system reproduces itself not much perceived by many, from the concrete to the abstract through the reification of the financial sector and the establishment of the production of non-tangible goods as the most important sector of the real economy. The dynamics of capitalism, since the 1st Industrial Revolution until the 1970s, was based on the mass-production and mass-consumption of goods. If in the Classical-Liberal State the rhetoric of liberalism was useful to guarantee the consolidation of the private property and the relations of social classes, with the crisis of the 1930s and the advent of the Keynesian States it was necessary to save capitalism from what could be its decline, by guaranteeing the mass production and consumption. In spite of the Keynesian economic policies acting only superficially, as they did not look to the core of the structure of the process of reproduction of capitalism, they obtained success in reverting, temporarily, the crisis. The years that followed the Great Depression, mainly those after World War II, were marked by the State planning of the economy in the capitalist block, both in the central and peripheral countries, to avoid systemic crises providing an indirect surplus of income as the Welfare State's social policies. This permitted people to consume on a larger scale and provided the necessary dynamism to the economy to grow and develop.

In the beginning of 1970s, numerous changes ended a period of economic growth and full-time employment in the advanced countries, sustained by strategies of active national State intervention in the regime of administration of the commercial and monetary policy under the hegemony of the United States (Hirst 1996). These changes include the effects of the collapse of the Bretton Woods system and the end of the dollar-gold standard, which permitted creation of wellness not to be limited by material criteria represented by the USA gold reserves, together with the effects of the III Industrial Revolution and the end of Keynesianism and the establishment of (neo)liberalism based in the Chicago's Neoclassical/monetarist approach as the main ideology in economics and in social sciences (Karnīte 2007; Freedman 2008).[2] This forged the base of the Knowledge Society and changed the meaning of the "economic development" concept. These structural changes resulted in the identity of economic growth = socioeconomic development to lose its validity together with many of the mainstream economic models, which are still dealing with the paradigms of an old economic model.[3]

---

[2]For an extended discussion about the changes in the reproductive dynamic of the capitalist system in the 1970s, see the second chapter of KARNĪTE, Raita, BĒRZIŅŠ, Ivans, POPOVIČA, Santa (2007). *Ārvalstu kapitāls Latvijas banku pamatkapitālā*. Riga, LZA EI, 128 lpp. For a debate about the strategies of Milton Friedman and George Stigler to promote the Neoclassical/monetarist approach as the only valid in economics, see Freedman (2008).

[3]Many scholars fear to be labelled as "Marxist", the same as to be accused to be a witch in the Middle Ages, if they make structural analysis of the economic system in force. This is an ideological consequence of the victory of the Neoclassical approach, mainly the Chicago's monetarist school in combination with Hayekian ideas, reducing Economics to econometrics based on Neoclassical assumptions—in other words, to a field (not the most noble one) of mathematics. This is part of the explanation of the poor level of economic analysis of the last 40 years.

Development and underdevelopment in the knowledge society

André Gunder Frank coined the notion of "development of underdevelopment" in his essay "The Development of Underdevelopment" published in the Monthly Review in September 1966. In the article he denied the idea of "traditional society" as the existence of an "original" underdevelopment. Also, he denied the notion of subsequent "stages of growth" and the analysis of development through neo-Parsonian social pattern variables and neo-Weberian cultural and psychological categories. According to Gunder Frank, underdevelopment "(…) is not due to the survival of archaic institutions and the existence of capital shortage in regions that have remained isolated from the stream of world history. On the contrary, underdevelopment was and still is generated by the very same historical process which also generated economic development: the development of capitalism itself" (Frank 1966).

The main idea was that the development of the core States would mean the underdevelopment and permanent subordination of the peripheral countries, through colonial exploitation. In this way, what was being reproduced, along with the development of the states at the centre of the capitalist world economy, were the underdevelopment and the permanent subordination of those states in the periphery. In other words, a situation of dependence, which in this case must be understood as the conditioning of the economies of a certain country by the development and expansion of other ones which the first is subjected to, when this expansion results in a negative effect on its immediate development (Santos 1970).

The reproduction of this situation of dependence would be maintained because of the inequalities in the relationships between a dependent economy and the dominant external economy in politics, military affairs and, last but not least, economics, which would shape the underdeveloped economy to fulfilling domestic needs of the dominant country. However, dependence is much more a political process and not a mere imposition from above to below through, for example, military force.[4] Rather, it is intrinsic to the system and spread in the cultural, economic, technical and financial arenas reflected in the political space, where groups try to establish the dominance.

Although this debate was mainly about the problems of underdevelopment in Latin America (and it is not feasible to deal with the notion of colonial exploitation nowadays) the concept of development of underdevelopment may be used to understand what the Knowledge Society means in economic terms. Thus, the main concepts that must be taken in consideration besides politics are free trade and differences in the terms of trade, international division of labour, foreign investments and financial (in-out) flows. While in the colonial times the use of military force was one of the presuppositions of dominance and impositions of policies (including economic policies), values and culture, at least in the occidental world, it

[4]Thus, it is not the result of a conspiracy theory, where evil countries try to dominate others, but the output of the Historical process. However, countries (evil or not) trying to dominate others is a common pattern in History, and a very actual issue, by the way.

is not necessary anymore. Much more effective is the use of multilateral agencies such as the IMF and the World Bank to impose, for example, economic policies on underdeveloped countries such as Latvia, for example.[5]

By the technical side, the Third Industrial Revolution enabled the technical progress to be incremental, depending on the accumulation of innovations. Technical progress at the time of the First and Second Industrial Revolutions could occur through ruptures without a previous accumulation of technical and scientific knowledge, since it was diffuse and universal. Nowadays, the new technical and scientific knowledge, by one side, is protected by patents and, by the other, it is ephemeral. In the same way, with the molecular-digital revolution, both science and technology remains together in the same process, in such way they are interdependent. The first consequence is that countries or regions that do not have a strong policy stimulating R&D can only copy the ephemeral but not the source of the technological and scientific paradigm; the second is that the process of economic reproduction that is carried on by copying the ephemeral also become obsolete rapidly, meaning that a strong effort to follow the innovative process could lead a country or region to remain in a subordinated position in the international scenario (Oliveira 2003).

Since the process of economic production and competition is increasingly dependent on new technologies, the leadership remains with the country or region that develops these technologies and detains the patents and the rights to use and to sell the rights for use in other countries or regions in a subordinated position. With the rise of a new mode of production as the result of socio-economic development, one part of the society starts to reproduce its existence within the new paradigms that are substituting the old ones, whilst another continues reproducing itself within the former structure. This occurs because of the idiosyncratic character of the process of innovation, which excludes those who do not or cannot adapt to the new form of economic reproduction. As these people have to continue to live, they reproduce their existence by the old forms, constituting themselves a living corpse of the old socio-economic organisation that does not integrate in the new society. In other words, it is like different societies, with different levels of development dividing and intersecting the same geographic space.

In this way, the same may be observed in the economic relationships between countries the economic leadership being assured to the countries where the process of innovation takes place, while the followers experiment a process of economic dependence to a larger or smaller scale. As a consequence, the economic growth results in socioeconomic development only when it may be reproduced in a sustained way, in other words, within the borders of the most advanced paradigms of reproduction of the economic system in force. Any form of economic growth based

[5]In a general manner this economic policies were based in the Washington Consensus' conclusions, which turned to be a religion whose 10 commandments were: (1) fiscal discipline; (2) prioritisation of the public expenses; (3) tax reforms; (4) financial liberalisation; (5) free exchange regime; (6) commercial liberalisation; (7) free direct foreign investment; (8) privatisation; (9) deregulation and (10) defence of intellectual property.

on paradigms already surpassed by the process of creative destruction implies the reproduction of the "old" and, thus, in the reproduction or development of underdevelopment (Schumpeter 1928, 1947).[6] The Knowledge Society represents the new.

2 Knowledge Society and Information Society

As what usually happens when a new phenomenon is started to be discussed, there is confusion about the basic concepts that may result in misunderstandings. In the case of the knowledge society, there have been parallel uses of other expressions to represent the same thing. One of the most common is the use of the term "information society" concomitant with "knowledge society", or "information economy" with "knowledge economy". Although used to represent the same thing, the terms have different meanings, as "information" is different from knowledge. The Merriam-Webster dictionary defines "information" as:

> (1) the communication or reception of knowledge or intelligence; (2) a. a knowledge obtained from investigation, study, or instruction; b. intelligence, news (3) a) facts, data b: the attribute inherent in and communicated by one of two or more alternative sequences or arrangements of something (as nucleotides in DNA or binary digits in a computer program) that produce specific effects c. a signal or character (as in a communication system or computer) representing data; something (as a message, experimental data, or a picture) which justifies change in a construct (as a plan or theory) that represents physical or mental experience or another construct d. a quantitative measure of the content of information; specifically a numerical quantity that measures the uncertainty in the outcome of an experiment to be performed (www.merriam-webster.com/dictionary/information).

At the same time, the definition of "knowledge" is:

> (..) (2) a. the fact or condition of knowing something with familiarity gained through experience or association; b. acquaintance with or understanding of a science, art, or technique; c. the fact or condition of being aware of something; d. the range of one's information or understanding (..) e. the circumstance or condition of apprehending truth or fact through reasoning; cognition f. the fact or condition of having information or of being learned; (..) (4) the sum of what is known; the body of truth, information, and principles acquired by humankind (www.merriam-webster.com/dictionary/knowledge).

Following both definitions, it is possible to conclude that "information" is part of "knowledge". In other words, that knowledge is the result of the process of creation while information is the expression of it; knowledge is the essence and information is the appearance of a part of the result of the creative process. Thus, in economic terms, a definition could be that knowledge is a process and information is a commodity. Applying this idea to the social process of economic reproduction, it is correct to use the terms "knowledge society" and "knowledge economics" to refer to the new way the capitalist system reproduces itself and its economics. Likewise, whilst "information society" refers to the sociologic and anthropologic aspect of a

[6]Creative destruction must be understood in a Schumpeterian way.

part of the society that deals with the availability of a huge quantity of information, and "information economics" is related to the process of commerce and trade of this information as the use of it to obtain profits.[7]

As discussed before, the conjunction of the Third Industrial revolution with the collapse of the Bretton Woods system, and the process of ideological (neo)liberalisation of the economy, and the politics, formed the base of the Knowledge Society. Since it represents a superior productive form of organisation in comparison to the First and the Second Industrial Revolutions, dynamics of the process of its socioeconomic reproduction is determined in different sectors, peculiar to this model and resulting from the process of creative destruction.[8] The following division may be made:

Knowledge society sectors
: research and development of new technologies and products; education; royalties and licenses; consulting and strategic management; business services; financial services; computer services; communications (development and commerce of); personal, cultural and recreational services; design.

Knowledge society appended sectors
: manufacturing of products of informatics and communications; administrative services; marketing services; utilisation of communication possibilities services;

Non-knowledge society sectors
: transportation services; travel services; construction services; insurance services; real estate services; manufacture in general (even of pharmaceuticals if not developed by the same producing company); agriculture.

There are two points that must be taken in consideration. The first is that this division is necessary since there is confusion about which sectors are part of the Knowledge Society and which are not, leading to some analytical mistakes. The most common is to put countries as China, Thailand and Hungary, among others, as examples of the Knowledge Society. They are not. Although these countries export products of high-technology, for example computers, they are merely assembling components to produce products developed elsewhere. In other words, they are reproducing their economy with the same paradigms of the First and Second Industrial Revolutions, reproducing the underdevelopment as they participate

[7]For example, the fact that some companies are using the internet as a vehicle to sell products is just a change in the way the information is distributed through the society. It doesn't represent the creation of new knowledge, but rather it is utilisation, being part of the concept of "information economics".

[8]The difference is that Schumpeter developed and applied this concept to the process of competition in specific industrial sectors, while in the case of the Knowledge Society in this text it is being applied to the process of destruction of modes of socioeconomic reproduction of the capitalist system.

Table 1 Key inputs in the 30 GB-5th generation iPod (video iPod)—2005

Input	Supplier	Supplier HQ country	Estimated input price (USD)	Price as percentage of the factory cost (%)	Supplier gross profit rate (%)	Estimated value capture (USD)
Hard drive	Toshiba	Japan	$73.39	50.77	26.5	$19.45
Display	Toshiba-Matsushita	Japan	$23.27	16.1	28.7	$6.68
Video/ multimedia processor	Broadcom	USA	$8.36	5.78	52.5	$4.39
Controller chip	Portal player	USA	$4.94	3.42	44.8	$2.21
Battery	Unknown	Unknown	$2.89	2	30	$0.87
Mobile SDRAM memory—32 MB	Samsung	Korea	$2.37	1.64	28.2	$0.67
Mobile RAM—8 MB	Elpida	Japan	$1.85	1.28	24	$0.46
NOR Flash Memory—1 MB	Spansion	USA	$0.84	0.58	10	$0.08
Sub-total			117.91	81.56		34.81
Other parts			$22.79	15.77		
Estimated assembly and test			$3.86	2.67		$3.86
Estimated factory cost			$144.56	100		$38.66

Source Portelligent, in Dedrick et al. (2008)

marginally in the Knowledge Society as a necessary but not fundamental appendix of its economics. The main characteristic of this case is the biggest part of the revenue from realisation of the products going to developers. A practical example could be Apple's iPod. Although not much of it is manufactured in the USA and by Apple, the majority of the value added is captured by Apple itself. The gross profit of Apple is greater than the price of any single input and so greater than the value added by its partners (Dedrick 2008). The Table 1 shows the Key inputs in the 30 GB-5th generation iPod.

As may be apprehended from Table 1, the most expensive and profitable inputs are products of the Knowledge Society, being the direct result of the process of research and development to produce smaller electronic components. The most inexpensive input is handwork, which is performed by China. From the total cost of producing an iPod, assembly and testing is the equivalent of US$3.96 or merely 2.67 %. The argument that China or Hungary are part of the Knowledge Society

Table 2 Distribution of captured value in a third generation iPod (video iPod)—2005

	Sales in the USA (USD)		Sales outside the USA (USD)	
Value chain segment	Apple	All other firms	Apple	All other firms
Apple gross margin (R&D, software, marketing)	$80		$80	
Part suppliers (key inputs only)		$34.86		$34.86
Manufacturing		$3.86		$3.86
Distribution		$30		$30
Retail	$23	$22	$11	$34
Total value capture	$103	$91	$91	$103
Percentage of total (%)	53	47	47	53

Source Portelligent, in Dedrick et al. (2008)

just does not fit.[9] They are an appendix. Table 2 shows how Apple fares are significantly better than any of its partners.

The total value capture is $80 for Apple, $75 for distribution and retail and $34.86 for key inputs, totalling nearly $194. Apple gets 53 % of this value from USA sales and 47 % from sales outside the USA. This is well beyond the 18 % captured by all suppliers of key parts or the share for distribution and non-Apple retail and shows the importance of innovation and strategic management (Dedrick 2008).

Table 3 shows that Apple has a margin of almost 36 % as gross profit. With exception of the video/multimedia processor and the controller chip, which are concentrated sectors tending to, at least, an oligopolised structure, the biggest value capture (35.71 %) was that of Apple. The three tables show that not only innovation, but rather knowledge innovation is the key to assure profitability. Changing from an individual company or from an industrial sector to a country, it is possible to discuss socioeconomic development. The countries with the biggest share of innovative and knowledge-intensive economic sectors are the leaders of welfare, in other words, of socioeconomic development. As said before, countries whose economies are based on non-Knowledge Society sectors and even those which are part of the margin—the appendices, have a natural tendency to underdevelopment. Since the process of economic growth results in a momentary increase of the living standards, there is the illusion of development. However, as it is not sustainable because of the dynamic nature of creative destruction of the Knowledge Society, the appearance gives place to its essence: underdevelopment. This is exactly the case of Latvia.

[9]China has two important financial centres: Shanghai and Hong Kong. They are part of the Knowledge Society. Continental China is not. The point is that assembling electronic components to produce computers, for example, doesn't make this activity to be part of the Knowledge Society as discussed before.

Table 3 Derivation of Apple's gross margin on a video iPod—2005

Retail price	$299	
Distributor discount (10 %)	($30)	
Retailer discount (15 %)	($45)	
Subtotal (estimated wholesale price)		$224
Factory cost	(144.56)	
Estimated Apple gross profit		$80
Apple gross margin		35.71 %

Source Portelligent, in Dedrick et al. (2008)

3 Knowledge Society and Latvia: Underdevelopment

The process of development of underdevelopment in Latvia began as a result of transition to capitalism, mainly by a combination of monetarist/Neoclassical policies known as "shock therapy" imposed by the international community, and inability of the local politicians to deal with economic paradigms of the (neo)liberal capitalism.[10] Since the return to independence, Latvia has passed through a process of deindustrialisation and establishment of static sectors—a practice aggravated by joining the European Union.

In theoretical terms, the main problem was again the non-pragmatic view that liberalisation and adoption of Neoclassical/monetarist policies would deliver the best option for development. In other words, that the invisible hand of the market would guide the countries in transition to an optimum level of development. The point again is the faith in the soundness of market forces resulting in an optimal point; though the market forces without any doubt would lead to equilibrium, nevertheless, the economic activity and development at the equilibrium point are not guaranteed to be the optimum for the society. At the same time, the presupposition that exposing an underdeveloped closed economy to the international system should result in development is false. The clash of the endogenous structural fragilities with the dynamics of the international economic system usually results in the development of underdevelopment. In the case of Latvia, the clash of her endogenous structural fragilities with the European economic system resulted in deepening the country's subordinated insertion in the international division of labour.[11]

[10]The international community, mainly through the IMF and World Bank, traded help for neoliberal reforms. Since the countries in transition a deep need for financial support, even in the case the politicians were able to deal pragmatically with the transition, the neoliberal policies would be implemented anyway.

[11]The idea is that fragile economies cannot deal with the pressures of the international system, being subordinated to foreign interests, which may not be the most valuable to a country's development.

To Latvia, the most significant issue after joining the European Union was the complete openness of the financial and capital accounts changing the structure of the credit market. Availability of credit being the most powerful instrument to promote economic development however does not guarantee that the development will occur. As a consequence of the strategy of foreign banks in Latvia, the structure of credit market changed, and the way the country (under)developed along with deterioration of the national accounts. Although the sector of financial services is deeply connected with the Knowledge Society, in Latvia it had much more characteristics of exploration from outside to inside, than the contrary. In other words, much more of the services in Latvia were imported than exported showing a subordinated position in the international financial system.

Discussions about Latvia becoming an international financial centre were rather a result of wishful (hallucinogenic) thinking—the effect of the intoxication by foreign money given as credit. The main consequences were deepening of de-industrialisation, speculation with Real Estate and consumption of durable goods as the main economic activities of the countries, and the illusionary reification of (neo) liberal capitalism to the common man as a system where anybody could have a Ferrari just going to the bank and asking for it. The high availability of money and disposition of banks lending it to non-innovative activities resulted in contraction of the real economy of the country. The same applies to the sectors of the Knowledge Society and to the Information Economics.

Performance of Latvia in the information economics

To analyse the sector, two indicators were chosen: Enterprises having received orders on-line as a share of the total and individuals having ordered/bought goods or services for private use from the Internet in the last three months, as they reflect the use of new technologies resulting in inter-sectorial economic activity. At the same time, they reflect the culturally determined disposition of innovation of both enterprises and individuals. Also, they show the size of the market of the economic agents. Enterprises using the internet as a channel of commerce are boosting their market both nationally and internationally, leaving the local and going to the global market. The result is the possibility to get clients all over the world increasing the scale of activity and, as a consequence, their profitability. On the side of the consumers/individuals, it represents the possibility of a wider choice, better prices and buying conditions/guarantees as a result of competition the global players are subject to.

The analysis of the indicators of the Information Economics shows that Latvia has a poor performance in this sector. Figures 1 and 2 show that both enterprises receiving orders on-line and individuals having ordered/bought goods or services over the internet are well below the average of the European Union. This is not the consequence of poor access to internet, as 53 % households of Latvia have access to the internet, but rather a consequence of the cultural idiosyncrasies of the Latvian society (EUROSTAT). Although this is not a structural issue that may result in underdevelopment, the opportunity cost associated to loss of prospective business

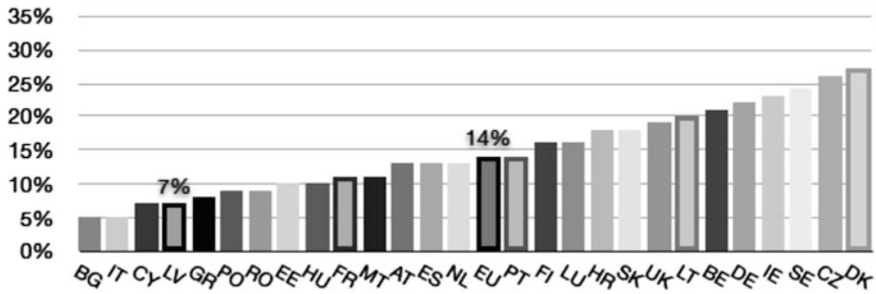


Fig. 1 Enterprises having received orders on-line as percentage of the total—2013, selected countries. *Source* EUROSTAT

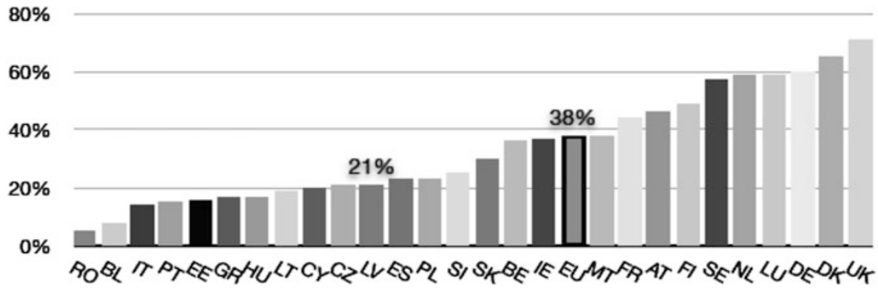


Fig. 2 Individuals having ordered/bought goods or services for private use over the Internet in the last three months—2013, selected countries. *Source* EUROSTAT

reduces the general economic profits, especially in the case of the exporting sectors, whilst also jeopardising the marginal efficiency of the capital. A possible consequence might be a vicious circle of the maintenance of low dynamism in these sectors reducing the level of investment, increasing the opportunity cost and reducing the economic profit.

Latvia and the knowledge society

If Latvia has a poor performance in the Information Economics, then in the domain of Knowledge Society it is even worse. The underdevelopment the country is facing since the middle 1990s has resulted in the atrophy of the determining sectors of the Knowledge Society becoming more dramatic during the last years (Bērziņš 2008). The main problem is that the consequence of this process is the capture of the country by a development of underdevelopment trap in a vicious circle. As mentioned before, the socio-economic performance nowadays depends on research and development which, in its turn, depends on investment or, in clearer words, on money.

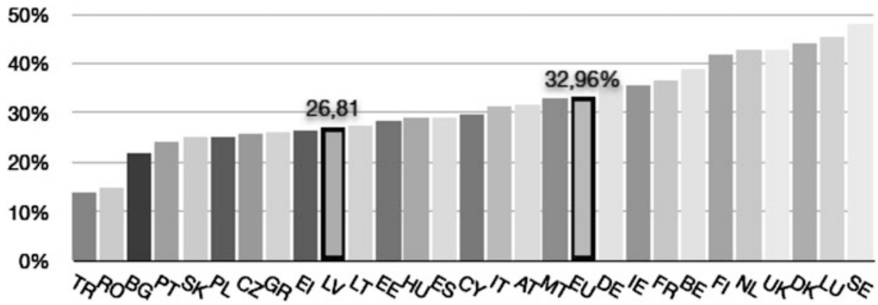


Fig. 3 Employment in knowledge-intensive service sectors, percentage of total—2008. *Source* EUROSTAT. This is the most recent data available. The data for BG, PL, EI, and SE is from 2007

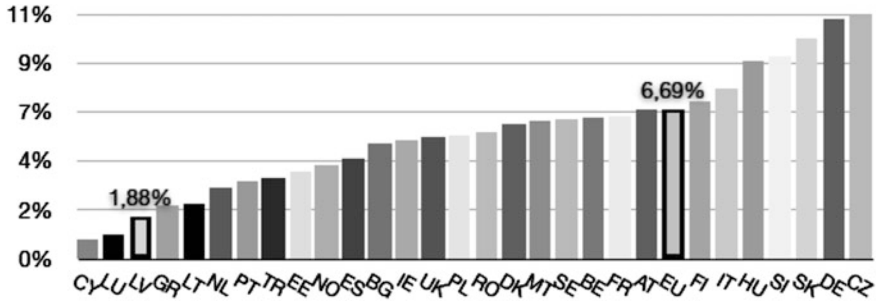


Fig. 4 Employment in high- and medium-high-technology manufacturing sectors, percentage of total—2008. *Source* EUROSTAT. This is the most recent data available

Figures 3 and 4 show the percentage of people working in services and manufactures related to the Knowledge Society. Figure 3 shows that 26.81 % of the employed in Latvia are in knowledge-intensive sectors. It has increased since 2008, but still is well below the average of the European Union (32.96 %) (Bērziņš 2009), which is mostly due to development of the financial sector since 2004 that has resulted in a boom of the credit market. In this way, it is necessary to look at this indicator with care. Most of the people employed in this sector do not deal with development of new investment strategies, new prospective markets and financial products or analysis, being the personnel dealing rather with issues of administration and public relations. Contraction of the sector being already under way, these people will be fired—they are not/would not be needed anymore[12] resulting in deterioration of the indicator. Figure 4 shows that 1.88 % of the employment in Latvia is related to high- and medium-high-technology manufacturing sectors. This performance is only better than Cyprus (0.8 %) and Luxembourg (1.08 %) and is considerably below the average of the European Union (6.69 %).

[12]The politically correct word for the process is "restructuration".

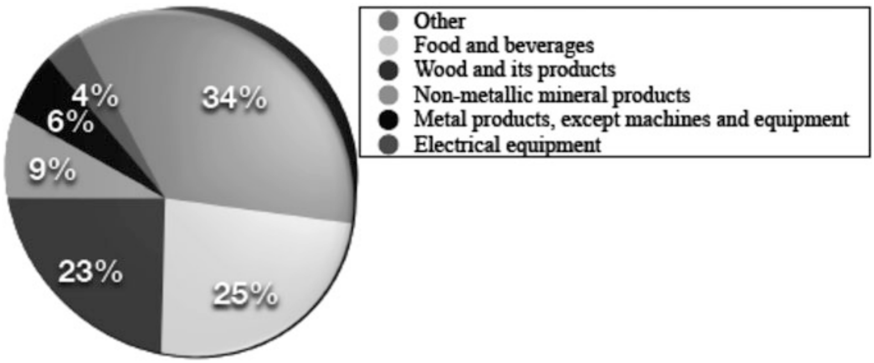


Fig. 5 Structure of Latvia's manufacturing sector, 2013 (Third quarter). *Source* Latvijas Republikas Centrālā statistikas pārvalde

The structure of the manufacturing sector of Latvia is explicated in Fig. 5. The most important sectors are food and beverages (25 %), wood and its products (23 %), non-metallic mineral products (9 %), metal products except machines and equipment (6 %), and electrical equipment. The sectors classified as "other" are not related to the Knowledge Society. This explains the low level of employment in high- and medium-high-technology manufacturing sectors. As a consequence, the level of high-tech exports of Latvia is very low, just better than Portugal, Greece, Bulgaria, Spain, Lithuania, and Poland. It is well below the average of the European Union (15.6 %) and of the United States (18 %) (Fig. 6).

As a consequence, the result is a persistent deficit on the Current Account, because of the difference of the terms of trade. Since the value of non-high-tech exports is usually lower than the high-tech imports, it is obviously impossible for a country to have a well-balanced trade. In the medium term, without socio-economic development and reversion of the situation, the outcome is contraction of the importing capacity and a consequent crisis. In the case of Latvia the deficit was financed by remittances to branches of foreign banks in Latvia and, as a

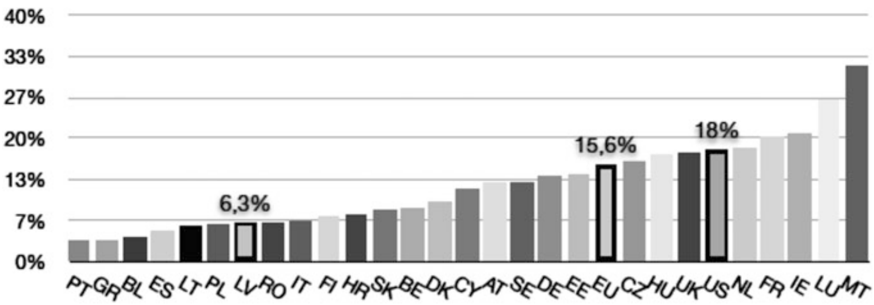


Fig. 6 High-tech exports as percentage of total—2012. *Source* EUROSTAT. For the United States, data is of 2011 from the World Bank

consequence, resulted in an increasing national external debt. The money was used to finance expansion of banking activities, mainly in the credit market. With the exhaustion of the market for credit in Latvia, the main source of financing the external imbalances drained. Allied with the effects of the international financial crisis, resulting in withdrawal by some investors of the money from the country, this model collapsed. The reason of poor performance in high-tech exports is the lack of people working in research and development in the country (Fig. 7).

The share of people employed in research and development in Latvia is one of the smallest in the European Union, less than in Estonia and Lithuania. In Latvia, as in other underdeveloped countries, the academic, research, and development personnel is not appropriately remunerated. As a result, most people follow other careers or leave the country to have a normal living standard. At the same time, more than a half (57.7 %) of the personnel involved in research and development are members of the staff of higher education institutions (Felix 2008). A special commentary has to be made: universities must rely on the triad of education, research, and extension. In the case of the Latvian system of higher education, practically only education is contemplated with funds while the funds directed to research and extension are negligible.

Lately there is a clear rhetoric that the base wage of the academic staff should depend on teaching. Whilst, on the one hand, this may be a good idea to prevent people from receiving undeserved money, on the other hand it results in avoiding activities other than teaching. To maintain a proper living standard the academic personnel holds a second job. At the university it is also teaching, not research. The university wages being low, the institutional compromising of the staff is also low. The strategy of financing research and development at universities and other scientific institutions in Latvia is leaving the researchers to find their own sources of funding. They are guaranteed a maximum basic wage of approximately 420 euro after taxes (November 2013), and shall find projects from outside to complement the income. It is true that some research institutions have been successful in attracting external funds, but this is the exception and not the rule. This way the separation of education and research is aggravated reducing the role of universities

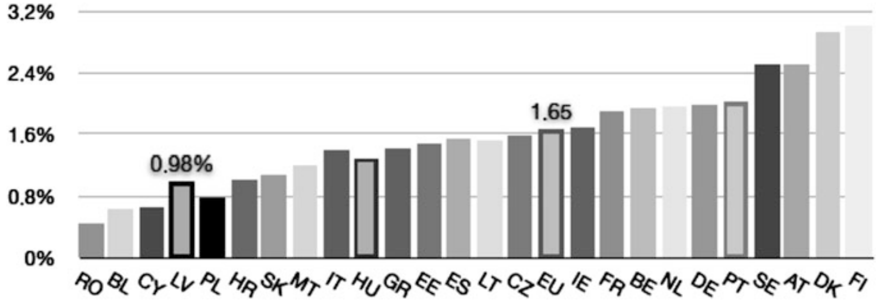


Fig. 7 Share of research and development personnel, percentage of total employed people—2012. *Source* EUROSTAT

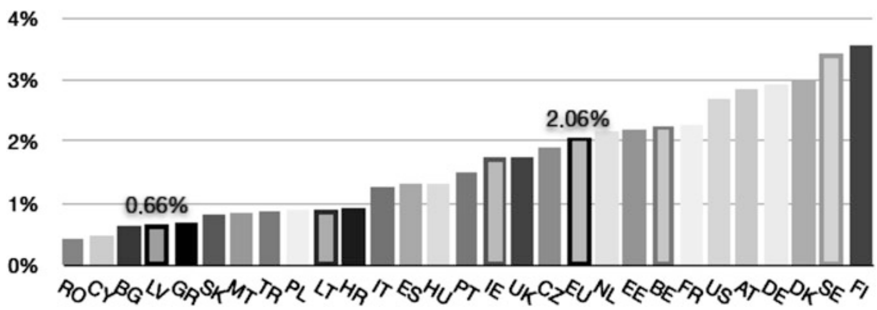


Fig. 8 Expenditure in R&D as percentage of the GDP—2012. *Source* EUROSTAT

to reproduction instead of creating knowledge, as evidenced by the marginal places of the Latvian universities in the international academic system (Fig. 8).[13]

Since the economic reproduction in Latvia is still rooted in the paradigms of the First and Second Industrial Revolution, the private companies are not pressured by necessity for research and development,[14] and the vicious circle of underdevelopment this way is being reinforced. Braking it requires a direct intervention by active development policies of the government. Figures 9 and 10 reflect the consequences. If by performance in applications to the European Patent Office Latvia is just better than Estonia and Croatia, the high-technology patents are as negligible as of Romania, Lithuania, and Bulgaria. Partly the situation is also due to complications imposed by legislation and the bureaucratic and administrative procedures. Luxembourg, for example, has been innovative in active policies to attract patent registrations providing very good performance in both indicators.[15]

The Summary Innovation Index (SII) is an indicator providing comparative assessment of the innovation performance of the EU member states. The index includes innovation indicators in five categories: innovation drivers (mainly education), creation of knowledge (mainly research and development), innovation and entrepreneurship (mainly innovative co-operation and expenditures), applications (mainly employment in and exports of high-technology services and products), and intellectual property (patents). Latvia is just better than Turkey and Romania and much below the average of the European Union. The leaders are Sweden, Finland, and Denmark. The European Innovation Scoreboard 2013 proposes a classification of the countries into four innovation groups (EC 2013):

The innovation leaders: Sweden, Denmark, Finland, Germany.

[13]Extension in the Latvian academic system occurs mainly in the health sectors.

[14]One exemption is the pharmaceutical sector.

[15]The newest available data set for patents is from 2005.

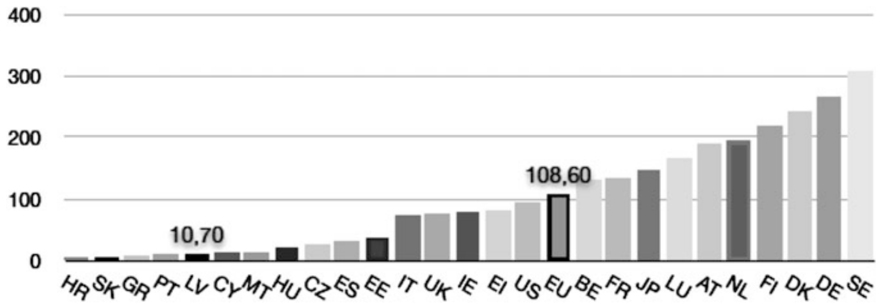


Fig. 9 Patent applications to the European Patent Office (EPO) per million inhabitants—2010. *Source* EUROSTAT

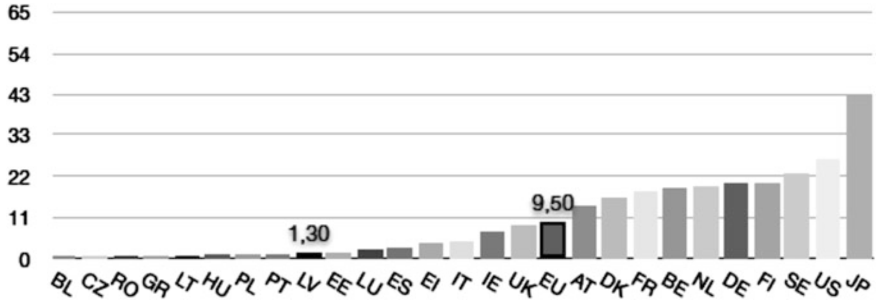


Fig. 10 European high-technology patents per million inhabitants—2009. *Source* EUROSTAT

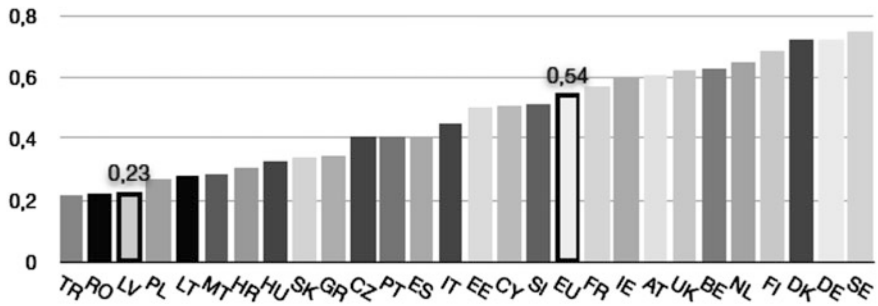


Fig. 11 Summary innovation index (SII)—2012. *Source* European innovation scoreboard 2013

The innovation followers: Estonia, Cyprus, Slovenia, France, Austria, Belgium, Ireland, Luxembourg, the Netherlands, and the United Kingdom.

The moderate innovators: Lithuania, Malta, Hungary, Slovakia, Greece, Czech Republic, Portugal, Spain, Italy.

The modest innovators: **Latvia**, Bulgaria, Poland, Romania (Fig. 11).

Latvia has a low performance in all five categories, although innovation and entrepreneurship fare comparatively better, albeit behind Estonia and Lithuania. Convergence with the average level of the European Union is not expected before 2030.[16] Being a small country, Latvia may reduce this period significantly by active and pragmatic policies promoting development. The biggest problem, however, is cultural. On the side of the population in general, there is a lack of the culture of innovation along with a misunderstanding of the capitalist economics. The absence of what Max Weber called the Protestant ethics and/or the spirit of capitalism is still characteristic to the Latvian society.

As mentioned, it is aggravated by the economic structure of Latvia being trapped into non-dynamic sectors. Since ordinary people have a limited economic rationality, they become victims of incompetence of the local political elite that predatory captured control in the country for private purposes, in a way (Rzymalabusse 2008).[17] These politicians are responsible for the bad performance of Latvia in research, development, and innovation. One could argue that Latvia is a success story, since it adopted the Euro in the beginning of 2014. However, currency is simply a means of payment. Although it can minimise the risk of the exchange rate, it cannot alter the economic structure of a country alone.

Since Latvia has the same structural problems it had in the beginning of the economic crisis in 2007, it is fair to say that the country is still in crisis, although the acute phase has passed. The crisis being structural, structural measures and policies stimulating innovation are necessary for improvement of the economic development. In short, the policies must:

Invest in the academic sector: this is the most obvious. The government must increase funding of the academic sector and start paying for research on equal terms with teaching. Also, it is necessary to increase the level of salaries for full-time employment at one institution. Likewise, the idea that all research must result in concrete products must be relaxed.

Change the legislation: it is necessary to make the legislation more flexible to facilitate establishing and survival of prospective businesses, including a special taxation regime to businesses related to Knowledge Society and Information Economics. This could be done through a special program of incentives, for example, special tax regimes for infant firms, tax exception for activities involving innovation and research and development. In general, the idea is to adapt a realistic legislation to the needs of the business sector as a way to facilitate incentives to start new businesses.

Establishment of a program to attract direct foreign investments: as Slovakia and Slovenia, Latvia must initiate a program stimulating incentives of foreign investors. This must be done by reforming the legislation as discussed earlier and also through more practical measures. Latvia needs a development bank

[16]Ibid.

[17]There are distinct indications of capture: clientelism, predation, fusion, exploitation, and formation of specific state institutions and capacities (Grzymala-Busse 2008).

committed to socio-economic development. As a development bank, it must establish a strong program of credit directed to the establishment and development of companies in strategic sectors of the Knowledge Society, such as financing research and development of innovative products and services taking the risks that private banks are not willing to. Credit must be given with the lowest possible interest rates and the bank's activity must be supervised by a commission of members of the government, of the private sector, the unions, and the society. At the same time, the state must use the public land to form technological and industrial parks providing physical space for investors.

4 Final Remarks

Development differs from growth related to the improvement of economic indicators only, in other words, economy of a country may grow without real development dependent on innovation. Also, there is a relationship between development and growth. Due to the dynamic and cyclical nature of capitalism, in a country experimenting economic growth without development, the increase of economic indicators eventually will cease and, most probably, start decreasing causing unemployment and the usual well-known social problems of underdeveloped countries.

That is exactly the case of Latvia, although some scholars have been defending the idea that Latvia is a developed country because the economy has been growing fast in the recent years. Feeling not comfortable with a different reality they do not like discussing developing the underdevelopment. By taking as benchmark the end of the Soviet Union and beginning of transition in the 1990s it is argued that the country is well-developed. However, the concept of development and underdevelopment is beyond the mere international division of labour and medium- or long-term sustainability of the growth. The problems of development in Latvia are partly a consequence of the situation in Social Sciences over the last 40 years—scientists have been looking at the appearances instead of the core processes.

The countries or regions that do not have a strong policy stimulating R&D can only copy the ephemeral, not the source of the technological and scientific paradigm. The process of economic reproduction carried as copying the ephemeral rapidly become obsolete, meaning that even with a strong effort to follow the innovative process a country or region remains in a subordinated position in the international community. It is necessary to end this era of religious ideology and blind faith in some theoretical approaches and turn a pragmatic view on the reality. The politicians must understand that the national structure exists to serve the society, not them. The capture of power in Latvia by some political groups of rent-seekers is one of the most determining factors of the development of underdevelopment in the country.

Here we come to an interesting point. In Latin America, the attitude to interventions of the International Monetary Fund often resulted in recession and in the deterioration of social indicators. In Latvia, most probably the contrary is going on. Since the economy is already deregulated, free and in a deep recession, the intervention of the IMF cannot make it worse. Since the control of the Latvian economic policies by the fund is expected to be very strict, the margins of action to local politicians and the government are going to be very limited, resulting at least in some improvement of the governance.

Only a profound change of the local political culture along with policies attracting direct foreign investment and channelling local savings to strategic sectors may change the current socio-economic situation. The economic crisis in Latvia came as a catalyser for changing the socio-economic structure. The main challenge now is making the changes to shape structures for the Knowledge Society as a way to guarantee a non-subordinated insertion of the country in the international division of labour, stabilising the economy, improving the macroeconomic performance and developing the country.

References

Bērziņš J (2008) Latvia and EU: the political economy of underdevelopment. In: 4th pan-European conference on EU politics' paper, Rīga

Bērziņš J (2009) Latvia and the knowledge society: development, underdevelopment and macroeconomic performance. Humanities 1(58):42–68

Dedrick J, Kraemer KL, Linden G (2008) Who profits from innovation in global value chains? A study of the iPod and notebook PCs. In: 2008 industry studies conference paper, Boston

European Comission (2013) Innovation union scoreboard 2013. Directorate-general for enterprise and industry, Brussels

EUROSTAT. http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/&product=REF_TB_information_society&depth=2. Accessed 31 Dec 2008

Félix B (2008) Patents and R&D personnel. Eurostat statistics in focus, 107/2008

Frank AG (1966) The development of underdevelopment. Monthly review, vol 18. http://findarticles.com/p/articles/mi_m1132/is_n2_v41/ai_7659725. Accessed in 28 Dec 2008

Freedman CF (2008) Chicago fundamentalism: ideology and methodology in economics. World Scientific, Singapore

Grzymala-Busse A (2008) Beyond clientelism: incumbent state capture and state formation. Comp Polit Stud 41(4–5):638–673

Hirst P, Thompson G (1996) Globalization in question: the international economy and the possibilities of governance. Thompson Polity Press, Cambridge

Karnīte R, Bērziņš I, Popoviča S (2007) Ārvalstu kapitāls Latvijas banku pamatkapitālā. LZA EI, 128 lpp, Riga

Oliveira F (2003) O ornitorrinco. Boitempo Editorial, São Paulo

Rzymalabusse A (2008) Beyond clientelism: incumbent state capture and state formation. Comp Polit Stud 41(4-5):638–673

Santos T (1970) The structure of dependence. In: American economy review: papers and proceedings, IX, 2(2)

Schumpeter J (1928) The instability of capitalism. Econ J 38(151):361–386

Schumpeter J (1947) The creative response in Economic History. J Econ Hist 7(2):149–159

Smith A (1994) An inquiry into the nature and the causes of the wealth of the nations. Modern Library, New York

Steuart J (1767) An inquiry into the principles of political economy. http://socserv2.socsci.mcmaster.ca/~econ/ugcm/3ll3/steuart/index.html. Accessed in 20 Dec 2008. www.merriam-webster.com/dictionary/information. Accessed in 29 Dec 2008. www.merriam-webster.com/dictionary/knowledge. Accessed in 29 Dec 2008

Part II
Plenary Lectures and Invited Contributions: Worldwide Expertise and Expectations: Sustainable Development and Future Smart Manufacturing

Interplay Between Sustainable Development, Knowledge Society, and Smart Future Manufacturing Technologies in EU RTD Policy Documents, in the Work Program of FP7 and Horizon 2020

Arnolds Ūbelis and Dina Bērziņa

Abstract

Modern societies create, share and use knowledge to grow wealth and well-being, in other words—to follow the principles of sustainable development on a broader scale. In such societies jobs no longer depend on basic manufacturing but on gaining and smartly applying the knowledge instead: developing and using the manufacturing technologies more efficiently. A knowledge-based society addresses the socio-economic challenges by international and inter-sectorial sharing of knowledge crucial for innovation. Sustainable development is a core EU objective ensuring our future being not compromised by our present socio-economic development. Policy-makers at the EU and Member State level have agreed that creation of wealth should merge with social cohesion and environmental protection for win–win solutions promoting further research in the interplay between the social, economic and ecological systems. The paper summarises the EU policy documents and research in knowledge-based society for smart future manufacturing.

Keywords

Knowledge-based society · Sustainable development · Smart manufacturing technologies · Factories of tomorrow technologies

A. Ūbelis · D. Bērziņa (✉)
Institute of Atomic Physics and Spectroscopy, University of Latvia,
Raiņa blvd. 19, Riga LV 1586, Latvia
e-mail: dinab@latnet.lv

A. Ūbelis
e-mail: arnolds@latnet.lv

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_5

1 Introduction

What is Sustainable Development? A lot of efforts are made in defining sustainable development, and currently more than 25 years after Brundtland Commission's Report, it is close to world-wide consensus that its conceptual base is behind the sentence; "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987). In another words—environmental, economic and social well-being for today and tomorrow (International Institute for Sustainable Development).

Now the pertinent questions are:

- Has the global society the capacity to follow and to implement the concept?
- How close are the EU Member states and the society to consensus?
- How effective is the unified European Research Area as a contributor?
- Are there tools on place ensuring global awareness, access to knowledge and participation in the decision making process at the society level to influence decision makers and governments?

We are members of a dynamically changing global society and emerging knowledge-based society growing by quantity and quality.

In general, the knowledge-based society is an innovative and life-long learning society, possessing a community of scholars, researchers, engineers, technicians, research networks, and companies engaged in research and production of high-technology goods and in provision of services.

There have always been organisations and institutions capable of creating and disseminating knowledge: from the medieval guilds to corporations of the early twentieth century, from the Cistercian abbeys to Royal Academies of Science emerging since the seventeenth century (David 2001). Even ancient Chinese appraised education and knowledge by saying "When planning for a year, plant corn. When planning for a decade plant trees. When planning for life, train and educate people" (Guanzi 9c).

2 Interplay Between Sustainable Development and Knowledge Society in the Landscape European Research Area

The World Science Forum in 2003 stated that in a knowledge-based society, the following items are important:

- all forms of knowledge (scientific, tacit, vernacular, embedded, practical or theoretical, etc.) are communicated in new ways;
- there is a continuous dialogue between society and science promoting scientific literacy and enhancing the advising role of science and scholarship;

- knowledge cannot be understood without culture, research at the interface between vernacular and scientific knowledge;
- access to knowledge as a civil right has to be protected from being limited by short-term industrial interests;
- the impact of use and misuse of knowledge is greater than ever before, and equal access to knowledge by the population is vital since it:
  - closes the growing gap between developed and developing countries on a political level;
  - is not gender-blind and encourages more women to choose science careers;
  - raises interest of the young generation in science and commitment to the knowledge-led future by introducing innovative teaching methods, and by changing the image of the scientist.

The EU Framework Programmes designed by the European Commission conceptually are more and more targeted to sustainable development and knowledge-based society, but, up to now, the interplay and interception between the concepts is not in place, and the expected synergy still pending.

Evidently, sustainable development, knowledge society, and smart future manufacturing technologies are conceptually linked together by the imperative precondition for the future of mankind on the planet. As a consequence, billions of euro-money of the framework programmes should be targeted to moving towards the goal.

On the other hand:

- work programmes are written by panels consisting of experts in the relevant sectors;
- project proposals are written and implemented by researchers deeply inside specific knowledge sectors having no resources to train their awareness on sustainable development specifically related to their fields;
- evaluators by definition, in particular, are obliged to take care about projects' scientific quality and corporate responsibility of the team to follow prescribed ethical norms towards specific issues but also to comment on a more global ethical responsibly. From the general practice it is well known that most of them have no time to use opportunities of global access to knowledge on sustainable development.

Europe is facing a number of structural weaknesses when it comes to the capacity of innovation and the ability to deliver new services, products and processes. In this study we attempted to highlight tendencies and some advanced examples where a conceptual interlink between sustainable development, knowledge society and smart future manufacturing technologies is present, not only in wording but in action, and also on the documental, work programmes and project level.

The European Economic Recovery Plan (COM (2008) 800) was launched a few years after the start of FP7, based on the need of direct short-term action to reinforce Europe's long-term competitiveness. The Plan sets out a comprehensive programme for smart investment to support innovation in manufacturing, particularly investing in:

- the appropriate skills for the needs of tomorrow;
- energy efficiency to create new jobs and save energy;
- clean technologies to boost sectors like construction and automobiles in the low-carbon markets of the future;
- the infrastructure and inter-connection to promote efficiency and innovation.

It helped the EU manufacturers across sectors by increasing the technological base of the EU manufacturing through development and integration of the enabling future technologies, such as engineering technologies for adaptable machines and industrial processes, ICT, and advanced materials. The EU level can act only as a catalyst for smart investments combining EU policies and funds to help Member States to create jobs, boost demand, and strengthen Europe's capacity to benefit from globalisation; the implementation, however, depends on the will and capabilities of the governments and the maturity and involvement of societies of the particular Member States.

The knowledge society produces top-value commodities of the intellectual capital. Knowledge and expertise constitute the crucial elements in production the information and communication technologies comprehensively supporting interaction, dissemination and exploitation of knowledge, plus provision and accessibility of services. Simultaneously it is evident that development involves progressive transformation of economy and society: physical sustainability cannot be secured unless development policies pay attention to such considerations as changes in access to resources and in the distribution of costs and benefits. Even the narrow notion of physical sustainability implies a concern for social equity between generations, a concern that must logically be extended to equity within each generation.

3 Activities at the EU RTD Policy and Framework Programmes Level

The Europe 2020 strategy (COM (2010) 2020) aims to ensure:

- *smart growth*: fostering knowledge, innovation, education, and digital society;
- *sustainable growth*: promoting a more resource efficient, more competitive and greener economy;
- *inclusive growth*: fostering a high-employment economy delivering social and territorial cohesion.

EC Joint Research Centre in 2007 has performed a study on "The Concept of Knowledge for a Knowledge-based Society", where "knowledge" is analysed as one of the most fashionable terms in the political and managerial sphere from ancient Greeks to present days, and concluding that knowledge and learning are difficult to define complex concepts.

DG Research has acknowledged that knowledge society should be considered as a complex issue of science and governance of five perspectives, starting with the central issue of innovation, moving to risk and normative discourses, addressing the role of public and mode of learning and collective experimentation (Taking European knowledge society seriously 2007).

Findings of the Aho Report (Creating an Innovative Europe) in 2006 stated that trends in the EU are unsustainable in terms of global competition and called to increase efforts for research and innovation to address Europe's productive and social challenges. At the Barcelona Council in 2002, the EU agreed to a target of spending at least 3 % of GDP on research by 2010, of which two thirds was to be financed by the business sector.

3.1 FP6—Citizens and Governance in a Knowledge-based society

The thematic priority "Citizens and Governance in a knowledge-based society" of the EC 6th Framework Programmes aimed to provide a sound knowledge base for managing the transition towards a European knowledge-based society by combining national, regional and local policies, programmes and actions, as well as informed decision-making by individual citizens, families and other social units. Three of the activities were directly dealing with knowledge-based society: improving the generation, distribution and use of knowledge and its impact on economic and social development; options and choices for the development of a Knowledge-Based society; and, the variety of paths towards a knowledge society (Citizenship, democracy, and new forms of governance).

3.2 FP7

The Seventh Framework Programmes for Research and Technological Development (FP7) is the biggest ever investment made so far by the EU to assure its future as a knowledge-based society. It built on the success and experience of previous FPs that have grown in ambition over the years and established stronger and better connections between research, innovation and education to be addressed—known as the "knowledge triangle". The FP7 was (and still is since some projects keep running) implemented in a period when European and global research and innovation systems were changing significantly. The business community has embraced a more open approach to innovation in which knowledge is sourced and accessed where it is being produced. New nodes and centres of agglomeration influence the structure of research and innovation systems and their attractiveness to financial resources and talent. European universities, research institutes, and companies develop into knowledge and innovation hubs attracting the most talented researchers from all over the world (Interim Evaluation of the Seventh Framework Programmes 2010).

Nano-sciences, Nano-technologies, Materials and new Production Technologies: This theme improved the competitiveness of European industry and generated knowledge to ensure its transformation from a resource-intensive to a knowledge-intensive industry by generating step changes in knowledge and implementing decisive knowledge for new applications at the crossroads between different technologies and disciplines. This is beneficial to both—new high-tech industries and a higher-value, as well as traditional knowledge-based industries with a special focus on the appropriate dissemination of RTD results to SMEs. These activities are primarily concerned with enabling technologies which impact all industrial sectors.

Private-Public-Partnership "Factories of the Future": The objective of this PPP initiative (operating also under Horizon 2020) is to help the EU manufacturers across sectors, in particular SMEs, to adapt to global competitive pressures. It does this by increasing the technological base of EU manufacturing through development and integration of the enabling technologies of the future, such as engineering technologies for adaptable machines and industrial processes, ICT, and advanced materials. Furthermore, topics in the Factories of the Future PPP are also suitable for collaboration at the international level, particularly under the Intelligent Manufacturing Systems (IMS) scheme.

Socio-Economic Sciences and the Humanities was the fourth consecutive programmes on socio-economic sciences and humanities since 1994. The emphasis was given to growth, employment and competitiveness in a knowledge society:

- innovation, competitiveness and labour market policies;
- education and life-long learning;
- economic structures and productivity.

3.3 Horizon 2020

Europe has set out its ambition to move to a new economic model based on smart, sustainable and inclusive growth. This type of transformation needs more than incremental improvements to current technologies. It will require much higher capacity for science-based innovation fuelled by radical new knowledge, allowing Europe to take a leading role in creating the technological paradigm shifts being the key drivers of productivity growth, competitiveness, wealth and social progress in the future.

Horizon 2020 has the general objective to build an economy based on knowledge and innovation over the whole Union, while contributing to sustainable development (Council Decision 3/12/2013). It supports the Europe 2020 strategy and other Union policies as well as the achievement and functioning of the European Research.

Completion of the European Research Area (ERA) is urgently needed to avoid costly overlaps and unnecessary duplication of activities; therefore, building a genuine single market for knowledge, research and innovation, enabling researchers, research institutions and businesses to circulate, compete and co-operate across borders is of primary importance.

The integration of the knowledge triangle—research, innovation, education—and collaboration inside the knowledge triangle lead to development of innovative products and processes. Therefore, to address the challenges it is essential to bring together a critical mass of resources and knowledge across different fields, technologies and scientific disciplines.

Excellent science. International and inter-sectorial knowledge-sharing is crucial for open innovation; therefore a new generation of creative and innovative researchers have to be trained, able to convert knowledge and ideas into products and services for economic and social benefit in the European Union.

Industrial leadership. Europe needs to accelerate innovation, transforming the knowledge generated to underpin and enhance the existing products, services and markets and to create new ones. Multidisciplinary, knowledge and capital-intensive technologies cut across many diverse sectors providing the basis for significant competitive advantage for the European industry. Resource-intensive manufacturing and process industries need to mobilise resources and knowledge further at the Union level and continue to invest in research, development and innovation to enable further progress towards a competitive low-carbon economy for adaptive, "knowledge-based" business models in customised approaches (COM (2009) 512).

Societal challenges. The research under social challenges aims to improve the knowledge base and develop innovative solutions for the cost-effective and environmentally friendly exploration, extraction, processing, recycling and recovery of raw materials and for their substitution by economically attractive alternatives of a lower environmental impact. Inclusive, innovative and secure societies ignore national borders and call for complex comparative analyses of mobility (of people, goods, services and capital, and of competences and knowledge). In order to build inclusive, innovative and secure societies, Europe has to develop new knowledge, technologies and capabilities as well as the identification of policy options.

Science with and for society. The strength of the European science and technology system depends on its capacity to attach talent and ideas from wherever they exist; this can only be achieved by a fruitful and rich dialogue and active cooperation between science and society to ensure a more responsible science and to enable development of policies more relevant to citizens. This horizontal programme effectively builds cooperation between science and society, fosters the recruitment of new talents for science, and pairs scientific excellence with social awareness and responsibility.

Spreading excellence and widening participation. There are significant disparities across Europe in research and innovation performance; therefore, specific measures will unlock excellence and innovation and will be distinct from, and where appropriate complementary and synergistic with policies and actions of the ESI Funds. These activities help to fully exploit the potential of Europe's talent pool and ensure that the benefits of an innovation-led economy are both maximised and widely distributed across the Union in accordance with the principle of excellence.

European Institute of Innovation and Technology. Among the main issues at hand are: Europe's relatively poor record in talent attraction and retention; the underutilisation of existing research strengths in creating economic or social value; a low entrepreneurial activity; insufficient resources at the poles of excellence to compete globally; and an excessive number of barriers for collaboration within the knowledge triangle of higher education, research and business at the European level.

All the mentioned above suggests the conclusion—to reinforce the innovation capacity of the Union the knowledge triangle of research, innovation and education is to be integrated.

4 Conclusions

The short survey provides the evidence that the interplay between sustainable development and knowledge society in the context of smart future manufacturing technologies is a future challenge requiring approaches and projects to create synergies for an impact of global scale.

References

Barcelona European Council (2002) Presidency Conclusions, 15–16 Mar 2002

Citizenship, democracy and new forms of governance. Expressions of Interest (EoI) to use the new instruments (Integrated Projects and Networks of Excellence). Available at: ftp://cordis.europa.eu/pub/eoi/1-1-7-ii_Citizenship_democracy_and_new_forms_of_governance.pdf

COM (2008) 800. A European Economic Recovery Plan

COM (2009) 512. Preparing for our future: Developing a common strategy for key enabling technologies in the EU

COM (2010) 2020. Europe 2020—A strategy for smart, sustainable and inclusive growth

Council Decision of 3 December 2013 establishing the specific programme implementing Horizon 2020—the Framework Programme for Research and Innovation (2014–2020)

Creating an Innovative Europe (2006) Report of the Independent Expert Group on R&D and Innovation chaired by Esko Aho. EC, ISBN 92-79-00964-8

David PA, Foray D (2001) An introduction to the economy of the knowledge society. University of Oxford, Department of Economics

Guanzi By: Guan, Zhong, d. 645 B.C.

Interim Evaluation of the Seventh Framework Programme (2010) Report of the Expert Group

International Institute for Sustainable Development. Available at: www.iisd.org/sd

Taking European knowledge society seriously (2007) Report of expert group on science and governance to the Directorate-General for Research, European Commission. EC, DG RTD, ISBN 978-92-79-04826-5

Villalba E (ed) (2007) The Concept of Knowledge for a Knowledge-based Society: from knowledge to learning. EC JRC Ispra, ISBN 978-92-79-06193-6

World Commission on Environment and Development (WCED) (1987) Our common future. Oxford University Press, p 43, ISBN 019282080X

World Science Forum—Budapest, Knowledge and Society, 8–10 Nov 2003

NANO*futures*, the *European* Technology Integrating and Innovation Platform: Nanotechnologies—Essential Part of Sustainable Development

P. Queipo, D. Gonzalez, A. Reinhardt, T. Zadrozny, M. Cioffi, A. Bianchin and P. Matteazzi

Abstract

The European Commission has identified six Key Enabling Technologies (KETs), including nanotechnology and micro and nanoelectronics, as a key priority of the new R&I Programme Horizon 2020 for the smart, sustainable and inclusive development of European growth. Moreover, it is well known that nanotechnologies contribute to scientific and technical progress across disciplines and sectors, with potential to help overcoming the big challenges that our society is facing. Within this framework, NANO*futures*, the European Integrating Technology and Innovation Platform on nanotechnology, was created to accelerate the safe and responsible uptake and use of nanotechnology.

Keywords

Key enabling technologies · Nanotechnologies · Sustainable development · Cross-ETP · Nanofutures

P. Queipo (✉) · D. Gonzalez
PRODINTEC, Avda. Jardin Botanico 1345, 33203 Gijon, Spain
e-mail: pqr@prodintec.com

A. Reinhardt
microTEC, Kaiserlauterer Strasse 353, 67098 Bad Durkheim, Germany

T. Zadrozny
NANOfutures aslb, Rue de la Presse 4, 1000 Brussels, Belgium

M. Cioffi
D'APPOLONIA, Largo Carlo Salinari 18/19, 00142 Rome, Italy

A. Bianchin · P. Matteazzi
5MBN, Via G. Bortolan 42, 31050 Vascon di Carbonera, Italy

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_6

1 Introduction

The European Commission has identified six Key Enabling Technologies (KETs) (High-Level Expert Group 2011), including nanotechnology (HLG KET working document 2010), and micro and nanoelectronics (Interim Thematic Report 2010), as a key priority of the new European Framework Programme for Research and Innovation (R&I) Horizon (2020) (www.ec.europa.eu/programmes/horizon2020/h2020-sections). KETs' deployment is crucial for the further development of the European economy and for strengthening Europe's capacity for industrial innovation (High-Level Expert Group on Key Enabling Technologies). Applications of KETs are considered to directly or indirectly stimulate competitiveness and generate jobs, indispensable for sustainable and inclusive European growth.

Regarding nanotechnology, it is well known that it contributes to scientific and technical progress across disciplines and sectors, with potential to help overcoming the big challenges that our society is facing. Nanotechnology-based innovation, however, calls for a horizontal approach that includes cross-sectorial strategic needs and broader socio-economic challenges going beyond technological gaps, if its development, application, and commercialisation are to be accomplished.

Within this framework NANO*futures*, the European Integrating Technology and Innovation Platform on nanotechnology (www.nanofutures.eu) started its activities in 2009. It intends to address all these issues and to coordinate the different on-going activities and projects at European, national and local level to reduce fragmentation and dispersion of efforts. Moreover, it aims to be a long-lasting hub connecting all the relevant nanotechnology related stakeholders. *NANOfutures* has a very novel approach as it has been created as an integrating platform very much focused on innovation and impact. Currently, it integrates more than 850 members representing industry, science, and society from EU and beyond.

2 NANOfutures: A Cross-European Technology Platform

In order to properly meet the great nanotechnology challenges of today, several issues need to be addressed, including cross-sectorial strategic needs, broader socioeconomic challenges going beyond technological gaps, which hinder the nanotechnology development and commercialisation. Although other already on-going European technology platforms have been capable of addressing the specific needs and challenges of their sector or technology areas effectively, covering such broader challenges requires an unusual multidisciplinary and cross-sectorial collaboration within the value and innovation chains. Within this frame, *NANOfutures* (www.nanofutures.eu) has been created in 2009 to help improve the situation and accelerate the safe and responsible uptake and use of nanotechnology. Recently, it was officially recognised as a Cross-European Technology Platform (ETP) Initiative by the European Commission (EC) in the context of the upcoming "Strategy for European Technology Platforms: ETP 2020" (2013). Within this strategy, the role of ETPs is recognised as part of the external advice and societal engagement needed to implement Horizon 2020, and thus the ETPs will be key elements in the European innovation ecosystem and will help turn Europe into an Innovation Union. Within the ETPs, specific cross-cutting initiatives bring together the interests of several ETPs, and in doing so, avoid duplication and fragmentation.

Nowadays, NANO*futures* counts more than 1050 members (~35 % from industry and industry associations) coming from over 60 countries (Fig. 1). It gathers different stakeholders with various backgrounds: SMEs, industry, regulatory bodies, public authorities, research institutes, academic community, the financial world, civil society, etc.

NANOfutures is governed by the Platform Steering Committee including 11 European Technology Platform representatives and 10 nanotechnology experts who chair the working groups on cross-sectoral "horizontal" issues. These working groups are related to the following topics:

- NanoSafety
- Critical Raw Materials
- Standardisation
- Technology Transfer and Innovation Financing
- Regulation
- Industrialisation and Nano-Manufacturing

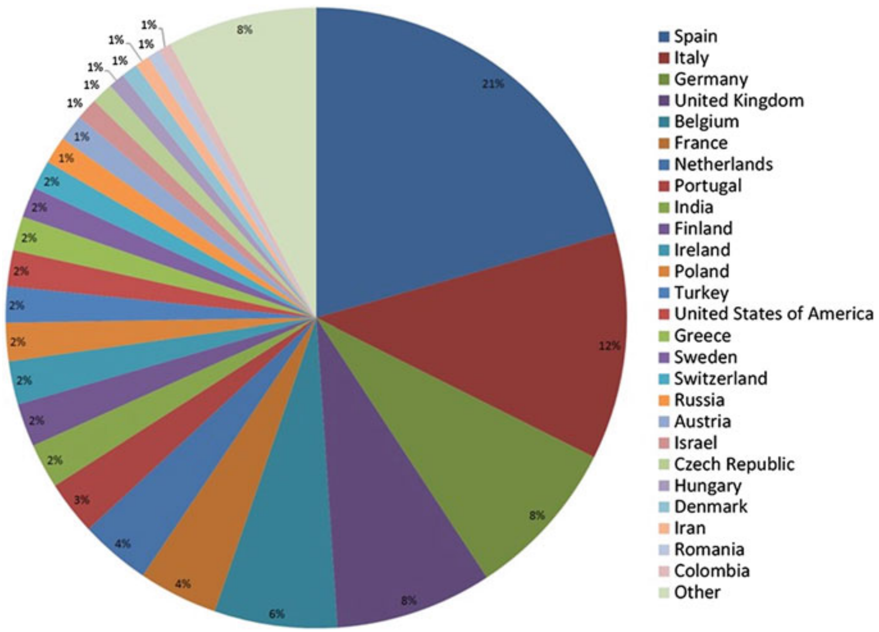


Fig. 1 NANOfutures member's distribution per country (n = 878)

- Skills and Education
- Networking
- Communication
- Research and Technology

With this structure it is able to connect and establish cooperation of all stakeholders that require nanotechnologies in their sector, and/or product. In this sense, NANO*futures* platform is instrumental in the industrialisation of nanotechnology by bridging the gap between research, technological innovation and company/market innovation aspects and carries nanotechnology industrialization forward to the benefit of European economy and its citizens. Thus, Platform structure and aims contribute to the Europe 2020 strategy growth drivers in the following manners:

- Smart: *fostering new market-oriented knowledge, boosting innovation narrowing the market science gap, adjusting nano education to industrial/society needs,….*
- Sustainable: *helping to create more sustainable and efficient products/services/ manufacturing process based on/for nano*
- Inclusive: *helping to generate skilled and high-quality jobs.*

NANO*futures* includes geographical coverage, analysis and experimentation that lead to recommendations for common models, protocols, guidelines, structures, mechanisms, policies and processes for use in all the Member States. It also includes raising awareness of EU-wide actions and change, sharing of lessons learned and their feed into European debate and policy making. NANO*futures* is designed by looking beyond the confines of nanotechnology to find a broader European relevance to other important issues, such as societal challenges and communication with society at large.

The crucial added value of NANO*futures* is its capacity to avoid duplication of work, learning from each other and having access to experts from all over Europe translating into a critical mass capable of increasing the valorisation of research in the public and private domains, and a real force to integrate all the concerned stakeholders within a common platform. NANO*futures* platform goes beyond the spheres of pure ‘additionality’, ‘subsidiarity’ or ‘complementarity’ rationales; it is also an adequate EU wide ‘integration’ tool.

3 Nanotechnology in H2020

Nanotechnology has important implications for most, if not all industrial sectors. Thus, the use of nanotechnology is accelerating. Its deployment is a major driver for the trend to improve existing products by creating smaller components and more functional performance materials. It enables the realisation of smaller, quicker, novel functionalities and properties improving existing products and applications or developing new market innovations. This is especially important due to the potential impact of nanotechnology on established industries and markets by introducing technological innovations to economically important sectors with an orientation towards "value-added" value chains.

Deployment of nanotechnology is a key factor for Europe to strengthen its manufacturing capacities while addressing societal challenges, through a rejuvenation of manufacturing technologies, processes and products as well as through creation of new businesses. The required ingredients are in place as Europe has a solid basic research that assures a well-developed science landscape, and a good industrial base for exploitation of the technology. In this sense, if effective alignment of private and public efforts over promising areas is guaranteed from short to long term, the European nanotechnology is expected to give an outstanding contribution to major grand challenges of our time. The European Commission has included nanotechnology as a theme in its research funding programmes over the past decade and has supported nano-scientists through the European Research Council (ERC). Within the new H2020 Programme, the existing research will be capitalised and the technology transfer addressed in order to move to a new phase where Europe's intellectual capital is turned into commercial technologies (Nanotechnology: the invisible giant tackling Europe's future challenges 2013).

The HLG KET report on nanotechnology (HLG KET working document) points out that according to some studies nanotechnology impacted US$254 billion worth of products in 2009. This impact is predicted to grow to perhaps US$2.5 trillion by 2015. According to BCC Research 2012 (Nanotechnology: A Realistic Market Assessment) the global market for nanotechnology was valued at nearly $20.1 billion in 2011. Total sales are expected to reach $48.9 billion in 2017 after increasing at a five-year compound annual growth rate (CAGR) of 18.7 %. Specifically nanomaterials are expected to have sales worth $37.3 billion in 2017, a CAGR of 18.6 %, while Nanotools should total $11.4 billion in 2017, a CAGR of 19.1 %. Moreover, nanotechnology offers a huge potential to impact employment and to provide solutions for major societal challenges. In this context, it is a major contributor to keep employment figures at high level in sectors, in which the EU is among global leaders. In this sense, it is estimated that by 2015 about 2 million nanotechnology workers will be needed worldwide, 0.3–0.4 million within Europe.

Within this framework, NANO*futures* published a roadmap in 2012 (Integrated Research and Industrial Roadmap for European Nanotechnology 2012) for the European nanotechnology [industry?] that focuses on several market-driven value chains (VCs), where both technological and non-technological actions are included to be able to address societal challenges (see Fig. 2). Moreover, cross-cutting actions, relevant for all VCs are also added.

A detailed implementation plan, focusing on action at short to medium terms (up to 2020) is provided, but a brief description of long-term actions is also provided. The vision behind the roadmap is in line with the Horizon 2020 strategy and takes into account actions for:

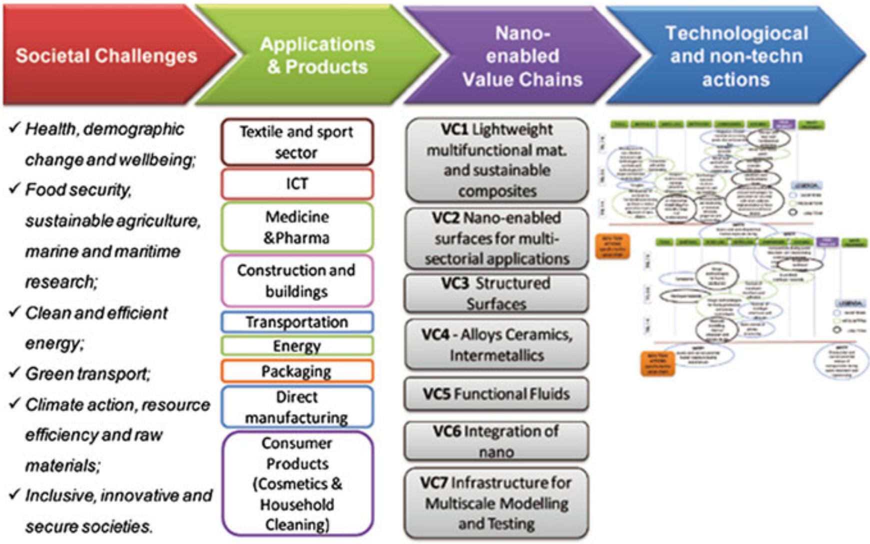


Fig. 2 From societal challenges to markets and products towards NANOfutures roadmap actions (*Source* Integrated Research and Industrial Roadmap for European Nanotechnology 2012)

- Excellence Science: the first steps of the VCs
- Societal Challenges: a broad view on the non-technological issues
- Industrial Leadership: a market-driven perspective for the development of successful and sustainable nanotechnology.

Implementation of these actions, together with coordination of policies, clustering efforts and supporting cross-collaborations will assure that a more favourable framework and effective commercialisation of nano-enabled products is created.

References

European Technology Platforms. www.cordis.europa.eu/technology-platforms/

High-Level Expert Group on Key Enabling Technologies: final report. European Commission. June 2011. http://ec.europa.eu/enterprise/sectors/ict/files/kets/hlg_report_final_en.pdf

HLG KET working document: Nanotechnology. December 2010. http://ec.europa.eu/enterprise/sectors/ict/files/kets/3_nanotechnology_final_report_en.pdf

Horizon 2020 programme. www.ec.europa.eu/research/horizon2020

Integrated Research and Industrial Roadmap for European Nanotechnology. NANOfutures, version: 2012. www.nanofutures.info/documents

Interim Thematic Report by the Micro/Nanoelectronics Sherpa Team. November 2010. www.ec.europa.eu/enterprise/sectors/ict/files/kets/1_micro_and_nano_thematic_report_nov_15_final_final_en.pdf

NANO*futures* web site: www.nanofutures.eu

Nanotechnology: A Realistic Market Assessment. BCC Research. September 2012. www.bccresearch.com/market-research/nanotechnology/nanotechnology-market-applications-products-nan031e.html
Nanotechnology: the invisible giant tackling Europe's future challenges (2013) European Commission, Unit G.4
Strategy for European Technology Platforms: ETP 2020. European Commission, July 2013

Urban Development and the Environmental Challenges—"Green" Systems Considerations for the EU

Uno Svedin

Abstract

The increased expansion of urban oriented challenges calls for the need to develop related policies in a sustainable development fashion. This means to be alert to the grand challenges to connect environmental/ecological—social—cultural—economic and technical factors. These challenges exist in all parts of the globalized world, not least in the EU domain. But the different parts of the world will have to find their specific ways to create solutions to these problems. Thus the need for a "green" development profile calls for integrated policy making and new ways to reflect on the urban-rural interface which is specific to the environmental, historical, social and technical specificities of the area in focus—e.g. the EU. Related management schemes will have to consider all sorts of environmentally oriented concerns, not least those connected to climate change. In the urban context such considerations have to be long term, systems oriented and resilience reflexive. The forms of decision making, the governance structure and the support measures for such activities have to be given careful attention. This should be done in a spirit of finding a wide range of innovative approaches including not only technical ones, but also those with a social and cultural orientation. In the not too long run such societal transformation strategies will be necessary in the new historical period of the Anthropocene.

U. Svedin (✉)
Department of Computer and Systems Sciences (DSV), Stockholm University, Stockholm, Sweden
e-mail: uno.svedin@gmail.com

U. Svedin
The Stockholm Resilience Centre (SRC), Stockholm University, Stockholm 10691, Sweden

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_7

Keywords
Anthropocene · Climate change · Decision making · Environment · EU-policy · European perspective · Futures studies · Governance · Grand challenges · Green issues · Indicators · Paths · Resilience · Scenarios · Socio-cultural · Solutions · Strategies · Sustainability · Systems · Tele connections · Transformations · Urban · Urban-rural links

1 Introduction

Sustainability considerations, i.e. about the systemic interplay between environmental/ecological, economic and socio/cultural factors are of strategic key importance in the future development of the urban sphere, not least in the European and EU contexts (Svedin/Cities of Tomorrow 2011b). Within this realm, you find challenges dealing with climate change, water availability and natural resources flows (including waste streams and their uses). Sustainability challenges with regard to the urban space are of key interest in discussing "green" urban issues. However, considerations about the urban development implications for other thematic domains are connected to a wider geographical area than just the urban one. This also has to be acknowledged in a broader analysis. This is reflected e.g. through the urban-rural links between the urban space and the natural resources production landscape of the supporting "hinterland"—both at regional and global scales. Also the increasing "tele connections" between the large urban centres of the world and their cooperative and competitive crosslinks are coming increasingly into focus (Seitzinger et al. 2012). Thus the impacts of the urban activities on the surrounding world is here at heart—in all its different environmental aspects, including climate change, water quality and quantity, biodiversity erosion, implications of the chemical impact on the ecological systems of the hinterland, and the competition over land-use as important examples.

Sometimes the character of the urban-rural connection has been considered—as seen e.g. from the rural side or by its proponents—mostly to be "negative" or at least unbalanced (e.g. with the urban space seen as an "intruder", "erosion force", and sometimes "destroyer" of rural realities). However, it is more interesting to point at the often intricate interplay between functions in the urban space and the rural space carrying reciprocated benefits, e.g. in terms of distribution of functional responsibilities of implementation. The two different spaces may thus manifest themselves as symbiotically linked and reciprocally reinforcing the needed systems vitality of key importance for the survival of both. This is not in opposition to the observation that there does exist an increasing and varying ecological global footprint in general from different countries—and increasingly with the origin from the quickly expanding urban sphere—on to the global "hinterland", not least with regard to biodiversity-oriented indicators (e.g. WWF 2014).

In addition the social aspects of urban life (e.g. demographic, value orientation, preferences and issues around wellbeing and human satisfaction) often have, or could have, positive or negative "green" connotations. For example, the climate change could induce a new water availability situation that in turn would strongly impinge on social life, thus pointing at the issue of allocation of societal priorities in such a situation. In earlier historical cases the management of desert towns provides vivid examples around such types of phenomena (see e.g. Sinclair et al. 2010).

Many of the "green" challenges, (e.g. climate change) are general phenomena (often planetary in scope) and not necessarily specifically connected to urban space. Their global and general features do not say much about their specific impacts on urban phenomena. A scrutiny over a number of such general "grand challenges" including "planetary boundaries" issues (Rockström et al. 2009a, b) has to be more precisely elaborated upon in order to identify the causal links specifically to urban situations—i.e. in terms of what is perceived to already have happened and about what could happen in the future. In order to have a better grasp on these matters it is necessary to outline the general landscape of the emergence of various "grand challenges" and how they may act as "drivers" for changes in various systems—including the urban ones.

An exploration of some of these relationships is attempted in the rest of this text highlighting a number of phenomena and their potentials as "problems" as well as sources of solutions. All this serves to meet the need for exploring the various future options, and serving the task to define criteria for possible actions that may be entailed and suggested for incorporation in various policy packages at local, subregional, national and EU levels respectively.

The current EU political context has several facets—some of very recent, some of older origin. The knowledge production for sure provides an important basis for policy formulations. Thus policies about the knowledge generation system—e.g. as reflected in the Lisbon agreements—support the general features and thought lines with regard to research and higher learning. However, the roots for this policy package are of earlier origin, as the formulations in the framing documents for a number of framework programs up to the 7 FP for research, and later through the Lund Declaration of 2009 with the focus on the grand challenges. This in turn has provided a basis for the perspectives on the links between research and innovation e.g. in the formulations laying the groundwork for activities in the emerging Horizon 2020 program currently coming into operation from 2014. The urban aspects of the EU "green" considerations are often mostly related to a broader context within which elements oriented towards urban issues can be identified.

The economic crisis of 2008–10 demonstrated the need for many new approaches to the economic problems at hand. The 'smart, sustainable and inclusive growth' slogan at the centre of the European 2020 agenda, points at possible lines of action for socio-economic development over the next decade. Long-term approaches to more drastic social transformations will have to be designed and implemented facing the time horizon leading up to 2050 and beyond. This also holds true not least for the specific urban problems in connection to general green challenges for European policy, such as a distinct shift towards a low-carbon paradigm (see e.g. the basis for the EU project COMPLEX 2012–2016). This is only one example of the frame of global drivers that Europe is facing today, sometimes called the 'grand challenges'. The 'smart' component of the solution package with connotation of 'knowledge and innovation as drivers of future growth' is specifically highlighted in the Europe 2020 agenda. To a large extent the urban area exemplifies this approach. The need to confront all the challenges at roughly the same time will also highlight the issue of probing paths to find better coherence between policies.

2 The Content of Grand Challenges—On Drivers and Their Implications

A broader presentation of the EU sustainability context is presented in the first chapter of this book.

2.1 The World of 2025 and Beyond. A European Perspective

When dealing with large structural challenges facing the world, i.e. the grand challenges—and not only for Europe—it is important to consider the priority profiles among the candidates of such challenges, related to the emergence and time frames of the solutions. This holds true not least for urban issues with connection to large infrastructure investments. These are needed to match future challenges and transcending the "historical momentum" of former solutions based on understandings of the past, constantly casting shadows into the future. The framework of analysis for many of these interconnected topics need to include understanding about complexity of systems, especially with regard to the interlinkages of different scalar levels from micro to macro (Liljenström and Svedin 2005).

Many of the "grand future challenges" have strong urban implications as:

- the *crisis of the world economic system* with its intrinsic instabilities pointing to a possible shift in leadership emerging in the world political arena in the not so far distant future (e.g. in what the EU 2025 foresight alluded to as "the Asian century") (EU 2009; Svedin 2009) and with a follow up study with the time horizon to 2050 (EU, European Commission 2012).
- the *demographic changes* in the world are of increasing importance, especially in terms of the changing age distribution (including "the aging society" in Europe), but also the social and cultural changes in connection with the immigration and emigration flows. The demographic interest is also due to other reasons, including the revolution of global information technologies as exemplified by the access and influence at micro-level to all sorts of globally available information through the internet and social media and through similar innovations paving the way for new concerns and solutions for the future.

- the *changes in the world "landscape" of knowledge and innovation production*, including the situation of global competitiveness shifting between the major regions i.e. highlighting the changed position of Europe. The competition in these areas is constantly increasing and perhaps faster than before.

Before leaving these issues and starting to reflect on the more specific "green slice" of the broader set of urban challenges it is important to make the comment that all the challenges are in one way or another systemically interwoven.

Thus, the *economic challenges* of course set a frame to what, and in which direction, investments could be done, in interplay with boundary conditions emerging from "green challenges". The economic frame also sets limits to how much solutions can be mobilised in urban territories to master global environmental impacts (such as increased temperature, more intense storms or increased sea water levels). However, the economic future is not a static entity and depends itself on how the "green issues" will be handled, especially with regard to mobilisation of the potential innovation capacities.

The *demographic changes* (including the aging of Europe and the immigration panorama) set strategic frames to what could be perceived as needed to change in terms of systems of functional structures of cities with regard to e.g. "green" living spaces, new forms of "close-by" food production in towns, or increased efficiencies in handling resource and waste flows. Issues about social spatial access in the urban sprawls increase in importance and point at future choices related to the development of public and private transport systems. These issues are often linked to where different age groups may tend to live. One obvious example is the connection between where retired people may want to live and the linking to the urban-rural system. Ideas about what constitutes the "good life" in different age groups will increasingly be of importance in this context. Such models may be more easily transmitted in the new global open-access communication culture.

Ideas about solutions with regard to the green structural issues may also be more widely distributed, which does not mean a uniformity of solutions—rather the reverse and highly dependent on geographical and historical contexts. This may raise various kinds of political pressures to develop a wider menu of urban space designs. In all these dimensions *formation of new knowledge production and innovation* will have a profound influence on ways to transform society, including the "green" aspects of planning.

When we thus are speaking about "Europe 2020" (as was started to be consolidated around 2010 through statements in the European Council), or speculating about Europe 2025 or 2030 or even 2050 (EU 2012) (as in some of the EU foresights dealing with these issues—see EU references above, but also European Commission (SCAR) 2011) such outlooks for the next few decades are needed to prepare for the large social transformations within half a generation. This timing has to match the speed of the pressures already manifesting themselves as strong and increasing boundary conditions. There is not only need to develop new perceptions, but also to increase the efforts to explore a wide set of factual solutions—environmental, technical, social and cultural.

It could also be argued—not least for the urban challenges—that what the Stern Committee (Stern 2007) argued for in terms of early investments to combat climate change also holds true for a much broader set of challenges. By tackling the challenges sufficiently early the needed transformations can be handled in a proper time frame and the efforts will also often boost the economic development e.g. in terms of "green growth" and mobilisation of innovation in Europe for such purposes. This will probably provide strong positive EU competitive advantages when operating in the world market in the future. What has been stated here in general terms holds true for the urban development panorama as well.

2.2 Specific Implications for Environment, Sustainability and "Green Development"

The focus will now proceed to the grand challenges more directly related to issues of environment, energy, and other natural resources, all of which are embedded in the broader panorama of ecological, economic and social/cultural sustainability considerations. Let us just make a few general observations and reflections on "green challenges" at global level providing the context of what has to be handled in society—be it in the urban or not so urban domains.

We start with *climate issues*, realising that climate is not the sole challenge related to sustainability. Rather, it serves as a very important starting point and is of central concern in a pool of connected systemic challenges. We start by referring to the well-known Intergovernmental Panel on Climate Change (IPCC) reflections on the concerns of climate change with regard to the 2007 report and the new 2013 and 2014 report packages. Here we note the further increase of the mean global temperature curve from the start of the industrial revolution in late 18th century up to now. Furthermore, we also note a distinct increase over the last half-century that corresponds to an acceleration of the change not seen in the time span over thousands of years. This holds true even if you take into account earlier historical variations of the means between warmer and colder periods (including colder periods in the middle of the European medieval period or in the last few decades of the 17th century). In addition, the 2013/2014 reports of the IPCC confirms and even in several instances strengthens the earlier argumentation and position statements.

We see a strong prognosis for further increases in temperature for the 21st century and beyond. The standard width of IPCC scenarios envisage an increase of the mean temperature by the end of the century of about +1.5 to +4.5 °C. The final outcome will be dependent on several factors in the future, including the intensity of global mitigation measures that has been mobilized at various stages. The more probable outcome would be in the higher end of the spectrum. The EU strategy aims at keeping the rise within +2°. If we are considering that global regional variations between different parts of the world are highly probable, then even stronger effects can be expected in some of the areas both with regard to mean temperature, related precipitation patterns (including droughts), and the frequency and intensity of storm/hurricane/flooding events.

Already relatively dry areas will most probably become even dryer as the regional prognosis for Southern Europe indicates. The different temperature scenarios correspond to different assumptions about the concentration of climate impacting compounds in the atmosphere, of which the carbon dioxide component is the most important but not the only one. All the greenhouse gases have somewhat different impacts and different origins. Thus, mitigation efforts must explore a wide range of solutions related to different types of challenges, all adding up to a total global impact with a regional differentiation.

In 2007 the IPCC probed into the relationship between the causal origin of the phenomena in terms of balance between natural and human sources. This has been done to explore the size and global geographic distribution of the human influence factor. Model systems using natural factors only cannot account for the development measured during the last few decades. This is what Nobel Prize winner Paul Crutzen and co-workers (Crutzen and Stoermer 2000; Crutzen 2002) have called the emergence of the new global historical time period of "Anthropocene" by which the current period having already started in our generation is named with reference to humankind taking over as the prime mover of natural cycles through the influence of human actions (including industrial activities, technological means, and the size and distribution of operations). This position is consolidated in the IPCC 2013/2014 reports.

According already to the IPCC (2007) report, different key "sectors" facing global warming (as e.g. water security and coastal community development) have different degrees of vulnerability. In general terms, when the rise of the global mean of temperature exceeds +2° the coping capacity in most "sectors" is quickly reduced. The rise by over 3 °C makes a high intensity of vulnerability increasingly more probable, including risks of systemic flip-flops to very different and uncomfortable states for humans at higher levels. (The general position of arguments have not changed in the 2013/2014 reports) (IPCC 2013/2014).

It is clearly understandable that most of the highlighted categories investigated for impacts have urban relevance. Temperature driven water scarcity (as seen in the southern part of Europe, e.g. in Spain) in this scenario is expected to intensify further, with severe consequences not only for the rural areas but for urban spaces as well. Many of the large cities of the world are situated along coastlines. The energy security is a relevant dimension for anybody, not least for urban activities. Major infrastructures are very often connected to urban space, frequently even being a manifestation of it. Climate related deaths often have urban connotations as was tragically demonstrated just a few years ago in France when summer temperatures shot up to very unfamiliar and uncomfortable levels hitting both the poorest segments of society that could not afford to combat the heat through artificial means, and the segment of old and sick people who are more vulnerable than individuals of other demographic segments. For tourism and food security—often having strong urban connotations—"vulnerability" indicators for sure are of significant importance. These distinctly point at very problematic futures if world surface mean temperature would rise +3 centigrade or worse.

The climate issues are not the only phenomena within the set of "green challenges". Many of the others—while being related to the climate—still have their own features. In an international study published in September 2009 in *Nature* (Rockström et al. 2009b) nine such challenges were explored and analysed in terms of their inherent problems with regard to "Planetary Boundaries" (see also Chap. 1 in this book) (and also at the same time and by the same authors a broader set of background and reflection material was published) (Rockström et al. 2009a). The analysis especially highlights three of these to be specifically and urgently problematic (i.e. involving a high level of threat): the climate change, the nitrogen cycle, and loss of biodiversity.

As with regard to climate change, all the other groups of phenomena, exemplified by the analysis of Planetary Boundaries, have *regional specificities*. All of them interplay with each other in nonlinear systemic relations through different kinds of driving feedbacks and feed-forwards generating uncertainty and drastic surprises.

What has been said is an illustration of the relation between various types of natural cycles (often of grand spatial extent) to impacts on the social domain. Social activities alluded to above in connection to the "Anthropocene" also have strong effects on the natural cycles, often being the strongest causal factor in our historical time. This distinctly has relevance for urban futures.

A major *fraction of the world population rather quickly have become city dwellers*, or at least spend their lives in urban conglomerates. This tendency will even further expand in the remaining period of this century. These urban dwellers are strongly dependent for their survival on food and other products drawn from "area-based" renewable resources. Thus, it would be a grave understatement to say that urban long-term planning only need a limited recognition of the connections to processes of change at planetary scale. Indeed, for the major large cities of the world you have to consider the vast "hinterlands" that always historically were needed in order to feed and serve these cities e.g. in Europe (such as London, Paris, Rome, Athens, Madrid, Budapest, and Vienna—to name but a few with archaeological remnants from their activities over millennia) and similarly in many other places in the world e.g. in Asia. The worldwide or super regional connections have often been strong for these types of large urban dwellings and an elaborate scheme of trade has made it possible to manage. Today these world connections are even stronger considering the reach and strength of the global character of material and immaterial flows of goods, waste, services—and ideas (not only in the domain of trade). The planetary connections to these urban centres are quickly growing, as is the urban part of human dwellings and action space.

2.3 Implications for Urban Development

What we now have said about the development in general terms—and mostly at global level concerning the global green challenges—has not only regional effects, but also strong, more specific urban connotations. As we already have covered, some overriding considerations about how the urbanised space activities relate to the "green" global challenges, we can now proceed to a number of more particular features.

First of all, the “urban space” is a very specific frame for human activities in terms of functions performed there, e.g. in terms of the compactness of the space within which life is pursued, but also in terms of the sophisticated relationship to the outside that makes all these urban endeavours possible in terms of survival (provisions of food, natural resources, etc.). This calls for a specifically urban oriented analysis. Attention should in this context be given to the governance system that should make the needed new solution pattern possible. This includes the collaborative “meta” institutions of the urban global system contributing to the international management of sustainability issues in a world when more than 70 % of its population will within half a generation live in urban areas (see e.g. Seitzinger et al. 2012).

In this sense the urban functions with green connotations have to be scrutinised both with regard to the urban space itself as well as in relation to the world outside (i.e. the urban/rural nexus, the global trade patterns, etc.). The corresponding knowledge and innovation production system about urban phenomena must have an interdisciplinary width to cover the nature of the most essential systemic urban causalities and phenomena.

We—in our generation—shall in this context have to design the principles for the conflux of natural and man-made phenomena, not least expressed in the creation of the urban space. The IPCC analysis did illustrate this systemic connectivity between the parts of the human and the natural systems and also pointed at how these earlier disjoint elements of knowledge now are interwoven in a grander “integrated socio-ecological” system. In such a system specific issues (e.g. of “resilience”) emerge as important to handle in all its combinatory features, and not only as a sum of features of partial systems of ecological, technical or social phenomena.

The human world is sometimes represented by various components of wellbeing. Examples are elements of security, basic material for good life, health, good social relations, and the freedom of choice of action—and what to some extent emerge from these other functions. This was elaborated by the Millennium Ecosystem Assessment from which study Fig. 1 has been drawn. Figure 1 presents all sorts of typical ingredients including those associated with urban life on right hand side. That is not to say that such features do not exist in non-urban life. But these functions take a special form in cities. This form in turn is partially shaped by the embedding of the ecological ecosystem services considerations as shown in Fig. 1 in the left-hand box. That box thus delivers a check-list for sustainability, including those related to urban realities. These items distinctly provide considerations for urban planning for the future, especially when linking the ecosystem issues to the right hand side in Fig. 1 covering “constituents of wellbeing”.

Since most connections of these intertwined systems are nonlinear, phenomena of sudden drastic changes could appear—even after reasonably long periods of consolidation—and thus seem to be more or less surprising. In addition, the planning processes of urban structures have to absorb the knowledge about these potential events, including the features of collapses of the sudden surprising eruptions. In the framework of sustainability considerations the need for careful designing does not only encompass the “green” components of urban space (such as parks or green geographically connected “corridors” (of which the Royal National

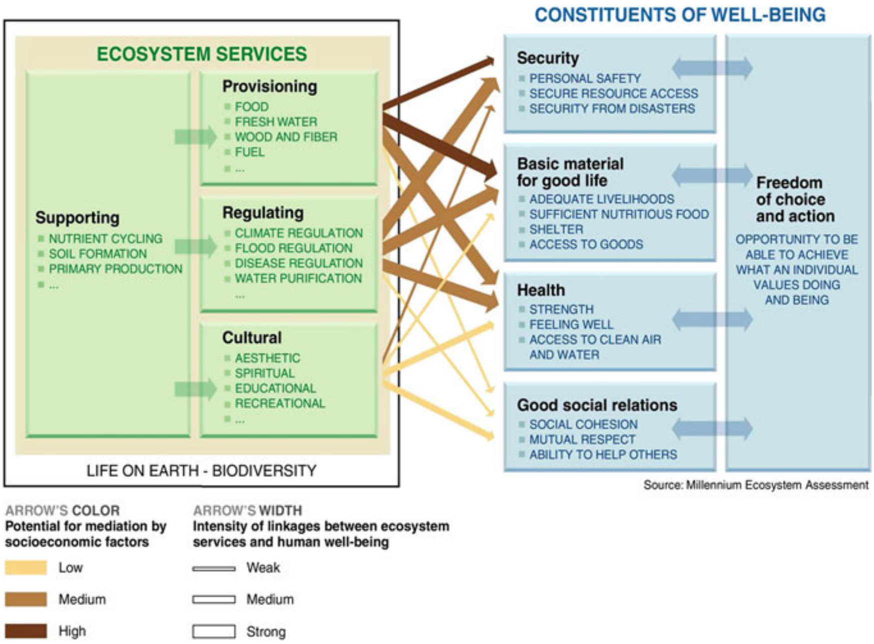


Fig. 1 The relationship between ecosystems and social constituents of well-being (according to the Millennium Ecosystem Assessment 2005)

City Park space in Stockholm is an example) (ref. Royal National City Park/ "nationalstadsparken"). It also has to deal with spatial, functional and social patterns of a broader eco-social design. Late 19th century visionaries of green town planning, e.g. expressed in terms of "Garden City" ideas in England and elsewhere, did demonstrate this interest of an earlier era in the design of urban space both for social needs as well as providing linkages with nature based on a number of reasons and visionary goals.

2.4 Natural Resources, Socio-economic Issues and the Urban Processes

When we are further penetrating the various aspects of the combined eco-socio urban system, there are several interesting part-functions to look closer into, e.g., climate and energy phenomena (including efficiency gains), water (quality and quantity), marine connectivity aspects (for coastal cities), land-use issues, ecological systems issues, biodiversity, etc.

Here a number of issues related to how we "measure" progress have to be considered, stressing the need to scrutinise both the explicit, but also the implicit views about the factors involved. The challenge is to find how to balance these factors to match a clearly stated set of goals in some sort of multidimensional compromise between different types of needs. (Examples of balancing mechanisms are measurements of "using less per function"; measurements connected to ways of finding structurally better solutions given a "new" goal structure; measurements related to processes aimed at summing up "needs" of different kinds, e.g. in relation to consumption patterns, exploring different sets of standards for the future to be judged against labels as "less is better" etc.). In the process of finding systemically sound solutions the image of the "substitution ladder" (from changing technical modules to changing subsystems in their technical performance, then to changing core ideas of broader systems and finally to the change of the value structures, e.g. through reflections on geographical mobility issues as "public transport versus other means" or about "the use of time by an individual" over a day, month, year, life). In the end, such reflections often have to fall back to basic fundamentals such as the biosphere's capacity to deliver functions ("ecosystem services"), setting the frame for what could be societally possible.

2.5 The Urban—Rural Connection

One of the systemic aspects has to do with connectivity between that which is inside the urban space and that which is outside. This has often been labelled as the urban-rural nexus. The streamlining of different land-use functions (including those that relate to the urban space in connection to rural space, may imply the need of new forms of networks of urban sprawl structures, with rural functions injected into these urban structures as "green spaces" with distinct features and roles. The systemic connection between urban space and the "hinterland" is also expressed through the "environmental shadow", whereby the urban impacting operations apply not only to the close-by non-urban space, but also far beyond the urban perimeters and into the global realm. The shadow of the environmental impact stretches –depending on the type of flows we are talking about—to far-away places as the carbon cycle connectivity demonstrates in binding together the local injections of carbon dioxide (and also other greenhouse gases) and the global geography—all feeding climate change. The interest in the issues about the urban-rural connection also is strongly related to perspectives on global food production with its many alternative possibilities to feed a future world population when 70 % of the world population will live in urban areas by the mid-21st century (IAASTD 2009; Falkenmark et al. 2009; UK Government 2011; European Commission/SCAR 2011; Svedin 2012).

2.6 Green Development and Urban Possibilities

The attention to the use of different flows will also provide, e.g. through "green growth" oriented technologies, possibilities mostly developed in urban societies and applied either at urban sites (as biological green roof coverage that can be seen on skyscrapers in Tokyo and New York City), or in more general terms as part of broader green developments based sometimes on high-tech, but also on deliberately culturally sensitive designs.

3 Green Urban Principles and Goals in Contemporary Urban Planning

The case of the Hammarby sjöstad, Sweden ("*Hammarby Sea City*") www.Hammarbysjostad.se.

Many of the principles and ideas we have referred to earlier in this presentation at the general level should be compared to current examples of city planning in order to see what the principles may mean when they are implemented.

The Hammarby sjöstad case in Stockholm, Sweden (see map in Fig. 2) illustrates well—among other issues what we have spoken about above, e.g.:

- an old industrial harbour site *versus* new built residential functions,
- sea scape *versus* landscape interactions,
- transport networks *and* new forms of transport combinations,

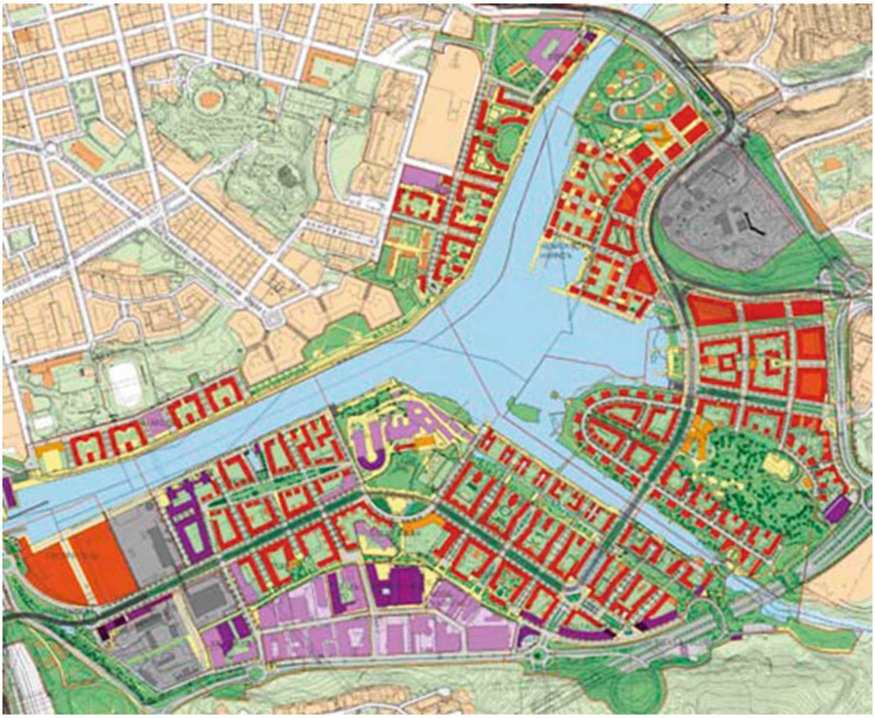


Fig. 2 The map of Hammarby sjöstad

- resource *and* waste flows handled in a new and sustainability oriented fashion,
- humans *and* Nature—a general approach also serving the inhabitants of the city with strong green qualities for wellbeing,
- humans *and* technology in using combinations of ultra-high tech and not so high tech in a deliberate way,
- rich *and* not so rich in the population to be connected,
- design to serve *several generations* at the same time and place.

The map in Fig. 2 shows this new part of Stockholm that has already been in existence for around a decade. (The principles developed in this part of Stockholm has now been further developed and used in other parts of the city in planning for future large scale town developments with sustainability ambitions).

Further examination in more detail would exemplify e.g. how:

- the combination of several types of communications provide an integrated frame,
- the streets of the town have been designed to provide a varied impression of the town,
- the handling of organic material waste is organised through compost delivery points,
- the handling of sorted waste systems entries are placed all over the town area,
- the locations of the central fetching points for waste are almost unnoticeable,
- the local central waste dump (e.g. of building material) also has been designed to provide new functional values by providing ski slopes in the central town setting,
- the manual labour functions are designed to be the carriers of sustainability functions,
- the houses provide living quarters for both younger and elderly people and are "integrated" in the broader town space,
- the design principles have highlighted creation of a living space and related qualities "for all" with concern for a design of "human wellbeing" in focus,
- the urban space has specifically been constructed to serve the needs of children of different ages—i.e., the "children are part of the new town" strategy.

Issues that a presentation of green urban challenges also need to include:

- the social and cultural dimensions of the urban "green" development
- "green" governance at local, regional and global levels
- connection between the political participatory oriented debates at local and regional levels.

Many of these concerns have been integral in the design of the new Stockholm Royal Seaport, which is the largest new urban development area at the moment in Sweden. It aims for 12.000 new homes and 35.000 workplaces by 2030.

4 Moving Towards the Period of Anthropocene

For the future—when we are possibly moving towards the "gardening of the planet" (Svedin contribution to the EU foresight "Rising Asia" 2011)—the accent on the period of Anthropocene will mean (Vitousek et al. 1997; Crutzen and Stoermer 2000; Crutzen 2002; Steffen et al. 2004, 2007, 2011):

- calling for a planetary management by humankind within which the urban roles will have to be given strong and increased attention,
- better matching between knowledge and action in the new context,
- enhanced importance of responsibility and ethics,
- increased need for implementation capacity and sustained drive.

In the urban perspective all this means being alert for the central and pivotal strategic role of the urban action space, including its development and specificities in the new global context.

5 Analysis in Terms of Perspectives

There are several perspectives within which future paths could be explored for the urban space and activities with a sustainability/green connotation in mind. There are many new possibilities emerging when you explore the social, economic or cultural spheres—and the overriding political and institutional surrounding. Within a sustainability focus, including the politics of it, we below list a few important issues and the arguments in a forward-looking approach.

5.1 The Resource Flows—Natural Resources and Waste Flows

The resource flows have gradually expanded as seen from the kernels of urban space to include increasingly broader "hinterlands". The classical urban study of Hong Kong in terms of its flows was completed several decades ago. Still this perspective is valid to some extent, although new aspects have been added and the general overall perspective has taken a new shape. What will happen more and more is that the hinterlands of the very big cities will be of a planetary kind. These centres of megacities and similar structures in the world will grow in number and size. Thus, they will emerge as global actors by themselves and will operate from a position of expanded "regional entities" as central actors. For smaller countries, such large urban entities (and also somewhat smaller ones) are already internationalizing themselves, and thus increase in importance in their domestic political frameworks. The international patterns of resource flow characteristics will call for strong collaborative efforts between groups of such urban entities in Europe as well as between involved nations, e.g. in large regional blocks in the EU. Such more or less formal collaborative structures are already operating in various forms including wide stretches of trans-national geographical urban connectivity structures as the Milan-Paris-Frankfurt, Rotterdam/Amsterdam-London “geographical band” indicates.

This will call for new forms of balances between a fierce competition and an absolutely necessary European cooperation. In the quickly emerging more globalised world and with its strong “Anthropocene” character, the competition around globally available resources will increase. However, there will also be a need of readiness to adjust common strategies to global impacts. (Today these efforts are often exemplified with the strategies for allowed gas emissions influencing climate, but increasingly also other issues may come into focus such as access to fresh drinking water, the control of nitrogen and phosphorous flows, etc.)

Earlier it might have been felt as somewhat of a surprise to suggest that urban leadership also will have to involve themselves in active participation to combat e.g. loss of biodiversity. Such surprises are not any longer the normal case. The understanding that responsibilities are widening for urban leadership (especially of the major urban entities) into a global arena is catching up. This responsibility covers a much broader space of influence than the urban space itself implies and opens up for collaborative approaches with the actors responsible in various ways for the non-urban parts of the world, including an increased co-responsibility for the food security issues related to large cities.

5.2 Climate and Energy

The climate factor seems to be the first of the grand environmental challenges that demonstrates the global extent of the challenges also at lower-scale levels. However, there will be others waiting in the queue. Focusing here on the specificities of just the climate (and its energy use correlate) warming up for some already dry parts of the world—including the Mediterranean basin—will obviously have a profound effect on the urban spaces. The call for increased efficiency of energy use is already strong. Mastering the approaches—sometimes to some extent inherited from earlier history in using e.g. architecture for passive cooling (including also the use of green space) will be needed in constructions of new ultra modern resource efficient solutions.

In other geographical areas e.g. the coastal cities (especially on lowland planes or, as in the Netherlands, even below the sea level) the challenges could be exemplified by the stronger storms generated by the temperature increase and the also connected gradual rise of sea level within a few decades (due to e.g. both the thermal expansion of the water bodies and the melting of the Arctic/Antarctic ice). The different risk scenarios highlighted by the IPCC and others in this regard will probably call for solidarity efforts within the EU to distribute between members the burdens of different kinds affecting different parts of Europe. It also may happen that not only technical and infrastructural approaches for the most vulnerable parts (e.g. the Netherlands in terms of storms and high water) will be needed, but also long-term planning of restraints to further expansion (as further use of low land coastal areas) in sites of growing vulnerability caused by these factors.

5.3 Housing Involving the Architectural Green Sustainability Oriented Technology

Within this perspective, you can find a vast number of emerging possibilities for low fossil energy designs, efficiency of flows, keeping buildings sufficiently warm through sophisticated computer controls of ventilation systems using new ICT solutions, new materials for insulation, and the use of solar and wind energy. It is here you already see the advances to more sustainable solutions at micro (individual building) level expected to be a very important line of further exploration and advancement.

5.4 Technological Systems Solutions

This includes green growth innovation in the infrastructure, transport, and food systems connected to urban sprawls. In addition, systemic designs of entire system functions in urban regions—including smart transport solutions—may also start to deliver contributions to the needed transformations of resources and environmentally benign solutions, building up from an array of partial contributions.

5.5 Socio-Ecological Resilience Systems and Their Development in Time

When dealing with the broader systemic solutions in cities and urban sprawls it has to be kept in mind that the designs of technical systems always have to go hand in hand with the formation of the related social systems which in turn are based on historical continuity and related cultural preferences. A combined system involving all these actors is an absolute necessity. During the next few decades, the designers will be encouraged to find even more skilful and smart ways to handle these interconnected, intertwined and to some extent integrated systems. The overall situation is severe enough as it is and it induces pressures on a wide range of actors to move strongly to transform the urban space as fast as possible, not least due to the involved long lag times and investment pattern dynamics.

However, the situation may grow more critical further on into this century i.e. within the time of a generation that already has been born, if the speed of transformations is not in pace with the emergence of the challenges. Thus, the time factor for development of the system change might be a pivotal point. A strong path dependence might be produced by the character of the steps that will be taken as a result of various choices and decisions—and by the way the steps are reacted upon in society at large. Certain steps are more possible in one type of sequence of events than in another. Thus, the importance of the urban leadership will increase in relative terms. This might be supported by and reinforced through a more widespread "urban-ness" in the mind-set of the population at large, perhaps due to the relatively fast increase of the fraction of population moving into town-like conditions. This may also hold true for Europe. Connected to that is the possibility of a distinct "green" aspect of perception by the public towards the urban space.

5.6 Geographical Scaling Perspectives

This relates to the connections between scales (local-regional-national-global) including urban-rural nexus considerations and other approaches of systems nature to match the "grand challenges" for entire societies.

By moving the urban decision makers attention and responsibility perception onto the need to face a broader picture than the regional space provides—that now often is the case—new phenomena for these decision makers and planners will emerge that will call for a widened type of consideration and the corresponding knowledge structure and experience. This relates not least to the need to integrate the designs of the urban and the rural space. This is not pointing at similarities in functional terms but highlighting rather the joint concerns and synergies between two inseparable parts of the design of a system. This will happen quite soon and call the already existing generation of decision makers and professionals as well as new actors to open up for changes in perceptions, exploring a sense of daring, and widened sense of responsibilities imposed by the need to bring the world into the period of the Anthropocene. The increased connectivity and relationships between the major urban nodal spaces—including the urban parts of the poor world—will also call for political attention and new efforts.

Even more integrated types of solutions need to be developed in the future i.e. responding to the grand challenges in the world not only as something to be known in principle, but now directly to be acted upon and impacting on the planning. This also relates to the increased need to expand the democratic debate on urban futures together with the population at large. This includes encouragements for a willingness to share responsibility for certain new measures of socio-technical kinds. (It could be exemplified in recent history by the request to individuals to deliver work in the form of separation of household waste into sorted fractions of the waste stream).

5.7 The Politics and Institutions that Will Provide the "Governance" Capacities, Including Responses to Surprises

Some of these tendencies we have already seen quickly growing during the last few years when climate change and other issues have become more evident. Environmental considerations have since long been of importance for urban planning. The classical industrialisation impacts over the last century, e.g. on local water and air conditions were the start of the environmental movement. These earlier challenges have in many cases been taken care of as in the case of eliminating the old "London smog". The empirically observed change of the vanishing of fish in many inland and coastal waters due to environmental stress have in many cases been reversed within the last few decades which could be exemplified with the improvements of Stockholm waters to much more healthy environmental conditions. This has been due to strong policies with public support and corresponding investments to treat such historical problems.

So what could be the surprises here? Maybe it could be the time development. New types of problems and forces of pressures may emerge at a faster rate than perceived earlier (i.e. through some sort of flip-flop phenomena in the combined socio-ecological systems). There might be surprises on the behavioural side around what people in general might be ready politically to agree with. Alternatively, the surprise might be that the political system is not capable of transforming itself sufficiently to match the need for change e.g. due to resistance in the population at large or from vested interests to accept sufficiently strong measures. Or, the surprise might be that facing the crisis the democratic system in Europe is capable to forcefully respond to the test. Solidarity between different parts of Europe—as a tentative positive surprise—may be stronger than could be perceived today. Or it could go the opposite way, i.e. resisting the measures and costs of the needed broad agreements and related common designs. The intensity of such draw backs could increase (as we have seen recent examples of at world level in the relative lack so far of sufficient capacity to combat climate change through common strategies and responsibilities).

Under such a scenario of not sufficient global transformative actions different local and sub-regional initiatives could be of central importance in mobilizing responsibilities to pool resources for a common good and boosting transformation activities at local and sub-regional levels. Another surprise could be if the flow of global environmental refugees emerges much sooner than envisaged due to the speed of the social responses to climate change. The size of such movements of population could turn out to be much larger and expand much sooner than envisaged. This might be connected to a quickly deteriorating global situation which in turn might change the perceptions of what is needed to face the crisis, involving global leadership initiatives and public support to the extent not yet seen. For sure all these potential scenario developments would have strong urban consequences.

6 Some Issues of Importance

6.1 The Increased Importance of Green Areas Within the City Space

This issue has not only to do with the still highly valued traditional importance of parks for social recreation and as cultural space, but also with more ecologically oriented arguments dealing with biodiversity related to green spatial connections between sub areas. Climate adaptation arguments are also important stressing the need for more areas for changes of the urban micro climate e.g. through plantations on rooftops (as has become an increased and deliberate practice in cities like Tokyo and New York City). Connected to these "green space" arguments is also the emerging debate on increased food production inside the urban space (perhaps in the beginning mostly oriented towards fresh vegetables).

6.2 The Importance of Developing New and More Sustainability Oriented (Both Mid-term and Long-term) Indicators for Urban Space, i.e. a More Relevant "Metrics"

In order to achieve a development that would match the criteria of sustainability, more effort has to be invested into finding appropriate "metrics" to make the green facet of this development sufficiently transparent. Future benchmarks of European cities will more than today have to consider how green policies and implementation shall be made visible in the accounting systems, in parallel to a reformed GDP type of measures.

6.3 The Innovation Aspect to Urban "Green Growth"

Both technological and social innovation schemes have to be designed and implemented in relationship to the development of European urban space. On the technological side the elements of eco-efficiency and the vast number of needed green technical innovations have to be further promoted to build up the new bio-based economy as an emerging possibility. This has to be done as an expression of a strong European competitive mobilisation at world level. Strong and deliberate policies and investment schemes are needed at regional (including cities), national and European levels. Connected to this the social innovation approaches should be vigorously mobilised for similar purposes. The overall support for the innovation efforts has to be based on a strengthened knowledge society that is apt, ready and interested in addressing the grand challenges and the corresponding needs at the level of implementation of the solutions in an interdisciplinary and cross-sectorial way.

6.4 The Role of the Economic Crises for Urban "Green Development"

The discussion has shifted from stressing that the economic crisis prevents investments in the implementation of green policies, to considering the crisis as a time and possibility for a more long-term strategic change. This is boosting new vigorous and "smart" policies and implementation of green solutions, not least in the urban sphere and with a strong world competitive connotation. Here you find new links to upgraded cohesion policy.

6.5 Vulnerability and Resilience Considerations of Systems Nature

The issues of current and future vulnerabilities in urban settings for sure has a strong sustainability/green connotation. The connected natural and socio-economic systems with urban connotations have to be analysed facing the future in terms of capacities to be resilient in periods of constant change and with stronger stresses on the whole system. The stresses could be of ecological/environmental kinds, but also coming from the side of demography topics and other connected issues. One aspect of these systemic issues is the interplay between the urban and the surrounding regional rural space, as has been noted above.

6.6 Time and Development Aspects

Issues around the sequence of needed steps are not only coming from the economic or social planning domains, but also with regard to the green connotations. It relates to setting priorities over time, including the steps for infrastructure investments and transport system design within the urban space. It also relates to the dynamics of changing patterns of connections between urban sub spaces and smaller cities in urban sprawls (if that is the way how the "urban-ness" expresses itself). The time aspect also involves various perceived intensities of urgency to act and the related risk panoramas.

6.7 Norms and Values

The basis for a possible stronger green urban strategic direction is the strengthening of the connected values at large that would support such development. Without such common and public support, it will be difficult to mobilise the resources needed and to face some of the risks that the larger environmental challenges will most probably provide (e.g. a need to quickly install a low fossil energy agenda due to climate change, water availability etc.). At the practical level of everyday life, the issue of sustainable consumption may emerge as a very important factor. A complex of norms relates to the approach to global issues in the population at large and ideas about the responsibility to address those—also from a more local/regional urban starting point. One unsettled issue concerns the question to what extent the green agenda—and the global connotations of it—will call for drastic value changes, or if the basic value fundaments in Europe still could harbour an adequate response to these types of challenges.

7 Scenario Reflection on European Urban Futures

Several of the thought lines explored above could be illustrated through a scenario approach. The choices of key variables is of course very subjective. But if you start by assuming that the urban aspects of society (and the corresponding geographical space) will continue to rise both in Europe and in the world at large, the rise does not in itself constitute an interesting variable. We just assume the rise to be a given assumption for all scenarios. It is rather how this expansion will take place in terms of policy emphasis (green/or less green; technological/economic or socio/cultural emphasis respectively). For the scenarios, there exists a short time frame up to 2025 corresponding to roughly a decade ahead. For long term planning purposes this study also opens up for a time profile up to 2050. All the scenarios aim for exploring urban futures as their focus.

The scenarios are represented in Fig. 3 in which the horizontal dimension explores greener emphasis (left in the picture) versus less green policy (right). In the vertical dimension an economic/technical approach is stressed at the top—and at the bottom a social/cultural approach is found. Thus, the emerging 2-by-2 matrix shown in Fig. 3 provides the frame for four scenarios represented in the respective four quadrants.

GREEN VS. LESS GREEN HORISONTAL DIMENSION ------------------------- *ECON.- TECH. VS. SOCIAL-CULTURAL VERTICAL DIMENSION*	**GREEN FOCUS** (reasonable economy)	**LESS GREEN FOCUS** (under econ. pressures)
ECON-TECHNOLOGY *EMPHASIS*	GREEN TECHNOLOGY BASED BIO-ECONOMY (A)	TRADITIONAL INDUSTRIAL GROWTH (C)
SOCIAL-CULTURAL *EMPHASIS*	VALUE ORIENTED NEW GREEN SOCIETY (B)	TACKLING ACUTE SOCIETAL PRESSURES (D)

Fig. 3 Scenarios providing contexts to alternative European Urban Futures

7.1 Green Technology Based Bio-economy (A)

7.1.1 Path and Characteristics

In this scenario the full emphasis is on a new technology-led bio-innovation and green-growth line. The aim is to boost the economy by transformation of the society to match the green grand challenges not only as a vehicle to solve the problems (e.g. climate change impacts) but to do it in a way that also creates European added value and competiveness at a global level. In this scenario full-fledged urban technology-led design, both at systems and sub-systems level matching the sustainability criteria are seen to solve the problems and to be an export-led economic success.

7.1.2 Bonuses and Problems

The advantage is that, if all this succeeds, the scenario reflects a venue of economic growth for Europe. It would also help contributing to matching the green challenges. But there is the competition from other parts of the world, not least from Asia or the USA working partly along the same similar lines. The trick is doing it in a European way, using the European value system and design traditions and to mobilise the innovation capacity needed combined with strong investments. In this technology-driven scenario it might be, if not complemented by other elements, somewhat of a technical fix disregarding the backside of such solutions in terms of differentiation of the economic gains, and also a preference to technological solutions concerning social problems. This will also drive big projects and the corresponding institutional forms of solutions. But it is a very green urban solution.

7.1.3 European Policy Demands

Innovation investments based on strong knowledge-based capacity development boosting e.g. the Lisbon EU agreement line. Strong common endeavours at European level: more cooperation than internal competition in Europe. Strong collaboration between the major cities of Europe to demonstrate the European way of creating "green urban solutions to global problems considering a plurality of conditions and historical experiences".

7.2 Value Oriented New Green Society (B)

7.2.1 Path and Characteristics

In this scenario, several technical supports are similar to the situation described in scenario A. However, here the normative outlook of the "new society" is at the centre. Here the issue is not only to find a set of technical solutions to serious sustainability issues—as important as that most probably is. In addition to this the scenario strongly stresses that the perceived needs to respond to demands from sustainability constraints call for a deep transformation of society. Thus, the social and cultural aspects are much more important in this scenario, although it has its technological correlates. That also means that the diversity needed to reflect the plurality of European experiences will be more at the front. Cooperation between European cities is needed, but not to the extent that the specificity of local conditions is totally lost and the plurality of European solutions is neglected.

7.2.2 Bonuses and Problems

In this scenario, the wider complexity of the system combining the human-made environment and the natural system is taken into account, which defines the starting point. Green technological solutions are welcome—but not at any price. The overriding vision is the creation of a broad societal solution for future life in a varied pattern of European urban settings. Thus, the complexity of the endeavour may put more stress on the political process than would be the case for a more straight forward industrial pathway of a more conventional management-oriented solution approach (as represented in scenario A). This broad transformation may limit the speed by which change could be manifested since the solutions here are not only technical in kind but also social and cultural. But it could also happen that if the societal transformation gains in momentum, the corresponding technological solutions may follow rather easily as the directionality of society is clearer and thus the needed investments will come forth. A long-term visionary outlook of the European political future is here at hand, where competitive advantages in relation to the other parts of the world deals not only with individual technological solutions but aims at broader systemic approaches and connected innovations. A stronger sense of public participation is encouraged in this scenario. If various types of goal conflicts may emerge between the technological solutions suggested and on the other hand new societal concerns about the grand change of social conditions and normatively led transformations, then the specific technical solutions will be looked for which are supportive of the societal visions.

7.2.3 European Policy Demands

Political leadership in Europe has many levels. Thus, there is a need in this scenario to find an interesting combination of "orchestrated" policy making at different levels of scale, from the local to the EU level. This is especially important in this scenario stressing the creative use of European plurality. The combination of boosting common policies that should streamline the strong common European experiments in the urban domain and at the same time encouraging the individual innovation stakeholders (also at local level) to develop solutions around particulars must be at the centre of such a two-pronged strategy outlined in this scenario. The encouragement of a participatory process must involve a wide presence of civil society as well as participation by industrial stakeholders and others in the mobilisation of common green solutions under a roof of diversity of European expressions.

7.3 Traditional Industrial Growth (C)

7.3.1 Path and Characteristics

In this scenario, the strong green face of economic growth has not taken hold sufficiently. It turned out that the transformation of the European industry into new types of new technological green solutions was not such an easy path as perceived earlier. One reason was that green solutions entailed new types of industrial—and political—stakeholders and the green markets were weaker than perceived, although the needs for the solutions were definitely still there. What remained was a continuity of a degree of conventional economic growth approaches, operating in more traditional sectors and with traditional means and towards more traditional customers. The risk perceptions about very large investments also changed as the economic crises continued which also exposed inner inconsistencies emerging between the visionary perceptions of possible green transformations and a more "realistic" continuation under problematic economic conditions. The support from the European population for more "risky" and new (and green) endeavours also cooled to some extent when the daily life was hurt by the harsh economic conditions. "Safety first" became a more pronounced strategy where even "business as usual" was considered as a possible approach to "do the best under these conditions".

7.3.2 Bonuses and Problems

In this scenario, the strategy of a milder form of green mobilisation has been connected to a continued difficult economic period over more than a decade. This is not to say that the continued elaboration of the green long-term needs of changing the society has gone away. The somewhat lower global economic activity also brought down the figures in some of the emission indicators for the energy sector related greenhouse gas emissions and thus moved the earlier concerns of urgency to be handled a bit later into the future when the economic situation has improved. Similar economic conditions all over the world also made it feel less important to run the specific aspects of green competitive technological innovations. All regions of the world under this economic situation have recoiled to "conventional" core issues of more short-term concerns. One of the problems is that neither the needed green investments, nor the grand technological system solutions have been promoted under this scenario to a greater extent, nor with sufficient speed.

7.3.3 European Policy Demands

This scenario exposes the strategic dilemma arising under a prolonged period of global economic turbulence. This alerts the European economic policy not to withdraw from needed long-term green investments even under harsher economic conditions in line with e.g. the Stern Review (Stern 2007) advise within the climate change domain, that climate related investments should be made sooner rather than later—also due to considerations of economic development. It also points at the responsibilities to do what is possible at many political levels—even under harsh conditions—stressing the need for solutions at the level of the cities of Europe, more leaning at capacities of their own. Still many actors are looking for EU level advice and promotion, especially in the technical and industrial domains.

7.4 Tackling Acute Societal Pressures (D)

7.4.1 Path and Characteristics

In this scenario, the tackling of the deteriorating social and economic situation in Europe has called for a very focused attention to the social unrest, the poverty challenges and the trickle down of these source problems to other cascading problems of social nature. This means that other issues, important as they may be; including the "green agenda" has thus been to some extent "postponed". The positive feedbacks that other situations could have opened for has not happened in this "emergency" case.

7.4.2 Bonuses and Problems

This scenario is mirroring a Europe "going down the drain" and also how it tries to survive under these conditions by postponing the longest-term types of issues in order to fix the immediate urgencies. The degree to which some elements of green attention could be supported under such conditions is up for discussion within the scenario and points at the possible window of some actions, especially at more local and regional levels. It also points at the importance—despite the situation—to give cultural and political signals that the policy spectrum cannot be contracted in a down-going spiral without injecting antidotes. Here there are distinct EU responsibilities. This will also help individual cities to maintain green policy elements wherever that is locally seen to be possible, and even as a potential way out of the downwards going spiral of economic and social unrest and cultural deterioration.

7.4.3 European Policy Demands

A special EU crisis task force is needed being appointed with sub branches in all member countries and involving a very broad number of stakeholders all over Europe to define and start "the way out", e.g. by highlighting good examples, even under miserable conditions. This is also a scenario for the mobilisation of civil society. Here there is an obvious EU role to give the potential of possible mobilisation some clear visibility and credibility. The key platform for action will be at local and regional level, but with support by all European policies of encouragement and re-pointing at the need to address green challenges—even during these circumstances.

8 Some Strategic Issues to Be Considered

8.1 Issues and Perspectives

Having now in the scenarios mirrored some of the earlier explored green challenges and connected issues it is time to round up with a reflection on a few selected strategic issues for further elaboration and discussion in Europe. Which issues are to be picked up depends on the perspectives we already touched upon in the segment on "Perspectives". There it became very evident that the types of questions you do choose to highlight depend on the context of interest—i.e. about "the perspective". However, there is a sort of stratification of generality of considerations. Some concerns are operating at a very high general and "generic" issue level, while others are more specific. Exploration of both of these classes of concern is important. Especially in the design of solutions to specific problems the latter group of concerns comes strongly into play, e.g. concerning new ways of making buildings resource-efficient, or how waste streams should be designed to encompass flows far beyond a city. Having this said we now focus on a few of the first type of generic issues alluded to above. What could these be?

8.2 Mobilising a "Right Mind" Set (Especially in Connecting "The Local" and "The Global")

In earlier periods up to quite recently urban planning has been very—and understandably so—local and regional. Even up to the last decade it all has been about how to handle a vast and complex object—also involving hundreds of thousands up to several millions of people. But the global connotations have not been very evident. The approach has been very "city oriented" in its selection of system boundary and thus been mostly oriented at the functions of the cities themselves and their close-by areas. But there has been an ongoing upscaling tendency as demonstrated by e.g. the broader regional concern as the Öresund area combining the Danish Copenhagen larger area with the similar urban structures in the South of Sweden ("Örestad"). In the Netherlands, there is a strong tendency to reflect on the combined system of the largest cities in the country. Similar moves hold true for the city groups around Milan in the northern part of Italy or the urban sprawls around Lyon in France (not to mention the larger Paris area). Still—and despite these enlarging moves—the embedding in the much larger global connotation contexts has been limited. This more local or sub-regional orientation period seems now to be quickly waning. Quickly growing fractions of the panoramas of the drivers are global in character. This holds true for the inward directed (towards the city itself) influencing forces, as well as the outgoing impacting effects on the world at large, especially from the big multi-million population cities. These influence zones are global in nature with impacts clearly seen not only in Europe itself but also at other continents as well including e.g. East Asia, Africa, and North and South America.

Reversely, the operations in these other continents are increasing in force, not least with regard to impacts directly on the European space. The emerging "tele-connections" (i.e. the causal links) between the large cities in the world will have to be further elaborated upon and better mirrored in the connectivity governance patterns now being more and more recognised and developed (see e.g. Seitzinger et al. 2012 and references in that article). So the urban policy ambitions must raise to this level without losing the fairly local concern of how to arrange the most useful living space for people living in just a very specific part of e.g. Europe. The "mind-set" therefore has to be more global for urban planning than before. However, it also has to encourage the "specificity" of the local solutions and the close, regional surroundings within which they are embedded.

8.3 Urban Policy as Seen from Inside-out with Regard to Cities, and from Outside-in

The points made above demonstrate the new appropriate "zooming in" character of urban policy in Europe from the widest possible global one down to the different cities and agglomerations of cities in terms of urban sprawls and the like. Thus, we have to operate at several levels simultaneously. The further development of a "classical" urban policy for the individual cities themselves still has an important role to play, i.e. to provide policies for "the urbanized space". However, the work with these policies and actions has to connect to the new "outbound" connectivity and collaborative tasks. In a certain way, we are facing a new situation where there is a need for an EU urban policy to be operating—in combination—at two levels simultaneously. One is a general European one (see the tendencies in all the four scenarios) and one has more of regional/sub-regional features encompassing individually all the political and managerial centres in the key urban spheres in Europe. (This holds true both for the already "historically existing" ones, but also for the newcomers under quick development and establishment.) The contents of the two levels of policy of course have to be linked, but not necessarily to become identical, as they serve different purposes. Both levels have to transform under the pressures of similar challenges, but in different ways.

In the case of European level urban policy it has to be generated and be given reasonable, constructive, innovative institutional forms taking into account the overall European EU current collaborative format of political cooperation at that level. However, it is also an area of institutional innovation for new times. This would involve a common European urban-rural policy field concerned with the European geographical space, to some extent coloured by the regional-ness of its political orchestration and management. Certain problems connected to the global "green/sustainability agenda" (e.g. of climate change, water resources developments and demography changes) may seem more or less important to various geographical parts of Europe. As seen from a "European overview" perspective the similarity of the challenges implies the need for common action at that level.

However, this is not counter to the need to develop policy processes at other levels to mobilize the existing diversity in facing the common challenges. This has also to be done.

At the same time, the connectivity between the specific “grand city” nodes in Europe will have to be used to improve European collaboration—even in times of strong competition within and outside of Europe—considering the nature of the common challenges. In addition, the “grand cities” themselves have to explore even further the connotation of the global scale of the ever increasing complexity of their mandates. These then no longer only relate to the important classical green city agendas of clean air and safe waters—and mostly these days rather successfully handled (e.g. just reflect as was done above on the relative absence of smog in present day London). The historical situation now has pushed the challenges further and the trans-boundary flows characteristics now point at the importance of addressing the responsibility structure in Europe for these wider concerns and how the various policy levels at different scales need to be harmonized and in some cases activated into new functions.

8.4 New Governance Structures (and Capacities to Match the Grand Challenges)

In the specific functional cases where new forms of governance will be in need to be further explored at all European levels this has to be done within a not too far away time frame. This will probably call not only for the orchestration of already existing and more regional entities in institutional terms—and to be built upon these—but also new institutional functions might be needed for new mechanisms that the grand challenges call for.

8.5 Need for Changes in the Knowledge Production System (Towards More of Systems Thinking)

The need to address new challenges in a new time within which the move towards the period of the Anthropocene (see e.g. Crutzen and Stoermer 2000; Crutzen 2002; Steffen et al. 2004, 2007, 2011; Richardson et al. 2009) will call for both the development of a deeper basis of understanding and the creation of corresponding innovation structures. This could be referred to as the upgrading of the knowledge production system with even more capacities to address issues about large complex systems in a multidisciplinary, interdisciplinary, and trans disciplinary way (see “Chap. 17” of the reference Svedin 2011a). This should be done by mobilising European talent, capacity, expertise and institutional momentum in the knowledge production sector—in this case addressing the large urban challenges of Europe.

8.6 Alertness to Demographic and Social Challenges

These endeavours indicated above addressing the increasing importance of the urban development issues in Europe will also call for increased participatory processes in the democratic tradition and increased transparency to the public at large. This holds true especially as the interwoven character of these phenomena will concern everybody in one way or the other. This is especially relevant for the green dimension of the urban challenges. The appropriate institutional processes will have to be creatively considered and implemented and provided adequate resources.

8.7 Not Forgetting Culture and Norms

As has to some extent been explored through the scenarios above it is evident that the development of norms (including some need of transforming some current values e.g. in the direction of a more conscious sustainability oriented consumption) it is important in the handling of the urban challenges and its green connotations to take account of the long cultural history in Europe and to take that as a foundation of the reform work needed under the new and quickly changing conditions.

8.8 Domains of Possible Surprises

What should we then expect of the unexpected after having elaborated upon many issues that we already see coming, but in relation to which we have to mobilise effort, innovative capacity, resources and political courage and implementation strengths. "The unexpected" may come in various forms.

The time profile of the challenges may be different from how we perceive them at the moment. The climate threats may go faster than perceived as is envisaged by the 2013-14 IPCC presentations in comparison with the IPCC statements of 2007 (but could also be slower due to unforeseen counteracting forces). It is due to the non-linearity in the coupled and integrated systems that the surprises may appear. If the time profile e.g. in the climate domain makes changes slower than feared that is all very good (e.g. limiting the harms from the heat rise in the South of Europe summer time and connected water shortage), but could definitely not be relied upon or even expected. Especially the now through (constantly upgraded) model simulations investigated flip-flop possibilities are hanging unsolved for the future (e.g. the speed by which the Greenland ice might melt and the consequences of that in terms of climate change and sea level rise and the time distribution for this). Thus it seems now that surprises are more probable to appear in terms of a faster than until now assessed expected development of threats.

The seriousness of the changes may be a surprise through cascading effects and other unforeseen phenomena. The IPCC investigation of vulnerabilities for various assumptions of world (and regional) impacts as with regard to impacts on various sectors provides an interesting material for such reflections. (See above in the beginning of this article on vulnerabilities connected to temperature scenarios.)

The social response to the changes may be a surprise (e.g. in terms of global migratory environmental refugee flows) but also in terms of capacity in time to mobilize counter acting forces to the threats, politically, in terms of knowledge and innovation creation and in terms of resources.

9 Summary—Specific EU Concerns and Possibilities in Relation to Green Urban Challenges

In rounding up this article a few points related to EU possibilities should be extracted, (although several of the points have already been touched upon at different occasions in the text).

- The further need for *improved integration of functions and policies at European level* (in addition to already existing regional functions);
- The need for further *political considerations about the time sequence* by which urban challenges with sustainability connotations should be met;
- The need for an investigation of the *wanted priority profile and design of policy developments and corresponding institutional build up*;
- The need for a "*green innovation boost*" in research, innovation and implementation policies. This has to connect to more traditional policy areas aimed at, e.g. changes in job compositions (not least considering the influence of improvements in the ICT and other high tech sectors) and new possibilities for green jobs creation.

There is a need to identify, in more general terms, which items should be on an *EU list for green urban consideration*. Interesting candidates include e.g. issues related to climate, water availability/drought potentials and counter measures for storm and flooding issues (perhaps in relation to re-evaluation of risk assessments for certain territories) and land use.

The needed priority-setting schedule has to treat both overall ambitions for Europe (as has already been done in the more general climate change policy arena in defining certain reductions of emissions to be completed at a certain time) as well as a differentiated timetable for actions in Europe.

An important part of what could be explored is the type of insurability that could be attached to such phenomena in terms of state (and EU) or private insurance responsibilities and capacities.

Still another important action domain is the complex of knowledge production and innovation structures. Regarding efforts in a specific geographic zone—or with regard to specific types of cities—such schemes should be developed, not least in order to boost discussions and processes to develop common European policies in these fields.

The overall European strengthened global cooperation is of central importance with regard to urban sustainability challenges and the relation to the global context. This is already promoted to some extent through the already increasing efforts made by especially the large EU cities to open up and consolidate contacts with other major urban areas in the world. However, this activity should be given further strong attention and support in appropriate bodies within the EU as well as in other international fora, where the EU has an important role to play—also for the urban futures.

Acknowledgments This text is based on—and further elaborated upon—a presentation material prepared by and used by the author at the DG Regio "Cities" Conference, 28–29 June 2010, Brussels. Here is acknowledged the support by the EU/DG Regio as well as an acknowledgement of the value of the conference and all its preparatory activities. I also acknowledge interesting discussions in the ongoing EU project COMPLEX (2012–2016), dealing with the societal transition towards a low carbon society by 2050 in Europe. Special thanks to the Swedish work package 4 part.

References

COMPLEX, EU-project 2012–2016, Knowledge Based Climate Mitigation Systems for a Low Carbon Economy, www.complex2050.eu

Crutzen PJ (2002) Geology of mankind: the Anthropocene. Nature 415:23

Crutzen PJ, Stoermer EF (2000) The "Anthropocene". Glob Change Newslett 41:17–18

EU, European Commission (2009) The world in 2025—Rising Asia and socio-ecological transition. Office for official publications of the European Communities, Luxembourg. ISBN 978-92-79-12485-3, ISSN 1018-5593, doi:10.2777/2539

European Commission, Standing Committee on Agricultural Research (SCAR) (2011) The 3rd SCAR foresight exercise (FEG3) (expert report), "Sustainable food consumption and production in a resource-constrained world". http://ec.europa.eu/research/agriculture/scar/pdf/scar_feg3_final_report_01_02_2011.pdf

EU, European Commission (2012) Global Europe 2050, Directorate-general for research and innovation, Directorate B, Unit B.5., Social Sciences and Humanities

Falkenmark M, Rockström J, Karlberg L (2009) Present and future water requirements for feeding humanity. Food Secur 1:59–69

Hammarby sjöstad www.Hammarbysjostad.se

IAASTD (2009) Agriculture at a crossroads. International Assessment of Agricultural Knowledge, Science and Technology for Development. Washington, DC

IPCC, AR4 SYR (2007) The United Nations intergovernmental panel on climate change. In: Pachauri RK, Reisinger A (eds) 4th assessment, synthesis report, core writing team

IPCC, AR5 (2013/2014) The United Nations intergovernmental panel on climate change, 5th assessment, WGI—climate change 2013: the physical basis, WGII—climate change 2014: impacts, adaptation and vulnerability; WGIII—climate change 2014: mitigation of climate change

Liljenström H, Svedin U (eds) (2005) Micro, meso, makro. Addressing complex systems couplings. World Scientific Publishing, New Jersey, London, Singapore, Beijing, Shanghai, Hong Kong, Taipei, Chennai

Reid WV et al (2005) Millennium ecosystem assessment, synthesis report, ecosystems and human well-being. www.wri.org/publication/millennium-ecosystem-assessment

Richardson K et al (2009) Synthesis report. Climate change: global risks, challenges and decisions. Cambridge University Press, Cambridge

Rockström J, Steffen W, Noone K, Persson Å, Chapin FS, Lambin EF, Lenton TM, Scheffer M, Folke C, Schellnhuber HJ, Nykvist B, de Wit CA, Hughes T, van der Leeuw S, Rodhe H, Sörlin S, Snyder PK, Costanza R, Svedin U, Falkenmark M, Karlberg L, Corell RW, Fabry VJ, Hansen J, Walker B, Liverman D, Richardson K, Crutzen P, Foley J (2009a) A safe operating space for humanity. Nature 461:472–475

Rockström J, Steffen W, Noone K, Persson Å, Chapin FS, Lambin EF, Lenton TM, Scheffer M, Folke C, Schellnhuber HJ, Nykvist B, de Wit CA, Hughes T, van der Leeuw S, Rodhe H, Sörlin S, Snyder PK, Costanza R, Svedin U, Falkenmark M, Karlberg L, Corell RW, Fabry VJ, Hansen J, Walker B, Liverman D, Richardson K, Crutzen P, Foley J (2009b) Planetary boundaries: exploring the safe operating space for humanity. Ecology and Society 14(2):32. http://www.ecologyandsociety.org/vol14/iss2/art32 (This is a more elaborated version at the same time and with the same authors of the article referred to below, i.e. Rockström et al in Nature, 2009b)

Royal National City Park Stockholm www.nationalstadsparken.se, www.visitstockholm.com

Seitzinger SP, Svedin U, Crumley C, Arif S, Alfsen C, Broadgate W, Biermann F, Bondre N, Dearing J, Deutsch L, Dhakal S, Farahbakhshazad N, Gaffney O, Haberl H, Lavorel S, Mbow C, McMichael AJ, Morais J, Olsson P, Pinho P, Seto K, Sinclair P, Stafford-Smith M, Steffen W, Sugar L (2012) Planetary stewardship in an urbanising world: beyond city limits. Ambio 41 (8):787–794

Sinclair PJJ, Nordquist G, Herschend F, Isendahl C (eds) (2010) The urban mind. Cultural and environmental dynamics. Studies in global Archaeology 15, Uppsala University, Sweden

Steffen W, Sanderson A, Tyson PD, Jäger J, Matson P, Moore B III, Oldfield F, Richardson K, Schellnhuber HJ, Turner BL, Wasson RJ (2004) Global change and the earth system: a planet under pressure., The IGBP global change series. Springer, Berlin

Steffen W, Crutzen PJ, McNeill JR (2007) The Anthropocene: are humans now overwhelming the great forces of nature. AMBIO: A J Hum Environ 36(8):614

Steffen W., Persson Å, Deutsch L, Zalasiewicz J, Williams M, Richardson K, Crumley C, Crutzen P, Folke C, Gordon L, Molina M, Ramanathan V, Rockström J, Scheffer M, Schellnhuber J, Svedin U (2011) The Anthropocene: from global change to planetary stewardship. In: Contribution (background report Nr. 2) to the 3rd Nobel Laureate Symposium on global Sustainability, Stockholm, May 2011 (Published in Ambio. 2011, doi:10.1007/s13280-011-0185-x)

Stern N (2007) The stern review: the economics of climate change, The British government (presented first time 2006) http://webarchive.nationalarchives.gov.uk/+/www.hm-treasury.gov.uk/sternreview_index.htm

Svedin U (2009) Towards the gardening of the planet in the period of the Anthropocene: the world as socio-bio-space (SBS). Future options and challenges. Report to the EU foresight study "The world in 2025. Rising Asia and socio-ecological transition" published in summary by the European Commission, DG Research, EUR 23921, Brussels

Svedin U (2011a) Issues that need to be addressed—assessing experience, Chapter 17. In: Kasperson RE, Berberian M (eds) Integrating science and policy—vulnerability and resilience in global environmental change. Science in society series. Earthscan, London and Washington DC

Svedin U (2011b) Thematic issue paper: urban development and the environmental challenges —'green' systems considerations. In: Cities of tomorrow, challenges, visions, ways forward. European Commission, DG Regio. http://ec.europa.eu/regional_policy/conferences/citiesoftomorrow/index_en.cfm (with specific reference to "urban environmental challenges")

Svedin U (2012) Global conditions for the future of agriculture in the "anthropocen". In Jacquet P, Pachauri RK, Tubiana L (eds) Development, the environment and food: towards agricultural change? A planet for life 2012, French Development Agency (AFD), The Energy and Resources Institute (TERI) and The Institute for Sustainable Development and International relations (IDDRI). TERI Press, New Delhi (A French version was published simultaneously under the name "2012 Regards sur la Terre. Développement, alimentation, environnement: changer l´agriculture?")

UK Government Office for Science (2011) The future of food and farming. Final report, London

Vitousek PM, Mooney HA, Lubchenco J, Melillo JM (1997) Human domination of Earth's ecosystems. Science 277:494–499

World Wildlife Fund (WWF), Living Planet Report 2014. Species and spaces, people and places. (The report uses vertebrate species populations from 1979 to 2010 through the Living Planet Index—a database maintained by the Zoological Society of London)

Technological Development and Lifestyle Changes

Lars Rydén

Abstract

The debate on technology and life style most often raises the question if one or the other is necessary/sufficient for sustainable development. In this paper I intend to demonstrate that interactions between them is more complex, arguing that technological development leads to life style changes, and vice versa that life style changes fosters new ways to use technology. Five different areas are described to illustrate this. Population growth has decreased in developed countries because of economic growth, improved health care, better education, and family planning tools all of which may be seen as part of technological development; it has led to a completely new family life with fewer children and decreasing population growth. In developed urban areas we see a reduced car use among a younger generation as public transport is improving; ICT offers new possibilities to meet without moving, also reducing travelling. Sharing music and films on the Internet is part of the life of younger generation; also many other forms of sharing resources rather than owning them can be pointed out. Finally working life is dramatically influenced by new technologies as increased automation is expected to lead to reduced working hours, while the private time may be influenced by raising interest for urban agriculture. Most life style changes discussed seem to be beneficial for sustainability.

Keywords

Sustainable development · Life style changes · Technological development · Population growth · Mobility · Car use · ICT · Sharing resources · Working life · Urban agriculture

L. Rydén (✉)
Centre for Sustainable Development, Uppsala University, Uppsala, Sweden
e-mail: lars.ryden@csduppsala.uu.se

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_8

1 Which Is First—Technology or Lifestyle Change?

One of the most persistent debates on sustainable development is if technology can do what is needed to achieve sustainability or are lifestyle changes necessary. Some years ago enthusiasts maintained that technological fixes are all we need and pointed to basic breakthroughs such as nanotechnology, new materials, ICT and so on or its applications for green cars, solar cells, smart grids, etc. Others, in particular Meadows and co-workers, pointed to the result of careful analysis showing that technology will never alone be able to remedy all the un-sustainable habits modern society has developed (Meadows et al. 2004).

In this paper I intend to show that the relationship between technology is not an 'either or' but much more complex. The one influences the other in many, often subtle ways. This is done by looking at five areas in which the conditions of and the ways we conduct our lives have changed radically either over many generations or in other cases just recently. The processes in the five cases have come far in the Western industrialised countries but seem to be on its way all over the world. For each of them we see that lifestyle issues and technological developments influence each other sometimes in beneficial, sometimes in destructive ways.

A fundamental issue of sustainable development is the flow of resources. It may be described as the product of three factors—the population, the lifestyle, and technology. Below it is simply shown as a three-factor equation with Population size (capita), Lifestyle (GDP per capita) and Technology (Resource flow per GDP). GDP = Gross Domestic Product is used as a measure of expenditures to maintain the lifestyle. Resources per GDP is a measure of efficiency, which some argue may be greatly increased through technological development.

$$\text{Resource flow} = \text{cap} \times \text{GDP}/\text{cap} \times \text{Resource flow}/\text{GDP}$$

In such a straightforward description, the three factors are not at all related to each other. In practice, however, we see a number of interrelationships and all three influence each other in a number of interesting ways, trivial and not trivial, increasing or decreasing sustainability. We may take the description much further by using systems theory and it has been done in the studies of Meadows et al. using System Dynamics in their famous studies on Limits to Growth (Meadows et al. 1972; 2004). Others have used Complex Systems Theory to dig deeper in the processes (See de Vries 2013, p. 297). The areas used to exemplify this describe man (human) in his/her efforts to reproduce, to be mobile, to own (economic man), to work and to feed.

2 Reproduction—from Large to Small Families

The biological purpose of man is to survive and reproduce. Before there was much of civilisation a woman during her reproductive years perhaps got 6 children of whom 2 survived. The balance between birth rate and death rate led to a fairly stable very slowly increasing population. When finally the death rates substantially decreased and families of more than 10 children became commonplace the population growth soared followed by a wave of decreasing birth rates (Rosling 2010). Big families became more unusual and finally the death rate and birth rate balanced on a lower level. This so-called *demographic transition* (Montgomery 2000) started with a period of rapid population growth ended with much slower growth, and finally, in many societies, with a decreasing population. This is now the case in all of Europe, West and East.

The change occurred at very different times in different societies. In Western Europe the demographic transition typically began during the 18th century. In Asia it started about one generation ago, and family size is decreasing. It is still to be expected in most African countries (Rosling 2010).

A consequence of the demographic transition is the aging society (de Vries 2013, p. 302), which means the change of a population dominated by younger taking care of a few elderly to many elderly living to old age.

The reasons for families to have fewer children are well known. Economic growth, education, especially of women, and improved health care are the main factors. In addition, means for family planning, such as contraceptives, are needed to make smaller families a practical possibility. We may certainly include improved health care and family planning tools in technological development. Technological developments have made possible for people to change their lifestyle in favour of smaller families and a more comfortable life and even emancipation for women. Improved and more widespread education possibilities are also part of technological developments, especially in today with education spreading through the developing world where higher education to new groups is improved by communication technologies and Internet access, including MOOC, Massive Open Online Courses (Bartholet 2013).

Raising smaller families, having a longer life, and staying healthy much of the time, is one of the most dramatic changes of life conditions and lifestyles in our world. It may be seen as part of modernisation. Technological advances were in the front of the changes in this development. In the spirit of sustainability science the processes discussed may be described in a systems diagram (Fig. 1). Here we find all the important parameters, including economics, education, and health, influencing the family size. The influence of education and health in the diagram is only indirect. I trust there are reasons to believe that the influence is more direct, and even might be quantified.

Smaller families and zero or even negative population growth is, of course, a prerequisite for sustainability, as there is a limit to growth also of the human population. However, the efforts to fight that are still strong. Thus, denied right to contraceptives, and bans on abortion are the main policies in the United States.

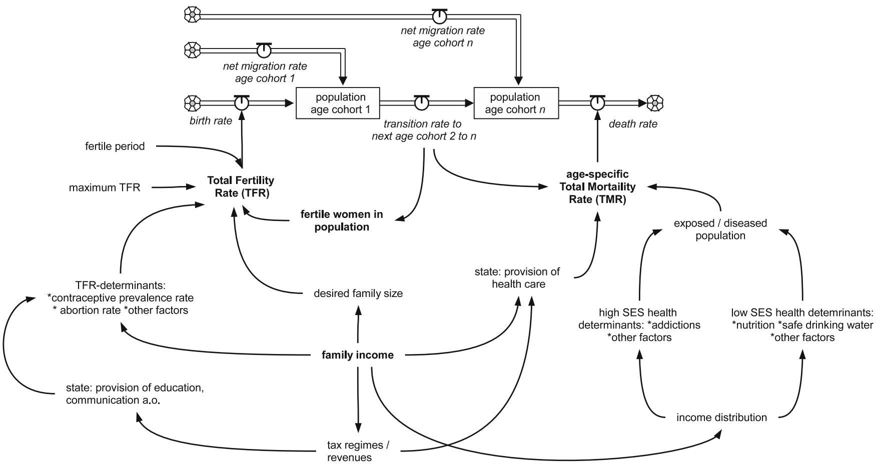


Fig. 1 Causal loop diagram (CLD) with determinants of population (from de Vries 2013, p. 304). The key determinants, birth rate and death rate are in bold. The influence of education and health on family size here is only indirect. There may be reasons to add *arrows* to indicate these as direct. Published with permission by Cambridge University Press and the author

3 Mobility—Beyond Peak Car

Mobility has increased manyfold in the industrialised countries. Over the last century the mean distance travelled by a person has increased from some km per day to about 50 or more (Vilhelmson 1997). This has been made possible through technical development and has also led to a large increase in resource use, especially fossil fuels. Today driving a car is the dominant form of travel in the European Union. The use of the private car is one of the most resource consuming forms of transport, next to air travel. The technical development has led to a completely unsustainable lifestyle, at least as long as the transport requires using fossil carbon. But again, technology may lead further and change this lifestyle in the end.

Car driving and car ownership in larger cities of the world has decreased during the last few years. We also see this in a decreased sale of cars and decreased production in main car factories. Many are asking if we may have reached “peak car”. In interviews young people explain that owning a car is not a priority in their lives, and the car is seen mostly as a question of transport and not a symbol of freedom and status; the car rather reduces freedom and costs too much (Sveriges Radio 2013). These changes of lifestyles depend on other means of mobility becoming broadly available. In big cities, public transport today is much better than just few years ago, and is treated as an issue of integrated urban development. In addition, the train communications between centres of population has increased. Railroad building in Europe today is bigger than it has been for a century. Trains are also more comfortable and faster than before. The high-speed trains have been an important part of this development, but also the ordinary trains are much faster with 200 km/h as a regular speed in many regions.

However, technology does not only offer more comfortable and faster mobility. It has also reduced the need for mobility. ICT, Information and Communications Technologies, is increasingly easy to use, and more widely available. For those with a job that may be done over Internet, telephone or using video or voice conferencing, there is much to be gained by not travelling. Increasingly people choose to work partly from home if their work tasks allow. This also applies to companies for business meetings. The largest Swedish Phone company Telia built smart conferencing rooms where the table in the meeting room continues into a screen where the other team, possibly very far away, is sitting to make the impression that all are in fact sitting at the same table (Wetterstrand 2012). Business travels have decreased, with less use of time, money and, of course, fossil fuel.

In the words of Michael Planasch (2006) we have moved from fixing the exhausts of the car (with catalytic converters), to making a more energy-efficient car (the 3 l car), to new forms of mobility (public transport) to asking the question "why mobility?" It may be seen as if we have moved from a Cleaner Production approach to changing the ways we behave and conduct our lives, that is, the change of lifestyle (Fig. 2).

A drawback with the new forms of transportation is that the efforts to reduce time for travel and, thus, increase the speed have high costs. The building of rapid train connection, so-called TGV (très grand vitesse), is extremely expensive. It may be possible to half the travelling time, but how much does it cost in terms of financing, environmental impact and change of landscape? What is the cost per saved minute? An alternative to investing in the reduction of time seems to be the possibility to use the time on the train productively, or as mentioned, not travel at all but using ICT instead.

Also energy costs per km for transport are soaring with increasing speed, obviously since energy increases as the speed square. This can be seen in car driving or, for that matter, in sea transport. Ships start to reduce speed as fuel costs increase and car drivers may save much money by keeping the speed at 90 km/h or less. Also here the answer may be using the time for mobility more constructively rather than just arriving at the destination sooner.

4 Consumption—Owning or Sharing?

The consumerist society dominating industrial countries is a problem for sustainability as the resource flows are large, and consumerism as a lifestyle is problematic. Which are the drivers for this lifestyle? Jackson (2009) points to consumerism as a way of social positioning, that is, if my neighbour has a certain thing, such as a second car or a new kitchen, I must have the same to be equally respected or worth in the social sense. Such sentiments driving the consumerist lifestyle is analysed in *Prosperity without Growth* (Jackson 2009) but also highlighted in the report

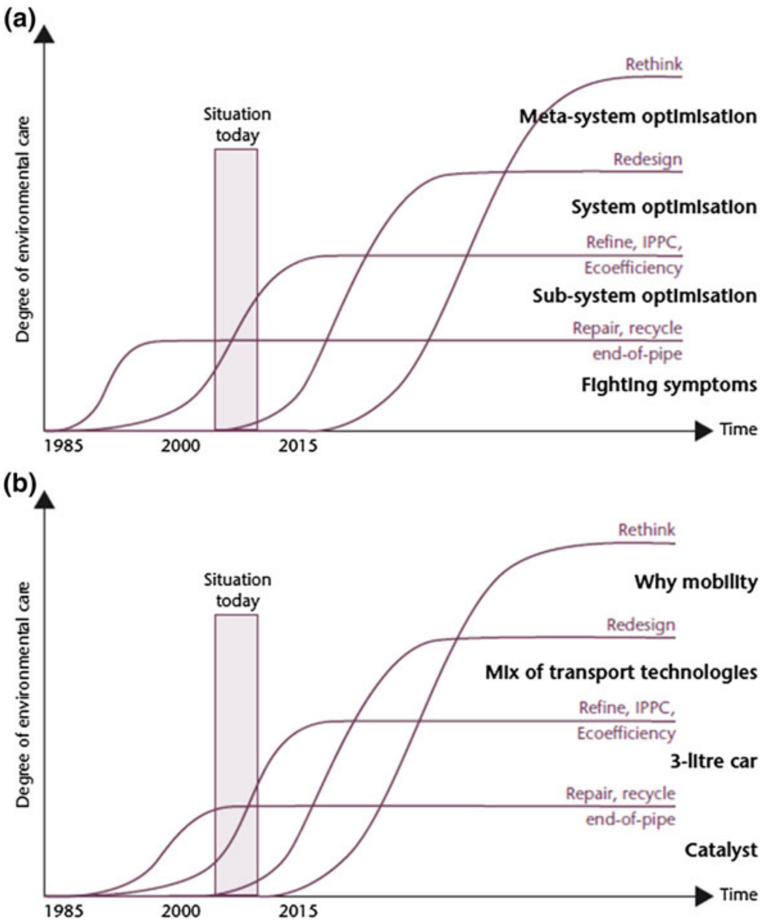


Fig. 2 **a** Technological development may lead to behavioural change. The process is here pictured in four stages. For many processes we are today at the beginning of the development, that is—in the repair, recycle or perhaps cleaner production stage. **b** For the issue of mobility the car may have come all the way; some previous car users today do not use the car at all (Planasch 2006)

Achieving Culture Change (Knott et al. 2008). It needs to be changed if sustainability is the goal.

There are other trends, however, pointing to a different direction. Communication technologies have been behind the explosive development of social media. These include Blogs, Facebook, and Twitter, and new forms appear regularly. To these means of communication are added possibilities to find all kinds of music on the Internet. Downloading is one way but there is also Spotify where it is possible to subscribe to an enormous repertoire of music and listen whenever you want. Similarly, we have Youtube with an enormous number of videos from minute-long privately produced videos to full-length professional movies. It is interesting to note that many in the young generation not only consider these possibilities of access to a common resource as normal part of life; they also require that more or less all productions should be available for free. The so-called Pirate Parties are political parties, existing in some 50 countries, and big in Sweden and Germany, work for such rights, seemingly without concern for copyrights or artistic or intellectual property rights.

This generation is thus growing up in a culture where it is normal to have common resources, rather than having these pieces of music, books or whatever as private property. Such an approach may go much outside the area we have talked about. Thus, private ownership of a car may be replaced by sharing car ownership or belonging to a car pool. Of course, having and using a resource together consumes less resource than having it individually. For carpooling some estimate that it reduces car driving by a factor of almost 5. Public transport is also a kind of common resource for mobility and this is expanded and improved in all big cities where an increasing share of the population lives. Many less dramatic parts of daily life may be seen in the same way. Thus, for washing our laundry we may use a laundry mat, for copying we may use a common printer, etc.

In context of business we see a growing interest to buy services rather than products. It goes together with the increasing trend to out-lease many functions which earlier were part of large companies. Even the personnel may be leased: the number of agency workers is steeply increasing in many western countries. This seems to be due to a policy to avoid responsibility for personnel or for that matter equipment, which may be expensive in times of economic recession. Nevertheless, it is an interesting trend towards sharing resources. An agency worker is normally shared between several working places, either over time or in parallel. The same holds for equipment.

There are other potential benefits from this policy. When a transport company rents rather than buys a truck from the producer of the truck, with maintenance as part of the contract, the producer has an advantage of building a truck which is long-lived and does not need too much maintenance. Today when the product is sold it is in the interest of the producer that the product is used only for a limited time and needs more maintenance as they may sell more products and maintenance. Renting equipment, including cars, exists already but is not common. It is more common for some other products, such as copying machines.

A related trend seen in many countries in the West is a growing interest for buying second-hand items. It may be clothes, then often more elegantly called ‘vintage’, but also many other things from pottery to furniture. This is the second best ‘re-use’ stage in the waste management hierarchy (reduce—reuse—recycle). It may be seen as sharing over time. It is also perceived as a lifestyle choice, especially when it comes to clothes.

5 Working—Machines or People?

Working life is another area of dramatic and large-scale changes during the last 100 or so years. Foremost we see a transition from the agrarian society where a large majority of the population lived in the countryside and worked in production of food and other natural products such as timber. The agrarian society changed into an industrial society when industry expanded and machines took over much of the work on the farms. Horses were replaced by tractors; grass was replaced by fossil fuels. The workers un-needed in the country were absorbed by an expanding industry requiring much workforce. Urbanisation and depopulation of the countryside was part of the changes. The industrialised society in turn slowly changed into the service-oriented society in which we live today.

Figures show the extent of the change. Sweden may serve as an example (Ingelstam 1995): around 1900 about 80 % of the population worked in agriculture, fishery and forestry; today it is about 2.5 %. At the peak of industrialisation around 1970 some 70 % of the workforce was employed in industry. Today it is about 15 %. Today jobs in the service sector completely dominate the labour market. In most other countries it is not as extreme but the trend is the same.

Some of the changes are due to globalisation and moving from self-supply to import of both agricultural products and manufactured goods, but technological development is the major force behind the changes. It may be seen on the trend of productivity. A worker has been producing about 3–4 % more each year over many years. Main factors have been automation, up-scaling, etc., all part of technological development.

Thus, from a society where work was in the centre of our lives we see a society where working hours and efforts have a smaller place. Working hours have decreased both because of fewer hours per week, longer vacations, and because of various forms of social benefits, such as longer schooling, study loans, and later, sickness leave, child care leave, and finally pensions (Ingelstam 1995).

Where will this development take us? Enquiries among the general population in Sweden show that a large majority wants to use increased economic means for even shorter working hours rather than increased salaries. The standard working hours—some 40 h per week—have in fact been constant over a long period. Interestingly the legendary British economist Keynes was at some point asked what he thought about the future. His answer was that the only he could say with certainty was that working hours would be reduced to perhaps half or so (Sanne 2007). People did not need to work as much to have a good life. In reality what has happened is that working hours have been almost the same from the 1930s to today, but economic income dramatically increased. Did this make us happier? According to many studies the answer is no. Increased income beyond a certain level does not improve perceived wellbeing.

Christer Sanne (2012) has attempted in a study to estimate how many working hours we may have in a future sustainable society. His starting point is that every working hour requires a resource flow and thus needs to be limited as part of the "limits to growth". Then, how much can we afford to work? His result proposes up to max 30 h per week.

The American study of machine-oriented society foresees an on-going automation and that there simply will not be more work places (Brynjolfsson 2011). The machines will take over! This additional aspect of future working life thus also suggests fewer working hours. An additional entry into the discussion is the limits to economic growth. In a no-growth economy again working hours will decrease and we have to share work to avoid massive unemployment (Jackson 2009). All these different approaches to working life thus suggest that in the near future there will be less working hours for the general population.

In this area technology leads to a major shift in lifestyles. Is it increasing sustainability? This depends on what we do with the so-called "free time". If the economic standard stays on the same level at least we will not be able to spend more money than today and thus by itself more free time does not decrease sustainability. It may, however, increase sustainability in several ways. More self-sufficiency, e.g. by growing your own food, is one possibility. Travelling with lower speed (e.g. ordinary train, or train rather than air) is another.

In a society in which there are greatly reduced employment opportunities one probably needs to rethink social benefits. Among the different social arrangements which may develop from this possible low work time future the discussion on so-called *basic income* is central in the sustainability discussion in some countries (see Wikipedia 2013). The basic income is understood as a state guaranteed basic economic standard for all in a country unrelated to work. It would replace sick leave, pensions, unemployment benefits etc. In this way it would greatly reduce administration. The costs for the government would not be overwhelming according to a Norwegian estimate, and the resistance against this proposal is thus not in the first place an economic one. It is rather moral. To get money for doing nothing is very much against the ethics of work at least in the western civilisation. In the few cases where it has been tried the results are mostly positive. The city of Dauphin, Manitoba, Canada took part in an experiment where the inhabitants were provided with basic income during 1974–1979; one consequence was reduced sick leaves. In an experiment with basic income in Namibia in Africa, the women used the money for new business activities. Others refer to the fact that those for which cultural activities, such as theatre, painting or music, are the most important in their lives and who do not earn an income on those interests, would much benefit from a basic income.

6 Food—Buying or Growing?

The large increase in world population has not led to a global starvation crisis as feared by the first thinkers on the issue, in particular Malthus in the 19th century. Food production has increased manyfold by new methods in agriculture, as well as the use of fertilisers, new crops and irrigation. There may still be a potential for increased food production needed for a world population which still is assumed to increase by at least 2 billion before mid-century. The food production of today, however, strongly depends on fossil fuel, not the least oil, used for machinery and nitrogen fixation. It is also dependent on phosphorus mined in a few places of the world and a non-renewable resource. Peak phosphorus is expected to occur in a few decades according to many estimates. Since 2010 prices of staple food such as wheat and rice have increased sharply and caused riots and misery in many poor countries. Maybe it is time to rethink also the world food production.

In some countries this has taken place both according to traditional lines and completely new thinking. Interest in growing one's own vegetables has increased in western countries. Since eternal times this has been done by families in their own gardens or on lots owned by the community. One may see the new trend as a return to being in contact with basic conditions of life. It is of course not enough for feeding the growers but contribute quite an important part to the daily intake of vegetables, berries and fruits. In a study on the leisure gardening in Uppsala, Sweden it provided 20 % of the total, and the capacity to increase was 4–6 times, that is in theory all fruit, berries and vegetables could be produced locally (Lönnerud 2012). But leisure gardening is foremost perceived as a lifestyle issue. People like to work in their gardens and the products of the gardens are an added value. This is done at all possible scales from tomatoes or herbs on the widow-sills in the apartments in a densely populated city, to large-scale undertakings in the gardens.

In parallel there has been a mounting interest in new ways of growing in the urban environment. These include greenhouses attached to the multi-apartment houses on ground level, green roofs where the inhabitants may have their gardens, growing along the walls, and building houses in terraces to allow small gardens on all stories. In most cases there seems to be lifestyle and social reasons for these arrangements. Thus, in attached greenhouses it is possible for not the least old inhabitants to meet, have a coffee and talk, and take care of tomatoes, cucumbers, and grapes. Urban agriculture has been part of some futuristic urban planning then on a scale that would allow the inhabitants to be virtually self-sufficient in food. In an area in Rio de Janeiro the local agriculture was decisive for a decent life of the poor population and turned out to constitute an extremely efficient use of resources (Bergquist and Angela 2011).

Some new technologies have been developed for urban agriculture and gardening, such as growing vegetables on a wall, or having plants without soil just in water containing nutrients. But basically lifestyle issues are pushing the trend of urban agriculture. In the future, the self-growing may be equally important for economic reasons. After peak oil one may expect prices for basic food to increase even more. Self-growing may also be promoted by shorter hours at work if and when the reform occurs.

7 An Alternative View—Social Organisation

In the discussion on lifestyle and technology changes it seems that often the wish that technology would make us to become sustainable assumes that the conditions of life remain unchanged. Thus, one talks about car-driving being sustained on the present levels by developing environmentally acceptable cars, or the consumerism may be acceptable because of some technological advances.

The possibility that technology and lifestyle fundamentally influence each other seems not to be very often part of the discussion. In the above examples I wanted to point to processes where this is the case. We see that technology is the driving force in the development of mobility patterns and means of mobility and perhaps also in the case of sharing common resources. In some of the other cases there seem to be clear processes where lifestyle is the driving force, e.g. when it comes to urban agriculture. Technological developments have the leading edge in the two other processes. Firstly, the process of reducing working hours is basically fuelled by automation and efficiencies, and secondly the development of smaller families was fuelled by better health-care and child survival, as well as access to education.

One may also look at this differently putting aside the two combatting views of technology and lifestyle to discuss social organisation. Industrialisation is also an issue of how to organise manufacturing. Market forces may be perceived as having the leading edge. Technology developed as a response to the requirements of the market, and lifestyles changed last by necessity, not want. The same may be said regarding the case of family size and the demographic transition. The first factor, health, is very much an issue of improved hygiene, healthy and sufficient food, which is social organisation, and not so much advanced hospital care. Likewise education being very important in decreasing the family size is not technology but an issue of social organisation and a well-functioning state.

It is clear that we need a more insightful discussion how to use all the three factors as tools in shaping our sustainable future.

References

Bartholet J (2013) MOOCs: hype and hope. Sci Am 309:45–53

Bergquist DA, Alcalá AB (2011) Building community from below—experiences from a local initiative to urban agriculture in Rio de Janeiro, Brazil. Urban Agriculture Magazine 25. RUAF, The Netherlands

Brynjolfsson E, McAfee A (2011) Race against the machine: how the digital revolution is accelerating innovation, driving productivity, and irreversibly transforming employment and the economy, Digital Frontier Press

de Vries BJM (2013) Sustainability Science, Cambridge University Press. http://en.wikipedia.org/wiki/Basic_income

Ingelstam L (1995) Ekonomi för en ny tid, Carlssons (in Swedish)

Jackson T (2009) Prosperity without growth? The transition to a sustainable economy, Sustainable Development Commission, London 2009. www.sd-commission.org.uk/data/files/publications/prosperity_without_growth_report.pdf

Knott D; Muers S, Aldridge S (2008) Achieving culture change: a policy framework strategy unit, British Government Office. http://webarchive.nationalarchives.gov.uk/20100125070726/http://cabinetoffice.gov.uk/media/cabinetoffice/strategy/assets/achieving_culture_change.pdf

Lönnerud A (2012) Facing peak oil and climate change: a pragmatic approach to a re-localised food production system in Uppsala, Sweden. Master thesis in Sustainable Development, Uppsala University 2012

Meadows DH, Meadows DL, Randers J, Behrens W III (1972) Limits to growth. Potomac Associates, New York

Meadows DL, Randers J, Meadows DH (2004) The limits to growth—the 30 year update. Chelsea Green Publishing Company, Post Mills

Michael P (2006) Presentation of cleaner production, The Baltic University Programmes Teachers Seminar, Rogow. See also Nilsson L, Persson PO, Rydén L, Darozhka S, Zaliauskiene A (2007) Cleaner production—technologies and tools for resource efficient production. Environmental Management Book 2, Baltic University Press, Uppsala. www.balticuniv.uu.se/index.php/boll-online-library/827-em-2-cleaner-production-technologies-and-tools-for-resource-efficient-production

Montgomery K (2000) The demographic transition, Department of Geography and Geology, University of Wisconsin. www.uwmc.uwc.edu/geography/demotrans/demtran.htm

Rosling H (2010) Global population growth, box by box. TED talk. www.youtube.com/watch?v=fTznEIZRkLg

Sanne Christer (2007) Keynes barnbarn- en bättre framtid med arbete och välfärd. Formas, Stockholm (in Swedish)

Sanne C (2012) Hur kan vi leva hållbart 2030? Swedish Environmental Protection Agency Report 6524, November 2012 (in Swedish)

Sveriges Radio (2013) *Beyond the car* a series of radio programs in Swedish Radio in August 2013

Vilhelmson B (1997) How and why—the development of mobility. In: Tengström E, Thynell M (eds) Towards sustainable mobility—transporting people and goods in the baltic region. A Sustainable Baltic Region, Session 6, Baltic University Press, Uppsala. www.balticuniv.uu.se/index.php/boll-online-library/819-a-sustainable-baltic-region

Wetterstrand M (2012) Private communication

Zero Emissions and Bio-refineries for Natural Fibres, Biomaterials and Energy: Genesis of Concepts. Review

Janis Gravitis, Valery Ozols-Kalnins, Arnis Kokorevics, Janis Abolins, Silvija Kukle, Anna Putnina, Martins Andzs, Ramunas Tupciauskas and Andris Veveris

Abstract

Depletion of world recourses, increasing pollution, and climate change make us to shift from linear economy to system economy—an economy of technologies integrated to reach a system of non-polluting zero emissions production. Transition to renewable resources requires replacing the present crude oil refinery by biomass refinery. Along with conventional biomass refinery technologies bioengineering and nano-technologies become significant players in systems designed as clusters of integrated bio-refinery technologies. The authors consider a number of case studies of biomass conversion into value-added chemicals and sources of energy, the steam explosion auto-hydrolysis (SEA) in particular. Research of wood and non-wood (hemp, etc.) fibres demonstrates feasibility, for

J. Gravitis (✉) · V. Ozols-Kalnins · A. Kokorevics · J. Abolins · A. Putnina · M. Andzs · R. Tupciauskas · A. Veveris
Laboratory of Biomass Eco-Efficient Conversion, Latvian State Institute of Wood Chemistry, Riga, Latvia
e-mail: jgravit@edi.lv

J. Abolins
e-mail: janis.abolins@lu.lv

S. Kukle · A. Putnina
Institute of Textile Materials Technologies and Design, Riga Technical University, Riga, Latvia

J. Abolins
Institute of Atomic Physics and Spectroscopy, University of Latvia, Riga, Latvia

M. Andzs · R. Tupciauskas
Forest Faculty, Latvia University of Agriculture, Jelgava, Latvia

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_9

example, of value added textiles, self-binding bio-composite boards, heat insulating micro- and nano-materials. Serious breakthroughs require revision of the structures of fundamental natural macromolecules, particularly the complexity, scaling and fractality of lignin.

Keywords
Zero emissions · Bio-refinery · Steam explosion · Lignin complexity · Natural fibres

1 Introduction

Abraham Maslow was an American psychologist. He is noted for his conceptualization of a "hierarchy of human needs", and is considered the founder of humanistic psychology (www.businessball.com/maslow.htm). Maslow's five-stage hierarchy model of needs includes:

- biological and physiological needs (basic life needs), the bottom level of the pyramid,
- safety needs (including stability),
- belongingness needs of love. Affection and belonging,
- needs for esteem,
- needs for self-actualization, the top level of the pyramid.

The authors concentrate on the first—bottom level. The current situation is illustrated by Hans Schnitzer's metaphor: "Stone age ended not due to lack of stones. Oil age won't end due to oil shortage" (www.joanneum.at, www.ipe.tugraz.at). The present short review is an attempt to show the role and limits of biomass, wood in particular, as a substitute for resources based on fossil oil (Campbell 1998; Kerr 1998).

2 Zero Emissions and Blue Economy

In 1994, the United Nations University launched the Zero Emissions Research Initiative program (UNU/ZERI) Gunter Pauli, a special advisor of the Rector de Souza, being the leader of the initiative (Pauli 1996, 1998). From the very first day, we have been honoured to participate in all the important Zero Emissions events worldwide (Gravitis 1998, 1999). Due to the continuing dramatic discussion with regard to the principal impossibility of zero emissions, some clarifying remarks on the subject are necessary.

According to the Second Law (Fig. 1) only minimising the "loss" of energy (enthalpy, H) or the increase of entropy (S) is possible.

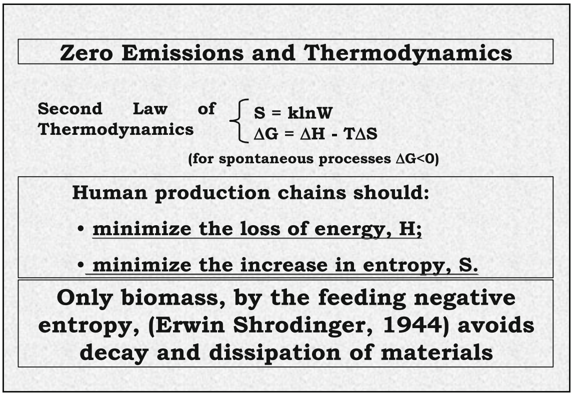


Fig. 1 Could we realize zero emissions? Yes, we (the nature) could (G—Gibbs free energy, S—entropy, H—enthalpy, W—a quantitative measure of disorder in a system, k—Boltzmann constant)

So, from the viewpoint of classical thermodynamics, Zero Emissions are impossible. From the long-term and cosmic-scale perspective, according to the Second Law, resources dissipate irreversibly. According to Shrodinger (1944), only the living biomass, by feeding on negative entropy avoids the decay and dissipation of matter. The problem considered within the human dimension at the scale of Earth systems is more complicated. Indeed, in principle, a Zero Emissions industrial cluster imitates the natural dynamic cycles to which the term “waste” does not apply. So, an open system far from thermodynamic equilibrium could be used. Unfortunately, this aspect of Zero Emissions so far has not been developed and is a really urgent theoretical task for Zero Emissions.

Zero Emissions are represented by two leading wings: industrial performance with increasing efficiency and resource consumption with reducing or eliminating waste and pollution. Our target is to show the application of this approach to biobased-systems using biomass refinery (bio-refinery) as an equivalent to crude oil refinery.

Gunter Pauli has recently introduced the term “blue economy”. “The blue economy is Zeri Philosophy in action” (personal information).

3 The Bio-refinery Concept

A bio-refinery can be compared to a fossil oil refinery where oil is replaced by biomass. Agricultural and forestry feedstock presently is processed to obtain mainly a single product: food, wood, or pulp, etc. On the way from the field and forest to the consumer, the resources undergo a number of processes (harvesting, pre-treatment, storage, transporting, cleaning, thermal, chemical and biological treatment). In all of these steps, energy and utilities are needed and waste (solid, liquid, gaseous) is produced. Today mainly the side products and waste are used as a source for new materials, bio-products, chemicals, and/or energy for a few exceptions.

The concept of a bio-refinery has the potential to overcome the flaws. It is taken for granted that petrochemical industry has been so successful in recent decades since it succeeds converting over 90 % of the input (crude oil) into valuable products. Forestry and pulp-paper industry is far from that wasting the major part of the primary product—**lignin**, hemicelluloses, etc., or merely burning the side products. A **crucial problem is utilisation of lignin**.

The value added processing of side products has the advantage of generating more additional products without the need of opening new industrial units, only exploiting the existing ones and involving advanced technologies. It is aimed at raising the efficiency of the use of organic matter, mainly by extending the utilisation of carbon and increasing efficiency of energy consumption.

Bio-refineries already demonstrate possibilities for generating value added products without the need of additional forest areas or, for instance, new pulp and paper production giants. Research and development efforts should concentrate on the existing production chains of forestry paying attention to resources presently unused.

4 Lignin Problem in Biorefinery. New Structural Approach to Understanding Lignin

The authors suspect the reason of the rather slow progress of applying lignin in biomaterials and chemicals is the lack of new concepts about the polymer structure of lignin. An attempt to explain the fractal self-organisation idea of lignin structure is made hereafter discussing the scaling, fractal geometry, universal classes, and other concepts with regard of lignin science.

4.1 General Approach

Comparing experimental scaling indexes of lignins, humic substances, coals, and fossil oil compounds of high molecular weight can elucidate genesis of natural carbon compounds. The unique real structure of lignin in situ is controlled biologically and stereo-chemically, by spin and electron being deterministic in that sense. However, the replication in vitro of identical copies of the structures existing in vivo being impossible is perceived as a strong evidence of a statistically averaged structure of lignin. Theoretically, some future genetic mutations or manipulations can provide homogeneous and linear “lignin” chains. Although such manipulation may be attractive to supreme industrial interest, the consequences of an artificial bifurcation and its threat to living systems are not clear. No doubt that lignin is a self-organising, ordered-chaos structure in adapting plant cell-wall evolution.

4.2 The Science of Complexity

Success of revealing the sequence of human genome has demonstrated unrestricted ability of science to study polymers of regular structure and to decode the information contained in the sequence of letters-monomers. It is much more complicated to study such abundant natural polymer as lignin comprising multiple monomers, diverse inter-monomer links and having a low degree of super-molecular order. In plants the genes responsible for lignin synthesis so far are not well known. Recently under the Japanese Ministry of Agriculture, Forestry and Fisheries and a consortium of some twenty Japanese companies the sequencing of 12 rice chromosomes has been started (Rice Genome Research Programme). However, such sequencing does not solve structural problems of lignin like proteins or DNA. "Lignin chemistry seems to be rather backward field of science when compared with the chemistry of other natural products" (Shevchenko et al. 2000). There are a number of factors in lignin biosynthesis not determined by genes. Recent discussions reflect a tendency to interpret the structure and biosynthesis of lignin as controlled, apart from genes, by stereo-chemical imperatives (Brunow 2000).

The question of how far the structure of lignin can be considered being statistically random or unique, completely deterministic, in the presented discourse is tried to be answered in terms of modern concepts. Speaking of lignin synthesis and structure in terms of classical and modernistic disciplines (scaling, fractals universal classes, etc.) is speaking the language spoken by the "science of complexity"; turning controversial beliefs and facts into new knowledge is the paradox of simplifying and exposing the lignin complexity.

4.3 Lignin as Ordered Structure

For the majority of scientists lignin has an amorphous, statistically random structure while a smaller number adhere to the opinion according to which lignin is considered as an ordered system.

As shown by theoretical data (Forss 1981) the lignin macromolecule consists of repeating regular ring-like units—fragments that can be presented as an inner core of 10 phenylpropane units connected to an outer core by 8 C_9 units. The 18 C_9 fragments make a compact 1.4 nm thick structure of 3 nm in diameter. Studies of lignin ordering promoted by powerful computers available for research of plant polymers are illustrated, for instance, by the helical order common to structures of ordered biopolymers also being revealed in the lowest energy conformation of threo- and erythro β-O-4 guaiacyl oligomer chains (Faulon 1994). Impressive simulations have been performed calculating molecular mechanics and molecular dynamics (Shevchenko 1995). A broad lignin helix may contain a carbohydrate ribbon inside it to form a highly stable lignin-carbohydrate complex without chemical bonding. The question whether computer simulation is a vision or an illusion remains open. Images obtained by scanning tunnelling microscopy of dehydrogenative polymers show long-range ordering (Moacacin 1955). An elementary unit consists of about 20 monomers compiled into larger assemblies—super-modules interconnected into an overall lattice-like polymer structure with or without spherical regions. The authors concluded extraordinary “that the process of lignification, even in vitro conditions, is highly ordered” (Gravitis 2007). Of course, the long-range order of such ordered systems must show up in X-ray diffraction. Nevertheless, the X-ray diffraction patterns of Bjorkman lignin as well as of hemicelluloses and the lignin-carbohydrate complexes are typical to disordered systems; only two diffuse halo peaks indicating local ordering have been observed (Gravitis 1995).

4.4 Experimental Difficulties and Complexity of Lignin

Wood cell wall cannot be described exactly in terms of atomic theory because:

- the number of cellulose diffractions is insufficient for resolution of the crystalline structure (the 3 N—3 problem),
- experimentally lignin is a completely amorphous polymer,
- X-ray diffraction studies of crystalline lignin model monomers, dilignols or trilignols at global energy minimum are far from the structure the real lignin—a polymer with many local free energy minimums,
- absence of detailed characterisation of interactions between cellulose, lignin, and hemicelluloses.

Many authors operate with the bimodal molecular weight distribution of lignin. Studies of lignin have clearly shown association and aggregation being characteristic properties of lignin solutions (Moacacin 1955). Therefore, it is not surprising that different authors specify different molecular weights. As a result of aggregation and poly-ionic effects, super-high molecular weights are observed. These super-high molecular peaks are artefacts and can be suppressed by adding different salts to the solvent. The next question is about the nature of the observed particles—usually balls, seen under electron microscope (Mlynar 1990). These are not single particles but agglomerates of many lignin fragments and the reason of agglomeration being thermodynamical incompatibility of wood cell wall components (Gravitis 1995).

4.5 Conventional Biosynthetic Lignification (Freudenberg 1965; Sarkanen and Ludvig 1981; Higuchi 1985)

Enzymatic pathway of the synthesis of precursors of syringyl, guaiacyl and p-hydroxyphenyl monolignols is well known (Biosynthesis and biodegradation of wood components). Amount, composition and structure of lignin can be altered by manipulating the genes and suppressing lignification enzymes (Osakabe 1999) confirming that *lignin is a biologically determined component of plants*. However, recent studies have shown possible involvement of monomers other than the three traditional starting lignols in polymerisation of lignin fragments (Ralph 2000)—the evidence of free radical generation by peroxidases of low selectivity.

4.6 Coupling of the Free Radicals of Monolignols

Synthesis of lignin in vitro (Freudenberg 1965) has provided conclusive evidence that p-hydroxycinnamyl alcohols are enzymatically dehydrogenated, delivering various radical mesomers combining into lignin polymer without participation of any enzyme. Enzymes merely trigger polymerization. Polymerization of lignin proceeds by random scenarios, which explains why the mild and selective degradation products of lignin lack optical activity in spite of the presence of many chiralities.

4.7 Non-biological Factors Enhancing Heterogeneity of Lignin Macromolecules

Apart from genetic regulation, experiments in vivo and in vitro have demonstrated important physical and chemical factors influencing lignin structure:

- pH of the environment,
- monomer structure and concentration ("bulk", "end-wise" (Lignins) or membrane dialysis tube (Tanahashi 1982) model approach synthesis of dehydropolymers),
- carbohydrate composition during artificial model synthesis (Gravitis 2006) or biosynthesis (Terashima 1990) of lignin,
- diffusion of chemically active radicals, quinone methides, oligolignins to sites of lignin polymerisation. Diffusion is especially important in understanding of the structure of lignin at averaged "self-similar" scales.

4.8 Scaling and Lignin Fractals

A picture from "Scaling Concept in Polymer Physics" (De Gennes 1979) by Nobel Prize winner De Gennes (Fig. 2) explains the essence of the present article.

If specific details are ignored, a wide class of systems show simple universality features at different scale levels. The scaling hypothesis is closely connected with the universality hypothesis. Under the same limiting conditions, various physical systems fall in the same universality class. In the present context significant limiting factors are:

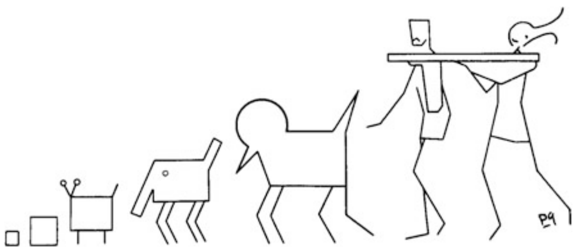


Fig. 2 Illustration of scaling idea according to de Gennes (1979)

- diffusion,
- reactivity of radicals and intermediates,
- reactivity of lignols and intensity of interaction between the growing lignin macromolecules,
- interaction rate: "fast" or "slow" aggregation and other factors mentioned above.

Universality classes are characterized by a set of scaling constants (indexes). Fractal dimension D_f is the most important index. In Mandelbrot's fractal geometry (Mandelbrot 1982) the fractal or Hausdorff-Besicovitch dimension D_f reflects the space-filling ability of lignin fragments. In fact, D_f values of lignin are not equal to 3 meaning that lignin fragments are not compact structures. The Witten-Sander diffusion-limited particle-cluster aggregation (DLA P-Cl) approximated growing lignin fragments (Witten and Sander 1983). DLA P-Cl is the universal model of systems formed under the following limiting conditions: the C_9 monomer makes the Brownian motion to approach a growing lignin fragment. The growing cluster is much larger than the unit, and the probability to add the particle to the exterior part of the cluster without entering its interior part is sufficiently high after the C_9 particle contacts the growing cluster. The random recombination of the phenylpropane free radical in vivo and in vitro satisfies such DLA P-CL limiting conditions. Computer simulation first realized by Witten and Sander (1983) depicts a DLA as a dendrite structure (Fig. 3).

The model allows cycles inside the branches, and growing proceeds under imbalanced conditions. The DLA P-Cl model adequately describes the lignin structure for the degree of polymerization range of ≈20–100 with scaling indexes: fractal dimension ≈2.5, spectral dimension characterising relaxation in the system ≈1.2–1.4, and minimal dimension characterising connection of the C_9 monomers equal to one (Ozols-Kalnins et al. 1987, 1988).

Scaling indexes can be transformed if the pH, temperature or concentration of the substrate is changed. From the viewpoint of universality, changing of the scaling index reflects the change of conditions limiting formation of the system. Hence, the jumps of scaling indexes of the lignin systems provide information about the mechanisms of transformation of the systems, for example, from DLA to reaction-limited aggregation. Monte-Carlo computer simulations (Ozols-Kalnins et al. 1987, 1988)

Fig. 3 Dendrite-like diffusion limited fractal aggregate (Witten 1983)

show the most possible structure of lignin at scales less than 20 monomers of fractal dimension equal to the Euclidean dimension and being compact.

The scaling approach and fractal geometry recently have been used to study other biopolymers similar to lignin, such as peat, coal and humus substances. Lignin connected with the evolutionary transformation of the plant biomass is well known to be the main basic compound of which they are formed.

The fractal dimension (D_f) has been recalculated from hydrodynamic properties related to scaling indexes of lignin fragments (Gravitis 1995; Kokorevics 1989): from intrinsic viscosity:

$$[\eta] \sim M^{a} \Rightarrow D_f = 3/(a + 1),$$

from diffusion coefficient:

$$D \sim M^{-b} \Rightarrow D_f = 1/b,$$

from sedimentation constant:

$$S \sim M^{c} \Rightarrow D_f = 1/(1 - c),$$

from g′ factor:

$$g' \sim M^{d} \Rightarrow D_f = 3/(d + 3/2),$$

where: M—mass parameter or parameter proportional to mass (degree of polymerization). The obtained values of D_f are presented in Table 1.

Hence, scaling indexes highlight the pathway for understanding the transformations.

According to such approach, the lignin layers of the secondary wall S_2 in wood is a network of connected poly-disperse fractals. The principal super-molecular

Table 1 Fractal dimension (D_f) of lignins (Gravitis 1995; Kokorevics 1989)

Specimens	Measured quantity	D_f
Slightly decomposed lignins		
Dioxane	g′	2.44 ± 0.01
Pine dioxane	[η], D, S_o	2.62 ± 0.02
Pine kraft	D	2.56
Spruce Björkman	[η], D	2.70 ± 0.05
Transformed lignins		
Acetylated pine kraft	D	3.33
Alkaline lignin	[η]	2.20 ± 0.10
Lignosulphonate	[η]	2.30 ± 0.10
Lignosulphonate	D	1.70 ± 0.30
Dehydropolymers (*DHP*)		
DHP bulk	[η], D, S_o, g′	2.62 ± 0.27
DHP end-wise	[η], D, S_o	1.66 ± 0.16

structure of the wood cell wall substance shown in Fig. 4 is a combination of fractal and trivial non-fractal objects.

The DLA model with D_f = 2.5 describes the structure of lignin the polymerization degree of which is within the range of ~20–100. In the case the scale of lignin clusters is less than 20, a compact structure of D_f = 3 seems to be more possible. Lignin in wood presents a network of connected poly-disperse DLA fractals of the degree of polymerization of 20–100. The technological lignin and lignin obtained under more drastic treatment conditions has a fractal structure reflecting the structure rearrangement caused by the treatment.

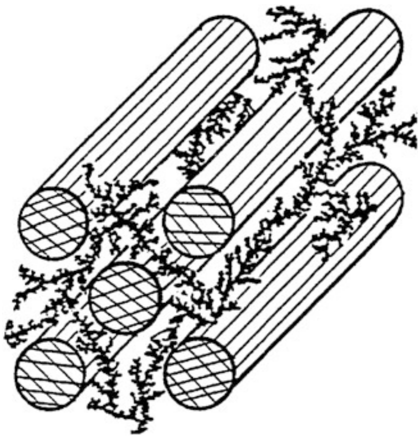


Fig. 4 Model of wood cell material in S_2 layer (Gravitis 1994). Cellulose microfibrils —rods and lignin fractals

5 Clustering Principle in Zero Emissions Biorefinery

Integration (clustering) of different technologies is the basic principle of organisation of the zero emissions biorefineries. In production of chemicals and materials the traditional 3R approach (reduce, reuse, recycle) by the integrated Zero Emissions Biomass refinery cluster (Fig. 5) is extended to 4R (replace, reduce, reuse, recycle) (Gravitis 1994) by which production of only a single main article (grain, sugar, oil, etc.) is replaced by multiple market products (Zero Emissions in Practice 2000).

The integrated flow diagram (Fig. 6) of wood and non-wood biomass processing is based on the methods and technologies developed or mastered in the Laboratory of Eco-Efficient Conversion of Biomass of the Latvian State Institute of Wood Chemistry, (Riga, Latvia) and in the Institute of Industrial Science of the University of Tokyo (Japan) and is realised within the framework of the Zero Emissions Biorefinery approach developed at the Institute of Advanced Studies of the United Nations University (Zero Emissions in Practice 2000). The treatment of biomass by steam at high temperature in the presence of small amounts of concentrated catalyst (the primary process) hydrolyses pentosans and dehydrates pentoses (Gravitis 1996). In parallel, furfural and acetic acid are obtained. The remaining lignocellulose bulk is further processed according to one of several versions (secondary processes). Part of the lignocellulose bulk as well as the whole pyroligneous vapour, non-condensable gases and surplus lignin are burned to provide the processing with energy, i.e. employ the flue gases and steam as a source of heat.

Clustering change the configuration and scale from laboratory to pilot, to industrial. It resembles "playing with children's blocks" (Gravitis 2000) to obtain optimum integration with respect to yield, profit, energy consumption, and pollution.

Schematic diagram of a completely integrated biomass-based block (one of possible) being the first potential biomass-based industrial cluster with different technological connections is shown in Fig. 7.

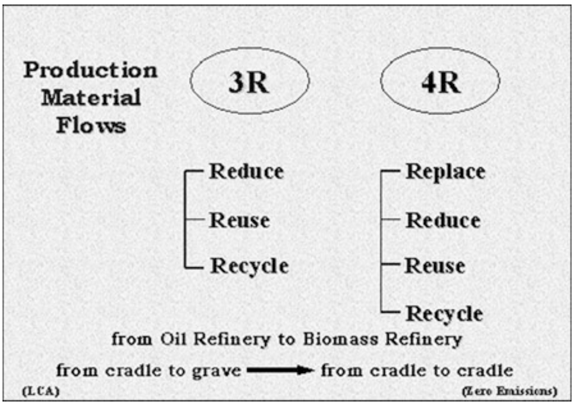


Fig. 5 Shift from 3R to 4R approach (Zero Emissions in Practice 2000). LCA—life cycle assessment

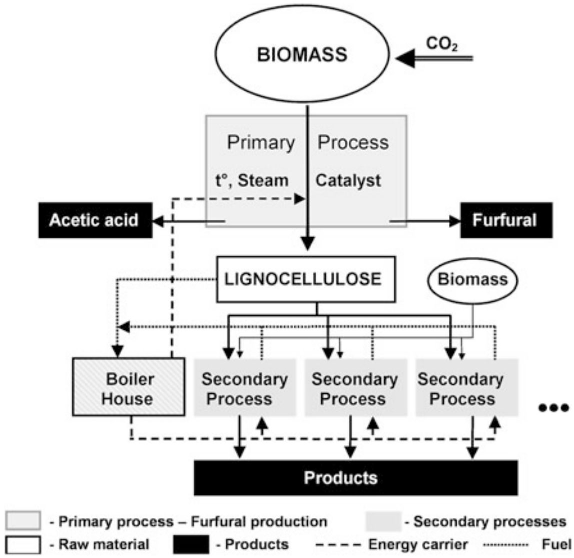


Fig. 6 Primary and secondary processes of the LSIWC biomass-based production system (Gravitis 2000)

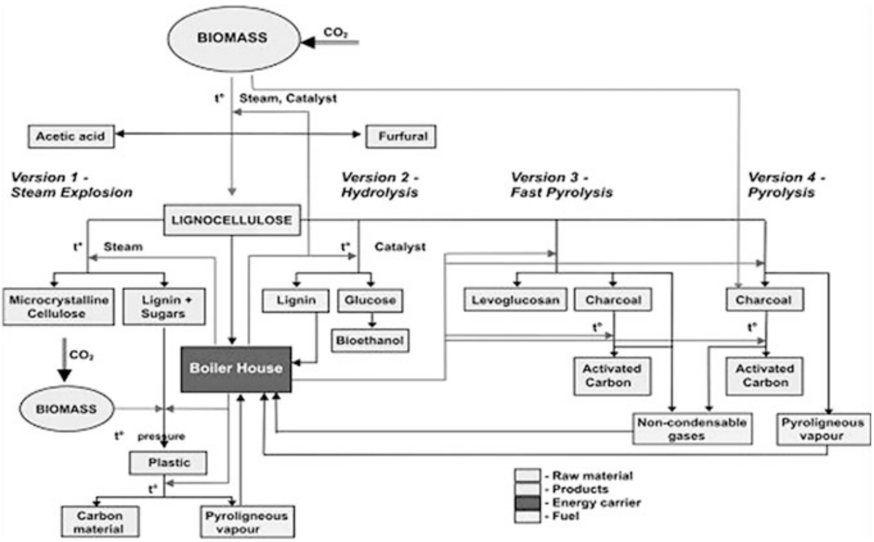


Fig. 7 Combination of biomass conversion technologies in a single integrated cluster according to the LSIWC/Laboratory of Biomass Eco-Effective Conversion

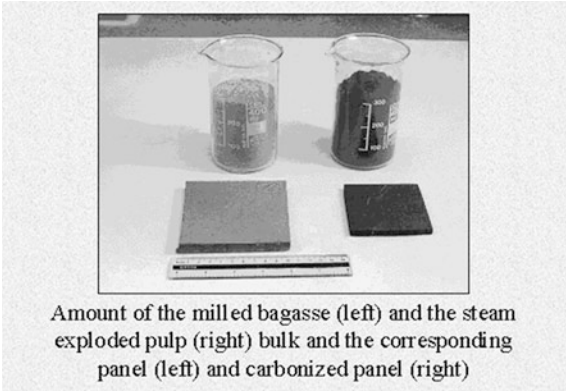


Fig. 8 New carbon-rich construction materials from sugar cane bagasse (Zandersons 2000)

The pyro-ligneous vapour of the carbonisation unit, non-condensable gases and the carbonaceous residue of the fast-pyrolysis reactor, as well as lignin and a portion of the lignocellulose remaining after furfural production (the latter being determined by economic considerations) are passed to boiler house. Depending on the structure of the industrial cluster, the self-sufficiency energy supply is endeavoured as far as possible. Establishing sound ecological foundations is the prime principle guiding the organisation of an industrial cluster. New materials of high-density carbon sequestration are also obtained (Fig. 8).

6 Steam-Explosion Auto-hydrolysis as a Technology for Biomass Pretreatment

Steam-explosion (SE) auto-hydrolysis (Fig. 9) is another way to process the lignocellulose remainder after pre-hydrolysis of hardwood chips for furfural production. The steam-explosion auto-hydrolysis treatment has been proposed as a method to obtain various value-added products from lignocellulosic biomass (Erins 1995) such as wood, corn cobs, sugar cane bagasse as well as lignocellulose residuals of furfural production. During the process, a wide range of chemical transformations occur: the functional groups are cut off, and thereby acid molecules are formed in the system (for example, acetic acid formed by acetyl groups of hemicelluloses) (Fig. 10). A two-stage extraction (by hot water and subsequently by 90 % ethanol) or a one-stage extraction by 90 % ethanol allows separation of reducing substances (mono- and oligosaccharides) and lignin from the material obtained after SE treatment. The remaining matter is partly destructed fibre material that can be used to prepare various products, e.g. microcrystalline cellulose.

During the last decade, a new trend has arisen in processing charcoal and carbonaceous materials: evaluation and production of carbonized fibreboard materials (e.g., wood ceramics) and slabs of charcoal fines with a phenol-formaldehyde binder. Synthetic phenol-formaldehyde resins have been replaced by lignin from SE

Fig. 9 Diagram of steam-explosion laboratory unit (Institute of Industrial Science, University of Tokyo)

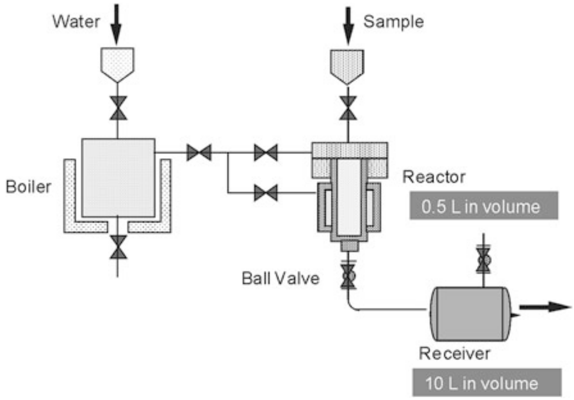


Fig. 10 Outline of possible transformations of plant biomass components during Steam Explosion treatment (Putnina 2012)

cellulose → oligomers → glucose
glucose → hydroxymethylfurfural
→ other secondary products
hemicelluloses → oligomers → pentose, hexose
hemicelluloses → deacylated hemicelluloses +
+ acids
pentoses → furfural → secondary products +
+ pseudolignin
lignin → depolymerization products
→ repolymerization products
lign.dep.prod. + pentoses + furfural →
→ pseudolignin
[wood] → products of thermolysis (CO_2, CO, H_2O, oth.)

biomass with admixture of reducing substances obtained from ethanol-water extracts to prepare fibreboard binders. Carbonaceous construction materials are obtained by further carbonisation of the fibreboards (11).

The application of SE in combination with subcritical water treatment (high temperature—high pressure water treatment) allows wide spectra of wood and non-wood biomass subsequently being turned into value-added products. Attractive prospects for effective utilisation of agro-wastes by combination of the method are demonstrated experimentally (Fig. 10). The solid part remaining after the SE action has been subjected to high temperature—high-pressure water treatment. Depending on the conditions of the subcritical water treatment process (temperature, pressure, time), a wide variety of products can be obtained, such as mono- and oligosugars applicable for fermentation, pyrolysis products (organic acids), low-molecular soluble lignins applicable as resins, phenol derivatives (phenylpropane), oil residue applicable as fuel, and the solid residue (carbonaceous material) (Fig. 11).

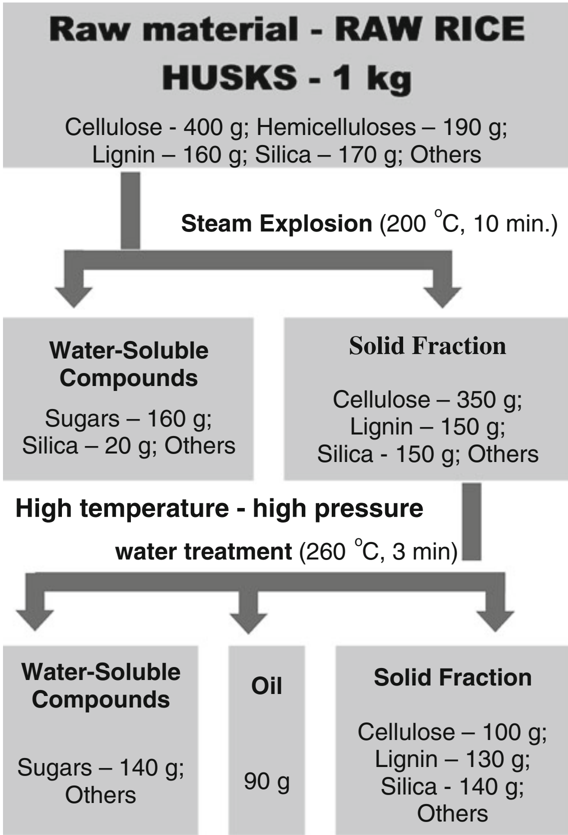


Fig. 11 Balance of materials estimated for rice husks treatment (Gravitis et al. 2000)

7 Some Case Studies of Laboratory of Biomass Eco-ficient Conversion of the Latvian Wood Research Institute

7.1 Natural Hemp Fibres Treated with Steam Explosion

Disintegration of hemp fibres separated from non-retted, dew-retted and dried stems of hemp plants grown in the Agricultural Science Centre of Latgale (Kraslava) at 2010 vegetation season of Latvian local genotype ‘Purini’ (Putnina 2012) and hemp fibres of the variety ‘Bialobrzeskie’ (Kukele 2012) by alkali treatment and steam explosion (SE) were investigated. As first method alkali treatment of both varieties of fibres under investigation with 4 wt% NaOH during 1 h at a temperature 80 °C is used.

Evaporation intensities corresponding to pressure range 16–23 bar are on the same level (7 %) (Table 2) and increase with the pressure 32 bar (23 bar—‘Bialobrzeskie’).

Table 2 Steam explosion treatment parameters of hemp fibres

Evaporable fractions (%)	STEX parameters				Residue (%)	Water solub. (%)	Resid. after wat. (%)	Alk. solub. (%)	Resid. after Alk. extr. (%)
	Time (s)	T (°C)	Pressure (bar)	$\log R_0$					
'Purini'									
0	0	0	0	0	100	7.3	92.7	4.5	88.2
7	60	200	16	2.94	93.3	5	88.4	2.8	85.5
7	60	220	23	3.53	92.5	10.7	81.6	4.5	77.3
14	60	235	32	3.97	86.2	10.9	75.3	7.1	68.3
'Bialobrzeskie'									
0	0	0	0	0	100	4.4	95.6	13.4	82.2
7	60	180	10	2.36	93	6.4	86.5	10.9	75.7
7	60	200	16	2.94	93	9.1	83.9	8.8	75.1
8.4	60	220	23	3.42	91.6	10.6	81	7.6	73.4

After SE treatment and following water and alkali dry residue is 68, 3 %, while fibres of the variety 'Bialobrzeskie'—73, 4 %. Part of NaOH soluble components have been converted in evaporable and water soluble substances during SE treatment and removed during first water treatment.

Parts of volatile substances released in retting process of hemp fibres, therefore volatile substances of SE treated dew-retted fibres are lower. It is seen from graph of Fig. 12 that weight loss of the dew-retted fibres with alkali pretreatment and SE treatment 16 bar is approximately the same as for sample without alkali pretreatment, but subjected SE under higher temperature (220 °C) and pressure (23 bar). Weight loss rapidly increase, when fibres are subjected to more severe SE (32 bar, temperature 235 °C), especially in case of non-retted fibres.

SEM micrographs (Figs. 13, 14) of both varieties of fibres show that after alkali treatment (4 wt% NaOH, 1 h, T 80 °C) part of fibre bundles are separated to a

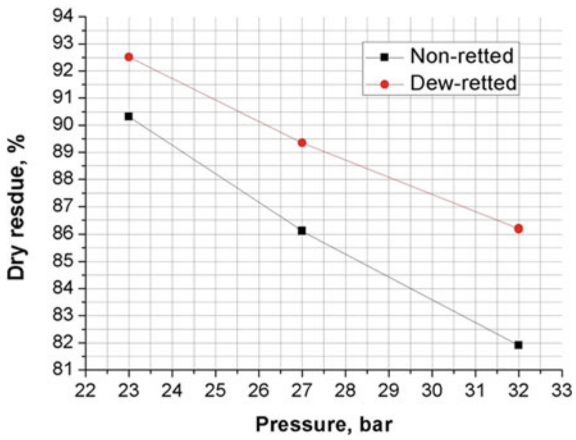


Fig. 12 Dry residue after SE treatments

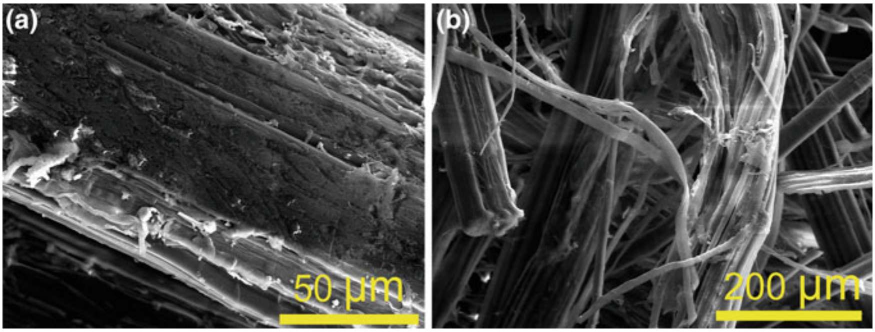


Fig. 13 SEM micrographs of hemp fibres (‘Purini’) without pre-treatment (**a**), dew-retted and alkali (4 wt% NaOH) treated (**b**)

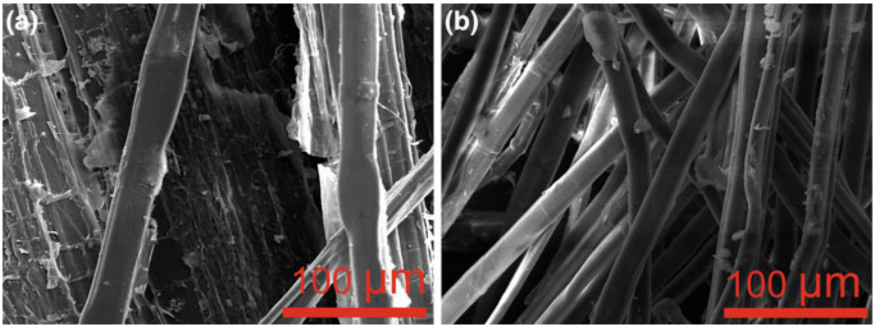


Fig. 14 SEM micrographs of hemp fibres (‘Bialobrzeskie’) without pre-treatment (**a**), dew-retted and alkali (4 wt% NaOH) treated (**b**)

smaller bundles or elementary fibres. After 4 wt% NaOH pre-treatment, SE, water extraction and 0.4 % NaOH extraction (Figs. 13b, 14b) hemp fibres are separated in elementary fibres and surface is clean, also insoluble substances are removed by 0.4 wt% NaOH after-treatment. An average intensive SE in combination with the hydro-thermal and alkali after-treatment allows decreasing the diameter of hemp fibres from 10–20 µm and reduce the concentration of non-celluloses components, among them hemicelluloses, pectin, waxes and water, by $\sim$26 % (Putnina 2012; Tupciauskas 2012). Also 4 % NaOH treatment and medium intensive SE conditions causes an increase of the cellulose crystalline index by 28 and 47 % respectively. It has proved that as a result of both treatments a depolymerisation of the molecular structure of the pure cellulose I take place, forming small crystallites (Kukle 2012).

7.2 Self-binding Boards of Grey Alder Particles Pre-treated by Steam Explosion

Fast growing hardwood species of grey alder (*alnus incana* (L.) Moench) was used to elaborate the technological process of self-binding boards without synthetic adhesives. The boards manufacturing input parameters vary as follows:

- raw material fraction 0.4–20 mm;
- steam explosion (SE) temperature 235 °C, time 0.5–3 min;
- SE pulp bulk density (105–152 kg m^{-3}) and moisture content before pressing 5–20 %;
- hot pressing temperature 150–190 °C, pressure 0.1–8 MPa, time 2–10 min;

The following properties of the boards investigated (in parenthesis minimal and maximal values):

- Density (D 475–1415 kg m^{-3});
- Moisture content (MC 4–10.3 %);
- Thickness swelling after immersion in water for 24 h (TS 6–19 %);
- Water absorption after immersion in water for 24 h (WA 3–143 %);
- Modulus of elasticity in bending (MOE 76–7256 N mm^{-2});
- Bending strength (MOR 0.5–53 N mm^{-2});
- Internal bond (IB 0.03–2 N mm-2);

The boards have excellent form stability (TS and WA) properties because of SE effect (Campbell 1998). The modified lignin coat the surface of the particles after the SE pre-treatment that significantly decreasing water absorbance.

The mechanical properties of the boards significantly increase with increasing density (see Fig. 15). Medium density boards (MDB) with density of 475–800 kg m^{-3} have low mechanical properties. It depends on SE effect that the pre-treated pulp has high bulk density (Tupciauskas 2011, 2012). The pressing pressure of MDB is too low (0.2 MPa) because of high bulk density of SE pulp. The low pressure provides not enough contacts between surfaces of the pre-treated particles. Therefore, not enough bonds are formed of the reacting agents of self-binding lignocellulosic complex.

High density boards (D > 1200 kg m^{-3}) have well enough mechanical properties that meet EN requirements of some standardized fibreboards and particleboards (Gravitis 2010). There was investigated that the best properties of the boards obtained depend on: SE pre-treatment time (1 min), raw material fraction (≤2 mm), moisture content of SE pulp (8 %), pressing temperature (160 °C) and pressure (3–8 MPa). The properties of the boards mostly improved with decreasing raw material fraction. Such dependence is significant on MOR property shown in Fig. 16.

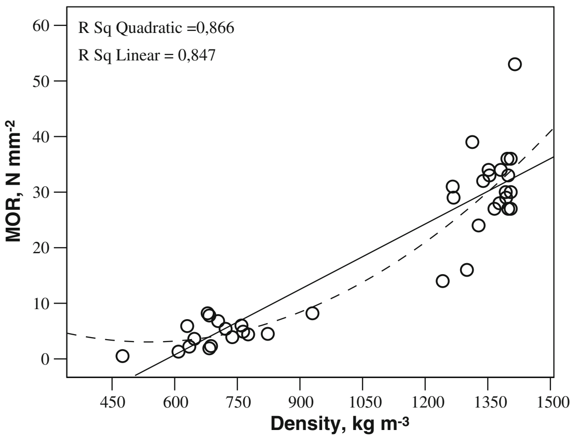


Fig. 15 MOR of self-binding boards versus density

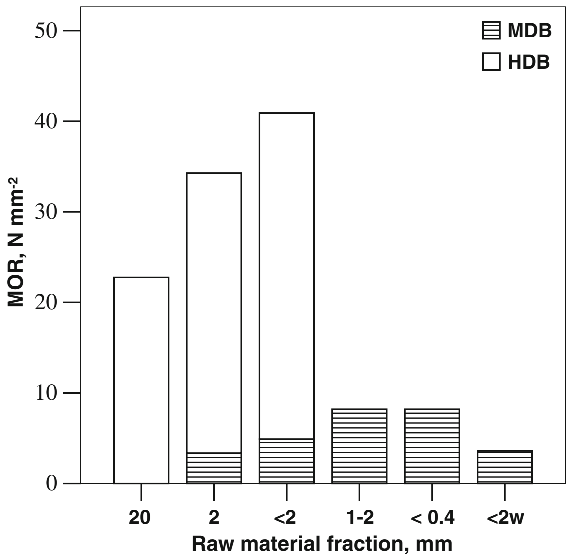


Fig. 16 MOR values depending on raw material fraction

The self-binding boards produced with parameters mentioned above meet the standardized requirements of general purpose fibreboards for use in humid conditions (EN 622-5 MDF.H) and of load-bearing particleboards for use in humid conditions (EN 312 Type P5). It should be noted that the self-binding board properties significantly depend on the finish temperature of pressing cycle that must be lower than 80 °C. Otherwise, delamination of the board occurs. This is the negative requirement of natural polymer such as lignin, which acts as bonding agent in self-binding boards.

Table 3 Steam explosion parameters

Sample	Time (min.)	T (°C)	Pressure (MP.)	Severity
R-00	0.0	235	3.2	1.87
R-05	0.5			3.67
R-10	1.0			3.98
S-30	3.0			4.45
S	Sheared dried 2.5 cm pieces of stalks			
R	Dry industrial dressing residues			

7.3 SE Hemp Shives as a Heat Insulating Composite (Andzs et al. 2012)

Compared with synthetic insulation materials hemp shives—the residue presenting a mixture of fragmented bits of hemp stalks and short fibres left after decortication and removal of the long fibres, have a lower resistance to heat transfer but being permeable are ideally suited for breathable constructions. The micro-porous stalk particles have a very fine capillary structure and are highly hygroscopic. These properties make them an excellent natural insulator and moisture buffer. SE conditions of hemp (*Cannabis sativa*) are presented in Table 3.

SE severity is an empirical parameter (Heitz et al. 1991), including temperature and time of the SE treatment.

Properties of SE shives are presented in Table 4. Pre-treatment by steam explosion improves the insulating properties of hemp shives increasing resistance to heat transfer from 13.2 $m \cdot K \cdot W^{-1}$ to 23.2 $m \cdot K \cdot W^{-1}$ the improvement being achieved along with higher mass recovery at decompressing the biomass as soon as the pressure is reached. Density and heat conductivity of the exploded mass increase with the time the biomass is held under high temperature and pressure in

Table 4 Properties of SE hemp biomass

Property		Samples			
		R-00	R-05	R-10	Reference
Mass recovery (%)		97.58	93.77	86.96	100
Density (g cm^{-3})		0.043	0.063	0.089	0.064
Heat conductivity [λ, W/(m·K)]		0.043	0.045	0.055	0.076
Particle size (mm)	<0.2	1.51 %	1.67 %	3.44 %	1.08 %
	0.2–0.4	2.30 %	2.87 %	5.15 %	1.0 %
	0.4–0.6	3.14 %	4.55 %	6.50 %	1.10 %
	0.6–0.8	3.61 %	4.50 %	6.73 %	1.48 %
	0.8–1.0	6.46 %	13.48 %	11.71 %	4.86 %
	1.0–2.0	32.18 %	29.72 %	32.25 %	35.65 %
	>2.0	50.79	43.20 %	34.21 %	54.83 %

危機

Fig. 17 Chinese character "kiki = crisis". The *left part* symbolizes "danger" and the *right part* "opportunity"

the reactor. Therefore, any protracted treatment of shives being prepared for heat insulation should be avoided.

8 Summary

In this report, we try to show genesis of sustainable development concepts and to balance the pessimism and optimism regarding our future and the way to solve our problems. What we need to change is in our heads and education system. Once Albert Einstein mentioned, "the world we have made as a result of the level of thinking we have done thus far creates problems that we cannot solve at the same level". The Chinese character "kiki" (Fig. 17) symbolize crisis with two parts, the left is "danger" and the right is "opportunity". Let us use our opportunity, the right side of character—Zero Emissions.

The present short review is an attempt to show the role and limits of biomass, wood in particular, as a substitute for resources based on fossil oil. Case studies demonstrated possibilities of smart fibres application and mimetic (or mimicry) approach opportunities.

Acknowledgments The studies have been supported by the National Research Program on sustainable use of local resources, new products, and technologies, and by EU Framework 7 Wood Wisdom program, Project ProLignin.

References

Andzs M, Gravitis J, Veveris A, Abolins J (2012) A novel ecological heat-insulating composite of steam exploded biomass. Accepted to 20th annual internationale conference on composites and nano engineering, Beijing, China, July 22–28

Brunow G, Syrjanen K, Ammalahti E, Gustafsson M (2000) Sixth European workshop on lignocellulosics and pulp, Sept 3–6, 2000, Bordeaux, France, pp 49–52

Campbell CI, Laherrere JH (1998) The end of cheap oil. Sci Am 278(3):78–83

De Gennes P-G (1979) Scaling concepts in polymer physics. Ithaca, London

Erins P, Belickis J (1995) The international symposium. Towards sustainable utilization of vegetal resources, Turku, September 11–13, 93

Faulon JR, Hatcher PG (1994) Is there any order in the structure of lignin?. Energy Fuels 8:402–407

Forss K, Fremer K-E (1981) Ekman-days, international symposium wood and pulping, vol 4. Stockholm, pp 29–38, 9–12 June 1981

Freudenberg K (1965) Lignin: its constitution and formation from p-hydroxycinnamyl alcohols: lignin is duplicated by dehydrogenation of these alcohols; intermediates explain formation and structure. Science 148(3670):595–600

Gravitis J (1994) Lignin Newslett 2:2–4

Gravitis J (1996) Material separation technologies and zero emissions. In: Proceeding of second annual UNU world congress on zero emissions, Chattanooga, Tennessee, May 29–31, pp 168–173

Gravitis J (1998) A Biochemical approach to attributing value to biodiversity—the concept of the zero emissions biorefinery. In: Presented at the 4th annual word congress on zero emissions in windhoek, Namibia

Gravitis J (1999) Biorefinery and lignocellulocics economy towards zero emissions. In: Iiyama K, Gravitis J, Sakoda A (eds) Biorefinery, chemical risk reduction, lignocellulosic economy. ANESC, Tokyo, pp 2–11

Gravitis J (2006) Green biobased chemistry platform for sustainability. Environmental education, communication and sustainability, 23: sustainable development in the baltic and beyond. Peter Lang Publishers House, Frankfurt am Maim, Berlin, pp 145–160

Gravitis J, Abolins J (2007) Biomass conversion to chemicals and nano-materials by steam explosion. In: 15th European biomass conference & exhibition, Berlin

Gravitis J, Suzuki M (1999) Biomass refinery—a way to produce value-added products and base for agricultural zero emissions system. In: Proceedings of international conference on agricultural engineering, Beijing

Gravitis J, Kokorevics A, Andersons B, Kallavus U, Teeäär R (1995) The 8th international symposium on Wood Pulping Chemisty, vol 1. Helsinki, pp 93–100, 6–9 June 1995

Gravitis J, Zandersons J, Kokorevics A, Vedernikovs N, Mochidzuki K, Sokoda A, Suzuki M (2000) Integrated biomass refinery industrial cluster for energy and chemicals. Preprints on sustainable energy: new challenges for agriculture and implications for land use, Wageningen, pp 1–4

Gravitis J, Abolins J, Tupciauskas R, Veveris A (2010) Lignin from steam-exploded wood as binder in wood composites. J Environ Eng Landscape Manag Technika Vilnius 18(2):75–84

Heitz M, Capek-Menard E, Keoberle PG et al (1991) Fractionation of populus tremuloides at the pilot plant scale: optimization of steam pretreatment conditions using the STAKE II technology, Biores Technol 35(1):23–32

Higuchi T (ed) (1985) Biosynthesis and biodegradation of wood components. Academic Press, Orlando

Kerr RA (1998) The next oil crisis looms large-and perhaps close. Science 281(5380):1128–1131

Kokorevics AH, Gravitis JA, Ozols-Kalnins VG (1989) Khim. Drev Wood Chem 1:3–24 (In Russian)

Kukle S, Gravitis J, Putnina A (2012) Processing parameters influence on disintegration intensity of technical hemp fibres. J Biobased Mater Bioenergy 6(4):440–448

Mandelbrot BB (1982) The fractal geometry of nature. San Francisco, p 460

Mlynar J, Kosikova B, Zakutna L, Micko M, Paszner L (1990) Take out. Cellul Chem Technol 24:475–488

Moacacin J, Felicetta VF, Haller W, MsCarthy JL (1955) Lignin. VI. Molecular weights of lignin sulfonates by light scattering. J Am Chem Soc 77:3470–3475

Osakabe K, Tsao CC, Li L, Popko JL, Umezawa DT, Carraway RH, Smeltzer RH, Joshi CP, Chiang VL (1999) Coniferyl aldehyde 5-hydroxylation and methylation direct syringyl lignin biosynthesis in angiosperms. Proc Natl Acad Sci USA 96:8955–8960

Ozols-Kalnins V, Kokorevics A, Gravitis J (1987) Anisotrophy of random clusters. Latv PSR Zinat Akad Vestis Fiz Tehn Zinatn Ser 6:69–75 (In Russian)

Ozols-Kalnins VG, Gravitis JA, Kokorevics AH (1988) Lignin network in vivo fractal model. Riga, p 15 (Preprint)

Pauli G (1996) Breakthroughs. What business can offer society, Epsilon Press Limited

Pauli G (1998) Upsizing. The road to zero emissions. more jobs, more income and no pollution. Greenleaf Publishing, Sheffield

Putnina A, Kukle S, Gravitis J (2012) Effect of steam explosion treatment on hemp fibres microstructure. In: 12th world textile conference AUTEX 2012 “innovative textile for high future demands”: book of proceedings, Croatia, pp 871–874

Ralph J (2000) Sixth European Workshop on Lignocellulosics and Pulp, Bordeaux, pp 33–36, , 3–6 Sept 2000

Rice Genome Research Programme (RGP) at STAFF Institute in Tsukuba. http://rgp.dna.affrc.go.jp/rgp/rgpintro.html

Sarkanen KV, Ludwig CH (eds) (1971) Lignins: occurence, formation, structure and reactions. New York

Shevchenko SM et al (2000) Depolymerization of lignin in woodwith molecular hydrogen lodide. Croat Chem Acta 73(3):831–841

Shevchenko SM, Bailey GW (1995) Third pan American chemical congress, Puerto Rico, PH-I-02, 10–15 Sept 1995

Shrodinger E (1944) What is life? the physical aspects of living cell. University Press, Cambridge

Tanahashi M, Aoki T, Higuchi T (1982) Dehydrogenative polymerization of monolignols by peroxidase and H2O2 in a dialysis tube. II. Estimation of molecular weights by thermal softening method. Holzforschung 36(3):117–122

Terashima NJ (1990) A new mechanism for formation of a structurally ordered protolignin macromolecule in the cell wall of tree xylem. Pulp Paper Sci 16:J150–J155

Tupciauskas R, Veveris A, Gravitis J (2011) Self-binding fiberboard made of steam exploded wood: the case of medium density. In: Larnoy E, Alfredsen G (eds) Proceedings of the 7th meeting of the Nordic Baltic network in wood material science & engineering. Oslo, pp 179–184

Tupciauskas R, Veveris A, Belkova L, Gravitis J, Tuherm H (2012) Grey alder pretreatment by steam explosion for self adhesive composites. In: Baltrusaistis A, Ukvalbergiene K (eds) Proceedings of the 8th meeting of the Northern European network for wood science and engineering (WSE), Kaunas, pp 214–220

Witten TA, Sander LM (1983) Phys Rev Ser B 27(9):5686–5697. www.businessball.com/maslow.htm.www.joanneum.at,ipe.tugraz.at

Zandersons J, Kokorevics A, Gravitis J, Kallavus U, Suzuki CK (2000) Studies of the modified bagasse plastics carbonization and a feasibility to produce carbon construction materials. UNU/IAS Working Paper 75:1–54

Zero Emissions in Practice (2000) Zero emissions and scientific research. http://www.unu.edu/zef/practice.html

Contribution to the Knowledge Development for Smart Cities

Daiva Jakutyte-Walangitang, Jessen Page, Olivier Pol, Ralf-Roman Schmidt and Ursula Mollay

Abstract

The complexity inherent to cities and urban systems is the core challenge in the attempts to measure their "smartness". Numerous debates about Smart Cities reveal opinions split among scientific groups, stakeholders and urban actors, all competing for the Smart City idea. The debate about the direction towards which cities should develop is as persistent as the magnitude of the impact that the on-going, worldwide urbanisation has on the environment and quality of life. Despite the different viewpoints regarding components defining a Smart City, there seems to be consensus on the need for urgent transformation beyond a simple reproduction of state-of-the-art. To achieve this transformation, an in-depth understanding of the existing and potential interactions between the urban energy systems and their context is required for effective solutions containing the prospect of fitting the complex nature of urban environments. "Making" a Smart City is an attempt to embed new concepts, processes, and technologies coupling specific knowledge with specific actions in the first place. However, it also raises difficult questions. Taking a wider urban context as an argumentative background, this article navigates between the inconsistencies in definitions of

D. Jakutyte-Walangitang (✉) · R.-R. Schmidt
Austrian Institute of Technology, Vienna, Austria
e-mail: daiva.walangitang@ait.ac.at

J. Page
University of Applied Sciences and Arts Western, Sion, Switzerland

O. Pol
ATP Architekten und Ingenieure, Innsbruck, Austria

U. Mollay
Austrian Institute for Regional Studies and Spatial Planning, Vienna, Austria

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_10

Smart City and development concepts in search for answers and approaches that would be capable to disentangle the complex and interlinked urban networks, systems, and respective forces in play. The article highlights the ambiguous relationship between the individually framed technological development and its urban context, exposed by specific Austrian examples that provide an insight into concrete challenges, barriers and solutions. Finally, the article proposes to explore the Smart City as a relational system between concepts, technologies and processes that reflect on the importance of knowledge exchange in a multi-layered urban set-up.

Keywords
Urbanisation · Energy · Progress · Smart City · Knowledge · Complexity

1 Urbanisation and City Labels

The proportion of world's inhabitants living in urban agglomerations is increasing rapidly. This inexorable speed of urban development presents many challenges and opportunities at the same time placing "the city" into the centre of attention. Composed of people, ideas, businesses, culture, buildings, public places and infrastructure, cities function as innovation hubs and multi-minded, complex systems. Cities enable a dense concentration of activities and contain an inherent talent to spark new ideas and technological breakthroughs. The access to a quick exchange of information and knowledge paired with the availability of human capital in cities form the essential ingredients for urban success (Glaeser 2011). This, in turn, feeds the dynamics of urban transformation and reinvention. However, cities are also notorious for their steadily growing appetite for energy, increasingly negative impact on the environment and being the focal point of conflicting interests. According to UN-Habitat, the world's cities emit 70 % of the global CO_2, while covering 2 % of its surface (United Nations Human Settlements Programme 2011). The increasing urban hunger for energy has been recorded in numerous reports and expressed by facts and figures (Larsen et al. 2011; United Nations Human Settlements Programme 2011). Balancing between growth and sustainability, consumption habits and available resources, climate change and urban resilience are ever more becoming the focal challenges of the 21st century.

Thus, it is no surprise that a number of concepts and ideas have emerged in the past few decades, centered on the topic of the city and presenting "the city as its own solution" (Davis 2011). These concepts carry a broad variety of labels: the e-Topia (Mitchell 1999), the intelligent city (Komninos 2002), the electric city (Conference 2012; Urban Age Electric City), the green city (My Green City 2011), the post oil city (ARCH+ 2011), the resilient city (Balbo et al. 2012), the Smart City (Mitchell 1999; Hollands 2008), the instant city (Wright 2008), etc. While the concepts behind each of the listed city labels present different connotations, topics, aims, and disciplines, they share a common suggestion that urban transformation is taking place and a significant change is both inevitable and necessary. The common sense complements various development initiatives, road maps, strategies and research telling the vital urgency of the transformation of urbanity towards a human habitat more compatible with the environment. At the same time, we cannot neglect the fact that the actual underpinning of these concepts with a critical mass of implemented examples, qualified enough to claim the status of "smart", "intelligent", "resilient" or "green" are still a relative rarity. Among the named concepts, the Smart City is currently one of the most dominant (e.g. research calls of the European Commission, national and international stakeholder platforms), partly because the related ideas provide huge market opportunities for companies active in infrastructure, information and communication services and technologies. Critical awareness about the self-acclaimed success that Smart City labels can entail leads towards search for knowledge-based and contested proof that the claimed success is indeed being lived. The factor making the proof even more complicated is the lack of a consistent Smart City definition.

2 Between Smart Cities and Smart City Definitions

In search for a reliable Smart City definition one gets swamped by numerous examples of Smart Cities, from Cairo, to Dubai, Vienna, Southampton and Yokohama, to name only a few. The range of cities, claiming the status of "smart" is as varied, as its definitions. The most common definition stresses the significance of the digital development, centred on the role of Information and Communication Technologies (ICT): "this all-encompassing digital system will create new linkages between cities and within cities" (Mitchell 1999, p. 19). The legitimacy of purely technological "hardwired" (Paskaleva 2009) urban progress has been questioned by some scholars (Hollands 2008) and since expanded to a broader definition of a Smart City. One of the most cited European projects (Giffinger et al. 2007) offers a Smart City definition encompassing smart economy, smart governance, smart mobility, smart environment, smart living and smart people. This definition overlaps with Paskaleva's view that Smart Cities are people-based, human and progressive in their deployment of digital technologies. With its Smart Cities and Communities Initiative launched in 2010, the European Commission has placed the focus of Smart Cities on the development and demonstration of urban energy efficiency, low carbon technologies, energy security while linking them with socio-economic advantages, quality of life, local employment and business and citizen empowerment (setis.ec.europa.eu 2012). This point of view is also shared by Saringer-Bory et al. (2012) when trying to define the crucial research questions to be addressed in Smart City development. It is this definition that the following sections of the article reflect upon, while focusing on the complexity of urban energy systems, their relationship with the urban context and the role of knowledge within. According to this definition, Smart City is not only intelligent, but also integrative, linked, efficient, effective, adaptive and attractive.

3 Complexity of Urban Energy Systems

One of the major challenges in adapting urban energy systems to present and future needs is the high level of complexity they entail. This complexity is mainly caused by simultaneous presence of different energy vectors available within a city: electricity, gas, heat and cold, and the related energy infrastructures for conversion, storage, and distribution. Multi-layered factors determine the performance of these integrated energy systems:

- an increasing share of distributed non-controllable and fluctuating energy sources (including renewables like solar or wind energy) beside traditional centralised generation plants,
- the variety of consumers (residential and non-residential buildings, industries, mobility services) who more than ever could play an active role in the energy system (via e.g. on-site renewable energy production, waste heat availability, demand side management),
- energy storage (e.g. thermal energy and electricity storages including batteries of electric vehicles) that can be installed on a central location (e.g. at a generation plant) or distributed within the network and at the customer end, and
- distribution networks (electricity and gas grids, district heating and cooling networks) that can appear at different scales (e.g. city-wide and micro-networks) and in different quality (e.g. temperature, voltage level).

Each of the infrastructure components consists of many sub-components ("system of systems") adding their own complexity. Furthermore, availability of various technologies bare complex interactions between the different components and energy vectors (Fig. 1). For example, the coupling of electricity and heat via cogeneration processes (Combined Heat and Power—CHP—plants) creates an interface between thermal and electricity grids. Such interfaces have optimisation potential that would enable bi-directional balancing of thermal and electrical energy, e.g. introducing heat pumps to generate heat when electricity from renewables is in excess or operating CHP when electricity prices are high. Other interfaces include the transformation of surplus electricity from wind or PV into hydrogen as an alternative fuel. Biogas, another alternative fuel, can be used to cover the demand for mobility either directly (in combustion engines) or by being used in CHP plants to produce heat and electricity for electric vehicles.

In addition to the internal complexity of an energy system, further interactions and interfaces have to be considered, e.g., to ICT networks, water, waste, the quality of life of citizens and socio-economic conditions as well, as different stakeholders with partly conflicting interests need to be involved (including energy utilities, industries and construction companies, building owners and operators, city administration, developers and last but not least the Inhabitants). For example,

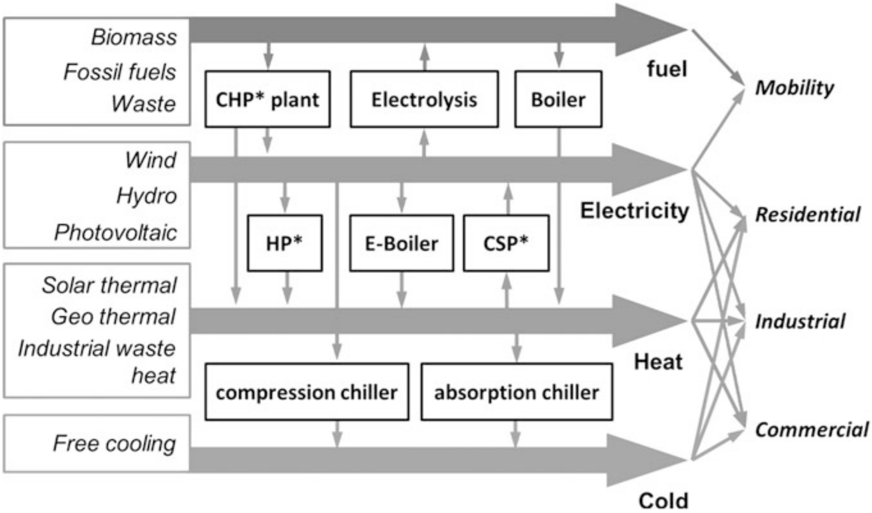


Fig. 1 Principal interfaces in the urban energy infrastructure, *HP* heat pump, *CHP* combined heat and power

urban planning parameters and processes are closely related to the technical and economic feasibility of urban energy systems and thermal networks in particular. This calls for an integrated planning exercise for these systems.

Many European cities have a long history. Their existing infrastructure has evolved over centuries and has been designed and implemented under different boundary conditions as well as different socio-cultural and economic contexts. To some extent this infrastructure is outdated but not easily replaceable. In addition, energy infrastructure is being planned, financed and operated within given contractual conditions. For example, operating plants and infrastructure have first to be completely financed before being replaced or re-powered. Also a network designed for operating under given conditions cannot be easily operated under different conditions. In addition, investment costs for installing new energy infrastructure in order to make the energy system future proof are rather high and the task of amending these conditions to facilitate further development of innovative energy concepts, therefore, is not an easy one.

From a technical point of view, possibilities for supply and demand side management targeting reduction of the peak loads and adaptation to fluctuating energy resources are restricted by the limitations in the current control systems (hydraulic limitations, e.g., for control of valves, and limited metering technologies). From a legal point of view on the demand-side activities, the possibilities for implementing load shifting measures in buildings often interfere with current contractual settings and customer comfort requirements.

4 Achieving Transformation Beyond the State-of-the-Art. How Do Cities Need to Change?

It is clear that handling the questions related to the way cities need to change requires knowledge that goes beyond the state-of-the-art and tools that make it possible to deal with the high degree of complexity. Different analyses of the performance and achievements of the latest progress in terms of sustainable neighbourhood developments (Pol and Lippert 2010; Di Nucci et al. 2010; Koch 2011; Robinson and Quiroga 2009; Marique and Reiter 2011) reveal that there is no example of excelling a neighbourhood with respect to all evaluation criteria. This is not only related to the contingency of implementation barriers and the fact that most of the developments are highly linked to and, therefore, hindered by existing infrastructure, standard implementation processes, and budget limitations, but mainly to the inherent complexity of the planning tasks. The promises of a Smart City by such examples of urban development like Masdar City serve as highlights for integrated planning. We shouldn't forget though, that the majority of existing cities are not being built from scratch and will need to go through the process of sustainable, step-by-step adaptation. Despite this fact, the future of Masdar City development and the lessons that it might teach still contain a potential of exposing challenges and solutions to be taken into account, developed further and implemented at the next attempt of Smart City planning.

A glance at the topics being addressed in current urban research reveals the rarity of such projects that reflect the existing complexity of urban energy systems. Research activities are still highly fragmented, depending on technologies, applications, levels of detail for analysis or the state of innovation. Such circumstances are partly caused by the fragmented nature of research funding schemes and mono-disciplinarity of the main university curricula. An analysis of 77 Austrian projects (Saringer-Bory et al. 2012) exposed the number of projects that would address the overall energy conversion chain being small (Fig. 2). Research activities focused on isolated aspects of energy systems and networks, technologies and components outweigh truly integrated, trans- and inter-disciplinary research. A new window is being opened by the latest Framework Program 7 Calls of the European Commission, which demand explicity for integrated research activities, addressing a number of interrelated urban energy issues. The future will show how ground-breaking, far-reaching and successful the outcomes of the funded projects will be.

The question of how to address the complexity of urban energy systems leads to an inevitable oxymoron. Handling complexity often calls for simplification, but how much simplification is acceptable before losing the sense of complexity? How to structure without dividing and how to follow a holistic perspective without in-depth understanding of the parts within the whole? A certain classification is necessary, even when we call for integration; the only point is how to do it. Within

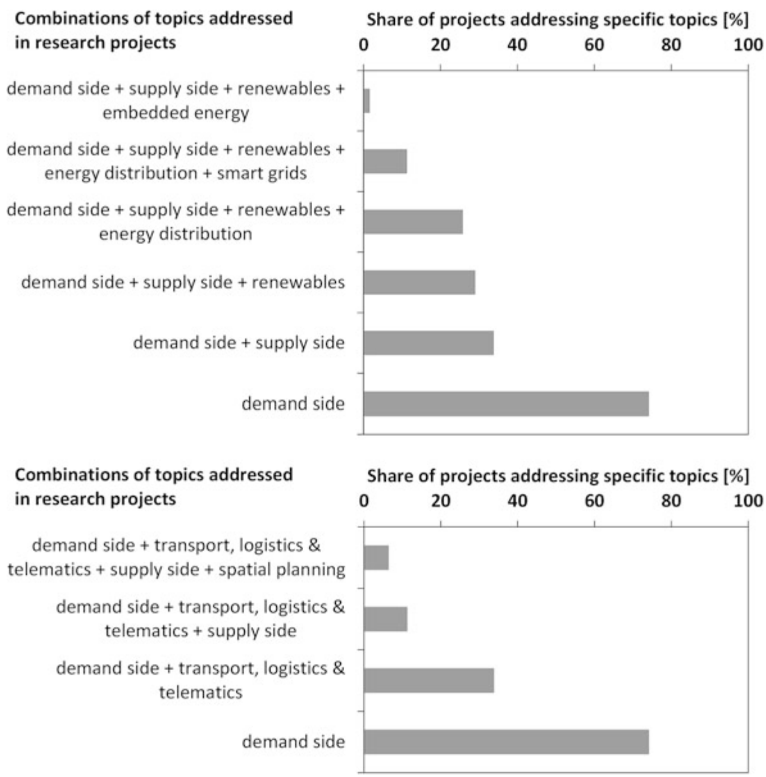


Fig. 2 Combinations of topics addressed in research projects

the different dimensions of knowledge for the Smart City, the work of (Saringer-Bory et al. 2012) could help to identify three fundamental knowledge dimensions that still allow for handling integration and dealing with complexity and inter-disciplinarity: concepts, technologies, and processes.

The first knowledge dimension encompasses concepts. Concepts are representations of urban structures and the innovations behind them. Concepts might be formulated in terms of an overall vision for an urban system or even of a detailed plan for a neighbourhood or a city. They express the idea of the Smart City and, therefore, should be at the core of research activities in the Smart City. But concepts are not reality yet. To be implemented, concepts and visions rely on two other pillars: technologies allowing for the physical realisation of the concepts (i.e. the "hard facts") and the processes enabling their implementation (i.e., the "how to"). It is easy to verify that each research project that would omit activities in one of these three dimensions would not be considered as Smart City project.

4.1 Concepts

The development of smart concepts for urban structures involves traditional urban and spatial planning activities with an emphasis on optimisation of the overall performance of the city. This includes aspects like zoning, neighbourhood master-planning, functional end-use mix definition as well as the planning of technical supply and disposal infrastructure for energy, water, waste water, waste, and transport. Even if these activities are traditionally embedded in university curricula, assigned to clear professional profiles and endorsed by planning codes and practice, knowledge is still needed to handle the complexity of the related strategic and operational planning activities. A concrete example would consist in planning urban green spaces beyond simply satisfying the minimal requirements specified in urban planning codes. The task would consist of looking into detail (using appropriate assessment methods based on modelling) at the potential impact of green spaces on the urban micro-climate, building energy demand, and possibilities to use renewable energy sources, acoustics, and quality of life.

4.2 Technologies

The technological backbone of the Smart City knowledge involves all technological developments and innovations that lead to an increased urban system efficiency and to a reduced amount of greenhouse gas emissions. This includes demand-side (building, energy and transport technologies) and supply-side measures (e.g. use of renewable energy sources, cascade use of resources) as well as innovations in Information and Communication Technologies (e.g. smart metering, operational optimisation systems, and mobile information systems). Therefore, further knowledge and research are needed for technologies at the interface between the different urban subsystems enabling their integration, e.g., building integrated energy conversion and storage technologies, network infrastructure technologies (e.g., process automation), and technologies allowing for cascade use of resources.

4.3 Processes

Conventional planning and implementation processes are no longer suitable to support the realisation of the Smart City. Knowledge is necessary on the theory and practice of these processes, ranging from stakeholder processes (e.g., decision making, public or targeted consultation) to the development of business models as well as the theory of long-term socio-economic processes or user behaviour. In particular, the legislative framework, rules and standards related to urban and spatial planning tasks have to be reviewed and assessed in order to provide recommendations on the way this framework would need to be adapted to enable the realisation of the smart city.

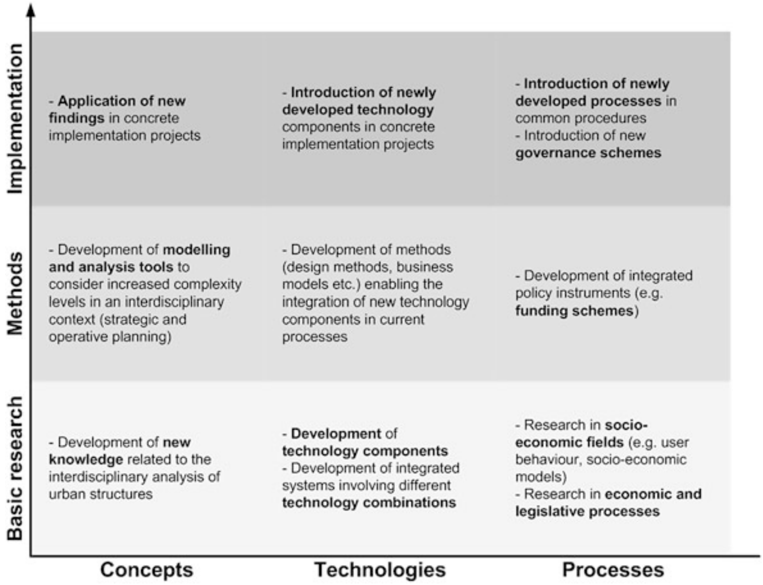


Fig. 3 Dimensions and levels of knowledge

Last but not least, the knowledge dimensions are to be associated with different levels of knowledge or R&D activities. Fundamentals are the basis for further knowledge development. This involves the most theoretical research activities in an interdisciplinary framework. To bring this fundamental knowledge towards implementation, there is a second level of knowledge dealing with methods and the models behind them. The application of the methods and implementation of the theoretical knowledge involve practical knowledge and real-life experience. This is the third level of knowledge that is requested for the realisation of the Smart City. Each of the three knowledge dimensions can be associated to one of the three different levels, leading to the matrix in Fig. 3.

5 Barriers to Achieving Transformation Beyond State-of-the-Art—Experiences from Austrian Research

5.1 A New Urban Planning Practice Is Needed

Implementation of holistic transformation processes—as necessary for Smart City development—is still at the very beginning in most cities. Even though broad basic knowledge in terms of necessary technical improvements and energy system specifications for Smart City development has been acquired already and research is being driven forward rapidly, implementation is challenging. One of the major challenges of triggering Smart City development is the necessity for interdisciplinary planning practices, especially for long-term developments, linking urban planning issues with the development of smart energy systems and with decisions on investments in infrastructure in general.

So far urban planning is being characterised by sectorial approach, with planning for each specific technical sector made separately (e.g. land use planning or zoning, development planning, supply of technical and social infrastructure, power supply). Even within sectors, internal competition between stakeholders takes place restricting chances for optimisation (e.g., the optimisation of urban heat supply strategies might compete with the interests of gas network operators). In such cases sub-optimal business solutions might hinder the diffusion of concepts that are optimal from a macroeconomic point of view.

The current planning practice, thereby, is hindering the holistic planning and optimisation of urban systems if not eliminating it altogether. Only by implementing joint, interdisciplinary planning processes, different options may be explored before setting basic framework conditions. Such an approach would allow for a greater scope of optimisation and open possibilities for introduction of new concepts and ideas to develop locally suitable, realistic specifications for smart development of cities and urban quarters. In addition, new approaches are needed to handle potential conflicts of interest (e.g., between local energy planning authorities and district heating network operators). Equally important is the development of new business models for energy related services to overcome traditional business models predominantly based on bilateral client-vendor relationships.

Such a situation calls for integrated planning and integrated decision-making processes. Isolated planning tasks that follow priorities set by the standard practices of separate disciplines (e.g., urban planners, energy system experts, landscape planners, sociologists, etc.) need to define urban development measures jointly, be it for a city or an urban district. This approach would lead to joint consideration and balance of issues concerning urban planning and architecture, energy systems, economy, ecology, and society, it would also allow for energy cascading and provide the foundation for developing considerably smarter solutions in comparison to the current standard practice.[1]

5.2 From General Barriers to Examples of Specific Problems

The current planning practice is not the only barrier to Smart City planning on the ground, there are a number of framework conditions—most often legislation—to be reshaped or adapted in support of Smart City developments.

One important example of specific problems of smart urban development is the improvement of the thermal quality of buildings by implementing renovation

[1]In the course of the FP7 project TRANSFORM (starting date 1.1.2013) this approach is being applied and evaluated for selected urban living labs in several European cities.

measures, especially for large multi-storey buildings. Although the economic feasibility of energy efficiency measures has been proven, the discrepancy between the bearers of the investment costs and those who benefit from the measures is still not solved. This so-called investor-user-dilemma describes the fact that house owners have to invest in a renovation providing lower energy costs and higher living comfort for tenants, without being able to profit from this improvement directly themselves in the current legislative framework conditions. Only in the long run do real estate owners benefit from the valorisation of their property. This issue plays a major role in the rental housing stock (multi-family buildings), hindering the broad improvement of thermal building quality so far (Amann et al. 2012).

Another problem related to the thermal quality of buildings (and other measures for improvement and modernisation) beyond pure maintenance arises in houses with several owners of flats. In the case of such co-ownership structures, decisions for improvement usually depend on the decision of a qualified majority. In some specific cases such decisions are even attached to the unanimity principle, making the decision process overly complicated (Amann and Weiler 2009).

A further example for barriers in Smart City development is the Viennese law of parking garages enforcing mandatory provision of parking space in new buildings. The law dictates a minimum number of car parking spaces (on site) for new building developments in Vienna instead of opening up the opportunity to use collective garages, or to encourage other forms of mobility. To date, only a few exceptions from the law have been implemented in Vienna [e.g., in the model for car-free residential housing in Vienna, the budget usually used for garages has been spent for shared facilities and more generously designed green spaces (Moser and Stocker 2008)]. In contrast to the governing general policy objectives to modify the modal split to favour public transport and other environmentally friendly modes of transport, the regulation causes higher production costs of living space and supports car traffic.

These few specific examples reveal the different barriers caused by counteracting effects of legislation and regulations. The range of issues and challenges to be solved in Smart City development is increasing. Nevertheless, at the same time the general awareness for such interdependencies rises allowing for a cautiously optimistic perspective into the future development of our urban environments.

6 Conclusions

Urban transition towards Smart Cities requires far-reaching changes in the structural, conceptual, technological and process related dimensions. The high level of complexity of urban development dynamics, energy systems, and technologies demands building up a profound understanding of the rapidly changing, living system—the city. To achieve the transformation of becoming smart, different forms of knowledge need to be advanced, exchanged, integrated and transferred among researchers, stakeholders, citizens and authorities, to be finally turned into actions, demonstrated and validated in concrete examples.

Smart City carries a good potential to become more than a sum of its physical parts compiled of passive homes and digital technologies. It indeed entails a promise that a sustainable form of urbanity can be achieved and the process of a significant change has started.

References

Amann W, Weiler T (2009) ZUWOG Zukunftsfähige Wohngebäudemodernisierung, Integrierte Konzepte u. Lösungen zu Wirtschaftlichkeit, Nutzerzufriedenheit, Praxistauglichkeit, Vienna, s.n

Amann W, Komendantova N, Mundt A (2012) Effizienzpotenziale in der Österreichischen Wohnungspolitik, Massnahmen zur Forcierung von Wohnungsneiubau und Sanierung, Vienna, s.n

ARCH+ (2011) Post-oil city, the history of the city's future. Stuttgart: ARCH+. The Institute for Foreign Cultural Relations

Balbo A, De Cock M, Dowling-Smith E, Gawler S (2012) ICLEI resilient cities 2012: congress report. ICLEI, Bonn

City MG (2011) My green city: back to nature with attitude and style. Klanten, Robert; Ehmann Sven; Ballhöfer, Kitty; Hrsg. Gestalten, Berlin

Conference (2012) Urban age electric city. London: organised by LSE cities at the london school of economics and political and the Alfred Herrhausen Society, the International Forum of Deutsche Bank

Davis M (2011) Who will build the ark? The utopian imperative in an age of catastrophe. In: ARCH+, Stuttgart, pp 4–9 (J Archit Urbanism)

Di Nucci M-R, Gigler U, Pol O, Spitzbart C (2010) CONCERTO, planning and implementation process assessment report. Österreichisches Forschungs- und Prüfzentrum Arsenal, Wien

Giffinger R, Fertner C, Kramar H, Pichler-Milanovic ME (2007) Online available at www.smart-cities.eu [Zugriff am 11 December 2012]

Glaeser E (2011) Triumph of the city. Pinguin Group, New York

Hollands RG (2008) Will the real smart city please stand up? City 12(3):302–320

Koch A (2011) IEA annex 51: energy efficient communities, subtask a report: description of the state-of-the art of energy efficiency projects on the scale of neighbourhoods. European Institute for Energy Research, Karlsruhe

Komninos N (2002) Intelligent cities: innovation, knowledge, systems and digital spaces. Spon Press, London

Larsen H, Petersen LES (2011) Riso energy report 10: energy for smart cities in an urbanized world, November 2011. Riso DTU, National Laboratory for Sustainable Energy, Denmark

Marique A-F, Reiter S (2011) Towards more sustainable neighbourhoods: are good practices reproducible and extensible. In: Proceedings of 27th PLEA conference on passive and low energy architecture, Belgium

Mitchell W (1999) e-topia: urban life, jim but not as you know it. MIT Press, Cambridge

Moser P, Stocker E (2008) Autofreies Wohnen, Evaluierung der Mustersiedlung in Wien Floridsdorf, September 2008. s.n, Vienna

Paskaleva KA (2009) Enabling the smart city: the progress of e-city governance in Europe. Int J Innov Reg Dev 1(4):405–422

Pol O, Lippert L (2010) CONCERTO, report overall energy performance of the 26 communities. Österreichisches Forschungs- und Prüfzentrum Arsenal, Wien

Robinson D, Quiroga C (2009) Sustainable master planning in practice: evaluation and synthesis. In: Proceedings of CISBAT conference, Lausanne, Switzerland

Saringer-Bory B et al (2012) SmartCitiesNet, Evaluierung von Forschungsthemen und Ausarbeitung von Handlungsempfehlungen für Smart Cities. Bundesministerium für Verkehr, Innovation und Technologie, Wien

setis.ec.europa.eu (2012) Online available at http://setis.ec.europa.eu/about-setis/technology-roadmap/european-initiative-on-smart-cities [Zugriff am 5 December 2012

United Nations Human Settlements Programme (2011) Cities and climate change, global report on human settlements. UN-Habitat, Nairobi

Wright H (2008) Instant cities. Black Dog Publishing Limited, London

Smart Cities—Imposed Requirement or Preferred Life-Style

Dina Bērziņa

Abstract

World is changing: the increasing population constantly impacts the natural and man-made environment; therefore, the next years are crucial for the deciding in which direction our planet will move forward. Today about ½ of the world's population lives in cities sustaining the tendency of expanding urbanisation. Each city is different, determined by geographical location, history, and the people who live there and govern it. The best solution for one place may be not applicable for another. However, there is already enough experience of best practices accumulated to draw general conclusions and elaborate sustainable future development designs for cities. The paper summarises: different Smart City concepts proposed by several authors placing technologies, management or people at the centre; existing sectorial initiatives complementing the approach of Smart Cities; activities of the European Commission interlinking energy, transport and ICT offering new interdisciplinary opportunities to improve services reducing overall consumption; best practices of six different European cities in creating smart environment and living. The author would like to make the reader think over whether the smart way of life is imposed by technologies and governments or it is an internal necessity of an individual becoming the life-style of a whole community regardless of size?

Keywords

Smart city · Sustainable development · Energy efficiency · Intelligent technologies · Quality of life · Climate change policy

D. Bērziņa (✉)
University of Latvia, Institute of Atomic Physics and Spectroscopy,
Raiņa Blvd. 19, 1586 Riga, Latvia
e-mail: dinab@latnet.lv

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_11

1 Introduction

According to UN data (World Urbanization Prospects 2012), in 2008, half of the total global population lives in cities and the forecast predicts about 2/3 living in urban areas by 2050 (Fig. 1). Europe is one of the most urbanised continents in the world: the majority of the population already lives in cities since 1950. Today, more than 2/3 of Europeans live in urban areas and this share will continue to grow to up to 80 % by 2050. Although during the last crisis, rural-to-urban migration declined, reaching even negative values in some countries, including Latvia, nevertheless by the 2030s, five of the world's eight billion people will live in cities.

Cities play a crucial role in the economy as places of creativity and innovation and centres of services for surrounding areas (Cities of tomorrow 2011). They simultaneously present a challenge and an opportunity for the climate change policy. European cities (MEMO/12/538):

- are the driving force in generating Europe's economic growth creating some 80 % of the EU's gross domestic product by concentrating trade, business and "people expertise";
- consume 70 % of energy accounting for 75 % of the total greenhouse gas emissions by the EU;
- urban transport is responsible for ¼ of all the emissions from road transport and congestion costs Europe about 1 % of GDP every year;
- information and communications technology (ICT) sector requires more and more electricity.

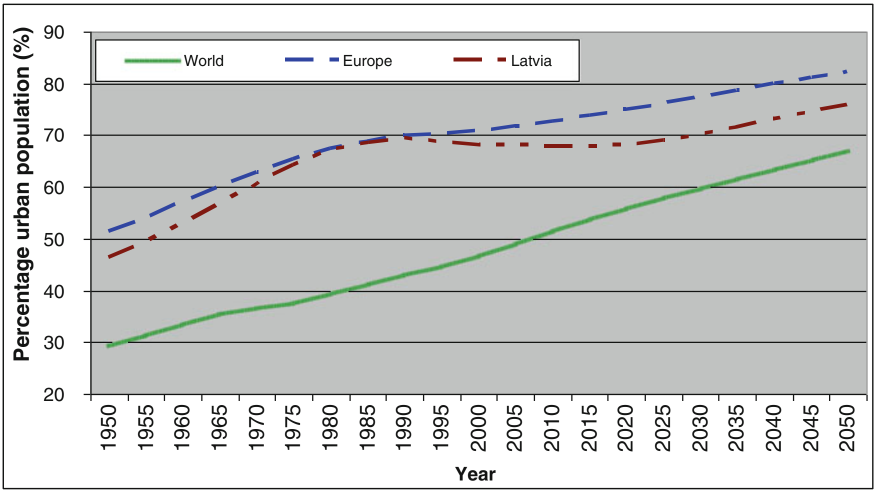


Fig. 1 Percentage of urban population since 1950 and forecast up to 2050. *Source* UN Department of Economic and Social Affairs, Data (on-line database)

This situation requires better use of existing resources. The high population density of the city increases strains on energy, transportation, water, buildings and public spaces, so "smart" solutions need to be found, i.e. both highly efficient and sustainable on the one hand, and generating economic prosperity and social well-being—on the other. Due to population and service density, cities offer a huge potential for energy savings and the move towards a carbon-neutral economy. This could be achieved by mobilising all resources of a city, by coordinating its actors in uses of new technologies and by forward-thinking interlinked policies.

Cities in Europe face the challenge of combining competitiveness and sustainable urban development simultaneously (Urban Europe, JPI 2010). In the immediate future, three interconnected factors will place even more emphasis on the role of cities in talent-based economic development (Dirks et al. 2009):

- unprecedented level of urbanisation;
- increasingly large share of the world's highly skilled, educated, creative and entrepreneurial population, giving rise to highly concentrated and diverse pools of knowledge and knowledge-creation networks;
- large-scale business and investment networks creating economies of scale in absorbing and extending innovation.

Therefore, we need to think about the cities of tomorrow, today, by integrating all the available concepts, tools, and resources in areas such as mobility, energy efficiency, environment, urban planning, knowledge economy, population management and involvement to ensure sustainable urban development for their inhabitants (Making our cities attractive 2010).

2 How Can a "Smart City" be Defined?

The label "Smart City" has become quite fashionable. It is proposed to call a city "smart" when it involves city planning, city organisation, implemented technologies and related business models that are able to accelerate the transition of Europe towards a low-carbon economy. Several approaches could be found:

- *narrow view*: cities which use ICT to deliver services to their citizens (Washburn 2010);
- *broader view*: cities which efficiently use resources across all sectors resulting in cost and energy savings, improved service and quality of life, and supporting innovation, smart technologies and the low-carbon economy leading to CO_2 neutrality (Rouhana 2011);
- *integrated approach*: investments in human and social capital along with transport and modern ICT infrastructure secure sustainable economic development and high quality of life, with a wise management of natural resources through participatory governance (Caragliu et al. 2009);

- *alternative approach*: substantial attention is devoted to the role of social capital in urban development—a smart city's community has learned to learn, adapt and innovate thereby shifting towards a knowledge-based economy (Coe et al. 2001).

Dirks et al. (2010) have discovered that living conditions have a profound influence on location decisions sometimes weighing even higher than potential earnings. In fact, they have a critical influence on the attractiveness of a location: migration to locations with more attractive living conditions can occur even if earnings in a destination are lower. Quality of life and the attractiveness of a city are substantially influenced by the core systems of a city: transport, government services and education, public safety and health.

Steinert et al. (2011) have defined Smart Cities along six main dimensions:

- *smart governance and participation*: interconnecting governmental organisations and administrations, improving community access to services, improving efficiency of organisational processes resulting in increased participation in decision-making, transparent governance, political strategies and perspectives;
- *smart people and human capital*: increasing inclusion by delivering more consistent educational experience resulting in increased level of qualification, attraction to life-long learning, creativity, open-mindedness, participation in public life;
- *smart environment and natural resources*: reducing energy consumption through the application of technology innovations while promoting energy conservation and material re-use resulting in amiability of natural conditions, pollution prevention, environmental protection, sustainable resource management;
- *smart mobility and ICT*: promoting efficient and intelligent transportation networks, along with new attitudes: car sharing, car-pooling, car-bike combinations resulting in local accessibility, sustainable, innovative and safe transport systems;
- *smart economy and competitiveness*: creating business opportunities, helping maintain population in rural areas resulting in innovative spirit, entrepreneurship, productivity, flexibility of labour market and ability to transform;
- *smart living and quality of life*: ensuring access to high-quality health care services including remote healthcare monitoring, easier access to social services of all kinds resulting in enlarged cultural facilities, improved health conditions, individual safety, housing quality, education facilities, social cohesion.

Smart city initiatives are spread across all six main smart dimensions, but most frequently focus on smart environment and smart mobility. According to recent mapping of EU cities (Mapping Smart Cities in the EU 2014) the only city in Latvia which qualifies under any of the characteristics is Riga—for environment. Also, for Lithuania the only city on the list is the capital Vilnius, which qualifies for mobility. Estonia is "smarter" and represented by two cities: the capital Tallinn—for economy, mobility, environment and people; but science city Tartu is smart in governance, economy and mobility.

Actually “smart city” is a complex concept, including a broad range of issues, but having the citizen at the centre since a Smart City requires a Smart Society and collaboration between different stakeholders: not only the public and private sector but also people, entrepreneurs, research centres and citizens through peer-to-peer services (Hallmarks of a sustainable city 2009).

3 Existing Initiatives and Experience

There are a number of focused sectorial initiatives, which complement to the approach of urban development and are constituent parts of “smart cities”:

- *CIVITAS initiative* (2002, www.civitas-initiative.org): City-Vitality-Sustainability or Cleaner and Better Transport in Cities encourages cities to introduce ambitious transport measures and policies towards sustainable urban mobility;
- *CONCERTO* (2005, www.concertoplus.eu/concerto): optimisation of energy efficiency in the building sector aiming to demonstrate that the optimisation of the whole communities is more efficient and cheaper than optimisation of each building individually;
- *European Urban Knowledge Network* (2005, www.eukn.org): shares knowledge and experience on tackling urban issues throughout Europe, bridging urban policy, research and practice;
- *Covenant of Mayors* (2008, www.eumayors.eu): European movement involving local and regional authorities, voluntarily committing to increasing energy efficiency and use of renewable energy sources.

Currently there are about 5580 Covenant of Mayors signatories also including countries outside Europe. 20 Latvian towns are involved in this movement (Table 1). The capital city Riga was the first to join the initiative in the fall of 2008 and the Mayor of Riga City Council Jānis Birks signed the Covenant of Mayors on the first annual ceremony in European Parliament, 10 February 2009 (Fig. 2).

- *Energy Efficient Buildings Public Private Partnership* (2008): aims at promoting green technologies and development of energy efficient systems and materials in new and renovated buildings radically reducing their energy consumption and CO_2 emissions (EEB PPP Multi-annual Roadmap 2010);
- *European Green Cars Initiative Public Private Partnership* (2008): supports the development of new, sustainable forms of road transport by supporting RD for achieving breakthroughs in the use of renewable and non-polluting energy sources, safety and traffic fluidity (GC PPP Multi-annual roadmap 2011);
- *Green Digital Charter* (2009, www.greendigitalcharter.eu): initiative committing cities to work together for delivering on the EU climate objectives using

Table 1 Covenant of Mayors Signatories in Latvia

Signatory	Population	Adhesion	Action plan (SEAP)
Rīga	753,000	30 Sep 2008	Approved 6 July 2010
Jēkabpils	26,468	18 Mar 2009	Approved 11 November 2010
Valmiera	27,569	19 Mar 2009	Signatory status on hold—SEAP submission deadline over
Jelgava	66,034	26 Mar 2009	Approved 25 November 2010
Tukums	19,722	24 Sep 2009	Approved 25 August 2011
Salaspils	21,102	31 Aug 2011	Approved 24 April 2013
Ikšķile	8850	30 Nov 2011	Approved 28 August 2013
Ogre	39,196	22 Dec 2011	Approved 19 December 2013
Lielvārde	6708	28 Dec 2011	Approved 25 September 2013
Ķegums	6200	11 Jan 2012	Approved 22 May 2013
Limbaži	17,564	25 Oct 2012	Approved 29 May 2014
Liepāja	82,413	15 Nov 2012	Approved 12 December 2013
Balvi	15,062	13 Dec 2012	Approved 16 January 2014
Saldus	28,156	18 Dec 2012	Approved 19 December 2013
Kārsava	6828	19 Dec 2012	Approved 27 December 2013
Ludza	14,226	20 Dec 2012	Approved 28 December 2013
Līvāni	13,579	27 Dec 2012	Approved 19 December 2013
Viļāni	6773	17 Jan 2013	Approved 16 January 2014
Jūrmala	66,034	21 Feb 2013	Approved 30 January 2014
Valka	10,195	28 Mar 2013	Approved 29 May 2014

Source The Covenant of Mayors: Signatories

Fig. 2 The Mayor of Riga City Council, Jānis Birks, signing the Covenant of Mayors on the first annual ceremony in European Parliament, 10 February 2009. © Dina Bērziņa

digital technologies to increase energy efficiency, facilitate emission reductions and prevent climate change;

- *European Green Capital Award* (2010, ec.europa.eu/environment/european-greencapital): for cities that have achieved high environmental standards, are committed to going on and ambitious goals for further environmental improvement and sustainable development;
- *Joint Programming Initiative "Urban Europe"* (2010, www.jpi-urbaneurope.eu): coordination of research to transform urban areas into centres of innovation and technology, implement eco-friendly and intelligent transport and logistic systems, ensure social cohesion and integration, reduce the ecological footprint and enhance climate neutrality.

4 European-Wide Initiatives

There are Smart Cities in all EU-28 countries, but they are not evenly distributed. The highest absolute number of Smart Cities is in the UK, Spain and Italy; the countries with the highest proportion of Smart Cities are Italy, Austria, Denmark, Norway, Sweden, Estonia, and Slovenia. Geographically "smart cities" are everywhere, but smart governance projects are mainly seen in older Member States: France, Spain, Germany, the UK, Italy, and Sweden (Mapping Smart Cities 2014).

Since cities are the place where most services are offered and consumed they are responsible for the use of major energy resources. Respecting the diversity of European cities and urban areas, Smart Cities and Communities activities leave substantial flexibility for cities in identifying the necessary and the most desirable actions.

For example:

- *Estonian Parliamentary election* in 2007 was the world's first national Internet election, but the election of 2011 was internationally recognised by Office of Security and Cooperation in Europe (OSCE) as trustworthy (Estonia: Parliamentary elections 2011);
- The fastest Internet in the Baltic States and the Nordic countries is in *Riga (Latvia)* according to the web application company "Akamai Technologies"; and Latvia has the sixth fastest Internet in the world (The Baltic Times 2014);
- *city of Vilnius (Lithuania)* is going to modernise street lighting by high efficiency modern LED sources that would reduce energy consumption by more than 70 % (Baltic Review 2014).

At the same time similarities in geographical, climatic, organisational, economic morphology, governance conditions may become criteria to team up in projects for achieving specific objectives faster (Mapping Smart Cities 2014).

4.1 Smart Cities and Communities Industrial Initiative

The Strategic Energy Technology Plan (COM (2009) 519 after its adoption enrolled also the Smart Cities and Communities Initiative aiming to make Europe's cities more efficient and sustainable in the area of energy, transport and ICT (SET-Plan 2010). This Initiative supports cities and regions in taking ambitious measures towards a 40 % reduction of greenhouse gas emissions through sustainable use and production of energy by 2020. In particular, measures on buildings, local energy networks and transport are the main components of the Initiative (SETIS, setis.ec.europa.eu):

- *Buildings*: new buildings with net zero energy requirements or net zero carbon emissions when averaged over the year by 2015 in different climatic zones; and refurbishing of the existing buildings bringing them to the lowest possible energy consumption levels (e.g. passive house standard) maintaining or increasing comfort;
- *Energy networks—Heating and Cooling*: innovative and cost-effective applications like biomass, solar thermal and geothermal applications; and highly efficient co-generation (combined heat and power, CHP) or tri-generation (combined cooling, heat and power, CCHP);
- *Energy networks—Electricity*: renewable generation, electric vehicles charging, storage, demand response and grid balancing; smart appliances and equipment, lighting (in particular solid state lighting for street and indoor); as well as fostering local RES electricity production, especially PV and wind applications;
- *Transport*: low carbon public/individual transport, smart applications for ticketing, intelligent traffic management and congestion avoidance, demand management, travel information and communication, freight distribution, walking and cycling.

4.2 Joint Programme on Smart Cities

With an aim of coordinating energy research for a low-Carbon Europe a Joint Programme on Smart Cities has been established under European Energy Research Alliance (2011, www.eera-set.eu). The entire Joint programme is structured in 4 sub-programmes (Energy in cities, Urban energy networks, Energy-efficient interactive buildings, Urban city related supply technologies) with a clear focus on energy efficiency and integration of renewable energy sources within urban areas. The main objective of the programme is the development of scientific tools and methods to enable an intelligent design, planning and operation of the energy system of the entire city in the near future.

4.3 Smart Cities and Communities Stakeholder Platform

The Smart Cities Stakeholder Platform (www.eu-smartcities.eu) has been designed to join the constituencies of the cities, communities and other public authorities, citizens, NGOs and relevant industrial sectors and aims to accelerate the development and market deployment of energy efficiency and low-carbon technology applications in the urban environment.

The Smart Cities Stakeholder Platform has six groups: four thematic expert Working Groups (energy efficiency and buildings; energy supply and networks; mobility and transport; ICT4Smart Cities) and two horizontal Coordination Groups (finance; roadmap). The main stakeholders are technical experts who are directly involved in developing, testing and demonstrating of new technologies. The Platform is one of the two governance bodies of the European Innovation Partnership on Smart Cities and Communities.

4.4 European Innovation Partnership on Smart Cities and Communities

In 2012 the European Commission launched the European Innovation Partnership on Smart Cities and Communities (EIP-SCC, COM (2012) 4701) aiming to support the development of smart technologies in cities and to pool resources for optimisation of energy, transport and ICT in urban areas. The central issue is technology integration to develop smart solutions for cities in transport, energy, waste, and water. Technology integration requires also the administrative integration of city authorities enabling to develop cross-cutting strategies by mixing the expertise of departments.

EIP-SCC brings together cities, industry and citizens to improve urban life through more sustainable integrated solutions. This includes applied innovation, better planning, a more participatory approach, higher energy efficiency, better transport solutions, and intelligent use of information and communication technologies. Former EC Vice President Neelie Kroes, Digital Agenda Commissioner has specified: “ICTs put the ‘smart’ in ‘smart cities’. It challenges legacy industries to rethink how to reduce congestion and increase energy efficiency in the urban environment enabling new business models and empowering people” (IP/12/760).

5 Smart Cities in Europe

In recent years, many cities have started initiatives focusing on the socio-economic development and regeneration of cities, building of advanced applications in societal domains such as healthcare, government services, energy efficiency, mobility and transport.

Considering Europe 2020 targets, taking into account of how cities perform in the context of country's national priorities and political and socioeconomic circumstances, the six most successful cities in EU for in-depth analysis were: Amsterdam (the Netherlands), Barcelona (Spain), Copenhagen (Denmark), Helsinki (Finland), Manchester (UK) and Vienna (Austria) (Mapping Smart Cities 2014).

It is important to note that virtually all Nordic Member State cities can be characterised as Smart Cities, as well as the majority of cities in Italy, Austria and the Netherlands, and approximately half of British, Spanish and French cities. Germany and Poland have relatively few Smart Cities. Percentage of Smart Cities in countries of Eastern European generally is less than the rest of EU-28. Cyprus, Luxemburg and Malta do not have any city with a population over 100,000 but otherwise qualify as Smart Cities.

This chapter surveys some examples presented on Smart Cities and Communities Initiative Launch Conference, 21 June 2011 that started the EU's initiative for the energy efficient cities of tomorrow; Smart Energy and Sustainable ICT Conference, 3–4 May 2012 which investigated how ICT can make cities greener by exchange of best practices including delivering transparent metrics around positive contribution of the ICT for solving energy and climate problems; Smart Cities and Communities European Innovation Partnership, Launch Conference, 10 July 2012 having proposed to pool resources for demonstration of energy, transport and ICT solutions in urban areas; as well as one Covenant of Mayors signatory in Latvia.

5.1 Barcelona, ES

Barcelona city is a pioneer in smart city movement and low-carbon solutions. It was among the first in the world to introduce a solar thermal ordinance and has announced developing a living lab for smart-city innovation. As an innovative city and a pioneer in implementing sustainable policies, it is the host of the Smart City Expo World Congresses (2011–2015, www.smartcityexpo.com/en/home).

Barcelona has developed:

- *new model for the urban habitat—4 interlinked layers of the urban environment*: environment that surrounds cities (food, water, energy); infrastructure, infrastructural systems (mobility, energy, matter, water and information); activities in the city (housing, working, facilities, services) which are taking place on different scales; information that the city generates;
- *new internal organisation*: living lab—development of a community of citizens; new opportunities for citizens to be more active and participative;
- *new framework for urban cooperation*: working together of national, state and local public and private organisations.

5.2 Copenhagen, DK

Copenhagen leads the way in sustainable energy planning: the city has elaborated strategy to reduce energy consumption by efficient district heating and power schemes from waste, wind, ground and spare heat from industry. Copenhagen has integrated its transport and public space policies, transforming the city centre and ensuring that the city's airport, rail and suburbs are all connected to the centre by the metro system. In the city centre, a combination of measures has encouraged an increase in walking and cycling and a decrease in private car use.

Copenhagen has set a goal to become CO_2 neutral in 2025 by extensive retrofitting of buildings, reorganisation of the energy supply and change in transport habits. Green growth and quality of life are the two main elements in Copenhagen's vision for the future; it has approved Green Growth strategy combining Green Growth with Quality of Life (Copenhagen: Solutions for Sustainable Cities 2012) to:

- *turn Copenhagen into a leading test-bed for new green solutions*: use the city as living lab for new green solutions in partnership of private partners and research institutions;
- *expand the visibility of the solutions that are tested and demonstrated in Copenhagen*: promote the city as an international showcase for smart green solutions by organising large energy and climate congresses and other means of showcasing.

5.3 Linköping, SE

Linköping has a long history as a city of learning the well-educated inhabitants being an asset of the city. The world-class high-tech development in the city started in 1937 with Saab aircraft manufacture.

Now Linköping has set a goal to achieve Zero carbon footprint in 2025 by replacing fossil fuels with biogas. Municipal efforts to reduce local emissions in the transport sector imply a modal transfer from the private car towards public transport and limiting emissions from urban public transport and fleets of vehicles. In the public bus system Linköping, along with several neighbouring municipalities, has started to use biogas produced from household and/or agricultural refuse.

The city is working to:

- heighten awareness of how energy consumption can be reduced and provide information about renewable energy sources for heating;
- encourage residents to make climate conscious travel choices, e.g. take the bus, cycle or walk;
- increase awareness of biogas as a vehicle fuel.

5.4 Lyon, FR

Lyon is the 2nd largest urban area in France. It has set the goal to design an innovative and smart city as the best place to live, work, learn, create and invest. The energy efficiency is a driving force for the innovation policy. Lyon has an elaborated integrated approach for:

- *mobility*: public transport, bicycle path, Pédibus (the walking school bus for 2000 pupils);
- *smart grid*: Zero emission building, PV charging system for shared electric car pool, energy management system;
- *clean Tech*: Lyon owns specific expertise in water, polluted soil, public lighting;
- *digital strategy*: 100 % coverage of the territory by Telecom network, new services in mobility, e-administration, culture, sustainable solutions, intelligent transportation system, working centres.

5.5 Rotterdam, NL

Rotterdam is one of the largest ports in the world. Starting as a dam constructed in 1270 on the Rotte River, Rotterdam has grown into a major international commercial centre and has set a goal to become a clean, green and healthy city. Rotterdam has dual task: to turn into sustainable city along with developing the port. It has set ten sustainability tasks (Investing in sustainable growth 2011):

- *reducing of CO_2 emissions*: particularly in industry, built environment, traffic and transport;
- *promoting energy savings*: reduce of annual primary energy consumption by 20 % by 2020 to reduce the dependence on imported fossil fuels;
- *converting to sustainable energy and biomass*: wind energy, solar energy and energy from biomass;
- *stimulating sustainable mobility and transport*: further growth of the port economy connecting city and port and becoming the most sustainable, healthy, clean, and attractive port city in the world;
- *reducing noise pollution and improving the air quality*: in 2010 1/3 of the population indicated that they were considering moving because of environmental factors: poor quality of air and high noise levels;
- *enlarging green areas in the city*: planting trees, bushes, shrubs, green facades, roof gardens to make the city more attractive and limiting the consequences of temperature upsurges, the risk of heat strokes;
- *stimulating sustainable products and services*: investing in green chemistry and energy, CCS, water and delta technology;

- *increasing public support*: making sustainability an integral part of the education system and a guiding principle for education and research to increase the public acceptance of the solutions and enthusiasm;
- *preparing for the consequences of climate change*: the rainfall causes more flooding in the city; upsurges of temperature expose people to heat strokes;
- *stimulating sustainable urban and regional development*: creating sustainable districts that are beneficial for the city and the people of Rotterdam.

5.6 Jelgava, LV

Jelgava is located in the central part of Latvia—the intersection of transit roads has contributed to the development of it as one of the most significant transit centres. Jelgava is a signatory of the Covenant of Mayors and has a vision to promote economic development by: reducing amount of CO_2 in economy, increasing the use of renewable energy resources, modernising the transport sector and facilitating the energy efficiency. It has set a goal to become a city with modern and sustainable environment for life by SEAP, Jeglava (2010):

- improving environmental factors: the quality of air, water, and soil;
- improving energy efficiency and promoting awareness of the society of the significance of the measures of energy efficiency;
- optimising and improving the heat supply system;
- enlarging and reconstructing the network of engineering communications;
- establishing the infrastructure for the public transport, improving the road safety and reducing the transit traffic flow within the city;
- developing new and renovating the existing residential fund;
- modernising and developing the infrastructure for education in education establishments of all levels;
- improving and developing the health care and social infrastructure.

6 Conclusions

Smart cities demonstrate the feasibility of rapid progress towards energy and climate objectives at a local level demonstrating to citizens improved quality of life and economies through investments in energy efficiency and reduction of carbon emissions. Many of these initiatives and strategies demonstrate a top-down orientation and are seeking a balance with bottom-up initiatives.

Technology is necessary for far-reaching changes to improve the quality of life, but it is not enough. Technologies can help to improve the carbon footprint of cities by moving to more intelligent use of energy; can enable a better use of energy in buildings, transport, street lighting, etc. While city developers consider only technological part of sustainable development and improved living conditions, Smart City is only an imposed requirement. Not simply a technical challenge, but organisational change in governments and society at large is just as essential. Making a city smart is, therefore, a multidisciplinary challenge, bringing together city officials, innovative suppliers, national and EU policymakers, academics and civil society. In fact, "Smart City" is a complex concept, including a broad range of issues and having the citizen at the centre. Sustainability should be inclusive: a democratic process, with participation and empowerment of people. Smart city governance means long-term political vision, cooperation, public-private partnerships, using innovative technical solutions.

Smart cities need smart politicians to change things, to act creatively in responding to the challenges; they also have to design innovative governance models and management to make the right decisions, to educate and involve a wide audience and place people in the centre by maximising synergies—when smart living is not only a possibility but as well a necessity for everybody, the urban area can be called the "Smart City" having transformed from imposed requirement to preferred life-style.

References

Baltic Review (2014) baltic-review.com/2014/04. Visited 30 Apr 2014

Caragliu A, Del Bo C, Nijkamp P (2009) Smart cities in Europe. Serie Research Memoranda 0048, VU University Amsterdam

Cities of Tomorrow (2011) Challenges, visions, ways forward. European Commission, Directorate General for Regional Policy. ISBN 978-92-79-21307-6

CIVITAS initiative (2002) www.civitas-initiative.org. Visited 15 Apr 2014

Coe A, Paquet G, Roy J (2001) E-governance and smart communities: a social learning challenge. Soc Sci Comp Rev 19(1):80–93

COM (2009) 519 Investing in the development of low carbon technologies (SET Plan)

COM (2012) 4701 Smart cities and communities—European Innovation Partnership

CONCERTO—A Cities' guide to a Sustainable built environment (2005) CONCERTO Initiative. http://www.concertoplus.eu/concerto

Copenhagen: Solutions for Sustainable Cities (2012) City of Copenhagen, City Hall. subsite.kk.dk/sitecore/content/Subsites/CityOfCopenhagen/SubsiteFrontpage/Business/Growth_and_international_affairs/Sustainable_solutions.aspx. Visited 30 Apr 2014

Covenant of Mayors (2008) www.eumayors.eu. Visited 15 Apr 2014

Dirks S, Gurdgiev C, Keeling M (2010) Smarter cities for smarter growth—how cities can optimize their systems for the talent-based economy. Executive Report by IBM Global Business Services

Dirks S, Keeling M (2009) A vision of smarter cities—how cities can lead the way into a prosperous and sustainable future. Executive Report by IBM Global Business Services

Energy-efficient Buildings Public-Private Partnership—Multi-annual Roadmap and longer term strategy (2010) European Commission, Directorate General for Research, Industrial Technologies. ISBN 978-92-79-15228-3

Estonia: Parliamentary Elections (2011) OSCE/ODIHR Election Assessment Mission Report (2011). www.osce.org/odihr/77557?download=true. Visited 30 Apr 2014

European Energy Research Alliance (2011) Joint programme on smart cities. www.eera-set.eu/index.php?index=30. Visited 15 Apr 2014
European Green Capital—Award (2010) ec.europa.eu/environment/europeangreencapital. Visited 15 Apr 2014
European Innovation Partnership on Smart Cities and Communities (EIP-SCC). ec.europa.eu/eip/smartcities/index_en.htm. Visited 15 Apr 2014
European Urban Knowledge Network—EUKN (2005) www.eukn.org. Visited 15 Apr 2014
Green Cars initiative Public-Private Partnership—Multi-annual roadmap and long-term strategy (2011). European Commission, Directorate General for Research and Innovation. ISBN 978-92-79-19710-9
Green Digital Charter (2009) www.greendigitalcharter.eu. Visited 15 Apr 2014
Hallmarks of a sustainable city, Brown (ed) (2009) Commission for Architecture and the Built Environment (CABE), London
Investing in sustainable growth (2011) Rotterdam programme on sustainability and climate change, City of Rotterdam
IP/12/760 Commission launches innovation partnership for Smart Cities and Communities, Brussels, 10 July 2012
Making our cities attractive and sustainable (2010) How the EU contributes to improving the urban environment. Publications Office of the European Union, ISBN 978-92-79-16298-5
Mapping Smart Cities in the EU (2014) European Parliament Study European Union; ISBN 978-92-823-4761-4
MEMO/12/538 Smart Cities and Communities Communication. Brussels, 10 July 2012
Rouhana K (2011) Going Local. Smart Cities Workshop, 22 Sep 2011, Budapest. ec.europa.eu/digital-agenda/events/cf/daelocal/item-display.cfm?id=7027. Visited 30 Apr 2014
SET-Plan (2010) European strategic energy technology plan—towards low carbon future. European Union. ISBN 978-92-79-15667-0
SETIS—Strategic Energy Technologies Information System (2014) setis.ec.europa.eu/about-setis/technology-roadmap/european-initiative-on-smart-cities. Visited 15 Apr 2014
Smart Cities and Communities Stakeholder Platform (2014) www.eu-smartcities.eu. Visited 15 Apr 2014
Smart City Expo World Congresses (2011–2015) Barcelona, Spain: www.smartcityexpo.com/en/home. Visited 15 Apr 2014
Steinert K, Marom R, Richard P, Veiga G, Witters L (2011) Making cities smart and sustainable. The Global Innovation Index 2011, pp 87–95
Sustainable Energy Action Plan of Jelgava City for the years (2010–2020) http://helpdesk.eumayors.eu/docs/seap/488_452_1301901045.pdf. Visited 30 Apr 2014
The Baltic Times (2014) www.baltictimes.com/news/articles/35015/#.VCxkcWeKWSo. Visited 30 June 2014
UN Department of Economic and Social Affairs, Population Division, Data on Urban and Rural Populations, Data (on-line database), October 2012 esa.un.org/unup/unup/index_panel1.html. Visited 15 Apr 2014
Urban Europe, Joint Programming Initiative (2010) Report for EC Assessment. jpi-urbaneurope.eu. Visited 15 Apr 2014
Washburn D, Sindhu U (2010) Helping CIOs understand “smart city” initiatives. Forrester Research, Inc, Cambridge
World Urbanization Prospects (2012) The 2011 revision, highlights, United Nations, Department of Economic and Social Affairs, Population Division, New York

Exploring the Dependence of Urban Systems on the Environment

Amalia Zucaro, Maddalena Ripa, Salvatore Mellino, Marco Ascione and Sergio Ulgiati

Abstract

A half-a-century historical series (1962–2008) of energy and resource consumption in the city of Rome (Italy) is investigated in order to ascertain the links between resource use and complexity change. Environmental, material, and energy inputs evaluated as actual energy and mass flows, are converted into impact indicators (local and cumulative abiotic material requirement, water demand, energy demand, airborne emissions and finally total emergy use). All calculated indicators are interpreted within a comprehensive framework SUMMA (SUstainability Multimethod Multiscale Assessment) capable to take into account different dimensions of the investigated systems. Based on the same set of input data, SUMMA generates consistent performance indicators, in which the results of each method are set up against each other and contribute to providing a comprehensive picture on which conclusions can be drawn. An evaluation of inter-linkages and synergies among the different resources and performance patterns in the city of Rome is also presented by decomposition equations to identify the major drivers of change within the period investigated as well as the future low-resource scenarios. Results show that sustainability of the urban system decreased steadily during the investigated period, as confirmed by intensive and extensive parameters. The increased fraction of imports compared to local sources, of non-renewables compared to renewables, as well

A. Zucaro (✉) · M. Ripa · S. Mellino · M. Ascione · S. Ulgiati
Department of Science and Technology, University of Naples Parthenope, Naples, Italy
e-mail: amalia.zucaro@uniparthenope.it

S. Mellino
e-mail: salvatore.mellino@uniparthenope.it

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_12

as of population and per capita income not accompanied by sufficient increase of energy and material efficiency are the major drivers of the pattern of unsustainability and call for policies that focus on optimisation of the patterns of production and consumption in times of unavoidable shrinking of the resource base.

Keywords
Integrated evaluation · Urban metabolism · Emergy synthesis · Decomposition analysis

1 Introduction

Eco-system thinking emphasises the concept of the city as a complex system characterised by a network of interactions and processes. Thus, cities can no longer be defined as built static spaces to manage, but as living organisms with a metabolism to control and support. Indeed, as all living organisms, cities can be described as highly dependent open systems relying on the provision of energy, food, materials, and information from other systems at different scales (municipal, regional, national) (Ramos-Martin et al. 2009). Cities would not exist without these inputs, and the metabolic processes can be described in terms of the transformation of inputs (sunlight, chemical energy, nutrients, water, and air) into useful products and wastes. An extreme view of urban metabolism was given by Odum (1971) pointing to the parasitic character of cities having a strong impact on natural and domesticated environments. Moreover, Odum and Odum (1981) have related the complexity of cities to ecological principles (hierarchies, feedbacks, maximum power) and energy flows. They described the growth of urban hierarchical structures in terms of uptake and transformation of resources and the regulatory role of cities with feedbacks to lower levels.

The use of an ecosystem approach to urban environment, emphasising the city as a complex system, provides a framework that enables a deep understanding of the urban internal dynamics, which is needed to move towards a circular sustainable metabolism. The problem of attaining sustainable urban development is thus an important challenge and the development of a method for assessing the status of sustainability of the urban development requires the definition of scientific and effective indicators and their integration. During the last few decades, several studies have developed a variety of indicators for assessment of urban ecosystems (Huang et al. 2009; Scipioni et al. 2009; Shen et al. 2010; Zellner et al. 2008) and have investigated performance of different urban spatial structures against sustainability criteria (e.g. Næss 1993, 2001; Tjallingii 1995; Newman and Kenworthy 1999; Williams et al. 2000; Schremmer et al. 2011, Ulgiati et al. 2011a, b). According to Ascione et al. (2009, 2011), the points still missing in most urban development studies are the integration of the quantitative (energy and material inputs) and qualitative (hierarchies, structures, information, and environmental services) indicators, the evolution of such indicators over time evaluating the standard of living, and the change of the assortment of products used by the population of a city with time. In this paper, the SUMMA approach (SUstainability Multimethod Multiscale Assessment) was applied to evaluate the material, energy and environmental performance of the city of Rome. Moreover, a decomposition analysis technique, based on the Advanced Sustainability Analysis (ASA) tool (Luukkanen and Malaska 2001) was also applied to identify the major drivers of sustainability change during the last half century (from 1962 to 2008), in the city of Rome.

2 Materials and Methods

The complex interactions and metabolism of urban systems require an integrated analysis model taking into account the amounts of all imported and local flows (energy and materials), their supply-side quality (environmental cost of resource generation), resource parameters and rates at which they are used, land-use and the change of land-use, configuration of the system and processes, interrelations between socioeconomic and natural systems, and finally decomposition of the obtained indicators to support policy choices.

2.1 The Accounting Framework: SUMMA

Life Cycle Assessment (LCA) has been widely adopted by the European Commission to support implementation of the EU Thematic Strategies on the Prevention and Recycling of Waste and on the Sustainable Use of Natural Resources, the Integrated Product Policy (IPP) Communication, and Sustainable Consumption and Production (SCP) Action Plan. LCA is also used worldwide to provide a basis for sustainable production, consumption, and disposal by measurement of the environmental burden related to resource use. LCA provides interesting information about the resource and environmental cost of a given product and/or process but accounts only the matter and energy flows subject to human control, whereas the flows outside of market dynamics (such as environmental services) and flows not associated to significant matter and energy carriers (such as labour, culture, information), in general, are not included. Moreover, the quality and renewability of resources, in terms of processes and time of the generation of biosphere activity are not taken into account in LCA evaluations. When sustainability comes into play as a major concern, the flows and qualities become relevant and cannot be disregarded. Emergy accounting (Odum 1988, 1996; Brown and Ulgiati 2004a, b) was suggested as a way to expand the focus of LCA to account properly for the contribution from environmental flows into sustainable dynamics of a system/process (Ulgiati et al. 2011a, b). Indeed, by means of Emergy accounting, all resources are referred to by the spatial and time scales of biosphere, their usefulness and quality being quantified, and compared with the generated product(s) on the same value basis.

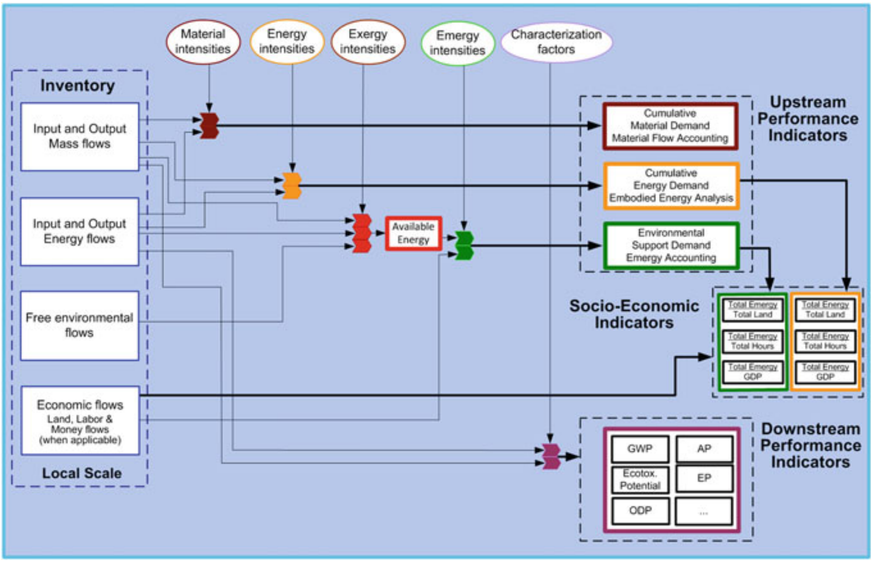


Fig. 1 Flow chart of SUMMA—the extended LCA approach

The Emergy method includes, and brings into the LCA accounting, the free environmental flows provided by Nature, the time needed for resource generation by processes in the biosphere, the economic and societal infrastructures and dynamics supporting the process (in terms of the flows of labour and services), and finally the optimisation strategies simultaneously carried out at all levels of the hierarchical network of biosphere.

In order to apply the Emergy accounting in association with other methods, an extended LCA approach—Sustainability Multiscale Multimethod Assessment (SUMMA) has been developed by Ulgiati et al. (2006, 2011a, b). This synergetic evaluation framework (Fig. 1) merges several upstream methods, such as the Material Flow Accounting (Schmidt-Bleek 1993; Hinterberger and Stiller 1998, Bargigli et al. 2004), the Embodied Energy Analysis (Slesser 1978; Herendeen 1998), the Emergy accounting (Odum 1988, 1996), and a selection of downstream impact assessment methods, e.g., the CML2 baseline (Leiden 2000), and the emergy-based environmental impact assessment of airborne emissions (Ulgiati and Brown 2002). The latter methods stem from stoichiometric evaluations or actual measures of airborne, waterborne and solid waste chemical releases for identification and characterization of specific impact categories. The analysed system or process is treated as a "black box" and a thorough inventory of all the foreground input and output flows is accomplished on its local scale first. This inventory forms a common basis for all subsequent background impact assessments carried out in parallel, thus ensuring the maximum consistency of the input data with the inherent assumptions (Brown et al. 2012). To generate performance and sustainability indicators inventory data are converted into cumulative material demand, cumulative energy demand, environmental support (emergy), and cumulative emissions. The amounts f_i of raw foreground inventory are multiplied by suitable conversion coefficients c_i (specific of each method applied), expressing the "intensity" of the flow, i.e. quantifying the background material, energy, or environmental cost associated with each flow. The coefficients are available in published reports of life cycle assessment and the energy and environmental accounting. The cumulative material, energy, and environmental "costs" associated with each flow are calculated by the generic equation:

$$C = \sum C_i = \sum \mathbf{f_i \, x \, c_i} \quad i = 1, \ldots, n \tag{1}$$

where:

- C cumulative material, energy or environmental cost associated to the investigated product or functional unit;
- C_i material, energy or environmental cost associated to the i-th inflow or outflow of matter or energy;
- f_i raw amount of the i-th flow of matter or energy;
- c_i material, energy or environmental unit cost coefficient of the i-th flow (from literature or calculated in this work)

The material, energy or environmental cost C is then divided by the process product, p, to find its unit cost, c_p, according to the method applied. Results are presented in comparative Tables where different impact indicators (energy intensity, global warming potential, Unit Emergy Values, etc.) are confronted in relation to different datasets (different years or different systems).

All the calculated upstream and downstream indicators provide a complete and consistent picture of the driving forces supporting the system and a clear understanding of its performance and the main sources of inefficiency. of merging and integrating conventional LCA and emergy has the advantage of accounting for the environmental quality of flows its set of calculated life cycle indicators carries information about the relation of the local process to the biosphere dynamics providing a much more comprehensive sustainability assessments.

2.2 Decomposition Analysis

The above-mentioned approach requires much attention to be applied at the level of the city, especially concerning its change over time—a very essential characteristic of sustainable development. From this point of view, focus should also be placed on identification and analysis of the different factors affecting changes of the indicators of sustainability at the macroeconomic level as well as changes in energy consumption, material flows, or greenhouse gas emissions and other more specific aspects. This is where the best features of the Advanced Sustainability Analysis (ASA) are revealed.

ASA is an approach/software of decomposition based on a mathematical information system developed by Finland Futures Research Centre (see e.g. Malaska et al. 1999; Kaivo-oja et al. 2001a, b; Luukkanen and Malaska 2001; Vehmas et al. 2008; Vehmas 2009) and is focused on changes over time between economic and environmental, economic and social, and social and environmental dimensions of sustainability measured with any preferred indicator or index.

Since the decomposition analysis is capable to assess the efficiency of using a given input affecting the results, it can be considered as a fundamental tool to ease the monitoring and evaluation of the sustainability of economies and productive sectors/processes (Hoffrén et al. 2000). The knowledge of the major factors that affect a process performance is essential for the design of new policy instruments and the evaluation of the implemented measures (Jungnitz 2008) over a desired pattern of sustainability.

An equation describing the relationship between the factors (e.g.: intensive factor V/X1 and extensive factor X1) contributing to variable V can be expressed in its simplest form as:

$$V = \frac{V}{X1} * X1 \tag{2}$$

The procedure can be also applied to multiple actors. The two-factor decomposition presented above can be continued by taking a result from the first decomposition as a starting point for further decompositions, and the new results can then be decomposed again. The equation which identifies the contributing variables can be formulated in a general form as:

$$V = \frac{X1}{X2} \times \frac{X2}{X3} \times \cdots \times \frac{X_n - 1}{X_n} \times X_n \quad (n \geq 2) \tag{3}$$

A more detailed explanation of the ASA approach and its underlying mathematical procedures can be found in the DECOIN (2008, http://www.decoin.eu/) and SMILE (2011, http://www.smile-fp7.eu/) websites.

2.3 Case Study Area: The City of Rome

Rome is the capital of Italy and the capital of Lazio Region. When Rome became the capital of the kingdom of Italy in 1871, its population was about 200,000 people; its present population is about 2.7 million people (ISTAT 2008). No significant population growth occurred in the last four decades (except for small fluctuations due to the oscillating intensity of immigration) (Fig. 2).

This stability was, however, accompanied by a change in the population structure (more single-person families; increased fraction of aged people; demand for temporary housing for people with business interests in the city; daily commuters; immigration flows) affecting the consumption of, and demand for, resources and services.

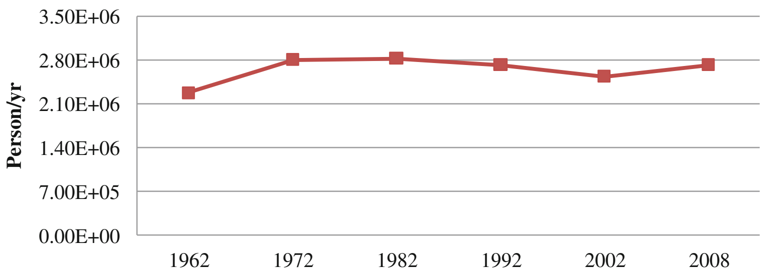


Fig. 2 Population growth in the city of Rome (1962–2008)

With the area of about 1500 km^2, Rome is the largest city in the country and the fourth largest in the European Union by population within the city limits. It is located in central Italy, in a hilly area crossed by the Tiber River, not far from the Tyrrhenian Sea. The river affected the urban development by favouring agriculture and trade and the physical landscape by moving large amounts of sediments and interacting with the coastal system of wetlands (now completely dried up but certainly responsible for land fertility and diversity). Although the economy of Rome is characterised by the absence of heavy industry, it is largely dominated by services, high-technology companies (information technology, aerospace, defence, telecommunications), research, construction and commercial activities (especially banking), and finally a very dynamic and economically relevant tourist sector. The fast growth of the tertiary sector required an increased investment effort to improve the road infrastructures, the subway and railway transportation services and the administrative structure through decentralisation and informatics.

3 Results and Discussion

The systems diagram, shown in Fig. 3, highlights the main components of the urban system as well as the main matter and energy inflows and outflows.

The inventory of the urban system of Rome from 1962 to 2008 is shown in Table 1, while the trends of the most important foreground flows are shown in Fig. 4. Fuels (diesel, gasoline, methane), electricity and building materials show a remarkable increase, while metals, wood and paper, plastics and chemicals (including fertilisers) also grow, but at a lower rate. Other items in Table 1 show oscillating behaviour (e.g. water, glass, textiles) while food quantity decreased most in recent years. Figure 5 shows the different growth of the GVA (Gross Value Added) of the city's economy, if calculated at current and constant prices. This distinction is important for a better understanding and comparison of the time series of performance indicators, because 1 € at constant prices ideally would require a different resource investment to be generated and would purchase a different amount of resources than 1 € at current prices (Lomas et al. 2007). In particular, the constant price GVA shows a different behaviour in the years before and after the

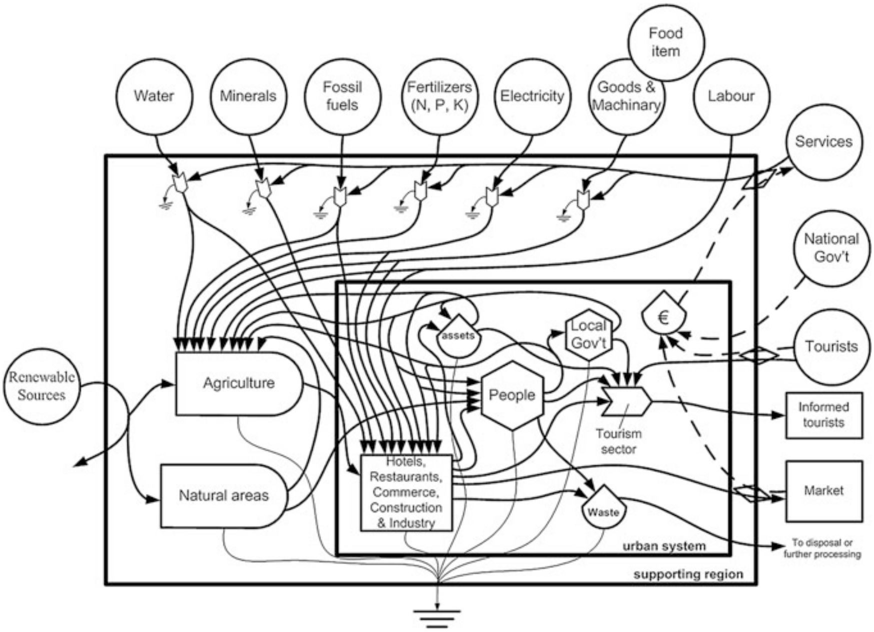


Fig. 3 Generic systems diagram of an urban system, showing the city structure, surrounding natural system, and the main input and output flows (Ascione et al. 2011)

reference year (Fig. 5), being below the current price GVA before, and above the current price GVA after the year 2000.

All renewable (e.g. sun, wind, rainfall, waves, etc.), locally non-renewable (i.e. soil erosion) and imported inputs (fuels chemicals, electricity, water, main food items, metals, building materials, etc.) are included in the account as the main items driving the development of this city over time. Services (i.e., indirect labour and information, expressed in terms of the total economic cost of all items imported into the system) are also an important factor to be accounted for.

Indeed, services are a rough measure of the resources that indirectly support the activities of designing, manufacturing and delivering goods and resources to the city of Rome (including infrastructures and societal organisation) all over their supply chain. Each imported item is identified by its raw amount (mass, energy) and by its associated services (indirect labour and infrastructure).

The main indicators calculated according to Eq. (2) are reported in Table 2, as:

- extensive indicators: cumulative abiotic material requirement, cumulative water requirement, embodied energy demand, total emergy use, selected airborne emissions;
- intensive indicators: (a) cumulative matter, energy, emergy and selected emissions per reference unit of income (€) and population.

Table 1 Foreground inventory of input and output flows in the city of Rome (2008)

	Unit	1962	1972	1982	1992	2002	2008
Renewable input (sun, wind, rain, etc.)	J/year	7.59E+18	7.59E+18	7.59E+18	6.46E+18	6.46E+18	6.46E+18
Nonrenewable input (top soil)	J/year	6.15E+11	6.15E+11	6.15E+11	6.15E+11	6.15E+11	6.15E+11
Imported input							
Fuels	J/year	2.95E+16	6.92E+16	8.95E+16	1.30E+17	1.91E+17	2.35E+17
Electricity	J/year	8.45E+15	1.60E+16	1.91E+16	2.77E+16	2.91E+16	5.90E+16
Water (from acqueduct)	g/year	1.93E+14	3.00E+14	3.02E+14	2.91E+14	3.28E+14	1.99E+14
Main food items (fish, meat, etc.)	g/year	1.66E+12	1.59E+12	1.82E+12	1.31E+12	6.69E+11	7.17E+11
Metals (steel, iron, copper, aluminum)	g/year	6.13E+11	2.48E+12	2.81E+12	3.32E+12	2.59E+12	3.08E+12
Building materials	g/year	7.26E+12	1.37E+13	8.89E+12	1.41E+13	1.84E+13	2.11E+13
Glass	g/year	1.12E+11	1.08E+11	1.50E+11	1.81E+11	2.35E+11	2.82E+11
Plastics	g/year	1.99E+10	9.66E+10	1.49E+11	2.71E+11	5.60E+11	6.73E+11
Chemicals	g/year	3.21E+11	3.84E+11	8.89E+11	1.29E+12	4.21E+11	1.84E+12
Wood	g/year	1.86E+11	2.56E+11	2.90E+11	4.85E+11	5.94E+11	6.95E+11
Textiles	g/year	4.14E+09	5.52E+09	1.82E+10	1.45E+10	5.13E+10	3.59E+10
Paper and derivatives	g/year	7.61E+10	1.97E+11	2.56E+11	3.43E+11	4.88E+11	5.61E+11
Services	€/year	2.76E+08	7.08E+08	5.72E+09	8.44E+09	1.19E+10	1.54E+10
Output flows (locally)							
Urban waste	ton/year	n.a.	n.a.	n.a	n.a.	1.59E+06	1.77E+06
Reference unit							
Economic product (GVA current price)	€/year	4.73E+08	2.03E+09	1.33E+10	4.59E+10	5.75E+10	1.24E+11
Economic product (GVA constant price)	€/year	n.a.	2.69E+10	3.59E+12	5.88E+10	5.38E+10	1.00E+11
People supported	Units/year	2.28E+06	2.81E+06	2.82E+06	2.72E+06	2.54E+06	2.72E+06

References for raw data were collected from ISTAT (National Institute of Statistics), Lazio Regional Statistics, Province of Rome Statistics, ASSOMET Statistics

Intensive indicators in Table 2 were calculated with reference to both a unit of population and a unit of current price GVA generated (€). Of course, a constant price GVA reference unit could also be adopted. According to Tables 1 and 2, one euro of GVA (Gross Value Added) at current price generated by the whole city required, in the year 2008, about 1.1 kg of abiotic matter, 21.2 kg of water, 7.0 MJ of energy (approximately 167.1 g of oil equivalent), 1.31E+12 solar equivalent Joules of environmental work for resource generation. The same euro of GVA generated global warming emissions equal to about 506.5 g of CO_2-equivalents and

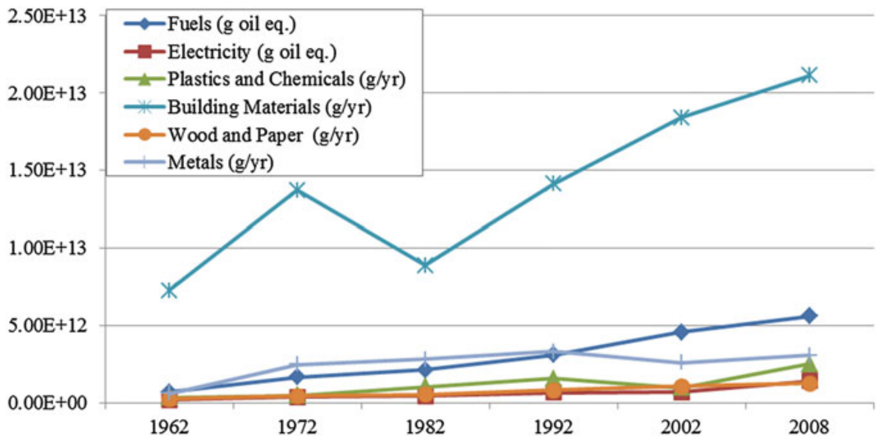


Fig. 4 Energy and material consumption by the city of Rome in the period 1962–2008

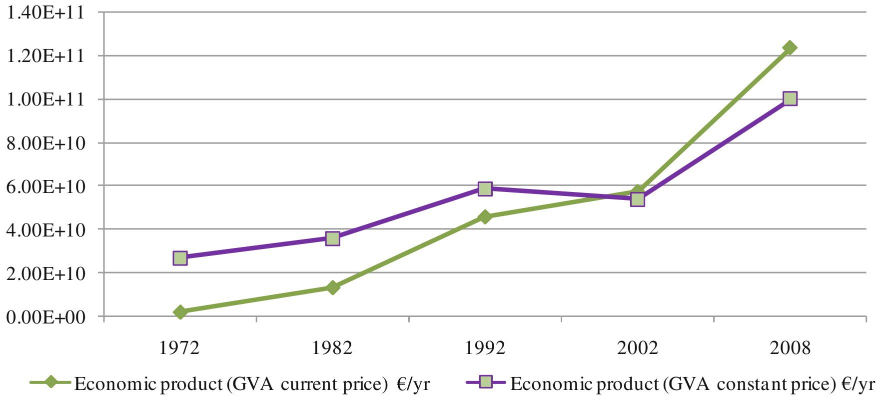


Fig. 5 Gross value added of Rome at constant price (referred to the year 2000) and current price over time (the GVA costant price for the year 1962 cannot be calculated due to lack of data)

contributed 0.6 g SO_2-equivalents to the acidification of rainfall. If reference is made to GVA at constant price, in the same year 2008, about 1.4 kg of abiotic matter, 26.2 kg of water, 8.7 MJ of energy (approximately 206.9 g of oil equivalent), 1.62E+12 solar equivalent Joules of environmental work, 627.0 g of CO_2-equivalents and 0.8 g SO_2-equivalents are calculated per € of GVA.

An appropriate selection of extensive indicators (cumulative flows referred to the global scale) from Table 2 is graphically shown in the radar diagram of Fig. 6. In order to compare data with different orders of magnitude in the same diagram, a normalisation procedure is applied (all values are divided by the value of the first year of investigation, 1962) in such a way that a larger area suggests a higher impact relative to the situation in the reference year.

Table 2 Selected extended LCA performance indicators of city of Rome

Indicators	1962	1972	1982	1992	2002	2008
Material resource depletion						
Material intensity abiotic (g/person)	1.72E+07	2.93E+07	2.82E+07	3.87E+07	4.50E+07	5.22E+07
Material intensity abiotic (g/€ current price)	8.27E+04	4.06E+04	5.98E+03	2.30E+03	1.99E+03	1.15E+03
Material intensity water (g/person)	3.19E+08	4.91E+08	5.65E+08	6.82E+08	8.16E+08	9.63E+08
Material intensity water (g/€ current price)	1.54E+06	6.82E+05	1.20E+05	4.05E+04	3.61E+04	2.12E+04
Total abiotic material requirement (g/year)	3.92E+13	8.23E+13	7.96E+13	1.05E+14	1.14E+14	1.42E+14
Total water demand (g/year)	7.27E+14	1.38E+15	1.59E+15	1.86E+15	2.07E+15	2.62E+15
Energy resource depletion						
Gross Energy Requirement (J/person)	6.34E+10	1.14E+11	1.48E+11	1.97E+11	2.73E+11	3.18E+11
Gross energy requirement (J/€ current price)	3.05E+08	1.58E+08	3.14E+07	1.17E+07	1.21E+07	7.00E+06
Oil equivalent (g/person)	1.52E+06	2.72E+06	3.54E+06	4.72E+06	6.51E+06	7.60E+06
Oil equivalent (g/€ current price)	7.30E+03	3.78E+03	7.51E+02	2.80E+02	2.28E+02	1.67E+12
Total energy demand (J/year)	1.45E+17	3.20E+17	4.18E+17	5.38E+17	6.93E+17	8.66E+17
Emergy, demand for environmental support						
Total emergy use, U (seJ/year)	5.95E+22	9.94E+22	1.11E+23	1.73E+23	1.38E+23	1.62E+23
Specific emergy (seJ/person)	2.61E+16	3.53E+16	3.92E+16	6.36E+16	5.45E+16	5.94E+16
Specific emergy (seJ/€ current price)	1.26E+14	4.91E+13	8.33E+12	3.78E+12	2.41E+12	1.31E+12
Empower density (seJ/m2)	3.95E+13	6.60E+13	7.35E+13	1.35E+14	1.08E+14	1.26E+14
EYR = U/(F + L + S)	1.05	1.03	1.02	1.01	1.02	1.01
ELR = (N + F + L + S)/(R)	40.85	61.94	52.38	94.73	64.47	65.25
ESI = EYR/ELR	0.03	0.02	0.02	0.01	0.02	0.02

(continued)

Table 2 (continued)

Indicators	1962	1972	1982	1992	2002	2008
Climate change						
Global warming (CO_2-equiv, g/person)	4.62E+06	8.42E+06	1.10E+07	1.44E+07	2.00E+07	2.30E+07
Global warming (total CO_2-equiv)	1.05E+13	2.37E+13	3.12E+13	3.93E+13	5.07E+13	6.27E+13
Acidification (SO_2-equiv, g/person)	6.07E+03	1.22E+04	1.55E+04	1.91E+04	2.40E+04	2.91E+04
Acidification (total SO_2-equiv)	1.38E+10	3.44E+10	4.37E+10	5.20E+10	6.10E+10	7.93E+10

Performance indicators per euro were calculated by using GVA at current price

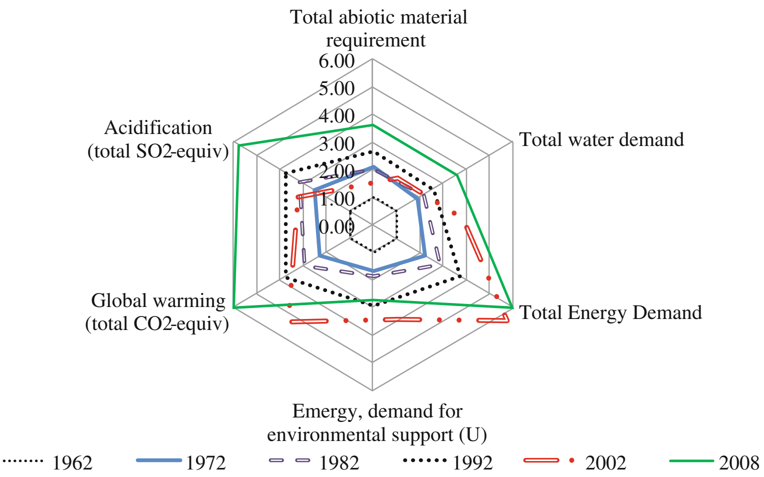


Fig. 6 The radar diagram shows selected upstream and downstream indicators of the city of Rome over time. Values are normalised from Table 1 with reference to the first year of investigation. As a consequence, they are dimensionless units. Units are reported in Table 2

Ascione et al. (2011) have shown that the global-to-local ratio of extensive flows such as those shown in Fig. 6 is always in the order of 2–4 to 1, which confirms an urban system being a parasitic structure that concentrates resources and exports environmental burden to the surrounding environment.

Results per person show increasing abiotic and water resource depletion over time. The GER (Gross Energy Requirement) and the oil equivalent steadily increase from 1962 to 2008, driven by the increase of the standard of living of the urban population. Global Warming Potential and Acidification per person increase over time following a similar pattern as energy consumption, to which they are strictly linked.

Other performance indicators can be calculated (Table 2) among which the EYR (Emergy Yield Ratio, a measure of ability to exploit local emergy resources), the ELR (Environmental Loading Ratio, a measure of distance from environmentally sustainable development), the ESI (Emergy Sustainability Index, an integrated measure of economic and environmental sustainability). The final performance in terms of ESI (Emergy Sustainability Index) of the whole city is very low (0.02), determined by a low reliance on local resources (EYR = 1.0) per unit of large-scale loading intensity (ELR = 65.3). These performance indicators can be used for comparison of the system's performance over time as well as for comparison with other urban systems elsewhere. The EYR (Emergy Yield Ratio) remains steadily close to 1 indicating that no significant use of local resources takes place within the city boundaries compared to an overwhelming amount of imported non-renewable sources. The city acts, in fact, as a resource conversion structure for generation of large amounts of primary and manufactured resources into high quality information flows (culture, money, policy). Finally, the emergy-based ESI, that evaluates the ratio between the local resource exploitation factor (EYR) and the system's distance from a purely environmental and renewable state (ELR), is steadily very low in the investigated period. This is due to both a low reliance on local resources and a high environmental loading, suggesting the need for global de-growth policies that decrease imports and more rely on renewables (e.g., capture of more renewable electricity from solar photovoltaic so decreasing the fossil electricity demand from the grid). A large fraction of resources supporting the city is converted outside of the city boundary (ELR increased by 58 % from 1962 to 2008) indicating its huge dependence on non-local sources and a heavy load on the surrounding environment and far-away regions of the world. Looking at consumption data (foreground) from the point of global (background) flows allows us to understand the overall impact of the urban system, while looking at the use per capita points out the extent of the average access of individuals to resources and the standard of life.

Efficiency of the resource use and its effect on the final result are assessed in a series of decomposition analysis equations. The cumulative CO_2 emissions for the selected case study are analysed first. On the basis of available data, the equation for Advanced Sustainability Analysis (ASA) developed as described in Sect. 2.1 is written as

$$CO_2 = \frac{CO_2}{TEC} \times \frac{TEC}{GVA} \times \frac{GVA}{POP} \times POP \tag{4}$$

where CO_2 is carbon dioxide emissions from fuel combustion, TEC is the cumulative Total Energy Consumption supporting all the energy and material demand by the city, GVA is the Gross Added Value of Rome at current prices and POP is the number of residents in the city (population). The first driver—CO_2/TEC represents CO_2 emission intensity of the energy used in support of the city over the supply chain, TEC/GVA indicates the cumulative energy intensity of the urban economy and GVA/POP is a measure of the individual standard of life.

CO_2 emissions from fuel combustion in the city of Rome have increased by six times during the 1962–2008 period (Table 2). Therefore, it is of paramount importance to identify the major contributing drivers. Figure 7 displays the results of ASA decomposition applied to CO_2 emissions with reference to the first investigated year (1962, not shown in the diagram), based on data and ratios listed in Table 3.

For each decade, the decomposition procedure points out the major drivers of change and their positive or negative effect on the trend of CO_2 emissions. In Fig. 7, the trends of each main driver from Eq. (4) are shown over the horizontal axis. Positive contributions are indicated by columns above the horizontal axis and vice versa; the height of the columns indicates the amount of this contribution relative to the reference year. Obviously, the increase of population (POP) contributes to emissions, although to a smaller extent than other drivers. The per-capita income, GVA/POP, directly correlates with the increase of CO_2 emissions, so that the increasing income per capita over the investigated period has generated increasing resource consumption and, therefore, increased the CO_2 emissions. The energy

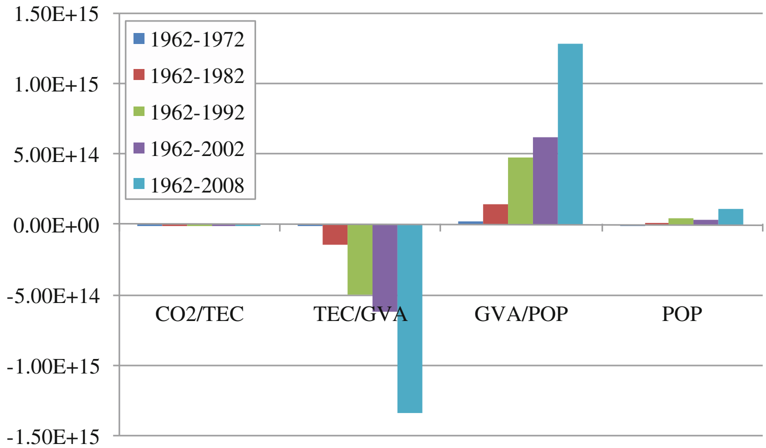


Fig. 7 The ASA decomposition analysis applied to cumulative CO_2 emissions of the city of Rome: identification of the drivers of change from 1972 to 2008. All bars are designed with reference to the year 1962

Table 3 Flows and intensities driving the CO_2 emissions of the urban system (1962–2008)

	Unit	1962	1972	1982	1992	2002	2008
CO_2	(g/year)	1.05E+13	2.37E+13	3.12E+13	3.93E+13	5.07E+13	6.27E+13
TEC	(J/year)	1.45E+17	3.20E+17	4.18E+17	5.38E+17	6.93E+17	8.66E+17
GVA	(€/year current price)	4.73E+08	2.03E+09	1.33E+10	4.59E+10	5.75E+10	1.24E+11
POP	(persons)	2.28E+06	2.81E+06	2.82E+06	2.72E+06	2.54E+06	2.72E+06
CO_2/TEC	(g/J)	7.24E−05	7.41E−05	7.46E−05	7.30E−05	7.32E−05	7.24E−05
TEC/GVA	(J/€)	3.06E+08	1.58E+08	3.14E+07	1.17E+07	1.21E+07	7.00E+06
GVA/POP	(€/person)	2.08E+02	7.20E+02	4.71E+03	1.68E+04	2.26E+04	4.54E+04
POP	(persons)	2.28E+06	2.81E+06	2.82E+06	2.72E+06	2.54E+06	2.72E+06

intensity of the economic product, TEC/GVA, also directly correlates with emissions, since a higher intensity means higher energy use per unit of GVA. In the investigated period, however, the energy intensity shows a steady decline (less energy per unit of GVA) that strongly decreased the CO_2 emissions. Behaviour of the CO_2 intensity per unit of fuel used, CO_2/TEC, is a bit more complex, being related to the price of energy, the kind of fuel used, and the technological progress. From 1962 to 1982, the CO_2 intensity has increased; after 1982, the parameter shows a steady decline, thus first contributing to the increase of the emissions, then to the decrease. Due to scale, (contribution is too small compared with other factors) the dynamics is not seen in Fig. 4. The extent to which technology, typology of fuel, economic performance, population, and the living standard affect emissions is obvious. This may provide directions for global warming policies: for example, shifting from coal and oil to natural gas (decreasing CO_2/TEC), or supporting industrial processes at lower energy intensity (TEC/GVA), and so on.

The second decomposition equation is developed to evaluate the relative importance of emergy-based performance indicators. The total emergy use (U), steadily increasing over the 1962–2008 period, is decomposed as

$$U = \frac{U}{F} \times \frac{F}{(R+N)} \times \frac{(R+N)}{POP} \times POP \qquad (5)$$

where F indicates non-renewable imported emergy flows, R is the value of all locally available renewable emergy flows, N refers to the locally available non-renewable emergy flows, and POP is the city population. According to Eq. (5), the change of total emergy, U, is affected by four determinants: U/F (i.e. the EYR—Emergy Yield Ratio); F/(R + N), (the ratio of imported to local emergy use); (R + N)/POP (the per-capita availability of local renewable and non-renewable emergy sources—a measure of local carrying capacity); and, finally, POP (population). Unlike the CO_2 trend, according to the emergy theory (Odum 1996; Brown and Ulgiati 2004a) and the maximum empower principle (Odum and Odum 2001), the trend of emergy use is not negative because it means the system is capable to bring in the resources it needs for its growth (size) and development (information, organization). When resources are abundant, system's growth (size, quantity) is favoured regardless to efficiency; when the resource base starts shrinking, development is the best choice (quality of uses, "more with less" strategies, recycling, and optimisation of efficiency). Decomposition results from 1972 to 2008, shown in Fig. 8 with reference to 1962, indicate the dominance of imports, F/(R + N), as a factor driving the growth of emergy use U. This means that the urban system is very

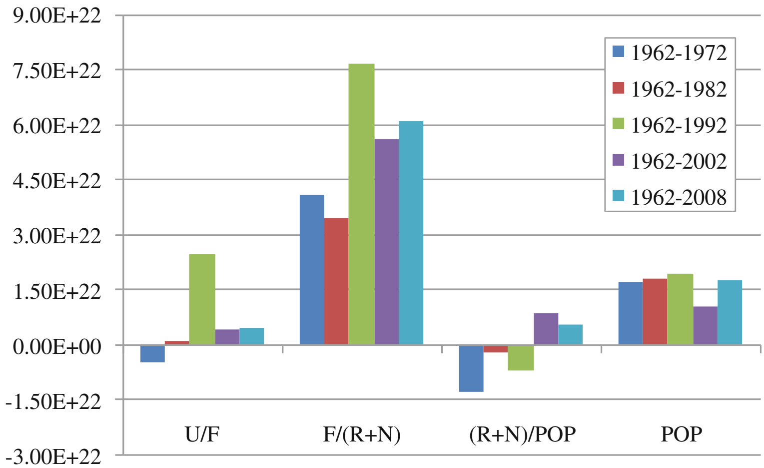


Fig. 8 The ASA decomposition of total Emergy use (U) in the city of Rome: identification of the drivers of change from 1972 to 2008 (all *bars* are designed with reference to 1962)

fragile, considering that the simultaneous demand of emergy from other countries of the world is likely to affect availability of cheap imports very soon (as seen in the figure with respect to the most recent years). The local resource basis (R + N) cannot be increased easily; therefore, an appropriate strategy would be to optimise its use (e.g., convert solar radiation into photovoltaic electricity to replace fossil fuels; recycling waste material resources to replace new raw imports, recycling water after appropriate treatment, decrease useless waste and luxury, etc.). The (R + N)/POP indicator also suggests policies decreasing population density, as also pointed out by Odum and Odum (2006), through voluntary relocation policies. By so doing, the locally available emergy resources might be sufficient to ensure the same living standard to a smaller population, in spite of the unavoidable shrinking of imports.

4 Conclusions

Sustainability of the urban system of Rome is assessed by combining a multi-method approach and decomposition analysis, techniques able to identify the factors that mostly have affected the changes in sustainability during the studied period. The use of the multi-method assessment (material, water, energy demand; environmental sustainability; emissions) helps avoid misleading interpretations based on mono-dimensional indicators only. The decomposition analysis helps to expose specific "drivers" (i.e., intensity and efficiency factors) affecting the changes of selected extensive variables (such as global CO_2 emissions and total emergy use, U). Results confirm fragility of the urban system of Rome and its economic performance (GVA), due to still increasing population, excess use of fossil energy, excess use of imports compared with local resources. The focus on specific drivers indicates population, energy and economic policies for a more sustainable future. The approach adopted in this study is suggested as a tool for designing scenarios depending on policy choices about resource use, resource efficiency, and resource availability in the near future.

References

Ascione M, Bargigli S, Campanella L, Ulgiati S (2011) Exploring an urban system's dependence on the environment as a source and a sink: the city of rome (Italy) across space and time scales. Chem Sus Chem 4:613–627

Ascione M, Campanella L, Cherubini F, Ulgiati S (2009) Environmental driving forces of urban growth and development. An emergy-based assessment of the city of Rome, Italy. Landscape Urban Plann 93:238–249

Bargigli S, Raugei M, Ulgiati S (2004) Mass flow analysis and mass-based indicators. Handbook of ecological indicators for assessment of ecosystem health. CRC Press, Boca Raton

Brown MT, Raugei M, Ulgiati S (2012) On boundaries and 'investments' in emergy synthesis and LCA: a case study on thermal versus photovoltaic electricity. Ecol Ind 15:227–235

Brown MT, Ulgiati S (2004a) Emergy analysis and environmental accounting. In: Cleveland C (ed) Encyclopedia of energy. Academic Press, Elsevier, pp 329–354

Brown MT, Ulgiati S (2004b) Energy quality, emergy, and transformity: H.T. Odum's contribution to quantifying and understanding systems. Ecol Model 178:201–213

DECOIN, Development and Comparison of Sustainability Indicators (2008) Report of decomposition analysis for indicators—Deliverable D.3.1. Research Project no. 044428, FP6-2005-SSP-5A, 2006–2009. http://www.decoin.eu/

Herendeen R (1998) Embodied Energy, embodied everything…now what? In: Ulgiati S, Brown MT, Giampietro M, Herendeen RA, Mayumi K (eds) Advances in energy studies. Energy flows in ecology and economy. Musis Publisher, Roma

Hinterberger F, Stiller H (1998) Energy and material flows. In: Book of proceedings of the 1st international workshop advances in energy studies. Energy flows in ecology and economy. Musis Publisher, Roma

Hoffrén J, Luukkanen J, Kaivo-oja J (2000) Decomposition analysis of finnish material flows: 1960–1996. J Ind Ecol 4(4):105–125

Huang SL, Yeh CT, Budd WW, Chen LL (2009) A sensitivity model (SM) approach to analyze urban development in Taiwan based on sustainability indicators. Environ Impact Assess Rev 29:116–125

ISTAT (2008) Annuario Statistico della Regione Lazio 2008. Available at the website: www.regione.lazio.it/statistica/annuario_statistico/anno_2008/14/54/0/2008/0/

Jungnitz A (2008) Decomposition analysis of greenhouse gas emissions and energy and material inputs in Germany. Deliverable of "petrE project"—resource productivity, environmental tax reform and sustainable growth in Europe. http://www.petre.org.uk/papers.htm

Kaivo-oja J, Luukkanen J, Malaska P (2001a) Advanced sustainability analysis. In: Tolba MK (ed) Our fragile world. Challenges and opportunities for sustainable development. Encyclopedia of life support systems and sustainable development, vol 2, pp 1529–1552

Kaivo-oja J, Luukkanen J, Malaska P (2001b) Sustainability evaluation frameworks and alternative analytical scenarios of national economies. Population and environment. J Interdisc Stud 23(2):193–215

Leiden (2000) CML-IA characterization factors, centre of environmental science, Leiden University, NL. http://cml.leiden.edu/software

Lomas PL, Cialani C, Ulgiati S (2007) Emergy analysis of nations. Lessons learned from historical series. In: Brown MT, Bardi E, Campbell D, Comar V, Huang SL, Rydberg T, Tilley DR, Ulgiati S (eds) Emergy synthesis. Theory and applications of the emergy methodology—4. The Center for Environmental Policy, University of Florida, Gainesville, pp 39.1–39.18. ISBN 0-9707325-3-8

Luukkanen J, Malaska P (2001) Advanced sustainability analysis. In: Tolba MK (ed) Our fragile word: overview of life support system and sustainable development. Encyclopedia of life supporting system EOLSS Forerunner Volume. EOLSS publishers Co. UNESCO, Oxford, pp 1525–1552

Malaska P, Kaivo-oja J, Luukkanen J (1999) Sustainability and economic growth: a theoretical framework and empirical demonstrations. Futu-publication 4/99. Finland Futures Research Centre, Turku School of Economics and Business Administration, Turku

Næss P (1993) Can urban development be made environmentally sound? J Environ Planning Manage 36:309–333

Næss P (2001) Urban planning and sustainable development. Eur Plan Stud 9:503–524

Newman PWG, Kenworthy JR (1999) Sustainability and cities. Overcoming automobile dependence. Island Press, Washington DC/Covelo (California)

Odum HT (1971) Environment, power, and society. Wiley-Inter Science, London

Odum HT (1988) Self organization, transformity and information. Science 242:1132–1139

Odum HT (1996) Environmental accounting. Emergy and environmental decision making. Wiley, NY

Odum HT, Odum EC (1981) Energy basis for man and nature. McGraw-Hill, New York

Odum HT, Odum EC (2001) A prosperous way down: principles and policies. Colorado University Press, Niwot

Odum HT, Odum EC (2006) A prosperous way down. Energy 31:21–32

Ramos-Martin J, Canellas-Bolta S, Giampietro M, Gamboa G (2009) Catalonia's energy metabolism: using the MuSIASEM approach at different scales. Energy Policy 37:4658–4671

Schmidt-Bleek F (1993) MIPS re-visited. Fresenius Environ Bull 2:407–412

Schremmer C, Mollay U, Saringer-Bory B (2011) Planning resource-efficient cities. SUME synthesis report. Österreichishes Institutfür Raumplanung, Vienna

Scipioni A, Mazzi A, Mason M, Manzardo A (2009) The dashboard of sustainability to measure the local urban sustainable development: the case study of Padua Municipality. Ecol Ind 9:364–380

Shen LY, Ochoa JJ, Shah MN, Zhang XL (2010) The application of urban sustainability indicators—a comparison between various practices. Habitat Int. doi:10.1016/j.habitatint.2010.03.006

Slesser M (1978) Energy in the economy. Macmillan, London

SMILE, Synergies in Multi-scale Inter-Linkages of Eco- systems (2011) Collaborative project no. 217213, FP7-SSH-2007-1, 2008–2011. www.smile-fp7.eu/

Tjallingii S (1995) Ecopolis: strategies for ecologically sound urban development. Backhuys, Leiden

Ulgiati S, Brown MT (2002) Quantifying the environmental support for the dilution and abatement of process emissions. The case of electricity production. J Clean Prod 10(4):335–348

Ulgiati S, Ascione M, Bargigli S, Cherubini F, Franzese PP, Raugei M, Viglia S, Zucaro A (2011a) Material, energy and environmental performance of technological and social systems under a life cycle assessment perspective. Ecol Model 222:176–189

Ulgiati S, Ascione M, Zucaro A, Campanella L (2011b) Emergy-based complexity measures in natural and social systems. Ecol Ind 11:1185–1190

Ulgiati S, Raugei M, Bargigli S (2006) Overcoming the inadequacy of single criterion approaches to life cycle assessment. Ecol Model 190:432–442

Vehmas J (2009) Decomposition analysis of CO_2 emissions from fuel combustion in selected countries. Int J Environ Technol Manage 11(1/2/3): 47–67

Vehmas J, Luukkanen J, Pihlajamäki M (2008) Development and comparison of sustainability indicators. DECOIN—Deliverable D3.1 of WP3

Williams K, Burton E, Jenks M (eds) (2000) Achieving sustainable urban form. Pion Limited, London

Zellner ML, Theis TL, Karunanithi AT, Garmestani AS, Cabezas H (2008) A new framework for urban sustainability assessments: linking complexity, information and policy. Comput Environ Urban Syst 32:474–488

Limits to Sustainable Use of Wood Biomass

Janis Abolins and Janis Gravitis

Abstract

Amounts of wood biomass from fast-growing forest stands are assessed with respect to maximum land productivity and with account for the capacity of photosynthesis. The results expressed in normalised coordinates of time and stock in general are relevant to any even-age stand. By comparing the energy densities of solar radiation transformed by photosynthesis and photovoltaic devices the authors argue that generating electricity by burning wood is an extremely inefficient use of land under conditions of sustainable supply of the fuel and conclude that transfer to bio-energy without radical changes in the existing economic system would further aggravate the environmental crisis.

Keywords

Biomass · Bioenergy · Sustainable forestry

1 Introduction

Retaining sustainable conditions for long-term supply of vital products is closely related to transfer from non-renewable to renewable resources and understanding the different factors limiting sustainable quantities of the renewable resources available

J. Abolins (✉)
University of Latvia, Institute of Atomic Physics and Spectroscopy,
19 Rainis Blvrd, Riga LV-1586, Latvia
e-mail: Janis.Abolins@lu.lv

J. Gravitis
Latvian State Institute of Wood Chemistry, Laboratory of Eco-Efficient
Conversion of Biomass, 27 Dzerbenes Str, Riga LV-1006, Latvia
e-mail: jgravit@edi.lv

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_13

for consumption by the still growing world population the limits to the growth of which are determined by those very conditions. So far, despite of serious warnings (Meadows 1972; Meadows et al. 1993) and actual failures of preserving economic sustainability by the existing financial system (Stiglitz 2010a, b; Ritholtz 2011; Ferguson 2012; Krugman 2012a, b), the vulnerabilities of the life-supporting systems have been ignored by the "business as usual". Regardless of unexpected catastrophic consequences to the global systems caused by technological discoveries (ozone depletion by CFCs and health hazards caused by PCBs, to name the most familiar), the illusion that technological progress will solve all the problems of further growth is still "walking strong", precaution neglected (NRDC 2008; Laskawy 2011; Gucciardi 2012; Royte 2012), and, finally, austerity offered instead of supporting social institutions that technological progress depends on Krugman (2012a, b), Stiglitz (2012).

The controversy of burning biofuels was brought up at least 5 years ago (Brahic 2007; Brewer 2007) and is still going on (Brutoco and Yau 2012; Staniškis 2012). Provincial biomass policies of Canada opening forest assets for burning have been criticised by Greenpeace (Mainville 2011) as destructive practices encouraged by "forest bioenergy boom" threatening the health of forest ecosystems since biomass as the source of energy cannot comply with the demand without destroying the life-supporting systems of the planet. The low energy densities and conversion efficiency of the present technologies utilising biomass (GCEP 2005) do not allow to meet the present levels of power consumption. The problem, however, is not as much in the efficiency of photosynthesis as in the greed for consumption leading to destructive practices of the "business as usual" (Staniškis 2012) working for profit and not for goals such as providing adequate food, drinkable water and creating a better physical and social environment for humans to live in Brutoco and Yau (2012).

With regard to biomass as a source of materials and energy, as it has been for the most part in human history, one has to be aware of the limits to sustainable use of the assets provided by the natural world a part of which the humans are. Considerations presented hereafter concern two basic closely related assets of the life-supporting systems—the land and the share of the energy flow it receives from the Sun, within the quantitative limits of which life on the planet can exist.

2 Factors Determining Sustainable Yields of Biomass

The main precondition of biomass production is the solar radiation supporting photosynthesis and the structures where the process of binding carbon dioxide into carbohydrates and other natural organic compounds is implemented—the plant biomass created by self-organisation over the time-span at least a billion years long in the evolution of life. Since most of biomass is being produced on land the land area of continents and islands available for the diverse plant species is another crucial precondition limiting the amount of radiation energy available for terrestrial photosynthesis. Availability of carbon dioxide, water, minerals and other nutrients, though no less indispensable, unless absent, are of minor importance since different plant species have adapted to the variety of habitats and environments. The combination of all the circumstances, however, affects the productivity of photosynthesis with respect to time and area the wetlands and rainforests being the most efficient sequesters of atmospheric carbon (Harte 1988).

Defining sustainable yield as the same amount of whatever is produced by photosynthesis being harvested annually for an unlimited span of time provides a simple condition under which cutting each year a certain area A_o of forest at a certain age t_c is sustainable—the total area A of forest stands of sequential ages from 1 to t_c should be equal to the product:

$$A = A_o \times t_c \tag{1}$$

It means that the amount of sustainable annual yields depending on the stock S at the age of cutting is limited by the total area available for growing forest:

$$A_o \times S(t_c) = \frac{A}{t_c} \times S(t_c) \tag{2}$$

The annual yield per unit area of the forest plantation then is equal to the mean annual increment of the stock:

$$\overline{\Delta S} = \frac{S(t_c)}{t_c} \tag{3}$$

that, as a function of the cutting age, has a maximum at $t_c \cong 1.8\ t_m$ where t_m is the age at which the forest stand reaches its maximum rate of growth (Abolins and Gravitis 2011). Harvesting wood at this age provides maximum land productivity. For that reason, the fast-growing species are more advantageous as a source of wood biomass for organic compounds or energy.

3 The Density of Energy

The average heat content of dry wood biomass being around 5.7 kWh kg^{-1} equivalent to between 2.0 and 3.3 MWh m^{-3} depending on species makes for 550 MWh ha^{-1} in case of best sites for species traditionally used as firewood (Daugavietis 2006). Energy per unit land area of a plantation providing sustainable annual yields of that size at rotation of 18 years, which is the optimum cutting age in the case considered (Abolins et al. 2010), is around 30.5 MWh of primary energy accumulated in wood biomass per ha.

If that amount of primary energy is used to generate electricity at efficiency between 35 and 50 %, the electricity obtained from 1 ha of the plantation area would be between 10.7 and 15.28 MWh, respectively. Utilisation of residual thermal energy for district heating at 85 % efficiency can provide additional heat between 16 and 13 MWh per ha of the plantation.

Generating electricity by burning biomass ultimately is a way of transforming the energy of solar radiation into electricity and, therefore, it can and should be compared with other available means used for the same purpose, such as photovoltaic panels transforming radiation into electricity directly. At mean annual insolation of the order of 1 MWh m^{-2} (10 GWh ha^{-1})[1] and 20 % conversion efficiency presently reachable by commercial photovoltaic transformers (Shanan 2011) the annual amount of electricity generated from an area of the size of 1 ha would be 2 GWh providing the density of electrical energy by two orders of magnitude exceeding that obtainable by burning wood. Sustaining a thermo-electric cogeneration power plant consuming the primary energy input flow at 1 MW would require burning about 8 m^3 of wood per day (2400 m^3 a year) and a plantation of fast-growing forest stands of the size of 180–200 ha to provide such amount on a daily basis.

The advantage of fossil energy carriers and photosynthesis is the energy being accumulated and stored while photovoltaic (or thermal) conversion of the energy of solar radiation requires additional storage capacities for use when needed. Usable heat stored at normal pressure and 99.9 °C in water would have the energy density of 93 kWh m^{-3} against between 2000 and 3000 kWh m^{-3} stored in biomass.

Compared with second-generation biofuels from cultivated crops wood has the advantage (at least so far) of not requiring either annual inputs of fertilisers, herbicides and pesticides, or annually consumed fuel for cultivating the soil and harvesting. The stands of fast-growing species rarely need thinning or other farming procedures before the time of harvesting.

4 The Biomass Alternative

Biomass, as a substitute to fossil oil, has the potential of being the renewable alternative as a carrier of energy and a source for the chemical industry since biorefineries can convert it to fuels for internal combustion engines or substitutes for materials presently made from fossil oil. The problems associated with making the transfer from non-renewable to renewable resources are not in the lack of technologies (IEA 2009). Humans have developed ways and learned to make and improve their tools during millennia of the history of civilisation. The problem is in the patterns of consumption the global economic system has imposed to hold up a permanent growth arranged for mining profit rather than satisfying the vital needs of the human population (Brutoco and Yau 2012; Staniškis 2012). The present rate of consumption and "business as usual", based on flawed principles (Brutoco and Yau 2012) ignoring the limits and constraints of available resources are obviously unsustainable. The reality of the existing limits is showing up as soon as one starts to estimate the available energy flows and the capacity of photo-synthesisers to produce the amount of biomass to satisfy the demand for biofuel feedstock to keep

[1] http://www.innovation.lv/fei/images/fei-solar.jpg.

going the economic system established for permanent growth. Querying the very necessity for and the logic behind perpetual economic growth Mary Dejevsky from *The Independent* has suggested trying to use what we have more rationally instead of being obsessed with growth for the sake of growth (Dejevsky 2011). President of the *Global Footprint Network* Mathis Wackernagel has concisely and exactly described the situation: “We are demanding more than the Earth can sustainably provide” (GFN 2012).

To use the existing limited assets sustainably the economy should be oriented neither to unlimited growth demanding unlimited resources, nor making profit instead of using the assets to make the planet more liveable (Brewer 2007). The profit initiative of the financial system presently driving the global economy is the main impediment to efforts pursuing sustainable and rational management of the assets. As pointed out by Contreras-Hermosilla in his review of forest policy strategy (Contreras-Hermosilla 1999), more profitable options including forest stock depletion or even using the land for other purposes, such as raising cattle, are preferred to sustainable management by private operators. The absence of market for the benefits of sustainable forest management together with mistaken government policies are mentioned as eventual reasons steering the motivation of forest managers in the wrong direction. The same problems with the reluctance of the private forest sector to follow more advanced and sustainable management methods are also observed by other authors (Larsen 2012). Another concern has shown up in the time-span between 1999 and 2012—how can the close-to-nature managed forest cope with the increased need for bio-energy production. Provincial policies of Canada opening forests for fuelling the market economy (Mainville 2011) have appeared to be devastating for the whole forest ecosystem of the country.

Excessive use of logging residues as a source of bioenergy is not harmless to forest ecosystems in the long run. A recent study of the removal of forest residues for bioenergy after harvesting (Clarke 2012) has shown possible risks for adverse effects on environmental services and biological diversity. More studies are needed to estimate the reasonable proportions of logging residues that should be left in the forest before making assessments of energy gains from the practice. The nutrient content of the forest floor has been found to be preserved by leaving the needles in a study of whole-tree harvesting practice of Norway spruce (Wall and Hytönen 2011).

Aggressive overuse is not the only risk of harmful mistreatment by harvesting forest for profit. A group of authors from Mendel University (Brno, Czech Republic) have studied the effects of the passage of heavy harvesting machines on soil structure and moisture content (Gebauer et al. 2012). The consequences of soil compaction are found to have considerable negative effects on plant physiology of the next forest generation. Under sustainable forest management harvesting should be a seasonal enterprise when the soil is hard and its structure is least affected by pressure. In the temperate zone for centuries, the logging has been practiced on frozen soil in winter. The tradition changed with the industrialisation of the forestry sector to the benefit of profitability, not sustainability.

The same market-nurtured "human factor"—the greed that drives the harvesting machinery into forest regardless to the season, presents another potential risk related to growing forest for bioenergy—the risk to biodiversity. Since the fast-growing species are more profitable because of providing higher land productivity, striving for profit will strongly expand the fast-growers eliminating to extinction all the less profitable varieties.

The biomass alternative is possible but the economic paradigm has to be changed first to make it work and provide the expected results. First of all the assets, such as water, land, air, and forest should stop to be regarded as means for making money, and money should end being the ultimate argument in making political decisions (Stiglitz 2010b; Brutoco and Yau 2012; Stiglitz 2012). The scale of the changes extending over the whole economic system and social structures requires that efforts are made at the national level. As Dr. Schmidt-Bleek has put it, only governments can accomplish the due changes of the economic framework to reach sustainability (Schmidt-Bleek 2004). The technological solutions for a more efficient and, consequently, more sustainable production systems are seen in the principles of interactions in natural ecosystems implemented through "Zero Emissions" approach in design of technological clusters (Pauli 2004; Suzuki 2004). To make the planet a better place for life, and for humans in particular, it is much more important to meet the challenges of a sustainable, or at least more sustainable than now, system of production and a fair system of distribution of goods and services than enforcing austerity to continue business as usual.

Acknowledgments The underlying studies have been supported by National Programmes of Research for sustainable use of local resources.

References

Abolins J, Gravitis J, (2011) A simple analytical model for remote assessment of the dynamics of biomass accumulation. In: Shaukat SS (ed) Progress in biomass and bioenergy production, InTech. ISBN:978-953-307-491-7, pp 91–106. Available from: www.intechopen.com/books/progress-in-biomass-and-bioenergy-production/a-simple-analytical-model-for-remote-assessment-of-the-dynamics-of-biomass-accumulation

Abolins J, Gravitis J, Kosmacha J (2010) Optimising the yield of energy from biomass by analytical models of the rate of growth. Latv J Phys Tec Sci 47(5):25–32

Brahic C (2007) Forget biofuels—burn oil and plant forests instead. NewScientist.com, Thursday, 16 Aug 2007

Brewer J (2007) The coming biofuels disaster. http://web.archive.org/web/20081025185709/http://www.rockridgeinstitute.org/research/rockridge/coming-biofuels-disaster.html

Brutoco R, Yau S (2012) From current business paradigm to the second renaissance. www.worldbusiness.org/fileadmin/user_upload/PDFs/common_cents/common_cents_012012.pdf

Clarke N (2012) Ecological consequences of increased biomass removal for bioenergy from boreal forests. In: Diez JJ (ed) Sustainable forest management—current research, InTech, Croatia, ISBN 978-953-51-0621-0

Contreras-Hermosilla A (1999) Towards sustainable forest management. Forestry Policy and Planning (FAO) Division, Rome, 1999. www.fao.org/docrep/003/X4107E/X4107E01.htm#TopOfPage

Daugavietis M (2006) Utilisation of grey alder. In: Kalnina (ed) Grey alder in Latvia. Silava, Latvia, pp 108–114, ISBN:978-9984-39-131-1 (in Latvian)
Dejevsky M (2011) Our irrational preoccupation with growth. The independent. www.independent.co.uk/voices/commentators/mary-dejevsky/mary-dejevsky-our-irrational-preoccupation-with-growth-6270645.html. Accessed on 2 Dec 2011
Ferguson C (2012) Inside job. Oneworld Publications, London. ISBN: 9781851689156
GCEP (2005) An assessment of biomass feedstock and conversion research opportunities. Stanford University, Global Climate & Energy Project. Available from: http://gcep.stanford.edu/pdfs/assessments/biomass_assessment.pdf
Gebauer R, Neruda J, Ulrich R, Martinková M (2012) Soil compaction—impact of harvesters' and forwarders' passages on plant growth. In: Diez JJ (ed) Sustainable forestry, sustainable forest management—current research. InTech, Croatia. ISBN:978-953-51-0621-0. Available from: www.intechopen.com/books/sustainable-forest-management-current-research/impact-of-heavy-machines-on-the-soil-root-system-and-plant-growth
GFN (2012) Global footprint network newsletter, 21 Nov 2012. Available at: http://www.footprintnetwork.org/en/index.php/newsletter/bv/the_financial_risks_of_ecological_limits
Gucciardi A (2012) Top US healthcare giant: GMOs are devastating health. http://naturalsociety.com/top-us-healthcare-giant-gmos-are-devastating-health/#ixzz2DgfgUikT
Harte J (1988) Consider a spherical cow. University Science Books, Sausalito, ISBN: 0-935702-58-X
Krugman P (2012a) The austerity agenda. New York Times, 31 May 2012
Krugman P (2012b) Europe's austerity madness. New York Times, 27 Sept 2012
Larsen JB (2012) Close-to-nature forest management: the Danish approach to sustainable forestry. In: Diez JJ (ed) Sustainable forest management—current research. InTech, Croatia. ISBN:978-953-51-0621-0. Available from: www.intechopen.com/books/sustainable-forest-management-current-research/sustainable-forestry-through-close-to-nature-management
Laskawy T (2011) The bugs that ate Monsanto. www.grist.org/industrial-agriculture/2011-12-13-the-bugs-that-ate-monsanto
Mainville N (2011) Fuelling a biomess, Greenpeace Canada. www.greenpeace.org/canada/en/System-templates/Site-Settings-Pages/Search/?all=Fuelling+a+BioMess
Meadows DH (1972) The limits to growth. Signet, New York. ISBN-10: 0451057678
Meadows DH, Randers J, Meadows D L (1993) Beyond the Limits: confronting global collapse, envisioning a sustainable future. Chelsea Green Publishing Company, Hartford, ISBN-10:0930031628
NRDC (2008) Vanishing bees. www.nrdc.org/wildlife/animals/bees.asp
Pauli G (2004) Reshaping competitive forces in the industrialized world. In: Filho WL, Ubelis A (eds) Integrative approaches towards sustainability in the Baltic Sea region Peter Lang, pp 59–66, ISBN: 3-631-52018-2
Ritholtz B (2011) What caused the financial crisis? the big lie goes viral. Washington Post, 6 Nov 2011. www.washingtonpost.com/business/what-caused-the-financial-crisis-the-big-lie-goes-viral/2011/10/31/gIQAXlSOqM_story.html
Royte E (2012) Fracking our food supply. The Nation. www.thenation.com/article/171504/fracking-our-food-supply. Accessed on 28 Nov 2012
Schmidt-Bleek F (2004) No sustainability without radical dematerialisation–technical and economic considerations. In: Filho WL, Ubelis A (eds) Integrative approaches towards sustainability in the Baltic Sea region. Peter Lang, pp 119–142. ISBN:3-631-52018-2
Shanan Z (2011) Sunpower panels awarded guinness world record. www.reuters.com/assets/print?aid=US110444863620110620
IEA (2009) Sustainable production of second-generation biofuels. http://www.iea.org/publications/freepublications/publication/name-3863-en.html
Staniškis JK (2012) Sustainable consumption and production. Clean Tech Environ Policy. 14:1013–1014

Stiglitz JE (2010a) Freefall: America, free markets, and the sinking of the world economy, Norton WW. ISBN: 978-0-303-07596-0

Stiglitz JE (2010b) Needed: a new economic paradigm. Financial Times. www.ft.com/intl/cms/s/0/d5108f90-abc2-11df-9f02-00144feabdc0.html#axzz2Dy5JROam, 19 Aug 2010

Stiglitz JE (2012) Politics is at the root of the problem. The European. www.theeuropean-magazine.com/633-stiglitz-joseph/634-austerity-and-a-new-recession, 23 Apr 2012

Suzuki M (2004) Visualisation of a sustainable industrialised society—zero emissions approach. In: Filho WL, Ubelis A (eds) Integrative approaches towards sustainability in the Baltic Sea region. Peter Lang, ISBN:3-631-52018-2, pp 29–40

Wall A, Hytönen J (2011) The long-term effects of logging residue removal on forest floor nutrient capital, foliar chemistry and growth of a Norway spruce stand. Biomass Bioenergy 35:3328–3334. www.footprintnetwork.org/en/index.php/newsletter/bv/the_financial_risks_of_ecological_limits, www.intechopen.com/books/sustainable-forest-management-current-research/ecological-consequences-of-increased-biomass-removal-for-bioenergy-from-boreal-forests

An Overview of Expected Progress and Outcomes from the UN Conference on Sustainable Development (Rio+): The Role of Universities

Walter Leal Filho

Abstract
The United Nations Conference on Sustainable Development (Rio+20) was held in Rio de Janeiro, Brazil, on 20–22 June 2012. This paper examines the policies and expected progresses, as well as outline the role of universities in this process.

Keywords
Sustainable development · Rio summit · Universities · Higher education · Progress

1 Introduction

Forty years after the Stockholm Conference on the Human Environment, twenty years after the 1992 Earth Summit in Rio de Janeiro—where countries adopted Agenda 21, the blueprint to rethink economic growth, advance social equity and ensure environmental protection, and ten years after the World Summit on Sustainable Development (WSSD) in Johannesburg in 2002, the UN decided to bring together governments, international institutions and major groups to discuss and agree on a range of measures to promote sustainable development. The chosen venue was again Rio de Janeiro, in Brazil, where an event with an emphasis on

W. Leal Filho (✉)
Research and Transfer Centre "Applications of Life Sciences", Faculty of Life Sciences, Hamburg University of Applied Sciences, Lohbrügger Kirchstraße 65, 21033 Hamburg, Germany
e-mail: walter.leal@haw-hamburg.de

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_14

matters such as poverty reduction, job promotion and clean energy, among others, was to be organized. This decision was in pursuance of General Assembly Resolution 64/236 (A/RES/64/236), of 24 December 2009.

The event, formally called the United Nations Conference on Sustainable Development—also known as Rio+20—was expected to mark a milestone in global action for climate and environment (UNCSD 2012a). Whereas the first (1992) Rio Conference placed sustainable development at the top of the global agenda of the UN and the international society, the Rio+20 event was expected to build on this foundation, with the aim of advancing the cause of global sustainability and development.

The event itself was a major international gathering. Held in the period of 20–22 June 2012, it was attended by over 100 presidents and prime ministers, as well as by thousands of other people representing government agencies, the private sector, NGOs and other groups. The main aim was to discuss ways to reduce poverty, advance social equity and ensure environmental protection. The objectives of the Rio+20 Conference were:

i. to secure renewed political commitment for sustainable development,
ii. to assess the progress to date and the remaining gaps in the implementation of the outcomes of the major summits on sustainable development and
iii. to address new and emerging challenges.

The preparations which led to Rio+20 and which have extended themselves for nearly three years highlighted seven areas which need priority attention. These were as follows (UN 2012b).

1.1 Area 1: Jobs

The Economic recession has taken a toll on both the quantity and quality of jobs. For the 190 million unemployed, and for over 500 million job seekers over the next 10 years, labour markets are vital not only for the production and generation of wealth, but equally for its distribution. Economic action and social policies to create gainful employment are critical for social cohesion and stability. It's also crucial that work is geared to the needs of the natural environment. "Green jobs" are positions in agriculture, industry, services and administration that contribute to preserving or restoring the quality of the environment.

1.2 Area 2: Energy

Energy is central to nearly every major challenge and opportunity the world faces today. Be it for jobs, security, climate change, food production or increasing incomes, access to energy for all is essential. Sustainable energy is needed for strengthening economies, protecting ecosystems and achieving equity. United Nations Secretary-General Ban Ki-moon is leading a Sustainable Energy for All initiative to ensure universal access to modern energy services, improve efficiency and increase use of renewable sources.

1.3 Area 3: Cities

Cities are hubs for ideas, commerce, culture, science, productivity, social development and much more. At their best, cities have enabled people to advance socially and economically. However, many challenges exist to maintaining cities in a way that continues to create jobs and prosperity while not straining land and resources. Common city challenges include congestion, lack of funds to provide basic services, a shortage of adequate housing and declining infrastructure. The challenges cities face can be overcome in ways that allow them to continue to thrive and grow, while improving resource use and reducing pollution and poverty.

1.4 Area 4: Food

It is time to rethink how we grow, share and consume our food. If done right, agriculture, forestry and fisheries can provide nutritious food for all and generate decent incomes, while supporting people-centred rural development and protecting the environment. But right now, our soils, freshwater, oceans, forests and biodiversity are being rapidly degraded. Climate change is putting even more pressure on the resources we depend on. A profound change of the global food and agriculture system is needed if we are to nourish today's 925 million hungry and the additional 2 billion people expected by 2050. The food and agriculture sector offers key solutions for development, and is central for hunger and poverty eradication.

1.5 Area 5: Water

Clean, accessible water for all is an essential part of the world we want to live in. There is sufficient fresh water on the planet to achieve this dream. But due to bad economics or poor infrastructure, every year millions of people, most of them children, die from diseases associated with inadequate water supply, sanitation and hygiene. Water scarcity, poor water quality and inadequate sanitation negatively impact food security, livelihood choices and educational opportunities for poor families across the world. Drought afflicts some of the world's poorest countries, worsening hunger and malnutrition. By 2050, at least one in four people is likely to live in a country affected by chronic or recurring shortages of fresh water.

1.6 Area 6: Oceans

The world's oceans—their temperature, chemistry, currents and life—drive global systems that make the Earth habitable for humankind. Our rainwater, drinking water, weather, climate, coastlines, much of our food, and even the oxygen in the air we breathe, are all ultimately provided and regulated by the sea. Throughout history, oceans and seas have been vital conduits for trade and transportation. Careful management of this essential global resource is a key feature of a sustainable future.

1.7 Area 7: Disasters

Disasters caused by earthquakes, floods, droughts, hurricanes, tsunamis and more can have devastating impacts on people, environments and economies. But resilience—the ability of people and places to withstand these impacts and recover quickly—remains possible. Smart choices help us recover from disasters, while poor choices make us more vulnerable. These choices relate to how we grow our food, where and how we build our homes, how our financial system works, what we teach in schools and more. With a quickening pace of natural disasters taking a greater toll on lives and property, and a higher degree of concentration of human settlements, a smart future means planning ahead and staying alert.

The ambition of UNCSD was that governments should adopt clear and focused practical measures for implementing sustainable development, especially on the seven priority areas, based on the many examples of success which have been seen over the last 20 years. Some facts which have guided the discussions at UNCSD were:

- The world today has 7 billion people—by 2050, there will be 9 billion.
- One out of every five people—1.4 billion—currently lives on $1.25 a day or less.
- A billion and half people in the world don't have access to electricity.
- Two and a half billion people don't have a toilet.
- Almost a billion people go hungry every day.
- Greenhouse gas emissions continue to rise, and more than a third of all known species could go extinct if climate change continues unchecked.

Similar to what happened at UNCED in 2002, it was envisaged that the official part of UNCSD would be accompanied by various parallel and side events, exhibitions, presentations and fairs, to be organized by a wide range of partners.

2 Outcomes and Expected Progress

The discussions held at Rio+20 were characterized by many exchanges of viewpoints but also by intensive negotiations. EU Member States have taken a common position at the Rio+20 negotiations, considering the event as a unique opportunity to secure renewed political commitment to sustainable development at all levels. To this purpose, the Danish EU-Presidency at the time EU submitted a 31 page document to the UN Rio+20 Conference Bureau, emphasizing the concept of a green economy, and proposing a roadmap with specific goals, objectives and actions at international level. The green economy roadmap encompassed areas such as sustainable energy, water, sustainable land management and ecosystems, oceans and resource efficiency, in particular waste, food, nutrition, sustainable agriculture, fisheries, forestry, sustainable cities and chemicals, as well as areas related to the sustainable management and restoration of natural resources. The roadmap also included cross-cutting issues such as elimination of subsidies with negative impact on the environment, green tax reforms and capacity building.

A further contribution from the EU was the emphasis on the need to improve international cooperation and a more effective international institutional framework for sustainable development, including a stronger United Nations Environment Programme (UNEP).

A major outcome from Rio+20 was the document "**The Future We Want**". The document, agreed by all UN Member States, defines the key principles that will guide the international community in the upcoming years to move the sustainable development agenda forward. Among other things, the document recognizes that poverty eradication, changing unsustainable and promoting sustainable patterns of consumption and production and protecting and managing the natural resource base of economic and social development, are the overarching objectives of and essential requirements for sustainable development. It also reaffirms the need to achieve sustainable development by promoting sustained, inclusive and equitable economic growth, creating greater opportunities for all, reducing inequalities, raising basic standards of living, fostering equitable social development and inclusion. Furthermore, "**The Future We Want**" (UN 2012a, b) reiteirates the need to promote integrated and sustainable management of natural resources and ecosystems that supports, inter alia, economic, social and human development while facilitating ecosystem conservation, regeneration and restoration and resilience in the face of new and emerging challenges.

In addition to the document "**The Future We Want**" more than US$ 513 billion was pledged to support initiatives and projects aimed at building a sustainable future.

More recently, i.e. in July 2013, the UN General Assembly established a new High-level Political Forum, which will replace the United Nations Commission on Sustainable Development, to boost efforts to tackle global economic, social and environmental challenges. In a resolution adopted by consensus, the 193-member Assembly emphasized the need for an improved and more effective institutional framework for sustainable development, and decided that the Forum should provide "a dynamic platform for regular dialogue and for stocktaking and agenda-setting to advance that process." The decision follows up on a key recommendation of '**The Future We Want**'. The Forum can provide the political leadership and the action-oriented recommendations needed to follow up on all the Rio recommendations and meet urgent global economic, social and environmental challenges. The Forum will convene annually at the ministerial level under the auspices of the UN Economic and Social Council (ECOSOC) and it will, every four years, bring together heads of State to provide added momentum for sustainable development.

This new body is tasked with providing political leadership, guidance and recommendations for sustainable development; reviewing progress in the implementation of related commitments; and enhancing integration of the three dimensions of sustainable development—economic, social and environmental (UN 2013).

Future expected progress is expected in the following areas:

(a) a stronger implementation focus with more emphasis to the integration of sustainable development in national policy priorities;
(b) a stronger emphasis to social issues, especially poverty alleviation
(c) more attention to issues related to renewable energy and energy efficiency
(d) more emphasis to the development of competencies, skills and knowledge needed to build a more sustainable society

Finally, it is important to encourage people to engage in participate more actively in local, national and global processes towards sustainable development.

3 The Role of Universities

It is widely acknowledged that higher education institutions as a whole, and universities in particular, can and should play a key role in implementing the principles and realizing the goals of sustainable development. This is so for three main reasons:

1. they provide a unique contribution to the training of professionals and decision-makers, shaping generations of professionals;
2. they act as majors centre of research, thus being uniquely placed to undertake ground-breaking and action research which can improve the ways sustainability is perceived and practiced;
3. they generate and disseminate new knowledge and insights to various stakeholders across society.

Much progress has been achieved in this field over the past 15 years, and many universities across the world have established a solid expertise on matters related to sustainability. But despite this positive background, a lot still needs to be done, so as to allow universities to fulfil their roles as centres for education, communication and research on sustainable development, and to realize their potential in terms of projects. Consistent with the above need, some activities have been organized in the context of Rio+20, with the aim of strengthening the contribution of universities to international attempts to implement sustainable development.

One of such initiatives was "World Symposium on Sustainable Development at Universities" (WSSD-U-2012), organised by the Research and Transfer Centre "Applications of Life Sciences" of the Hamburg University of Applied Sciences (Germany), under the auspices of the RCE Hamburg and Region. The event took place in Rio de Janeiro, Brazil, on 5–6 June 2012, and was officially accredited and an acknowledged parallel event to Rio+20. The aims of the WSSD-U-2012 were:

(a) to provide universities all round the world with an opportunity to display and present their works (i.e. curriculum innovation, research, activities, practical projects) as they relate to education for sustainable development at university level;
(b) to foster the exchange of information, ideas and experiences acquired in the execution of projects, from successful initiatives and good practice; to discuss methodological approaches and projects which aim to integrate the topic of sustainable development in the curriculum of universities;
(c) to network the participants and provide a platform so they can explore possibilities for cooperation.

WSSD-U-2012 was attended by over 120 delegates from 26 countries, representing all geographical regions. A summary of the event and follow-up activities is as follows:

1. *Commitment to Universities towards sustainability*: perhaps one of the key messages from WSSD-U-2012 is that universities should make firm commitments at the institutional level and that researchers ensure they document, record and disseminate their work nationally and internationally, networking themselves and supporting each other. In doing so, they can measure progress and assess the extent to which things are improving over time. Since the various international declarations on sustainable development at universities prepared in the past have largely failed to yield any concrete benefit, a focus at the institutional level is likely to help to make a difference and show, on the ground, what is possible and what can be done.
2. As an attempt to promote and disseminate the work performed by attendees to WSSD-U-2012, the book "Sustainable Development at Universities: New Horizons" was launched in launched in September 2012, as Volume 34 of the series "Environmental Education, Communication and Sustainability" (Leal Filho 2012). This ground-breaking publication on the theory and practice of sustainable development, is one of the most comprehensive publications on sustainability at universities ever produced, focusing on both industrialised and developing nations.

A further scheme was the “Higher Education Sustainability Imitative for Rio+20”, which produced a Declaration, whose content is as follows:

> As Chancellors, Presidents, Rectors, Deans and Leaders of Higher Education Institutions and related organizations, we acknowledge the responsibility that we bear in the international pursuit of sustainable development. On the occasion of the United Nations Conference on Sustainable Development, held in Rio de Janeiro from 20–22 June 2012, we agree to support the following actions:
>
> - ***Teach sustainable development concepts***, ensuring that they form a part of the core curriculum across all disciplines so that future higher education graduates develop skills necessary to enter sustainable development workforces and have an explicit understanding of how to achieve a society that values people, the planet and profits in a manner that respects the finite resource boundaries of the earth. Higher Education Institutions are also encouraged to provide sustainability training to professionals and practitioners;
> - ***Encourage research on sustainable development issues***, to improve scientific understanding through exchanges of scientific and technological knowledge, enhancing the development, adaptation, diffusion and transfer of knowledge, including new and innovative technologies.
> - ***Green our campuses*** by: (i) reducing the environmental footprint through energy, water and material resource efficiencies in our buildings and facilities; (ii) adopting sustainable procurement practices in our supply chains and catering services; (iii) providing sustainable mobility options for students and faculty; (iv) adopting effective programmes for waste minimization, recycling and reuse, and (v) encouraging more sustainable lifestyles.
> - ***Support sustainability efforts*** in the communities in which we reside, working with local authorities and civil society to foster more liveable, resource-efficient communities that are socially inclusive and have small environmental footprints.
> - ***Engage with and share results through international frameworks***, such as the UN Decade of Education for Sustainable Development, led by UNESCO, the UN University system, the UN Academic Impact, the Global Compact, the UN-supported Principles for Responsible Management Education initiative and the UN Environment Programmes Environmental Education and Training initiatives, in order to exchange knowledge and experiences and to report regularly on progress and challenges (Higher Education Sustainability Initative for Rio+20).

The initiative is supported by the UN Academic Impact, UNESCO, the UN Environmental Programme, the Global Compact, PRME—Principles for Responsible Management Education—and the United Nations University. So far some 129 universities and over 30 networks, associations and student organisations in 43 countries have signed the declaration and the list is growing.

Moreover, “The People’s Sustainability Treaty on Higher Education” was also produced by a group of over 30 agencies, organisations and associations, aimed at influencing Rio+20 dialogues. These stakeholders are rooted in different regions of the globe and actively engaged in sustainable development at the higher education level. The partnership, led by Copernicus Alliance with the support of UNU IAS and the International Association of Universities generated the so-called “Higher Education Treaty for Rio+20”. This Treaty is one of a series of People’s Treaties developed to influence Rio+20 but also to make visible commitments across various sectors.

These initiatives illustrate the emphasis given to the implementation of research and educational programmes in the area of sustainable development in and by higher education institutions, with the aim of encouraging further and more active participation in this rapidly growing field.

4 Conclusions

The UN Conference on Environment and Sustainable Development has brought the discussion on sustainable development to new levels and achieved new heights. By recognizing that people should be at the centre of sustainable development, the event has provided a solid basis to promote sustained and inclusive economic growth, social development and environmental protection, worldwide. Universities are in this context able to provide a substantial contribution, and their engagement may promote integrated and sustainable management of natural resources and ecosystems on the one hand, but also foster economic, social and human development on the other, while facilitating ecosystem conservation. Whereas an intergovernmental process is currently underway to implement the recommendations from Rio+20 and universal sustainable development goals, universities can greatly support the implementation and monitoring of these processes.

References

Leal Filho W (ed) (2012) Sustainable development at Universities: New Horizons. Peter Lang Scientific Publishers, Frankfurt

United Nations (2012a) Report of the united nations on sustainable development. UN Publications Office, New York

United Nations (2012b) The future we want. UN Publications Office, New York

United Nations News Centre (2013) UN sets-up high-level political forum. Press Release, United Nations News Centre, New York

Part III
Invited Articles from Contributors to Poster Sessions of the Conference: Social Corporate Responsibility and Environment

Analysis of Mercury Pollution in Air in Urban Area of Riga Using Atomic Absorption Spectrometry

Egils Bogans, Janis Skudra, Anda Svagere and Zanda Gavare

Abstract

Toxicity of mercury and its compounds is well known, and they are considered as substances of heightened concern. Though mercury is to some extent released into the environment by natural processes such as volcanic eruptions, additional releases from anthropogenic sources have increased the environmental exposure and deposition significantly. There are many commonly used items containing mercury, for instance, mercury light bulbs, switches, and mercury thermometers, the disposal of which into trashcans can cause an increase of mercury concentration in the air of the local area. The paper reports mercury pollution surveys performed in several districts of Riga (the capital of Latvia). Using an RA 915+ Zeeman atomic absorption spectrometer, the concentration of mercury was measured in the air above objects of interest. The measurements mainly made from driving a car equipped with a GPS receiver have allowed the assignment of Hg concentration to a particular place to provide a digitised pollution database in geographic coordinates at different times. Results of the surveys show the background concentration of atmospheric mercury in Riga generally did not exceed 5 ng/m^3 while some places of increased mercury pollution need particular attention and clean-up. Examples of such surveys are shown.

Keywords

Environmental pollution · Mercury · Atomic absorption spectroscopy

E. Bogans (✉) · J. Skudra · A. Svagere · Z. Gavare
Laboratory of High-Resolution Spectroscopy and Light Source Technology,
Institute of Atomic Physics and Spectroscopy, University of Latvia,
Raina Blvd. 19, Riga, Latvia
e-mail: egils.bogans@gmail.com

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_15

1 Introduction

Mercury is a naturally available element, unique for its property to be the only liquid metal at room temperature. In nature it is normally found in a bound state as a part of minerals, e.g., in cinnabar. If those minerals are processed or otherwise destroyed, mercury is released into free circulation being dispersed through atmosphere, water and soil.

To some extent the release of mercury into environment is caused by natural processes such as volcanic eruptions. At the same time, due to its specific properties, mercury has been mined and is widely used by humans in industrial processes, medicine, etc., and allowed to spread with the products produced or as a by-product. Other human activities, like burning fossil fuels, also releases mercury, and presently such anthropogenic sources account for a significant share of increased environmental exposure and deposition (Hylander and Meili 2003; Lindberg et al. 2007).

Still, there is no essential biological function known to be performed by mercury, while mercury and its compounds are highly toxic and dangerous to human health for which reason a growing international effort is taken to limit the use of mercury and to stop the spread of mercury pollution. Part of such effort is the European Community Strategy Concerning Mercury (2010).

When significant anthropogenic sources of mercury are considered, a number of mercury uses are mentioned most often. Mercury pollution is still important in mercury mining regions, e.g., Almaden (Millán et al. 2006), Idrija (Kotnik et al. 2005), Guizhou (Qiu et al. 2006). Though intended to be phased-out, chlor-alkali process in some places is still in use for alkali production (Hylander and Meili 2003). Artisanal gold mining is a hard-to-replace economical factor in poor countries (Veiga et al. 2006). If previously mentioned uses are specific to particular locations and regions, consumption of fossil fuels—petrol and coal, is a wide-spread cause of anthropogenic mercury release all over the world (Sznopek and Goonan 2000).

In 2011 37 % of electricity in Latvia was produced by power plants using fossil fuels (Latvijas Statistika 2013)—but they are not of a significant size at the global scale and the major share of energy in Latvia is still being produced from renewable sources. There are no large industrial facilities that would use mercury in some form as a material or consumable. So, one might ask the question—what is the situation in Riga? Is mercury of concern in Latvia at all?

The paper provides information about a number of mercury monitoring efforts in Riga, the capital city of Latvia.

2 Experimental

An RA 915+ atomic absorption spectrometer employing Zeeman Effect and high-frequency modulation of light polarization to correct for background signal and to prevent undesired interferences was exploited for the surveys of mercury pollution.

The mercury 254 nm resonance band from a mercury light bulb placed into strong permanent magnetic field is split up into three differently polarized components (π, σ−, and σ+, respectively). With the π component being discarded, the σ− and σ+ beams of different but close wavelengths, one of which coinciding with the natural mercury absorption maximum, while the other being just off the normal mercury absorption curve, propagate along the same optical path. The difference between signal intensities from the two is measured by switching polarization. In absence of mercury in the analytical cell, intensities of both σ components are equal; when absorbing atoms appear in the cell, the difference between the intensities of the σ components increases with the mercury concentration. The device has been featured in several articles, e.g. Sholupov et al. (2010), and the method is approved by the European Standard 15852 (2010).

Important characteristics of the equipment include:

- High sensitivity with the mercury detection limit in air being between 1 and 2 ng/m^3.
- The ability to perform measurements in real-time right at the place of interest and the readout of measurements occurs each second.
- Portability, thus allowing measurements of mercury concentration to take place in the field without the need of pre-concentration or sample collection for later processing in lab—the analyser of dimensions of 460 × 210 × 110 mm itself weighs only 7.5 kg and can be carried in a haversack during the measurement process. Apart from using the standard 50/60 Hz AC outlet of 220/110 V it can be powered from a built-in 10/14 V DC source.

Though the equipment is suitable for completely portable hand-held use, the monitoring was often made driving a car to cover a wider area. In such cases, the coordinates of the particular location were registered by a Magellan Meridian Color or Magellan eXplorist GPS receiver and processed together with mercury concentrations as arrays of value-time data on a connected PC.

A custom-built inlet was placed in the side window of the car for monitoring mercury while driving the roadside air sampling being taken about 1.5 m above the ground. When measuring mercury on a pedestrian walk, the air was sampled at the height of about 0.7 m above the ground, and for specific objects—right above the area of interest within the distance of 2–5 cm.

The accuracy of measured mercury concentration depends on the on-site weather conditions, potentially showing diminished values due to dispersal by wind, and with detection boundary of the analyser set to the lowest limit of 1–2 ng/m^3. The accuracy of geographical location determined by the limitations of the GPS receivers was said to be within ±(3–10) m.

The visualisation of mercury concentration maps, where appropriate, was performed using the on-line service of GPSVisualizer.com (http://www.gpsvisualizer.com/map_input?form=data), which in turn relies on Google maps functionality.

Fig. 1 Mercury concentrations in Riga city centre (May 25, 2011, from drive-by car)

3 Background Air Concentration of Mercury in Riga

The numerous drive-around measurement sessions during 2005–2012 cover different seasons, weather conditions, and times of the day. Whilst the assembled dataset is not sufficient to provide a systematic view on temporal variations of mercury background concentration, it is nevertheless extensive enough for an estimate of the average overall mercury background concentration of 2–5 ng/m^3. The value is slightly higher than the overall background value of the Northern hemisphere (Lindberg et al. 2007), but quite reasonable for urban area. Locations where the values significantly reach out of that range can be considered as local pollution spots. An example of mapped concentrations in the central part of Riga is given in Fig. 1.

4 Detected Mercury Spills

Two spills of significant amounts of mercury in Riga have been detected and monitored.

On the 17th of June, 2005, the Leta news agency reported that 0.5 kg of liquid mercury had been scattered between living blocks on Spilves street over an area of around 30 m^2, the clean-up was ongoing at the time (Leta 2005). A drive-by measurement of mercury concentration was made after 3 days. The site was approached at a distance of up to approximately 10 m; because of high concentrations, no attempts to walk closer were made. Results are presented in Fig. 2.

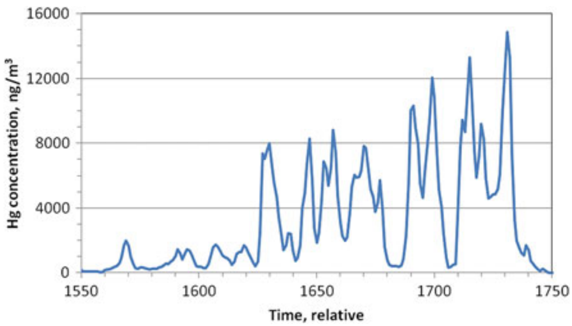


Fig. 2 Mercury concentrations in air on Spilves street (June 20, 2005, car drive-by only, no on-site walk)

The fluctuations of values measured in open space are caused by wind dispersing the mercury vapour, the maximum registered concentration being almost 15,000 ng/m^3. After 1.5 months, on the 2nd of August, 2005, the mercury concentration having diminished though, still reached peaks over 2800 ng/m^3. The mercury was observed being spread over surrounding footpaths in a star-like pattern by pedestrians crossing the spill area. Mercury concentrations exceeding 400 ng/m^3 were still found by measurements made on the 11th of April, 2006, 10 months after the spill. Measurements at the site were continued on a semi-regular basis throughout the following years providing a chart of maximum registered concentrations shown in Fig. 3 (Bogans et al. 2011). The authors supposed that after 6 years, the mercury spill would have evaporated, and the concentrations would have returned to background levels. However, the measurements of the 2nd of May 2012 (Fig. 4) still show mercury evaporating. Apart from the amount of mercury evaporated in the ambient air around the spill site, some mercury had accumulated in the nearby wastewater manhole. As shown in Fig. 5, evaporation in a closed space creates significant mercury concentrations therein.

Another significant spill in Riga known to the authors occurred on Gobas Street. On the 25th of April, 2012, the BNS agency reported approximately 0.5 l of liquid mercury having been spilled the day before near a bus stop (BNS 2012). A survey of the situation was made after 8 days. Results obtained from driving the car are presented in Fig. 6, with the maximum registered concentration being 354 ng/m^3.

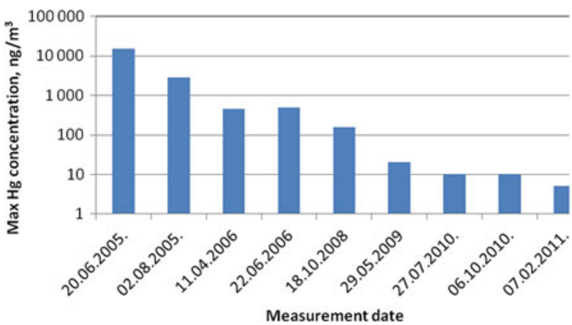


Fig. 3 Evolution of the registered Hg concentration maximums in air at Spilves street spill site

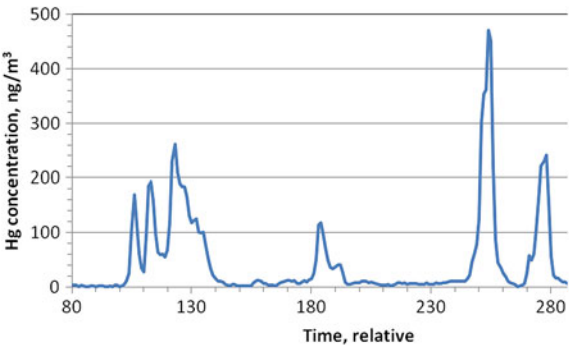


Fig. 4 Mercury concentration in air on Spilves street (May 2, 2012, on-site walk)

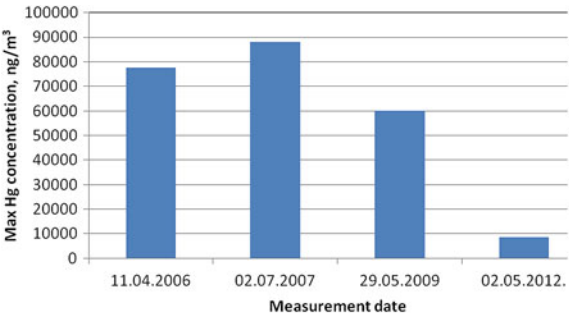


Fig. 5 Registered Hg maximum concentrations in air of wastewater manhole at Spilves street spill site

Fig. 6 Map-projected mercury concentration in air on Gobas street (May 2, 2012, registered from drive-by car)

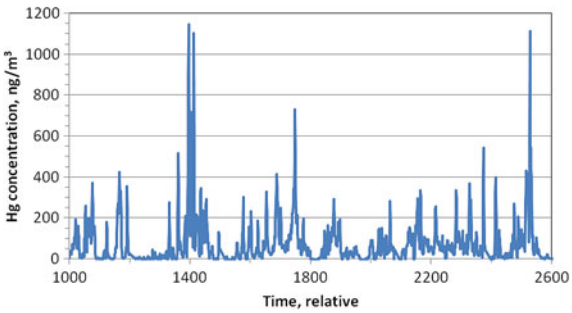


Fig. 7 Mercury concentration in air on Gobas street (May 2, 2012, walk over the street)

Investigating the site on foot revealed concentrations over 1100 ng/m^3 (Fig. 7). Nevertheless, despite the larger spill, even taking into account the time passed since the incident, the site was much cleaner compared with that on the Spilves Street, possibly due to specifics of the location—asphalted road surface instead of vegetation-covered soil.

5 Locations of Minor Mercury Pollution

Mercury spills such as the ones on Spilves and Gobas streets are not frequent; only small spots of somewhat higher mercury concentrations are usually found. Judging from the location and size of the contaminated area, they are mostly related to

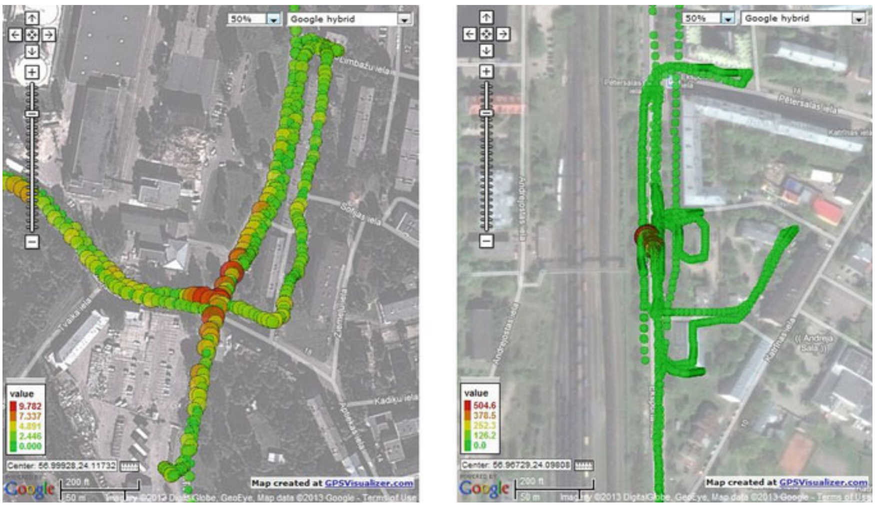


Fig. 8 Slightly increased Hg concentrations on the intersection of Tvaika and Aptiekas streets (February 7, 2011, from drive-by car)—*left*, and mercury pollution on Eksporta street (May 25, 2011, from drive-by car)—*right*

disposal of some mercury-containing waste. Examples of such places are shown in Fig. 8. Mercury being either scattered over some area (as in the case of Tvaika-Aptiekas intersection), or mixed with soil (e.g., on Exporta Street), the walk-around surveys of such sites usually do not provide much information about causes of the pollution.

6 Mercury in Waste

Many of the commonly used objects contain mercury, for instance, mercury lamps, switches, and mercury thermometers. Disposed objects are usually thrown into trashcans, that in turn go to landfill.

An investigation of waste delivered to landfills was made by measuring mercury concentration in air over arriving trucks transporting waste. Increased mercury concentrations were detected in one out of every 5 or 6 trucks (Gavare et al. 2007).

Medical services, especially dentistry (Shraim et al. 2011), are still widely using mercury. Accordingly, mercury is detected in medical waste. Measurements over trash cans around dentistry institutions have been presented by Bogans et al. (2006). Hopefully the situation now is changing for the better—Latvia participated in the recently finished UNDP project "Demonstrating and promoting best techniques and practices for reducing health-care waste to avoid environmental releases of dioxins and mercury", providing guidelines for handling dangerous waste and trying to raise the awareness of pollution to medical personnel.

The current trend to minimise energy consumption (thus minimising mercury emissions from burning fossil fuel) leads to increasing attention of another area—the increasing usage of so-called economy light-bulbs, which, albeit in small quantities, still contain mercury.

In 2011, attempts were made to determine locations of elevated mercury levels in dump-sites of waste to find eventual links with the origin of waste, which did not succeed since the used waste packaging practices scatter mercury over all the whole area of waste disposal making it impossible to trace the origin. The registered concentrations were wildly volatile in the range from the background level up to 90 ng/m^3.

The authors have been invited by the responsible personnel of wastewater processing facilities to investigate possible sources of mercury. In such facilities wastewater is treated by appropriate biological procedures, and the sludge produced as a side-product is delivered to landfills and used as fertiliser. Mercury in the waste ends up in the sludge and possibly on crop fields. Analysis of water is typically made with limited frequency, testing of multiple samples from different sources of the collection pipeline network taking much time and effort. To track the distribution of mercury pollution, the concentration of mercury was measured in the air of the pipeline network sub-stations. The results of session are presented in Fig. 9. Though it was not possible to quantify the amount of mercury directly in wastewater, the relative elevation of mercury concentration in air can be used as a strong indication that analysis of water from a particular object is necessary.

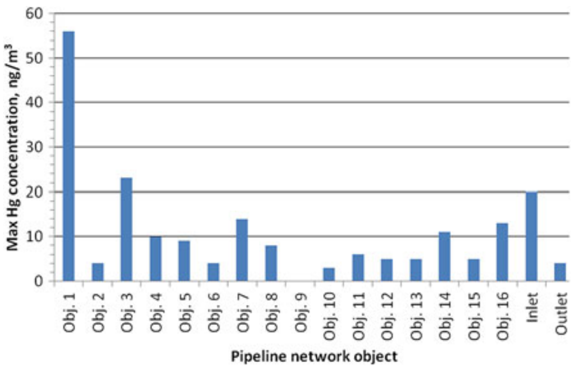


Fig. 9 Mercury concentrations in air over waste-water processing plant facilities (June 14, 2011)

7 Conclusion

Neither major pollution sources, nor indications that Riga has any significant overall mercury pollution have been discovered during the measurement sessions. Results of surveys show the background atmospheric mercury concentration in Riga not exceeding 5 ng/m^3. At the same time, larger and smaller localised pollution sites have been detected with some larger ones persisting for significant periods of time and, accordingly, requiring particular attention and clean-up.

Due to the nature of a global pollutant and bioaccumulation mercury is easily transferred over large distances and locations not having their own mercury sources may end up with significant pollution levels. It is therefore necessary to ensure ongoing monitoring of mercury concentrations even on a low-level scale.

Paying attention to waste collection and processing facilities contributing to mercury pollution is a welcome corporate responsibility. Hopefully professional groups, such as medical workers, will acquire skills of properly handling mercury and mercury derivatives.

What still remains an open question is the awareness of mercury as a harmful pollutant by the general public. Starting with small spills all around and especially with regard to both larger mercury spills mentioned in the paper having occurred in the Pardaugava region of Riga can hardly be attributed to some legal professional activity, and one might ask—where are the deposits of spare mercury stored and by whom?

Acknowledgments The work has been partially supported by the European Regional Development Fund project No. 2010/0260/2DP/2.1.1.1.0/10/APIA/VIAA/166.

References

BNS (Baltic News Service) news agency (2012) Starp dzīvojamajām mājām izlijis dzīvsudrabs. News item in Latvian on 25 Apr 2012

Bogans E, Briedis S, Gavare Z, Skudra A (2006) Mercury pollution determination in Riga. In: Abstracts of international conference EcoBalt 2006, pp 71–72

Bogans E, Gavare Z, Svagere A, Poikane R, Skudra J (2011) Mercury pollution exploration in Latvia with high-sensitivity zeeman atomic absorption spectrometry. Sci J Riga Tech Univ Environ Clim Technol 7:39–45

Communication from the Commission to the European Parliament and the Council (2010) On the review of the community strategy concerning mercury, Brussels 7 Dec 2010, COM (2010) 723 final

European Standard (2010) Ambient air quality. Standard method for the determination of total gaseous mercury. BS EN 15852:2010

Gavare Z, Bogans E, Skudra A, Svagere A (2007) Mercury pollution surveys in Riga (Latvia). In: Abstracts of 11th workshop on progress in analytical methodologies for trace metal speciation, Munster, Germany, p 78

Hylander LD, Meili M (2003) 500 years of mercury production: global annual inventory by region until 2000 and associated emissions. Sci Total Environ 304(1–3):13–27

Kotnik J, Horvat M, Dizdarevič T (2005) Current and past mercury distribution in air over the Idrija Hg mine region, Slovenia. Atmos Environ 39(39):7570–7579

Latvijas Statistika (2013) Electricity production, imports, exports and consumption. Official statistical information of State of Latvia, available online at www.csb.gov.lv/en/dati/electricity-production-imports-exports-and-consumption-mln-kwh-30667.html

Leta News Agency (2005) Starp dzīvojamajām mājām izlijis dzīvsudrabs. News item in Latvian on 17 June 2005

Lindberg S, Bullock R, Ebinghaus R, Engstrom D, Feng X, Fitzgerald W, Pirrone N, Prestbo E, Seigneur C (2007) A synthesis of progress and uncertainties in attributing the sources of mercury in deposition. Ambio 36(1):19–32

Millán R, Gamarra R, Schmid T, Sierra MJ, Quejido AJ, Sánchez DM, Cardona AI, Fernández M, Vera R (2006) Mercury content in vegetation and soils of the Almadén mining area (Spain). Sci Total Environ 368(1):79–87

Qiu G, Feng X, Wang S, Shang L (2006) Environmental contamination of mercury from Hg-mining areas in Wuchuan, northeastern Guizhou, China. Environ Pollut 142(3):549–558

Sholupov S, Pogarev S, Ryzhov V, Skudra A, Bogans E (2010) Zeeman AA monitors for determination of background mercury concentration in ambient air and gases without absorption traps. In: Proceedings of 15th international conference on heavy metals in the environment (15th ICHMET), Gdansk, Poland, pp 259–261

Shraim A, Alsuhaimi A, Al-Thakafy JT (2011) Dental clinics: a point pollution source, not only of mercury but also of other amalgam constituents. Chemosphere 84(8):1133–1139

Sznopek JL, Goonan TG (2000) The materials flow of mercury in the economies of the United States and the World. US Geological Survey Circular 1197, Version 1.0. Available online at http://greenwood.cr.usgs.gov/pub/circulars/c1197/

Veiga MM, Maxson PA, Hylander LD (2006) Origin and consumption of mercury in small-scale gold mining. J Clean Prod 14(3–4):436–447

Investigation of the Influence of Corporate Social and Environmental Responsibility on the Energy Efficiency of Russian Companies

Anastasia Pavlova

Abstract

Expansion of social and environmental responsibility of businesses is a trend recognised worldwide; companies perceive the corporate social and environmental responsibility (CSER) as a tool for reducing non-financial risks, increasing competitiveness, improving relations with the government and society. Meanwhile, in Russia the CSER is gradually growing in large corporations, particularly in the fuel and oil companies. The feature specific to the Russian version of CSER is a significant emphasis on the administrative approach and development of social responsibility taking place under the pressure by government. The paper considers the adaptation possibilities of Russian companies to the requirements of energy efficiency and energy saving in the emerging "green" economy as a new economic course. We used the results of surveys of managers of Russian companies and representatives of education and science institutions in 2011–2012.

Keywords

Energy efficiency · Low-carbon economy · Corporate social and environmental responsibility

A. Pavlova (✉)
Department of Industrial Ecology, University ITMO, Institute of Refrigeration and Biotechnologies, Lomonosova str., 9, Saint Petersburg 191002, Russia
e-mail: nastya.vasilyeva@gmail.com

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_16

1 Improving Energy Efficiency in the Context of "Green Economy" Development in Russia

The principles of "green economy" developed in the framework of sustainable development more than 20 years ago, as noted at the recent "Rio +20" conference, despite many failures and crises, continue developing and moving around the world, in particular as a result of acute energy problems caused by the shortage of fossil fuels and global climate change. Many countries are moving toward a new course of "green" or "low carbon" economic development in order to; change the structure of global fuel consumption, develop renewable energy and high-tech sectors of the economy and implement sustainable agriculture and water management. Development of the "green economy" should not only help to prevent the exhaustion of non-renewable natural resources, but also reduce the risks of environmental pollution, improve welfare and ensure environmental safety and social justice of the world population (Summing up the conference "Rio +20" 2012).

In our country, which has huge reserves of natural resources, the development of the "green" economy principles will require implementation of the existing potential of energy saving, energy efficiency, and technological upgrading of industries.

According to Russian researchers, extraction of fossil fuels per a capita was increased by 1.3 times, the part of reusing pollutants removed by gas treatment facilities was decreased by 6 %, the area of degraded land deduced from economic turnover amounted to 1.2 million hectares from 1995 to 2010 (Reteyum 2011). From 2002 to 2007, the energy intensity of the Russian economy has been decreasing by about 4.2 % per a year, and the estimated technical potential for energy efficiency was not less than 45 % of energy consumption in 2005. As of 2009, its implementation is equivalent to the extraction of approximately 57 % of oil and 54 % of natural gas with a corresponding reduction in greenhouse gas emissions by 2.9 % of the global amount. However, investments in the unit of primary energy produced by increasing the volume of its production, is about 2–3 times more the capital investments required to realise the potential of energy efficiency (Shoes 2009).

Despite the scientific and technological progress, a rapid implementation of technical capacity is almost impossible because of the need for new technologies, primarily in housing, industry and construction, mining and transportation of oil and natural gas, utilisation of associated gas, power generation, and in transport. It is required for systematic work on energy saving and energy efficiency in various sectors of the Russian economy. The work was actually started after adoption of the Federal Law 261 from 23.11.2009 "About energy saving and energy efficiency" and development of the National program of "Energy saving and energy efficiency until 2020" by the Ministry of Energy in 2010 (Federal Law 261 from 23.11.2009; The state program "Energy saving…" 2010).

Energy efficiency and conservation are currently among the most important strategic priorities for the technological development of Russia. The modernisation of the Russian economy has set an ambitious goal of reducing energy intensity in 2020 by 40 % compared to 2007, which will require not only a perfect management system of energy efficiency and energy saving, but also a greater environmental responsibility from producers.

The main areas of implementation of the planned large-scale issues are the housing sector and industry. The government mandates increased responsibility of companies for non-compliance with the standards of permissible environmental impact in order to stimulate transition to energy-saving and environmentally friendly technologies. The mandate also requires businesses to conduct energy audits, to install meters for energy accounting, to develop energy passports, to use eco-labels for energy consumption goods.

However, as mentioned in the materials of the "Energy passports development" seminar in St. Petersburg in 2012, within the framework of the Russian-British project of "Energy Efficiency business in St. Petersburg through the promotion of the use of energy passports", there is a significant bias in favour of expensive energy audits and energy passports (Dzekker 2012). The costs of the obligations are significant, even for sustainable and successful companies. Any questions about economic stimulation and development of energy saving, energy efficiency management, improvement of staff awareness, propaganda and education in energy efficiency are not considered by the legislation and not realised in the companies.

The shift to a "low-carbon" scenario, along with strengthening of the State environmental policy and use of traditional economic tools like taxes and penalties, will require companies to review priorities and goals in accordance with the concept of sustainable development. Encouraging compliance with the law and motivating the company to complete additional social and environmental obligations would not only improve its environmental reputation but would promote sustainable development and the gradual restructuring of Russian legislation. The best international experience and practices primarily from the European Union should be applied to advance the social and environmental corporate responsibility of Russian businesses.

2 Possible Advancement of Energy Efficiency as Part of Social and Environmental Responsibility of Russian Companies

To identify the readiness of Russian companies for transition to energy-efficient development a review of 37 enterprises and organizations was conducted in 2011–2012. About a third of them were large Russian companies stable in the market and the rest were sustainable Russian companies with 100 % of foreign capital. Respondents were top managers in the building materials industry as well as food, oil and gas, and electrical industries, representatives of research institutions, teachers as well as postgraduate students. The socio-demographic characteristics of respondents and characteristics of the enterprises they work with are shown in Tables 1 and 2.

The main purpose of the study was to test the hypothesis that the main driving force behind the advancement of social and environmental corporate responsibility for energy efficiency of Russian companies is the government, while in large

Table 1 The socio-demographic characteristics of respondents

Item	Share in the sample (%)
Gender	
Female	86
Male	14
Age	
17–24 years	37
25–29 years	26
30–39 years	14
40–49 years	11
50–59 years	9
60 years and over	3
Education	
Bachelor/Master	91
Degree	9
Position	
Manager, senior manager	40
Supervisor, specialist	16
Researcher/Teacher	44

corporations with foreign capital it is the pressure from foreign top management. The study was based on the participatory back-casting methodology, which is a type of a scenario approach (Quist and Vergragt 2006).

According to Pavlova (2012), this approach allows the creation of a desirable (sustainable) future vision or a normative scenario. This is then followed by looking back at how this desirable future could be achieved before defining and planning follow-up activities and developing strategies leading towards that desirable future.

A participatory back-casting approach has also been applied to focus on the diversity in views, visions, and interests among a wide range of stakeholders involved in a debate on different futures and a development strategy to achieve it.

In the survey, respondents were asked to identify the main problems of energy efficiency, to formulate the current trends and to describe the desired image of an energy-efficient company in the future. Furthermore, respondents were asked to describe the future possibilities of the development of the energy-efficient company.

Results of the survey showed solving the problems of energy efficiency development being constrained by several factors that can be classified as environmental, economic, political and cultural (Fig. 1).

The diagram shows the economic aspect being the main factor hindering development of energy-efficient companies. Respondents noted that lack of funding and lack of readiness to invest in projects with a payback period exceeding two years are slowing down development.

Despite the actions taken by the Government to promote energy efficiency, the businesses focus on the lack of a systematic approach to the issue. For example, according to the participants of survey, undertaking an energy audit and the

Table 2 Characteristics of enterprises and organizations having participated in the survey

Item	Share in the sample (%)
Company location (economic regions)	
Central	24
Southern	12
North-western	34
Far Eastern	3
Siberian	12
Urals	6
Volga	9
Branch	
Construction industry	10
Fuel and energy	7
Mining	7
Engineering	3
Metallurgy	3
Production of building materials	3
Electrical	7
Jewellery production	3
Food	14
Research institutions and universities	17
The services (environmental consulting)	26
The share of foreign capital	
Russian enterprises	73
Corporations with foreign capital	27

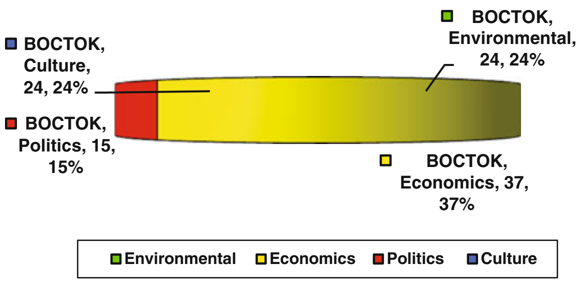


Fig. 1 Identification of the problems of energy efficiency development in the Russian enterprises

development of energy passports do not guarantee the implementation of energy saving measures. This is connected with the fact that existing incentive programs do not fully encourage organisations to implement energy-efficient innovations; there is no database of successful energy efficiency projects. The energy monitoring and control by the government of the implementation of energy-saving programs is not efficient.

Respondents have referred to geographical features of the country as the main factor affecting energy consumption and environment. The extremely cold climate and extent of communication networks have instigated a high energy intensity of the Russian economy by 2–4 times exceeding the energy intensity of GDP in Western countries.

A rather low awareness of experts about modern energy-efficient equipment and technologies, the lack of strategic corporate management of energy saving, a formal attitude of enterprises to energy audits and energy passport create cultural problems in developing measures of energy efficiency in Russia. Relating to Russian mentality, respondents have made statements like: "… we are rich with natural resources" and "… it's enough for my life".

Participants in the survey were asked to formulate the aspects stimulating enterprises to implement energy efficiency policies. Figure 2 shows that principally the economic factor gives a strong impetus to the dynamic development of energy efficiency in the companies. Companies are interested in reducing production costs by tax exemptions or subsidies for modernisation of the enterprise. In other words, managers expect development of the market approach, profitable energy efficiency programs supported by the government. However, today there is a strong administrative pressure on businesses through tariff increases and approval of new regulations and orders (Government Decree 442 from 04.05.2012) requiring that businesses install expensive automated systems for commercial energy accounting, as well as the introduction of energy passports with mandatory involvement of experts from outside. The economic incentives are closely connected with the political aspects given the second place of importance by respondents.

However, the cultural factor is no less important for the advancement of energy efficiency, especially increasing awareness of experts and the senior management and creating an energy saving culture by involvement of academics and experts in the development and implementation of programs in the companies. Respondents told about the need to divide responsibilities between the government, businesses, and society to achieve sustainable development.

Finally, respondents were asked to describe an ideal energy-efficient enterprise. According to representatives of business, the enterprise should be "… safe during all life cycle of the product", "… energy-independent, with its own alternative energy sources", "… absolutely transparent and with high level of corporate social

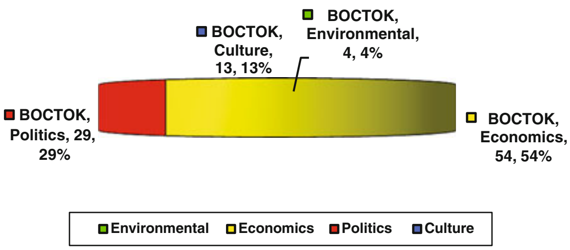


Fig. 2 Analysis of aspects stimulating development of energy efficiency in the Russian enterprises

and environmental responsibility," as well as "… have a strong integrated management system in which all targets are interrelated and connected with energy efficiency." A high competitiveness in the domestic and international markets, investment attractiveness, trust and loyalty from the government are identified by the participants as the main advantages of such enterprises.

3 Conclusion

Results of the survey confirm that the main driver of increasing the energy efficiency in companies, both Russian and foreign operating in the Russian Federation, is a government still devoted exclusively to traditional economic approach to management. However, the problem of energy efficiency in companies cannot be solved by using only traditional economic tools; it requires a significant change of business management and related changes in the thinking of the senior managers.

It should be noted that during the interviews the representatives of companies of successful social and environmental policies emphasised that corporate responsibility links environmental protection with saving energy. The systems approach to management allows the formation of the right strategy and energy efficiency programs by the companies to achieve its goals and objectives. Today it is extremely important that Russia makes an innovative breakthrough in the energy efficiency by means of an appropriate institutional environment to supporting the development of social and environmental corporate responsibility and sustainability of Russian businesses.

References

Dzekker N (2012) Improving energy efficiency of business in St. Petersburg, through the promotion of energy certificates. Access mode: www.ctcspb.ru

Federal Law 261 from 23.11.2009 (2009) About energy saving and energy efficiency. Russ Gazeta 5050:12–25

Government Decree 442 from 04.05.2012 (2012) On the functioning of retail electricity markets, complete and (or) partially limited power consumption mode. Access mode: www.respectrb.ru/node/3963

Pavlova A (2012) On the application of forecasting techniques for the development of social and environmental responsibility. Econ Environ Manage (Electronic resource: Electronic scientific journal) 1. Access mode: http://economics.open-mechanics.com

Quist J, Vergragt P (2006) Past and future of backcasting: the shift to stakeholder participation and a proposal for a methodological framework. Futures 38:1027–1045

Reteyum A (2011) Prospects for the development of "green" economy. In: Proceeding of prospects for a "green economy", Moscow, pp 14–32

Shoes I (2009) Russian energy resources: the scope, costs and benefits. Econ Issues 2:71–89

Summing up the conference "Rio +20" (2012). ECE J 10. Access mode: www.unece.org

The state program "Energy saving and energy efficiency for the period until the year 2020" (2010), Moscow. Access mode: www.rg.ru/2011/01/25/energosberejenie-site-dok.html

Part IV
Invited Articles from Contributors to Poster Sessions of the Conference: Science On/For Sustainable Development

Urban Trees: Which Future?

Ladislav Bakay

Abstract

Urban trees inevitably grow under conditions different from the conditions of the natural habitat. Compressed soil, bad water regime of soils, human activity, emissions and traffic reduce the life span of trees forcing researchers to select new species or cultivars for urban conditions. But, is this the right way? The article deals with a new technology of using different climbing plants in autonomous pots (vegetation units) and constructions at different urban sites. The new vegetation unit can solve problems at sites of bad soil, frequent traffic, and lacking space. The additional construction serving the climber as support can be designed in various shapes. Nutrition is supplied by hydroponic systems. A closed-soil growing system would eliminate the main problems of urban sites: water regime, soil compression, presence of solved salts. The new technology is economical and eco-friendly with the vegetation fulfilling all its functions.

Keywords

Urban vegetation · Hydroponics systems · Climbers

1 Introduction

The environment of urban areas is significantly different from the natural habitat of tree species. Conditions in such changed environment do not benefit the overall health and growth of woodland plants destroying their vitality (Balder et al. 1997;

L. Bakay (✉)
Faculty of Horticulture and Landscape Engineering, Department of planting design and maintenance, Slovak University of Agriculture, Tulipánová 7, 94901 Nitra, Slovakia
e-mail: lazlo.bakay@gmail.com

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_17

Kollár 2007). Urban sites are very heterogeneous, and different stresses or different degrees of stress may be present even at adjacent planting sites (Berrang et al. 1985). Kolařík et al. (2003) identified the main stress factors of the urban environment as follows:

1. Water availability in the soil
2. Air availability in the soil
3. Chemical properties of the soil and soil reaction
4. Soil contamination
5. Air pollution
6. Climatic conditions.

The stress factors are site specific and combinations of stress factors can occur. One of the crucial determinants of the urban soil is water deficiency (Whitlow and Bassuk 1987) or water excess (Berrang et al. 1985). Soil compaction can cause hypoxia or water deficiency, even if there is enough precipitation (Kolařík et al. 2005). Investigations by Poleno (1985) showed that 5 % of precipitation was infiltrated in compacted urban soils. Most of urban soils have anthropogenic origin, with higher pH reaction. All these factors lead to a decrease of nutrient uptake and a reduced rate of growth and vitality (Kolařík et al. 2003, 2005). Municipalities, researchers and growers try to solve the problems of urban trees in different ways:

1. Species selection: Urban tree selection and breeding programs were carried out on national and international levels (Schmidt 2010). In Germany the results are summarized in works such as the German GALK List, which is the official design manual for horticulturists and landscape architects. The future of possible breeding programs of urban trees in Central Europe was delineated by Climate–Specie–Matrix approach (Roloff et al. 2009). A greater plant diversity can be maintained if trees are selected by tolerance to stresses present at a specific site, rather than tolerance to all urban stresses (Berrang et al. 1985).
2. Bio-techniques are used to mitigate the unfavourable conditions of the urban habitat. There is a number of techniques and products facilitating increased growth, survival and vitality of urban trees including, the application of mycorrhizal fungi (Abbey and Rathier 2005), horizontal and vertical mulching (Arnold et al. 2005) or growth stimulators (Gilman 2004).
3. Alternative plantings (pot plantings, vertical plantings, roof gardens) are site specific where the spatial restrictions above and underground are not sufficient for growth of urban trees.

Although a lot of energy is invested into the problem of urban tree planting, the results are insufficient. Municipalities, landscape architects, and horticulturists fail to plant and maintain vital urban trees effectively in order to fulfill the functions of vegetation in urban environments. The high costs do not reflect the results.

2 Vegetation Units with Climbers: A Solution

The vegetation unit (Fig. 1) is more or less independent from the urban soil conditions. Due to separation of the vegetation unit from the soil we eliminate water scarcity and soil compaction and we promote nutrition uptake from the substrate. Rain water cannot flow into the vegetation pot. This can mechanically exclude the problems with thawing salts. Only fast growing climbing plants building up biomass in a short time are used in vegetation units. The optimal growing conditions for the plant are regulated by the content of nutrients and water through a dispenser. The growth of the vegetation unit is shaped by a construction for climbing plants, the shape being site specific. The climbing plants are easy to maintain and do not threaten pedestrians and property. There are no problems with statics, which is a major problem when considering urban tree plantings. Only plants of fast growth are suitable for this kind of planting, such as *Humulus lupulus* L., *Clematis vitalba* L., *Fallopia baldshuanica* (Regel) Holub. The potential of these undemanding, frugal plants should be used efficiently, especially in areas such as the urban landscape.

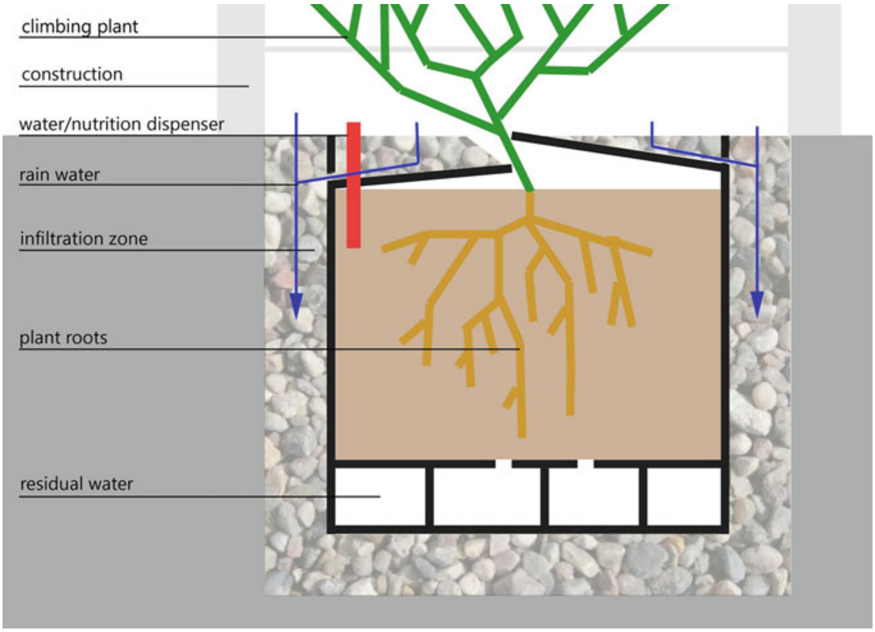


Fig. 1 Schematic section of the vegetation unit

References

Abbey T, Rathier T (2005) Effects of mycorrhizal fungi, biostimulants and water absorbing polymers on the growth and survival of four landscape plant species. J Environ Hortic 23: 108–111

Arnold MA, McDonald GV, Bryan DL (2005) Planting depth and mulch thickness affect establishment of green ash (*Fraxinus pennsylvanica*) and bougainvillea goldenraintree (*Koelreuteria bipinnata*). J Arboric 31:163–167

Balder H, Ehlebracht K, Mahler E (1997) Strassen Bäume—Planen, Pflanzen, Pflege am Beispiel Berlin. Patzer Verlag, Berlin, pp 54–60

Berrang P, Karnosky FD, Stanton BJ (1985) Environmental factors affecting tree health in New York City. J Arboric 11(6):185–189

Gilman EF (2004) Effects of amendments, soil additives, and irrigation on tree survival and growth. J Arboric 30:301–310

Kolářik J, Hora D, Pešout P, Businský R, Burian S, Bulíř P, Jech D, Žďárský M, Smýkal F, Wágner P, Reš B (2003) Péče o dřeviny rostouci mimo les—I. ČSOP Vlašim, pp 66–67

Kolářik J, Martinková M, Čermák M, Gebauer R, Špinlerová S, Dienstbier F, Horáček P, Praus L, Cudlín P, Krejčiřík P, Reš B, Romanský M, Jankonský L, Beránek J, Čermák P, Lička D, Wessolly L (2005) Péče o dřeviny rostouci mimo les—II. ČSOP Vlašim, pp 66–67

Kollár J (2007) The harmful entomofaunaof woody plants in Slovakia. Acta Entomologica Serbica 12(1):67–79

Poleno Z (1985) Příměstské lesy. Státní zemědělské vydavatelství, Praha, p 176

Roloff A, Korn S, Gillner S (2009) The Climate-Species-Matrix to select tree species for urban habitats considering climate change. Urban Forest Urban Greening 8:295–308

Schmidt G (2010) Breeding of urban trees at Corvinus University of Budapest. In: Acta horticulturae et regiotecturae, vol 13. Slovenská poľnohospodárska univerzita, Nitra, pp 55–57

Whitlow HT, Bassuk NL (1987) Trees in difficult sites. J Arboric 13(1):10–17

Preparation and Characterisation of Novel Biodegradable Material Based on Chitosan and Poly(Itaconic Acid) as Adsorbent for Removal of Reactive Orange 16 Dye from Wastewater

Aleksandra R. Nesic, Antonije Onjia, Sava J. Velickovic and Dusan G. Antonovic

Abstract

Environmental protection has been a topic of great interest in recent years. Discharging azo dyes in aquatic systems contaminates water and causes serious ecological problems. Azo dyes are bio-accumulative, and, due to allergenic, carcinogenic and mutagenic properties, are a grave threat to people and the environment. Because of economic feasibility, simplicity and a high efficiency, adsorption is the most suitable process for treatment of wastewater. The increasingly interesting bio-degradable adsorbents are those that stem from ecologically and economically sustainable sources. The aim of the study is preparation and characterisation of polymer complexes based on naturally occurring polysaccharide-chitosan and poly(itaconic acid), as an adsorbent for removal of Reactive Orange 16 dye from wastewater. The complexes are characterised by Fourier-Transform Infrared Spectroscopy and Scanning electron microscopy. The effect of initial dye concentration, temperature and pH value of the solution on the adsorption capacities is investigated. Comparison of the obtained results with reported data shows the studied complex being an efficiently replacement for conventional adsorbents removing Reactive Orange 16 from wastewater.

Keywords

Chitosan · Poly(itaconic acid) · Adsorption · Azo dye

A.R. Nesic (✉) · A. Onjia
Institute for Nuclear Science, University of Belgrade, Belgrade, Serbia
e-mail: anesic@vin.bg.ac.rs

S.J. Velickovic · D.G. Antonovic
Faculty of technology and metallurgy, University of Belgrade, Belgrade, Serbia

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_18

1 Introduction

Dyes have become one of the main sources of severe water pollution as a result of the rapid development of the textile industry. Dyes are primarily based on substituted aromatic and heterocyclic groups and are represented by a wide range of different chemical structures. A large part of textile dyes in use nowadays is azo compounds that contain an azo bridge in the structure. The removal of these dyes from water is very important for environmental health. Adsorption of dyes onto various materials appears to be a good way for treatment of wastewaters where even a minuscule amount of remaining dye can endanger existing bio-systems. Discharging even a small amount of dye into water can affect aquatic life and food webs due to carcinogenic and mutagenic effects of azo dyes (Stephen et al. 2006). The search for a low-cost adsorbent of high adsorption capacity is the main task of promoting a large-size efficient adsorption process. Essential advantages of such materials is being biodegradable and easily applied regardless of the scale (Gong et al. 2005; Saiano et al. 2005; Hameed et al. 2008; Crini 2005).

As a natural polymer, chitosan is one of the most promising materials for adsorption of dyes and metal ions due to the presence of amine and hydroxyl groups serving as active sites (Kamari et al. 2011; Hu et al. 2006). It is nontoxic, biodegradable, hydrophilic, and insoluble in water, alkali and organic solvents. Chitosan is the N-deacetylated derivative of chitin—a naturally abundant polysaccharide and supporting material of crustaceans, insects, etc. It is easily obtained from crustacean shells (such as prawns and crabs), insects and fungi (Hamdine et al. 2005; Wan Ngah and Isa 1998). Chitosan and its derivatives have been widely studied as sorbents for dyes (Kumar et al. 2010; Hasan et al. 2008; Huang et al. 2011; Copello et al. 2011).

The sorption capacity of chitosan-based materials depends on the origin of the polysaccharide, the degree of N-acetylation, molecular weight and solution properties and varies with crystallinity, affinity for water, percent of deacetylation and content of amino groups. The main drawback of chitosan as an adsorbent is its pH sensibility. Depending on pH, it can gel, swell or dissolve (Chiou et al. 2004). In acidic solution, amine groups present in chitosan are protonated, which induce an electrostatic interaction between these group and dye molecules. Otherwise, chitosan has very poor sorption capability in alkaline solution. Another problem with chitosan is its poor physicochemical characteristics, in particular porosity. These disadvantages can be somewhat remedied by complexation of synthetic polyacid electrolytes with chitosan (Smitha et al. 2004; Kolodynska 2012; Dai et al. 2010). A very attractive choice among synthetic polyacid electrolytes is poly(itaconic acid) (PIA), because it has two negatively charged carboxylic groups in a macromolecular unit, and also because it is obtained from bio-renewable resources (Aspergillus itaconicus, Aspergillus terreus yeasts from molasses or starch) (Riscaldati et al. 2000; Kirimura et al. 1997). So it is presumed that PIA would be a more effective reactant than other polyacid electrolytes, such as poly(acrylic acid), poly(maleic acid), poly(3-

methacryloyloxypropane-1 sulfonic acid), poly(4-vinylbenzoic acid), which contain just a single anionic acid group (Sugama and Cook 2000).

The aim of this study is the application of chitosan and PIA complex that can be used as adsorbent for Reactive Orange 16 dye. This dye is widely employed for dyeing silk and cotton, so there is a great interest in removing this dye from industrial wastewaters. The chitosan's free amine groups form hydrogen bonds with carboxylic groups from PIA, and make stable complexes in different pH solution.

2 Experimental

2.1 Materials

Chitosan (low viscous) was obtained from Acros Organic and used without any further purification. According to the producer data, its molecular weight is 100 000–300 000 g/mol, degree of deacetylation 80 %.

Poly(itaconic acid) (PIA) was prepared in our laboratory by polymerization of aqueous solution of itaconic acid in 0.1 M HCl (Molar mass of the obtained PIA, measured by limiting viscosity number was $\bar{M}_v = 48$ kDa) by our previously reported procedure (Velickovic et al. 2008). Reactive Orange 16 (also known as Remazol Brilliant Orange 3R, or Bezactiv Orange V-3R) was a gift from Bezema AG and was used as received.

2.2 Preparation of the Adsorbent

The complex of chitosan and PIA was prepared by mixing solutions of the two constituents. Chitosan (1 wt%) was dissolved in 2 % acetic acid at 50 °C and the obtained solution was mixed with PIA solution (1 wt%). The PIA amount in final mixture was 10 % by mass. The obtained mixtures were dried to constant mass at 40 °C, and films were obtained.

The obtained complex film was investigated by FTIR on a Bomem MB 100 FTIR spectrophotometer from KBr pellets. SEM/EDX was used to investigate the morphology of the prepared complexes. Measurements were taken on a JEOL JSM-5800 scanning electron microscope.

2.3 Adsorption Batch Experiments

Experiments were carried out by adding 15 mg of film into 50 ml of dye solution with desired concentration, temperature of solution and appropriate pH. The effect of dye concentration was investigated at pH = 6, at 20 °C for the concentration range of 30–100 mg/L. For pH dependence studies, 50 ml of 80 mg/L dye solution was adjusted to pH ranging from 4–7.4. The effect of temperature on adsorption of dyes was studied at 8, 20, 37 and 55 °C at 80 mg/L dye concentration.

Capacity of the adsorbed dye was calculated according to equation:

$$q_e = (C_0 - C_e)\frac{V}{m} \tag{1}$$

where q_e (mg/g) is the amount of dye adsorbed on the film, C_0 (mg/L) is the initial concentration of dye, C_e is the equilibrium concentration of dye in solution, V(L) is volume of the used dye solution and m(g) is the mass of the used film. Each experiment was repeated three times under the same controlled conditions.

3 Results and Discussion

3.1 FTIR Characterisation

In order to confirm formation of the complex between chitosan and PIA, FTIR studies were conducted. Figure 1 presents the FTIR spectra of pure chitosan, and the complex of chitosan/PIA 90/10 before and after adsorption of the Reactive Orange 16 azo dye. The characteristic peaks of chitosan are located at 3441 and at 1641 cm^{-1}—the hydroxyl and amide groups, respectively. The hydroxyl and amide group frequencies in the complex are shifted to 3427 and 1670 cm^{-1}, respectively. Formation of a new peak at 1583 cm^{-1} in the spectra of chitosan/PIA complex is assigned to the symmetric $–NH_3^+$ bond' indicating the complexation between these two polymers. The new peak around 1580 cm^{-1} is evidenced in a similar system—chitosan/poly(acrylic acid) blend as reported by Smitha et al. (2004). The authors suggested that this may be assigned to the symmetric $–NH^{3+}$ deformation resulting

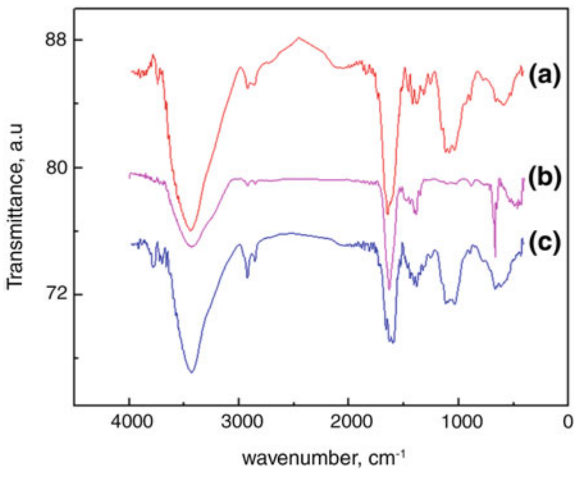


Fig. 1 FTIR spectra of pure chitosan (**a**), loaded chitosan/PIA 90/10 complex (**b**), and unloaded chitosan/PIA 90/10 complex (**c**)

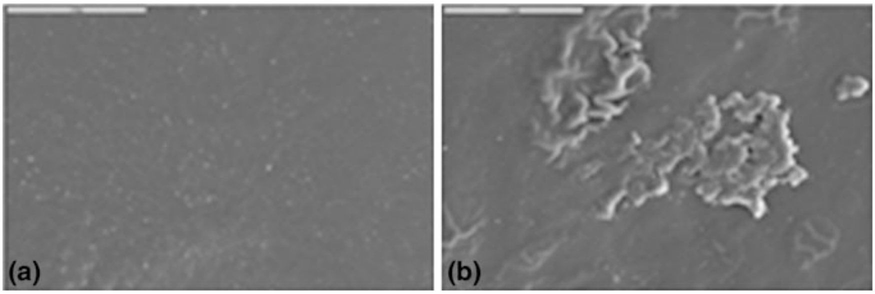


Fig. 2 SEM micrograms of chitosan/PIA 90/10 (**a**) chitosan/PIA 90/10 after adsorption of the dye (**b**). Increasing was 20 μm

by blending the two polymers. Comparing the FTIR spectra of unloaded and loaded chitosan/PIA complex, the peaks for characteristic hydroxyl, amide and amine groups are shifted to lower wavenumbers indicating involvement of these groups in adsorption.

3.2 Scanning Electron Microscopy

In order to determine the morphological characteristics of chitosan/PIA complexes and changes in surface morphology of these complexes after adsorption of the Reactive Orange 16 dye, scanning electron microscopy (SEM) was used (Fig. 2). The micrographs of complexes indicate smooth structure where the PIA domains are scatered in a form of small dots through homogenous chitosan matrix. Adsorption of the dye is not completely uniform but is in form of clusters.

3.3 Effects of Dye Concentration, pH and Temperature on Adsorption Capacity

The dye adsorption kinetics were studied at initial dye concentrations of 30, 50, 80 and 100 mg/L. The dependences of q_e versus t are shown in Fig. 3. It can be seen that the adsorption capacity increases with the increase of dye concentration, and it reaches the maximum at 288 mg/g at dye concentration of 80 mg/L.

Figure 4 shows the adsorption capacities of the Reactive Orange 16 onto chitosan/PIA complexes in different pH solutions. The adsorption capacity increases with the increase of pH from 4–6, then decreases in alkaline solution. These results are expected because in the case of chitosan, the pKa value of the amino group ($R{-}NH_2$) in the structure of chitosan is 6.3 (Uzun 2006), so at lower pH values the deacetylated amino groups in chitosan will be protonated to form $-NH_3^+$ groups and subsequently interact with the sulfonyl groups of acid dye to form the $NH_3^+ \ {}^{-}O_3SR$ organic complex. In other words, at acidic pH values protonated

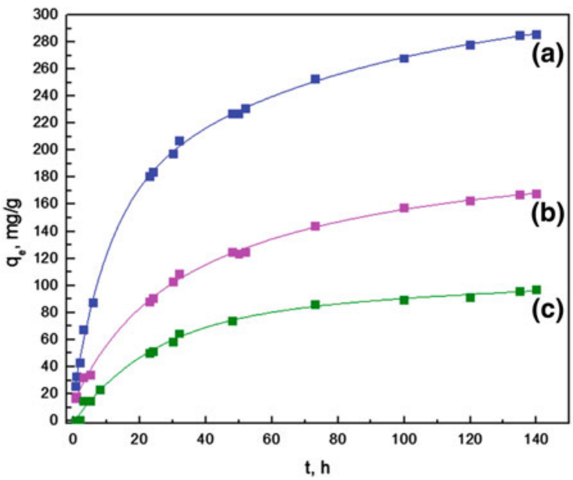
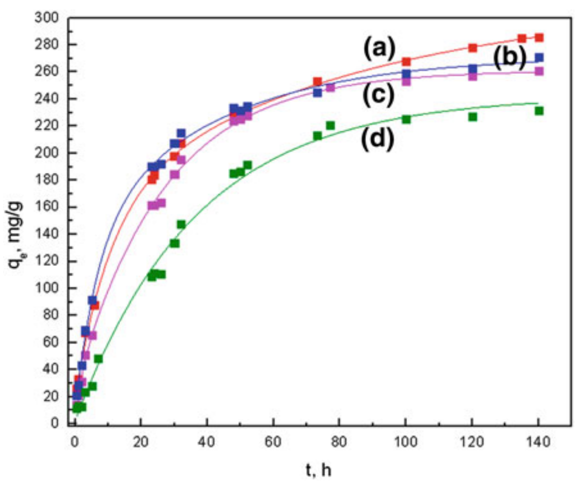


Fig. 3 Adsorption capacity of Reactive Orange 16 onto chitosan/PIA complex at initial concentrations of 80 ppm (**a**), 50 ppm (**b**) and 30 ppm (**c**). Adsorbent mass 15 mg; pH = 6

amino groups will enhance the electrostatic attractions between dye anions and adsorption sites of chitosan and increase dye adsorption (Guibal 2004; Yoshida et al. 1991). The adsorption capacity decreases in alkaline solution because of deprotonating amine groups in chitosan, resulting in poor reaction between adsorbent and dye.

The effect of temperature on adsorption of Reactive Orange 16 dye onto chitosan/PIA complex is shown in Fig. 5. An increase of temperature from 8 to 37 °C increases adsorption capacity. At further increases in the temperature of the

Fig. 4 Adsorption capacity of Reactive Orange 16 onto chitosan/PIA complex at different pH values of the solution: pH = 6 (**a**), pH = 5 (**b**), pH = 4 (**c**) and pH = 7.4 (**d**). Initial concentration—80 ppm, mass of adsorbent—15 mg



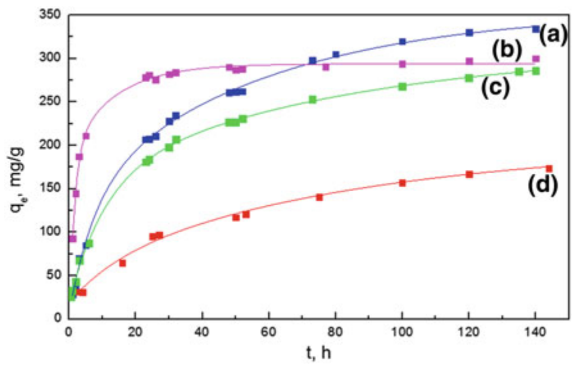


Fig. 5 The effect of temperature on the adsorption capacity of the Reactive Orange 16 dye onto chitosan/PIA complex at 37 °C (**a**), 55 °C (**b**), 25 °C (**c**) and 8 °C (**d**). Initial conditions: concentration of dye—80 ppm, mass of adsorbent—15 mg

Table 1 Comparison of adsorption capacities of the studied system reported with published data of other adsorbents for removal of the Reactive Orange 16 dye

Sorbent	Adsorption capacity (mg/g)	Reference
Carbon adsorbents prepared from Brazilian-pine fruit shell	239	Calvete et al. (2010)
Sludge	159	Won et al. (2006)
Ethylenediamine modified rice hull	16	Ong et al. (2007)
Activated carbon	97	Furlan et al. (2010)
Coffee husk-based activated carbon	76	Ahmad and Rahman (2011)
Organofunctionalised kenyaite	33	Royer et al. (2009)
Chitosan/PIA	288	The present study

solution up to 55 °C adsorption capacity decreases, the time needed for the sample to attain equilibrium is significantly shorter. This is mainly due to a decrease of surface activity and ion mobility suggesting that adsorption of the Reactive Orange 16 onto chitosan/PIA complex at 55 °C is an exothermic process.

The Comparison of the results of removal of the Reactive Orange 16 dye obtained in the present study with published data of other adsorbents are presented in Table 1. As seen from the table, the H/PIA 90/10 film has a better adsorption capacity than pure montmorillonite and other sorbents used to remove Reactive Orange 16. These films can efficiently replace conventional sorbents for dye removal.

4 Conclusions

The aim of this study was to develop a new sorbent based on chitosan and poly (itaconic acid) for removal of the Reactive Orange 16 dye from wastewater. A complex of chitosan and PIA was prepared by mixing solutions of 90 % chitosan and 10 % PIA by mass and the adsorption kinetics of the Bezactiv Orange dye onto the complex studied as a function of concentration, pH and temperature. Chitosan in combination with PIA has a good adsorbing capacity under low acidic conditions, which is the main disadvantage of pure chitosan as sorbent. Adsorption capacity increases with the increase of the dye concentration in the solution reaching its maximum at 37 °C temperature of the dye solution. Due to decreasing surface activity and ion mobility adsorption capacity decreases at further increase of temperature of the dye solution.

Acknowledgments The authors acknowledge the Ministry of Science, Technology and Development of the Republic Serbia for funding the Science Projects No. 43009 and 172062.

References

Ahmad MA, Rahman NK (2011) Equilibrium, kinetics and thermodynamic of Remazol Brilliant Orange 3R dye adsorption on coffee husk-based activated carbon. Chem Eng J 170:154–161

Calvete T, Lima EC, Cardoso NF, Vaghetti JCP, Dias SLP, Pavan FA (2010) Application of carbon adsorbents prepared from Brazilian-pine fruit shell for the removal of Bezactiv Orange 16 from aqueous solution: Kinetic, equilibrium, and thermodynamic studies. J Environ Manage 91:1695–1706

Chiou MS, Ho PY, Li HY (2004) Adsorption of anionic dyes in acid solutions using chemically cross-linked chitosan beads. Dyes Pigm 60:69–84

Copello GJ, Mebert AM, Raineri M, Pesentia MP, Diaz LE (2011) Removal of dyes from water using chitosan hydrogel/SiO2 and chitin hydrogel/SiO2 hybrid materials obtained by the sol–gel method. J Hazard Mater 186:932–939

Crini G (2005) Recent developments in polysaccharide-based materials used as adsorbents in wastewater treatment. Prog Polym Sci 30:38–70

Dai J, Yan H, Yang H, Cheng R (2010) Simple method for preparation of chitosan/poly(acrylic acid) blending hydrogel beads and adsorption of copper(II) from aqueous solutions. Chem Eng J 165:240–249

Furlan FR, de Melo da Silva LG, Morgado AF, de Souza AAU, Ulson de Souza SMAG (2010) Removal of reactive dyes from aqueous solutions using combined coagulation/flocculation and adsorption on activated carbon. Resour Conserv Recyc 54:283–290

Gong R, Ding Y, Li M, Yang C, Liu H, Sun Y (2005) Utilization of powdered peanut hull as biosorbent for removal of anionic dyes from aqueous solution. Dyes Pigment 64:187–192

Guibal E (2004) Interactions of metal ions with chitosan-based sorbents: a review. Sep Purif Technol 38:43–74

Hamdine M, Heuzey MC, Begin A (2005) Effect of organic and inorganic acids on concentrated chitosan solutions and gels. Int J Biol Macromol 37:134–142

Hameed BH, Mahmoud DK, Ahmad AL (2008) Equilibrium modeling and kinetic studies on the adsorption of basic dye by a low-cost adsorbent: coconut (Cocos nucifera) bunch waste. J Hazard Mater 158:65–72

Hasan M, Ahmad AL, Hameed BH (2008) Adsorption of reactive dye onto cross-linked chitosan/oil palm ash composite beads. Chem Eng J 136:164–172

Hu ZG, Zhang J, Chan WL, Szeto YS (2006) The sorption of acid dye onto chitosan nanoparticles. Polymer 47:5838–5842
Huang XY, Mao XY, Bu HT, Yu XY, Jiang GB, Zeng MH (2011) Chemical modification of chitosan by tetraethylenepentamine and adsorption study for anionic dye removal. Carbohydr Res 346:1232–1240
Kamari A. Pulford ID, Hargreaves JSJ (2011) Binding of heavy metal contaminants onto chitosan: an evaluation for remediation of metal contaminated soil and water, J Enviro Manage 92: 2675–2682
Kirimura K, Sato T, Nakanishi N, Terada M, Usami S (1997) Breeding of starch-utilizing and itaconic-acid-producing koji molds by interspecific protoplast fusion between Aspergillus terreus and Aspergillus usamii. Appl Microbiol Biotechnol 47:127–131
Kołodynska D (2012) Adsorption characteristics of chitosan modified by chelating agents of a new generation. Chem Eng J 179:33–43
Kumar Konaganti V, Kota R, Patil S, Madras G (2010) Adsorption of anionic dyes on chitosan grafted poly(alkyl methacrylate)s. Chem Eng J 158:393–401
Ong ST, Lee CK, Zainal Z (2007) Removal of basic and reactive dyes using ethylenediamine modified rice hull. Biores Technol 98:2792–2799
Riscaldati E, Moresi M, Federici F, Petruccioli M (2000) Effect of pH and stirring rate on itaconate production by Aspergillus terreus. J Biotechnol 83:219–230
Royer B, Cardoso NF, Lima EC, Ruiz VSO, Macedo TR, Airoldi C (2009) Organofunctionalized kenyaite for dye removal from aqueous solution. J Colloid Interface Sci 336:398–405
Saiano F, Ciofalo M, Cacciola SO, Ramirez S (2005) Metal ion adsorption by Phomopsis sp. biomaterial in laboratory experiments and real wastewater treatments. Water Res 39: 2273–2280
Smitha B, Sridhar S, Khan AA (2004) Polyelectrolyte complexes of chitosan and poly(acrylic acid) as proton exchange membranes for fuel cells. Macromolecules 37:2233–2239
Stephen B, Chiu CP, Ho GH, Yang J, Chen BH (2006) Removal of cationic dyes from aqueous solution using an anionic poly-glutamic acid-based adsorbent. J Hazard Mater 137(1):226–234
Sugama T, Cook M (2000) Poly(itaconic acid)-modified chitosan coatings for mitigating corrosion of aluminum substrates. Prog Organic Coat 38:79–87
Uzun I (2006) Kinetics of the adsorption of reactive dyes by chitosan. Dyes Pigment 70:76–83
Velickovic SJ, Dzunuzovic ES, Griffiths PC, Lacik I, Filipovic J, Popovic IG (2008) Polymerization of Itaconic Acid Initiated by a Potassium Persulfate/N,N-Dimethylethanolamine System. J Appl Polym Sci 110:3275–3282
Wan Ngah WS, Isa IM (1998) Comparison study of copper ion adsorption on chitosan dowex A-1 and zerolit 225. J Appl Polym Sci 67:1067–1070
Won SW, Choi SB, Yun YS (2006) Performance and mechanism in binding of Bezactiv Orange 16 to various types of sludge. Biochem Eng J 28:208–214
Yoshida H, Fukuda S, Okamoto A, Kataoka T (1991) Recovery of direct dye and acid dye by adsorption on chitosan fiber-equilibria. Water Sci Technol 23:1667–1676

Multiscale Integrated Evaluation of Agricultural Systems. An Extended LCA Approach

Amalia Zucaro, Silvio Viglia and Sergio Ulgiati

Abstract
The overall goal of the present study is to find integrated patterns and synergies among different approaches for the evaluation of complex production systems. In order to merge the different methodological, spatial and time-scale perspectives, an extended LCA framework (SUMMA, *Sustainability Multi-method Multi-scale Assessment*) is developed and tested focusing on the dynamics and performance of the agricultural sector in Italy. The SUMMA framework builds on LCA inventory and results complemented by the quality and time perspectives of the Emergy Synthesis method by which the free renewable flows, embodied time, direct and indirect labour, as well as economic and quality aspects are accounted for. The study, carried out within the EU funded SMILE project, is aimed at developing an integrated evaluation tool taking into account environmental, economic and social aspects, identification of drivers for change, and potential synergies. The development of an integrated model is crucial: the flows of energy and materials, land use, the rate of using resources, interrelations of socioeconomic and natural systems, and the time and spatial scales are all interlinked and cannot be evaluated separately without losing generality and wholeness. Most often, the economic performance, due to links with employment and social parameters (economic and social sustainability), is the aspect considered with more interest by policy

A. Zucaro (✉) · S. Viglia · S. Ulgiati
Department of Sciences and Technology,
University of Naples Parthenope, Naples, Italy
e-mail: amalia.zucaro@uniparthenope.it

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_19

makers and managers. Nevertheless, a comprehensive assessment cannot disregard environmental aspects and use of resource being important requisites of sustainability for the evaluation of different sectors or processes.

Keywords
Life cycle assessment · Agriculture · Integrated evaluation · SUMMA

1 Introduction and Background

Environmental degradation and depletion of natural resources induced by human activities have caused growing concerns in the last thirty years having made evident the need for planning authorities to rely on sound information about possible environmental consequences of the policy and development actions. A widespread tool to meet such a demand for environmental information is represented by Life Cycle Assessment (LCA) (ISO 14040:2006, 14044:2006). This internationally standardised method is based on systematic identification and evaluation of resource use and environmental impacts generated by a process or a system. LCA accounts for matter and energy flows occurring under human control, while flows outside of market dynamics (such as environmental services) as well as flows which are not associated to significant matter and energy carriers (such as the information content of labour and human services) are not generally included. The Emergy Synthesis method was suggested as a way to expand the focus of LCA by including the direct and indirect contributions provided by environmental flows to dynamics of a system or process (Ulgiati et al. 2011, 168–176). The Emergy approach evaluates and brings into the LCA the free environmental flows provided by nature, the time needed for the resource regeneration within the biosphere cycles, the economic flows associated to human labour as well as those associated to goods and resources from outside the system. The latter are assumed as a measure of indirect labour and information or, in other words, a measure of the societal infrastructures and activities supporting the investigated process (Ulgiati et al. 2007, 1–14). In order to apply the Emergy Synthesis in association with other upstream and downstream methods, an extended LCA, named SUstainability Multi-method Multi-scale Assessment (SUMMA), has been developed by Ulgiati et al. (2006, 432–442; 2011, 168–176).

The LCA/SUMMA takes into account the different methodological, spatial and time-scale perspectives to describe and explain performance and constraining factors of the process under investigation; it also simultaneously applies optimisation strategies at all levels of the hierarchical network of the system. Compared to usual and standardised life cycle procedures, SUMMA brings into the LCA the broader time and spatial scale of the emergy approach (with inclusion of renewable sources), and, at the same time, it also includes the economic assessment through the evaluation of direct and indirect labour (services) in monetary and emergy terms.

In the present study the application of the integrated assessment by LCA/SUMMA is focused on evaluation of the dynamics and performance of the Italian agricultural sector.

Many aspects must be considered to obtain a global picture of an agricultural system: materials and energy that support it, products that are delivered to and consumed by the society, material flows that need to be disposed, economic dynamics, waste energy, and emissions. All these aspects are consistently integrated within the LCA/SUMMA framework to generate a set of performance indicators identifying the strengths and weaknesses as well as showing the impact generated in terms of depletion of resources and downstream consequences.

2 Materials and Methods

The complex interactions and metabolism of agricultural systems require development of an integrated model for analysis taking into account all the imported and local flows (energy and materials), parameters and rates of resources use, land use and land use change, configuration, processes, interrelations of socioeconomic and natural systems at different hierarchical levels, and finally scenarios related to choices of policy and technologies.

2.1 The Accounting Framework

LCA/SUMMA is based on the joint application of different evaluation methods, which can be divided in two broad categories (Fig. 1): those that are focused on the amount of resources supplied ("upstream" methods), and those that deal with the consequences of the system's operations ("downstream" methods).[1] The 'upstream' methods are concerned with the impacts on the input side, and account for the use and/or depletion of environmental resources (minerals, energy, natural capital and environmental services), while the 'downstream' methods are applied to the outputs, and look at the environmental consequences of the emissions in all steps. The upstream methods selected in the LCA/SUMMA approach are *Material Flow Accounting, Embodied Energy Analysis* and *Emergy Accounting*, while the downstream methods are based on the inventory of main airborne and waterborne emissions (estimated according to CORINAIR 2007) as well as of solid waste and heat release. The main impacts were modelled with reference to the *CML2 baseline 2000* framework (Leiden, 2000). Each individual assessment method is applied

[1]This "upstream" and "downstream" categorisation is different from the usual "foreground" and "background" categorisation used in LCA. The latter refers to the typology of data used, respectively indicating if they are under the direct control of the process operator or not (JRC 2010), while the former focuses on the aggregate methods used to describe the impacts. The two viewpoints are complementary and come into play in two different steps of the analysis (Impact Assessment and Inventory).

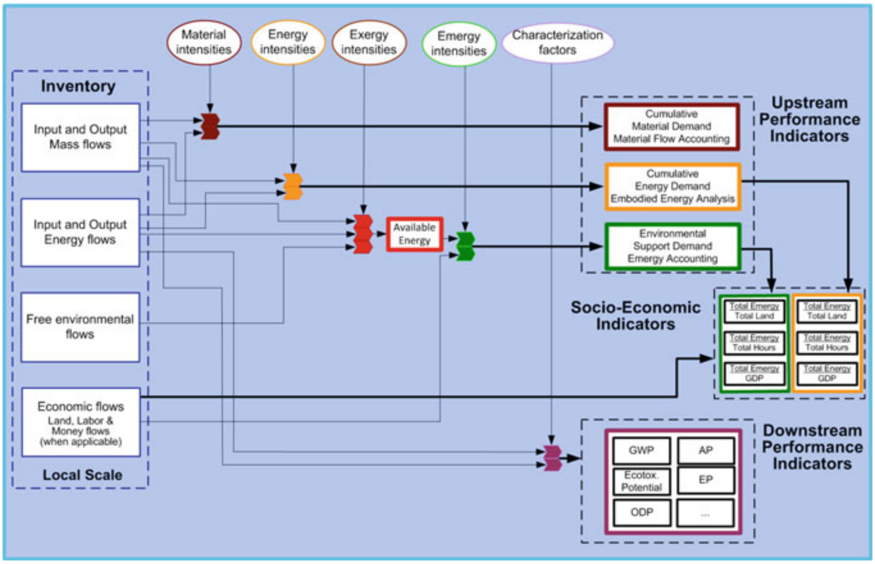


Fig. 1 The flow chart of SUMMA (SUstainability Multimethod Multiscale Assessment) (Zucaro 2011)

according to its own set of rules. Detailed description of each method can be found in Ulgiati et al. (2006, 432–442; 2011, 168–176).

The analysed system or process is treated as a "black box" and a thorough inventory of all input and output flows is firstly performed on its local scale. Such inventory is the common basis for all subsequent impact assessments carried out in parallel and ensuring maximum consistency of the input data with the inherent assumptions. In this way calculated upstream and downstream indicators provide a complete and consistent picture of the driving forces supporting the system and allow a clear understanding of its performance and the main sources of inefficiency.

2.2 The Agricultural System

The LCA/SUMMA approach was applied to the Italian agricultural sector across levels from local scale (olive, lemon and grape farms) to regional scale (Campania region) up to the national scale (Italy). The evolution over time (from 1985 to 2006) was also investigated to understand how the performance and demand for resources have changed in the last two decades.

The agricultural sector in Italy is still a very important economic, environmental and social activity supporting a large fraction of people directly involved in agricultural production and agro-industrial manufacture of food. Campania region, due to the highly fertile volcanic soil, is one of the best in Italy for agricultural productivity and high quality, water availability and climate. The entire agricultural system was investigated at the national and regional levels. On the farm scale the focus was placed on the three most important crops grown in the Campania region—grapes, olives and lemon. These crops are important from two different points of view: the economic value of the products ("limoncello" liquor from lemon farms; olive oil from olive farms; wine from vineyards) and the amount of land used, i.e., 20 % of the total cropped area in Campania region. All data for the three different levels were provided by ISTAT (1985, 1993, 2001, 2006) at the national and regional scales, as well as by local and regional agencies and statistical surveys (at local scale).

3 Results

Assessments were made at three different levels:

- The Italian agricultural sector as a whole, hereafter referred to as level $n + 1$;
- The Campania region (southern Italy), hereafter referred to as level n;
- Selected individual farms in the Campania region, hereafter referred to as level $n - 1$.

Evaluation at levels n and $n + 1$ was made by monitoring performance (1985, 1993, 2002, 2006 for both regional and national scales). Unfortunately, due to the lack of statistical environmental and energy data of the individual farms, such monitoring was not feasible at level $n - 1$. The three levels ($n + 1$, n, $n - 1$) are separately presented hereafter. Time trends are discussed, when applicable. Results at all the three levels $n + 1$, n and $n - 1$ in 2006 are compared on unit area (1 ha) basis.

3.1 National Scale: Performance of the Italian Agricultural Sector Over Time

Inventory of the Italian agricultural sector is provided in Table 1. Fertilisers, chemicals, fuels and electricity, irrigation water, machinery and labour are the main items driving development of the sector over time. Services (indirect labour and information inferred from the total economic cost of all items used in the process) are also an important factor to be accounted for. Indeed, services are a measure of resources supporting previous activities of designing, manufacturing and delivering goods and resources to the process (including infrastructures and societal organisation). Each item of the process is identified by its raw amount and associated services that made its supply possible.

Table 1 shows a steady decline of agricultural land use (about 20 % less in 2006 compared to 1985). In Northern Italy this trend is mainly linked to the expansion of built environment (roads, cities, commercial areas) and industrial activities, while in the South, due to illegal disposal of waste and industrial chemicals, the role of land pollution is far from negligible. The total mass of agricultural production (dry

Table 1 Direct supply, land use and products in the Italian agricultural sector from 1985 to 2006

Flows	Unit	1985	1993	2002	2006
Total land cropped	ha/year	1.70E+07	1.50E+07	1.45E+07	1.37E+07
Rainfall	g/year	1.19E+17	9.71E+16	1.09E+17	1.03E+17
Nitrogen (N)	g/year	1.01E+12	9.45E+11	8.51E+11	8.27E+11
Phosphate (PO_4)	g/year	6.10E+11	6.39E+11	4.27E+11	3.61E+11
Potassium (K_2O)	g/year	3.40E+11	3.91E+11	3.19E+11	2.94E+11
Fungicides	g/year	8.39E+10	9.48E+10	9.06E+10	7.35E+10
Insecticides	g/year	3.45E+10	3.37E+10	3.27E+10	2.28E+10
Acaricides	g/year	1.94E+09	8.49E+08	3.14E+10	1.82E+10
Electricity	J/year	1.18E+16	1.66E+16	1.76E+16	1.98E+16
Water for irrigation	g/year	7.89E+15	4.64E+15	3.41E+15	2.35E+15
Liquid fuels	J/year	7.92E+16	1.04E+17	8.46E+16	9.60E+16
Machinery	kg/year	2.58E+08	2.32E+08	2.25E+08	2.17E+08
Direct labor	h/year	2.19E+09	2.00E+09	1.88E+09	1.75E+09
Direct labor	€/year	4.58E+09	8.31E+09	1.61E+10	1.75E+10
Indirect labor (services)	€/year	3.43E+09	5.54E+09	6.46E+09	8.11E+09
Products					
Mass of agricultural production (dry matter)	g d.m./year	1.25E+14	1.12E+14	1.03E+14	9.63E+13
Energy content of agricultural production	J/year	2.02E+18	1.81E+18	1.66E+18	1.55E+18
Economic value of agricultural production	€/year	1.85E+10	2.26E+10	2.73E+10	2.53E+10
Agricultural residues	t d.m./year	7.81E+06	7.01E+06	6.42E+06	6.02E+06

matter) had also decreased (about 23 %), from 1.25×10^8 dry tons/year in 1985 to 9.63×10^7 dry tons/year in 2006. In spite of the increasing use of nitrogen fertilisers (about 2 %), potassium fertilisers (about 7 %), fungicides, insecticides, acaricides, and pesticides (in total an approximate increase of 18 %), the productivity of the Italian agriculture decreased by 5 % over the investigated period. A gradual decrease of the applied human labour (from 2.16×10^9 to 1.75×10^9 h/year) is also evident from Table 1, with an overall shift to a more intensive use of machinery (about 5 % more, from 1985 to 2006).

From the point of the economic profitability, the net income (economic value of production minus economic value of labour and services) gradually decreased from 10,500 M€/year in 1985 to a net loss of 270 M€/year in 2006, launching alarming signals about the ability of agriculture to provide any income to farmers and entrepreneurs in the near future. Instead, at regional level the average net income, although slightly declining, is still positive.

Table 2 Selected performance indicators of the Italian agricultural sector (1985–2006)

Indicators	1985	1993	2002	2006
Material resource depletion				
Abiotic material intensity per unit mass ($g_{abiot}/g_{d.m.}$)	0.55	0.61	0.60	0.63
Abiotic material intensity per unit currency (g_{abiot}/€)	3.69E+03	3.02E+03	2.27E+03	2.39E+03
Water material intensity per unit mass ($g_{water}/g_{d.m.}$)	65.56	44.48	36.37	27.92
Water material intensity per unit currency (g_{water}/€)	4.43E+05	2.21E+05	1.37E+05	1.06E+05
Total abiotic material requirement (g/year)	6.83E+13	6.82E+13	6.21E+13	6.07E+13
Total water demand (g/year)	8.19E+15	4.98E+15	3.73E+15	2.69E+15
Energy resource depletion				
Gross energy requirement per unit mass ($J/g_{d.m.}$)	2.21E+03	2.63E+03	2.52E+03	2.76E+03
Gross energy requirement per unit currency (J/€)	1.49E+07	1.30E+07	9.47E+06	1.05E+07
Oil equivalent per unit mass ($g_{oil}/g_{d.m.}$)	0.05	0.06	0.06	0.07
Oil equivalent per unit currency (g_{oil}/€)	357	311	226	250
EROI (energy of products/total embodied energy applied)	7.30	6.15	6.42	5.86
Emergy, demand for environmental support				
Specific emergy per unit mass (with L and S) ($seJ/g_{d.m.}$)	6.07E+08	7.34E+08	9.68E+08	1.11E+09
Specific emergy per unit currency (with L and S) (seJ/€)	4.10E+12	3.64E+12	3.64E+12	4.23E+12
Emergy yield ratio (with L and S) = U/(F + L + S)	1.14	1.11	1.10	1.08
Environmental loading ratio (with L and S) = (N + F + L + S)/(R)	8.41	11.49	12.40	14.39
%REN (with L and S)	0.11	0.08	0.07	0.06
Emergy sustainability index = EYR/ELR (with L and S)	0.14	0.10	0.09	0.08
Total emergy, U = (R + N + F + L + S) (seJ/year)	7.59E+22	8.23E+22	9.94E+22	1.07E+23
Climate change				
Global warming per unit mass (CO_2-equiv, $g/g_{d.m.}$)	0.17	0.20	0.18	0.20
Global warming per unit currency (CO_2-equiv, g/€)	1156	987	692	760
Acidification per unit mass (SO_2-equiv, $g/g_{d.m.}$)	5.82E−04	7.39E−04	1.17E−03	1.22E−03
Acidification per unit currency (SO_2-equiv, g/€)	3.93	3.67	4.40	4.62

To generate performance indicators, inventory data from Table 1 were converted into cumulative material demand, cumulative energy demand, environmental support, and cumulative emissions. The main calculated indicators (Table 2) include:

- extensive indicators: cumulative abiotic material requirement, cumulative water requirement, and demand of total environmental support, among others;
- intensive indicators: abiotic material intensity and water intensity (i.e., abiotic matter and water used and degraded in all the steps of the process); energy intensity (demand of embodied commercial energy); emergy intensity (global environmental work supporting the process); airborne and waterborne emission intensities (according to selected LCA impact categories). These indicators are calculated in relation to selected functional units (namely: produced dry mass, generated gross income, energy in the product; hours of invested labour; area of cropped land), but only the first two typologies (per unit mass and unit income) are shown;
- performance indicators: EROI (Energy Return on Investment, a measure of the energy advantage gained), EYR (Emergy Yield Ratio, a measure of ability to exploit local emergy resources), ELR (Environmental Loading Ratio, a measure of distance from renewable development), ESI (Emergy Sustainability Index, an integrated measure of economic and environmental sustainability), %REN (the fraction of renewable emergy used).

As seen from Table 2, one euro of GDP generated by the agricultural product in 2006 required about 2.4 kg of abiotic matter, 106 m^3 of water, 10.5 MJ of energy (approximately 250 g of oil equivalent), and 4.23×10^{12} solar equivalent joules of environmental work for resource generation. The same euro of GDP produced global-warming emissions equal to about 760 g of CO_2-equivalents and contributed 4.6 g of SO_2-equivalents to the acidification of rainfall. The final product was characterised by an EROI (Energy Return on Investment) equal to about 5.8:1 in the same year, while its ESI (Emergy Sustainability Index) was as low as 0.08, determined by a low reliance on local resources (EYR = 1.08) per unit of large scale loading intensity (ELR = 14.4).

These results and other performance indicators (Table 2) can be used for comparison of the system's performance over time or with other national systems or finally for comparison with smaller scale (regional and local) systems. An appropriate selection of indicators from Table 2 is graphically shown as a radar diagram in Fig. 2. To compare data of different orders of magnitude in the same radar, a normalisation procedure was applied (all values are presented in relation to 1985 considered as reference year) in such a way the size of the area shows a measure of the overall environmental impact associated to each year.

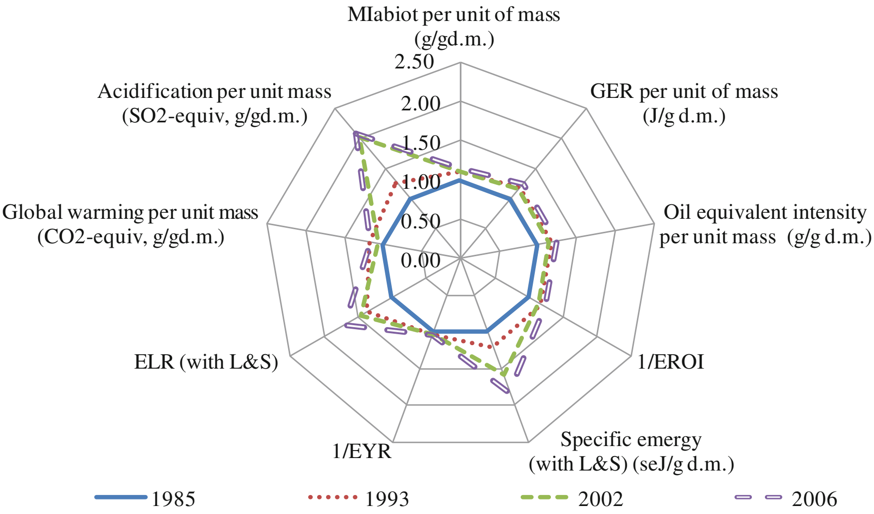


Fig. 2 The radar diagram shows selected upstream and downstream indicators of Italian agriculture over time. Values are normalised from Table 2 with reference to the first year of investigation (1985). As a consequence, they are dimensionless units. Real units are those reported in Table 2

3.2 The Regional Agricultural System: Case Study of Campania

The case study of the agricultural sector of Campania region (Southern Italy) was performed in a similar way of national system analyzing its performance over a time span of 20 years. Calculated performance indicators are listed in Table 3.

A comparison radar diagram with selected upstream and downstream performance indicators from Table 3 is shown in Fig. 3. A normalisation procedure was applied so that a larger area suggests a higher impact.

Figure 3 provides a pictorial assessment of the increasing impact of regional agriculture. The calculated performance per unit of dry matter of the product shows worse indicators, except for water consumption and Emergy Yield Ratio which remaining more or less constant.

Extensive indicators per hectare (cumulative abiotic material, cumulative water use, total emergy) always show decreasing trends at both national and regional scales that mainly follow the decreasing trend of cropped land (Tables 2 and 3). Most intensive indicators were calculated per unit of mass and per unit of generated income. LCA results per unit of dry mass show increasing depletion of abiotic resource over time at the national and regional levels, while water demand steadily decreases. Global Warming Potential and Acidification Potential increase over time at both scales. The demand for environmental support (measured in emergy units) also increases over time. The same indicators, calculated per unit of generated gross income, always show decreasing trends at national and regional levels some

Table 3 Selected performance indicators of Campania Region agricultural sector (1985–2006)

Indicators	1985	1993	2002	2006
Material resource depletion				
Abiotic material intensity per unit mass ($g_{abiot}/g_{d.m.}$)	0.30	0.24	0.60	0.57
Abiotic material intensity per unit currency (g_{abiot}/€)	2.31E+03	1.84E+03	1.28E+03	1.30E+03
Water material intensity per unit mass ($g_{water}/g_{d.m.}$)	38.38	18.88	32.27	23.67
Water material intensity per unit currency (g_{water}/€)	2.98E+05	1.43E+05	6.91E+04	5.43E+04
Total abiotic material requirement (g/year)	3.53E+12	3.16E+12	3.14E+12	2.88E+12
Total water demand (g/year)	4.57E+14	2.45E+14	1.70E+14	1.20E+14
Energy resource depletion and energy efficiency				
Gross Energy Requirement per unit mass ($J/g_{d.m.}$)	1.24E+03	1.32E+03	2.80E+03	2.97E+03
Gross Energy Requirement per unit currency (J/€)	9.65E+06	9.97E+06	6.00E+06	6.82E+06
Oil equivalent per unit mass ($g_{oil}/g_{d.m.}$)	0.03	0.03	0.07	0.07
Oil equivalent per unit currency (g_{oil}/€)	230	238	143	163
EROI (energy of products/total embodied energy applied)	13.41	12.59	5.78	5.28
Emergy, demand for environmental support				
Specific emergy per unit mass (with L and S) ($seJ/g_{d.m.}$)	3.71E+08	3.96E+08	9.48E+08	1.06E+09
Specific emergy per unit currency (with L and S) (seJ/€)	2.89E+12	2.99E+12	2.03E+12	2.42E+12
Emergy yield ratio (with L and S)	1.16	1.10	1.09	1.08
Environmental loading ratio (with L and S)	7.58	12.66	13.25	15.26
%REN (with L and S)	0.12	0.07	0.07	0.06
Emergy sustainability index = EYR/ELR (with L and S)	0.15	0.09	0.08	0.07
Total Emergy (with L and S), U = (R + N + F + L + S) (seJ/year)	4.42E+21	5.15E+21	4.99E+21	5.38E+21
Climate change				
Global warming per unit mass (CO_2-equiv, $g/g_{d.m.}$)	0.10	0.10	0.20	0.21
Global warming per unit currency (CO_2-equiv, g/€)	754	761	435	491
Acidification per unit mass (SO_2-equiv, $g/g_{d.m.}$)	3.04E−04	3.30E−04	6.27E−04	6.24E−04
Acidification per unit currency (SO_2-equiv, g/€)	2.36	2.50	1.34	1.43

oscillations being due to the variability of market prices. Finally, most performance indicators (EROI, EYR, ESI) steadily decrease at both levels. The ELR grows up twice from 1985 to 2006 for both investigated systems.

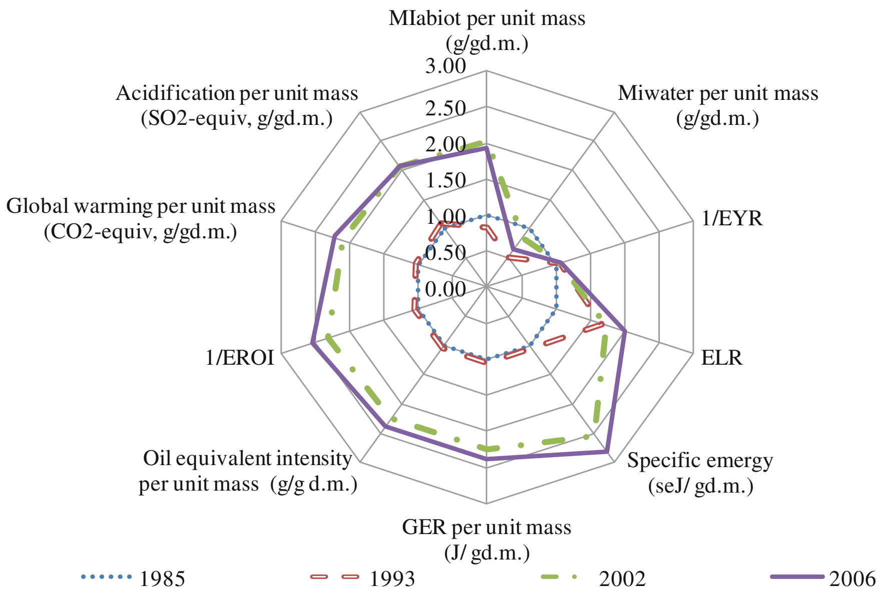


Fig. 3 Radar diagrams with selected upstream and downstream performance indicators of the agricultural system of Campania region over time. Values are normalised with reference to 1985, so that the diagram has dimensionless units. Real units are those reported in Table 3

3.3 The Local Agricultural System: Selected Farms

To investigate the local level of agricultural sector in Italy the lemon, olive and grape farms were selected as the most representative typologies of agricultural productions in Campania region. In so doing the calculated performance indicators are specific of each individual crop, not an average production as for the regional and national scales. Selected indicators for the three farms are listed in Table 4 and compared in Fig. 4 (normalisation applied with reference to the total impact generated: each point in the radar diagram was calculated by dividing the value of the indicator I_j by the sum of all the values ΣI_j in each dataset) so that a larger area in the diagram again suggests a higher relative impact.

3.4 Comparison Across Levels

For a better understanding the dynamics of the agricultural sectors the national, regional and local scales were compared (Table 4).

For the sake of clarity, a functional unit of one ha of cropped land in 2006 is used as a reference in Table 4. Of course, at the national and regional levels such a functional unit refers to an average of different crops, while at the local level it

Table 4 Indicators of agricultural performance per hectare in Italy, Campania region and selected farms (2006)

	Italy	Campania	Lemon	Olive	Grape
Material resource depletion					
Abiotic material intensity per unit mass ($g_{abiot}/g_{d.m.}$)	0.63	0.57	3.18	2.37	2.14
Abiotic material intensity per currency unit (g_{abiot}/€)	2390	1300	606	1570	1760
Water material intensity per unit mass ($g_{water}/g_{d.m.}$)	27.92	23.67	442.22	9.30	6.60
Water material intensity per currency unit (g_{water}/€)	1.06E+05	5.43E+04	8.44E+04	6.17E+03	5.42E+03
Total abiotic material requirement (g/ha/year)	4.43E+06	4.78E+06	1.00E+07	5.50E+06	6.34E+06
Total water demand (g/ha/year)	1.96E+08	2.00E+08	1.39E+09	2.16E+07	1.95E+07
Energy resource depletion					
Gross energy requirement per unit mass ($J/g_{d.m.}$)	2.76E+03	2.97E+03	1.60E+04	1.17E+04	1.06E+04
Gross energy requirement per currency unit (J/€)	1.05E+07	6.82E+06	3.06E+06	7.76E+06	8.69E+06
Oil equivalent per unit mass ($g_{oil}/g_{d.m.}$)	0.07	0.07	0.38	0.28	0.25
Oil equivalent per currency unit (g_{oil}/€)	250	163	73	185	208
EROI (energy of products/total embodied energy applied)	5.86	5.28	0.27	2.19	1.24
Emergy, demand for environmental support					
Specific emergy per unit mass (with L and S) ($seJ/g_{d.m.}$)	1.11E+09	1.06E+09	1.24E+10	1.07E+10	1.02E+10
Specific emergy per currency unit (with L and S) (seJ/€)	4.23E+12	2.42E+12	2.36E+12	7.07E+12	8.35E+12
Emergy yield ratio (with L and S)	1.08	1.08	1.02	1.02	1.02
Environmental loading ratio (with L and S)	14.39	15.26	62.11	53.70	49.30
%REN (with L and S)	0.06	0.06	0.02	0.02	0.02
Emergy sustainability index (with L and S)	0.08	0.07	0.02	0.02	0.02
Total Emergy (with L and S), $U = (R + N + F + L + S)$ (seJ/ha/year)	7.83E+15	8.93E+15	3.90E+16	2.47E+16	2.91E+16
Climate change					
Global warming per unit mass (CO_2-equiv, $g/g_{d.m.}$)	0.20	0.21	1.17	0.87	0.79
Global warming per currency unit (CO_2-equiv, g/€)	760	491	224	578	645
Acidification per unit mass (SO_2-equiv, $g/g_{d.m.}$)	1.22E−03	6.24E−04	4.08E−03	3.04E−03	2.74E−03
Acidification per currency unit (SO_2-equiv, g/€)	4.62	1.43	0.78	2.01	2.25

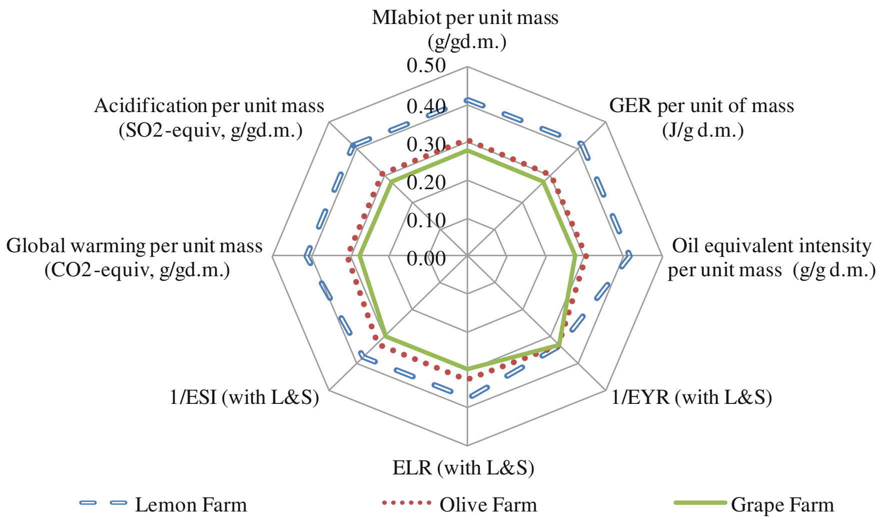


Fig. 4 Radar diagrams with selected upstream and downstream performance indicators of the investigated farms in Campania region on hectare basis (year 2006). Values from Table 4 are normalised

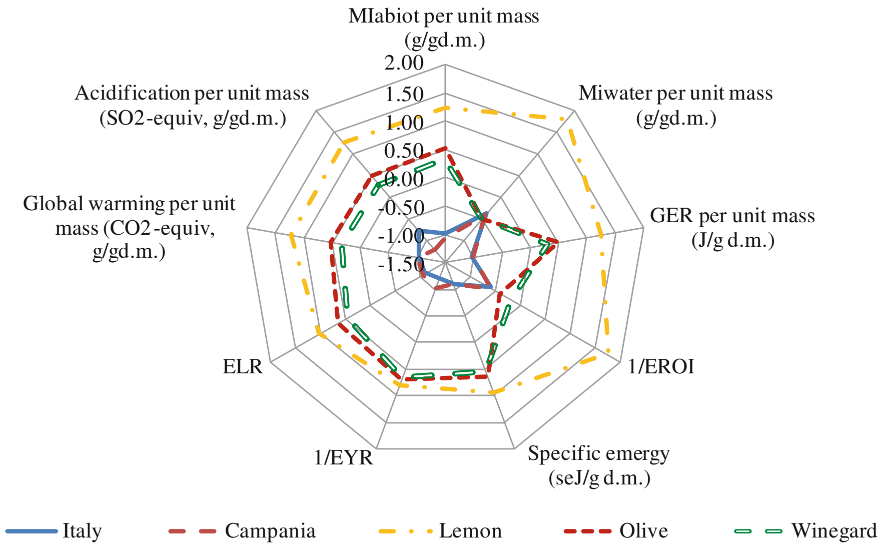


Fig. 5 The radar diagram of performance indicators per hectare in Italy, Campania and local farms (lemon, olive and vineyard) in 2006. Values from Table 4 are normalised

refers to specific crops and production practices. The main factors affecting the operation of the investigated systems and their performance indicators are the choice of crops mix, machinery use, climate (mainly rainfall), and market value of products and labour. The normalised calculated performance indicators are presented in the diagram in Fig. 5.

Because of the lack of data, the comparison of the three arboriculture farms (Table 4; Figs. 4 and 5) is limited to 2006. Their intensity values per unit of mass as well as per hectare are much higher than the average hectare for regional and national levels (up to the huge water demand by lemon, an irrigated crop), while values per unit of income are more or less comparable. The values of calculated indicators of the arboriculture crops show a lower EROI and worse emergy performance indicators.

4 Discussion and Conclusions

Results indicate that local farms (lemon, olive and vineyard) are characterised by worse environmental performances from all the points of view. At the farm level, results are affected by local specificity in resource use, management, environmental conditions and specific crops. Moreover, arboriculture crops require excessive care and providing comparatively smaller yields per hectare. The much higher requirement of the abiotic material calculated for the lemon farm compared to the other arboriculture farms as well as the national and regional averages is related to the use of its typical woody support infrastructure ("pergolato") affecting the cumulative energy and emergy indicators and calls for wood recycling patterns (e.g., energy use after the end of useful life). Cumulative energy indicators of the three investigated arboriculture farms are higher than Campania region and Italy as a consequence of the much higher fuel consumption and usage of more fertilisers.

The Italian agriculture as a whole seems less intensive than the studied regional and local cases. It should be noted that a large fraction of agricultural production at national level is composed of herbaceous and starchy crops providing higher yields. Herbaceous and starchy crops require less intensive care and their higher yields make lower intensity indicators per unit mass, energy, and income.

Figures 2, 3, 4 and 5 clearly show an overall increase of the global impact from the investigated systems. Moreover, Fig. 5 suggests that national and regional agricultural systems are more efficient and have a smaller impact than the local family-managed arboriculture farms. This can also be attributed to a factor of scale: the average national and regional farms, in general, are much larger actual size than the investigated local farms.

At all levels of the investigated hierarchy of systems, one € of the generated economic value is supported by 73–250 g of crude oil, the cost of which is in the range of 4.4–14.8 cent of €. Therefore, it is the low cost of oil that allows such an oil-intensive agriculture. As pointed out earlier in Sect. 3.1, the economic return of the agricultural activity is small. The latter can still survive thanks to the very profitable price of fossil fuels (partially subsidised through low taxes and other incentives), but its sustainability depending on the market oscillations of oil prices is at risk.

Considering the energy content of harvested products, the EROI (Energy return on Investment) is smaller for Campania than for Italy and even smaller for the local arboriculture farms. Unless a breakthrough technological improvement allows the use of lignocellulosic residues for bioenergy and biomaterial, the conventional agricultural system is unlikely to be able to support even a small fraction of the energy needs of the country or region.

In conclusion, the evaluation of agricultural sectors over time has highlighted an increasingly unsustainable trend of the demand for energy, mass, and emergy along with an intensive use of land retaining a higher productivity in spite of decreasing arable land. In this way the agricultural sector is becoming less and less sustainable and increasingly dependent on imported resources at all scales. New strategies are needed to improve the quality of agricultural processes, decrease the level of industrialisation and develop more sustainable agricultural practices.

Acknowledgments The Authors gratefully acknowledge the financial support received from the European Commission within the 7th Framework Program, Project no. 217213, SMILE—Synergies in Multi-scale Inter-Linkages of Eco-social systems (www.smile-fp7.eu/). Socioeconomic Sciences and Humanities (SSH) Collaborative Project FP7-SSH-2007-1.

References

CORINAIR (2007) Working Group on emission factors, EMEP/CORINAIR emission inventory guidebook 2007. http://www.eea.europa.eu/publications/EMEPCORINAIR5/

ISO 14040 (2006) Environmental management—life cycle assessment—principles and framework. Brussels, 20 pp

ISO 14044 (2006) Environmental management—life cycle assessment—requirements and guidelines. Brussels, 46 pp

ISTAT (National Statistical Institute) (1985, 1993, 2001, 2006) National institute of statistics, Agricultural statistics. ISTAT, Rome

JRC (2010) Joint Research Center, European Commission. ILCD handbook: general guide for life cycle assessment: detailed guidance. European Commission, Ispra, Italy, 414 pp. Downloaded from http://lct.jrc.ec.europa.eu/pdf-directory/ILCD-Handbook-General-guide-for-LCA-DETAIL-online-12March2010.pdf

Leiden (2000) CML2 baseline 2000. www.pre.nl/simapro/impact_assessment_methods.htm

Ulgiati S, Raugei M, Bargigli S (2006) Overcoming the inadequacy of single-criterion approaches to life cycle assessment. Ecol Model 190:432–442

Ulgiati S, Bargigli S, Raugei M (2007) An emergy evaluation of complexity, information and technology, towards maximum power and zero emissions. J Clean Prod 182:1–14

Ulgiati S, Ascione M, Bargigli S, Cherubini F, Franzese PP, Raugei M, Viglia S, Zucaro A (2011) Material, energy and environmental performance of technological and social systems under a life cycle assessment perspective. Ecol Model 222:168–176

Zucaro (2011) Assessing the performance of agricultural systems across time and spatial scales. An extended LCA approach. A dissertation submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in "Environment, Resources and Sustainable Development". Parthenope University, Naples, Italy, 2011

Part V
Invited Articles from Contributors to Poster Sessions of the Conference: Smart Future Manufacturing and Zero Emissions Concept

Emissions of Greenhouse Gases and Climate Politics in the Latvian Waste Sector

Rūta Bendere, Ināra Teibe and Dace Āriņa

Abstract

According IPCC guidelines for determination of greenhouse gases in waste management (IPCC 2006) the quantity of greenhouse gases must be determined for the emissions of CO_2, CH_4, N_2O for such treatment activities: disposal of solid waste, biological treatment of solid waste and incineration and open burning of waste. Presented report reviles the current situation of this field in Latvia and conclusions on its minimization actions. The data received from Latvian environmental data bases shows that the quantity of disposed unsorted municipal waste is rising and created sanitary landfill system with anaerobic digestion of bio mas (the content of it in the disposed waste reaches 40–50 %) is promoting the emission of greenhouse gasses. Mathematical calculations shows that due to large quantity of unsorted solid waste disposed in sanitary landfills during years 2002–2010, it provides more than 50 Gg of methane per year. The data of the test experiments in four largest sanitary landfills—Getlini Eko, Pentuli, Daibe and Kivites shows that gas collection is organised only in the biggest landfills, but comparison of tested and estimated data shows that only 30 % of produced gas can be collected and transformed for electricity and heat production. The article reflects the main possibilities how to reduce the landfill gas emission introducing the pre-sorting facilities and reducing the disposal of biomass. The pre-treatment

R. Bendere (✉)
Institute of Physical Energetics, Riga, Latvia
e-mail: bendere@edi.lv

I. Teibe
University of Latvia, Riga, Latvia
e-mail: inara.teibe@gmail.com

D. Āriņa
University of Agriculture of Latvia, Jelgava, Latvia

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_20

of unsorted waste and use of bio degradable fraction separately can facilitate the "green energy" production in our country and to be one of the possibilities to implement the decision on replacing fossil fuel for renewable materials in the European Commission (EC).

Keywords
Greenhouse gases · Disposal of waste · Pre-treatment of mixed waste · Mathematical modelling of waste management

1 Introduction

According to *2006 IPCC Guidelines for National Greenhouse Gas Inventories* guidelines for determining GHG emissions in waste management, it is required to quantify emissions of CO_2, CH_4, N_2O for treatment activities such as disposal of solid waste, biological treatment of solid waste, incineration and open burning of waste.

Data obtained from Latvian environmental data bases (LEGMC 2012) show that during 2002–2010 the quantity of disposed municipal waste at landfills has risen in spite of on-going waste sorting and recycling activities. Calculations show that a large amount (up to 40–50 % of the total unsorted solid waste) disposed of in sanitary landfills during 2002–2010 annually has generated more than 50 Gg of methane (Teibe et al. 2012). Data from the test experiments at four of the largest sanitary landfills—Getlini Eko, Pentuli, Daibe and Kivites—show that gas collection is undertaken only at the biggest landfills; but comparison of tested and estimated data shows that only 30 % of the produced gas could be collected and used for electricity and heat (Bendere et al. 2012).

In order to avoid generating disposed waste biogas in the sanitary landfills, where anaerobic digestion of biomass produces 6 % of the total amount of GHG in the country every year, the elaborated Waste Management Plan is promoting separate collection of biomass and sorting of municipal waste before depositing in the landfill. The estimated quantities of GHG production in line with planned activities are identified and compared with different models of waste management for the purpose of minimising the impact on the environment.

2 Modelling Tools

Nowadays, considering strategic options and planning of the management of municipal waste would be difficult without decision-making support tools, such as mathematical models of waste management based on life cycle assessments (LCA) and life cycle costs (LCC). So far in regional waste management planning in Latvia the waste management models have not been used as waste management decision-making tools. The present paper reports using the Waste Management Planning

System (WAMPS) software application developed by the Swedish Environmental Research Institute (IVL) as part of the Reco Baltic 21 Tech Project "Towards Sustainable Waste Management in the Baltic Sea Region," as a decision-making tool.

WAMPS is an easy-to-use application tool for waste management decision-making and planning. The software is most appropriate for environmental analyses of waste management system in particular areas that meet certain specific conditions and requires basic knowledge in waste management and a certain level of LCA expertise on the part of the user.

WAMPS comprises five consecutive steps:

1. waste composition (input data for 24 waste fractions, amounts, and source);
2. waste sorting (recycled waste material from each waste fraction at the source);
3. waste treatment (composting, anaerobic digestion, incineration, combustion, landfill);
4. waste collection (environmental performance of waste collection);
5. waste transportation (specifies parameters affecting the environmental performance of long distance transportation).

Environmental performance of every waste management system is shown and divided into categories by environmental impact: global warming, acidification, eutrophication, and photo-oxidant formation, all possible impacts of the processes of waste management being summarised in environmental costs.

3 Regional Waste Management Plans

In order to implement and manage a centralized waste management system, the Parliament of Latvia enacted in 2005 the National Waste Management Plan for 2006–2012, wherein the territory of Latvia is divided into ten regions of waste management planning (WMPR) each of which has its own regional waste management plan and sanitary landfill. The total area and number of inhabitants within a waste management planning region is shown in Table 1; Fig. 1.

4 Environmental Impact from Disposed Unsorted Wase

On the whole, according to national statistics, the total amount of solid landfill refuse in 2010 was around 634,000 tonnes the largest part, 94.3 % or 603,000 tonnes, comprised of unsorted refuse collected from households and other sources of similar waste material (LEGMC 2012). Half of the produced household waste in Latvia is being disposed at the Getlini Eko landfill.

Table 1 WMP regions and collected municipal waste per capita in 2010

Waste management planning region	Area (km^2)	Inhabitants	Collected municipal waste per capita	
			Tonnes	%
Ventspils	4474	85,000	0.235	3.8
Ziemelvidzeme	10,146	178,275	0.182	13.9
Malienas	7040	80,510	0.118	10.7
Vidusdaugava	8646	129,084	0.192	0.7
Austrumlatgale	5518	107,095	0.187	8.1
Piejura	5304	155,595	0.344	2.2
Liepaja	6425	168,246	0.283	5.7
Zemgale	4624	181,172	0.235	1.6
Dienvidlatgale	6927	203,269	0.218	0.4
Riga and Pieriga	5526	949,503	0.366	2.0

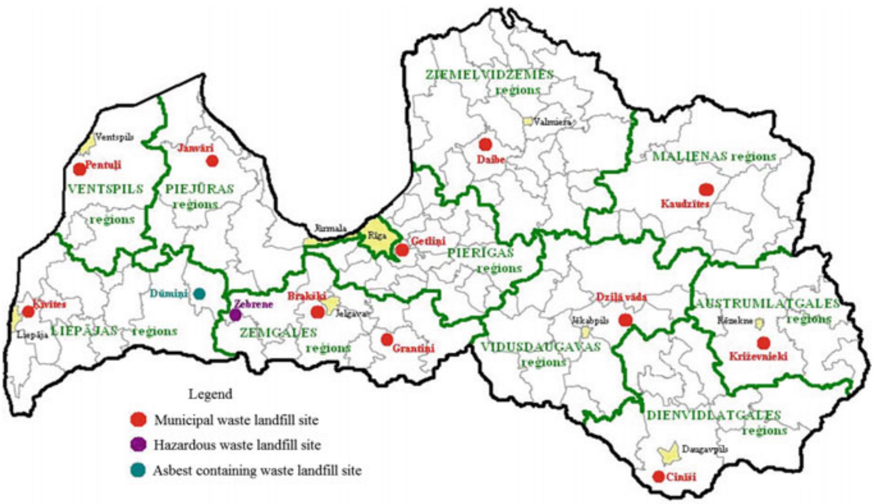


Fig. 1 Waste management regions in Latvia

The landfilled waste composition at four regional landfills: Daibe (Ziemelvidzeme), Kivites (Liepaja), Getlini (Riga and Pieriga), and Pentuli (Ventspils) has been assessed within the project of *Latvia's national greenhouse gas emission inventory* reported in 2011. The results presented in Table 2 below show that the amount of bio-waste comprises up to 52 % of the total unsorted waste at 3 regional landfills. At Daibe, the unsorted waste being pre-treated before disposal at the location, it is 29.4 % (Virsma Ltd 2011).

Table 2 Disposed unsorted waste amount in 2010 and its fraction in 2011 at the four landfills

Landfill	Disposed unsorted waste amount, in Gg	Waste fraction in total disposed unsorted waste amount, in %							
		Paper, cardboard	Plastic	Organic, household hygiene	Wood	Textile, rubber, leather	Inert waste	Glass	Metal
Pentuļi	16.19	8	11.8	51.7	3.2	2.2	8	10.9	4.2
Kivites	35.32	5.7	4.7	51.9	2	8.6	9.5	13.8	3.8
Getlini	287.34	7	10.3	50.3	1.7	3	6.7	19	2
Daibe	28.00	18.2	21.2	29.4	1.8	5.4	4.7	14.4	4.9

Environmental impacts from disposed unsorted waste at the four landfills were analysed and compared by using the WAMPS software. Findings (Fig. 2) show environmental impact in terms of global warming, (tonnes of CO_2 eqv per ton of disposed waste): Daibe—1.68 tonnes of CO_2-eqv; Getlini—1.47 tonnes of CO_2-eqv, Kivites—1.89 tonnes of CO_2 –eqv, and Pentuli 2.29 tonnes of CO_2–eqv. The largest environmental impact at the Pentuļi landfill is due to disposal without recovery of energy. The smallest environmental impact at the Getlini landfill is achieved by energy recovery from a large amount of unsorted waste. It should be noted that while energy recovery is a rather effective way of waste treatment, there is only one landfill of such size in Latvia and one regional example—the Daibe

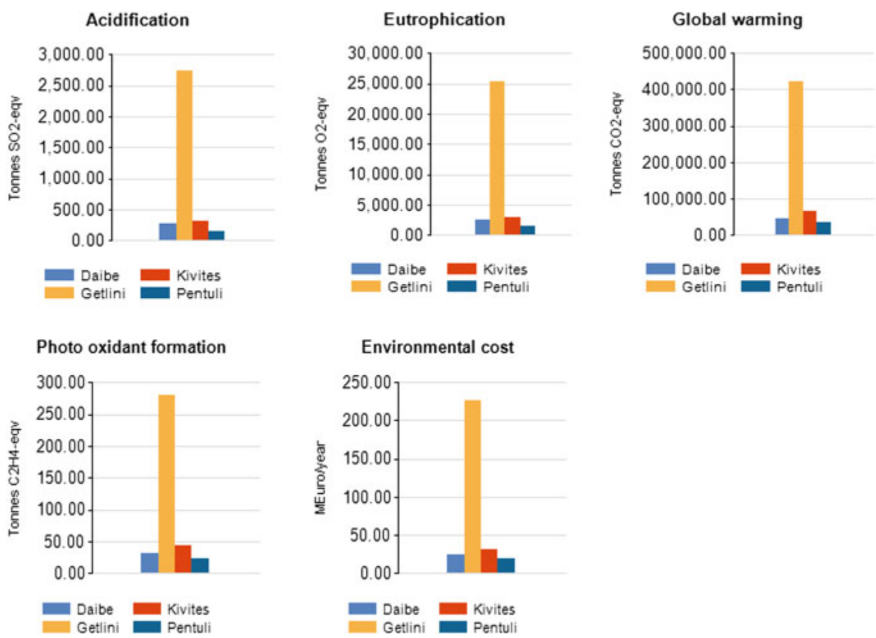


Fig. 2 Environmental impact from disposed unsorted waste at the four landfills

waste landfill being the first mechanical waste pre-treatment centre. Environmental impact at the Daibe landfill shows that reducing the GHG emissions is possible by a pre-treatment system.

5 The Input Data Used for Modelling

Contents and characteristics of unsorted municipal solid waste (after mechanical pre-treatment) in the Ziemelvidzeme region has been used as modelling input data in the WAMPS waste treatment step mentioned above. The mechanical waste pre-treatment centre in Daibe provides shredding, screening, and separation. The metal from the unsorted solid municipal waste is separated by magnets. The unsorted waste after pre-treatment is screened into 3 fractions (coarse, medium and fine). The coarse fraction is used for production of fuel. The fine fraction is composted at the landfill area and afterwards used for coverage of the landfill. The medium fraction is disposed of in the landfill. The separated metal is going for raw material. Additionally, the Ziemelvidzeme waste region has the longest practice of separated waste collection from households.

Depending on characteristics of waste, for modelling purposes it was assumed that the coarse fraction would be used for production of alternative fuel, the medium disposed of in the landfill, the fine—composted to cover the landfill, the metal—recycled. The average content of waste fractions is shown in Table 3. Approximate proportions of material separated as a result of mechanical pre-treatment of unsorted waste mass: coarse fraction—22 %, medium fraction—40 %, fine fraction—35 %, and metal—3 %.

It was assumed that hazardous household waste belongs to fine fraction categories (fine <10 mm), which is 1 % of the fine fraction and 0.1 % of metal. The rest of hazardous household waste was separated at its source (Arina et al. 2012).

Table 3 The average content of waste fractions (%, dry mass)

	Coarse fraction (%)	Medium fraction (%)	Fine fraction (%)
Paper, cardboard	40.1	23.9	2.4
Soft plastic	25.2	14.0	1.0
Rigid plastic	12.6	10.6	1.1
Biological waste (food, green)	0.7	6.6	12.2
Fines (any material <10 mm)	3.4	6.3	43.4
Tissue (diaper, napkins)	5.2	7.1	0.8
Fabric	5.6	4.0	0.1
Leather, rubber	4.1	3.4	0.1
Wood	1.1	3.6	0.5
Metals (iron, nonferrous)	1.5	3.5	0.5
Glass	0.2	9.0	32.4
Stone, pottery	0.4	8.1	5.5
Total	100	100	100

6 Pilot Project in Piejura Waste Management Planning Region

In reference to the Piejura waste management planning region, (see Table 1), WAMPS software, within the INTERREG program Reco 2010–2013, has been used to assess the optimal scenarios of waste management. Data on producers, composition and amount of the municipal waste has been taken from the INTERREG III program RECO 2007 implemented in Tukums, a town of 19,535 inhabitants at the time, located in the Piejura region producing on average 13,068 tonnes of solid waste per annum.

The percentage of waste producers of the total municipal waste structure, as estimated in the RECO project 2007, included: households—31 %, services and institutions—33 %, and manufacturing enterprises—36 %. Although the proportion of produced waste is similar, there is a significant difference between each waste producer's activities as to the amount of waste material is separated within the system of centralised waste collection. Results of the RECO 2007 research show that only 1.5 % of households have been involved in separating the waste material, 26 % of small enterprises and institutions, and 86 % of manufacturing enterprises. The composition of municipal waste and percentage amount generated by type and source per annum is shown in Table 4.

The average waste composition from households, services and institutions, and a small amount of unsorted waste from manufacturing enterprises is shown in Table 4. Environmental impact was estimated for five possible waste management scenarios:

1. Municipal waste is disposed in sanitary landfill without energy recovery.
2. Municipal waste is disposed in sanitary landfill with energy recovery.
3. Municipal waste is sorted automatically; the separated biomass is composted and used as covering material at the landfill; burnable fractions (wood, paper, etc.) are used for RDF production.
4. Municipal waste is partly sorted (30 %) at its source; biomass is used for compost and biogas production; paper and wood are recycled; unsorted fractions are disposed in the landfill.
5. Municipal waste is partly sorted (15 %) at its source; biomass is used for compost and biogas production; paper and wood are recycled. Before disposal at the landfill municipal waste is sorted automatically and sorted biomass is stabilised at the bio-cell and used as covering material; the burnable fractions (wood, paper, etc.) are used for RDF production.

As shown in Fig. 3, the major impacts on global warming and environmental costs derive from the first and the second scenarios, where the main routine of waste treatment is disposal in landfill.

Scenarios 3 and 5 including treatment of the waste material for RDF production to save fossil resources for incineration in kilns provide the best environmental performance. However, due to the incineration emissions they have a significant

Table 4 Composition of municipal waste and percentage amount generated by sources in Tukums in 2007

Type of waste	Households (%)	Services and institutions (%)	Manufacturing enterprises (%)	Average waste composition for WAMPS (%)
Plastic packaging (hard)	19.1		0.6	6.1
Plastic packaging (soft)			21.8	7.9
Glass	6.5	1.2	4.9	4.2
Steel and metal scrap (mixed)		0.6	3.8	1.6
Metal packaging (aluminium)	0.9			0.3
Paper packaging	7.3	3	10.5	7.0
Newspapers, magazines ect.	17.2	6.9	21.3	15.3
Biodegradable material (mixed)	35.2	85.1	16	44.8
Organic degradable kitchen waste		0.9	6.3	2.6
Garden waste	4.5		1.5	1.9
Wood			0.7	0.3
Hazardous waste (mixed)		0.3	2.5	1.9
Rubber, incl. tires		0.3	0.7	1.2
Clothes, shoes, textiles, leather			0.7	0.3
Inert waste	8.7	0.2	4	4.2
Others				0.6

impact on global warming, and may have high economic risks due to demands for quality and large quantity of the RDF material and competition of suppliers. Recycling of the waste material is one of the best waste management scenarios for the Piejura region but, to implement it correctly, local waste recycling facilities must be developed.

7 Scenarios of Waste Management Planning for Latvia

In order to reach the goals of the Waste Management Plan for the 2013–2020 planning period, the results of research in the Piejura region are used for the National waste management. According to the Waste Management Plan 650,000 tonnes of waste disposed in landfills is expected in 2020 and around 640,000 tonnes in 2015. The authors suppose the amount of household waste would

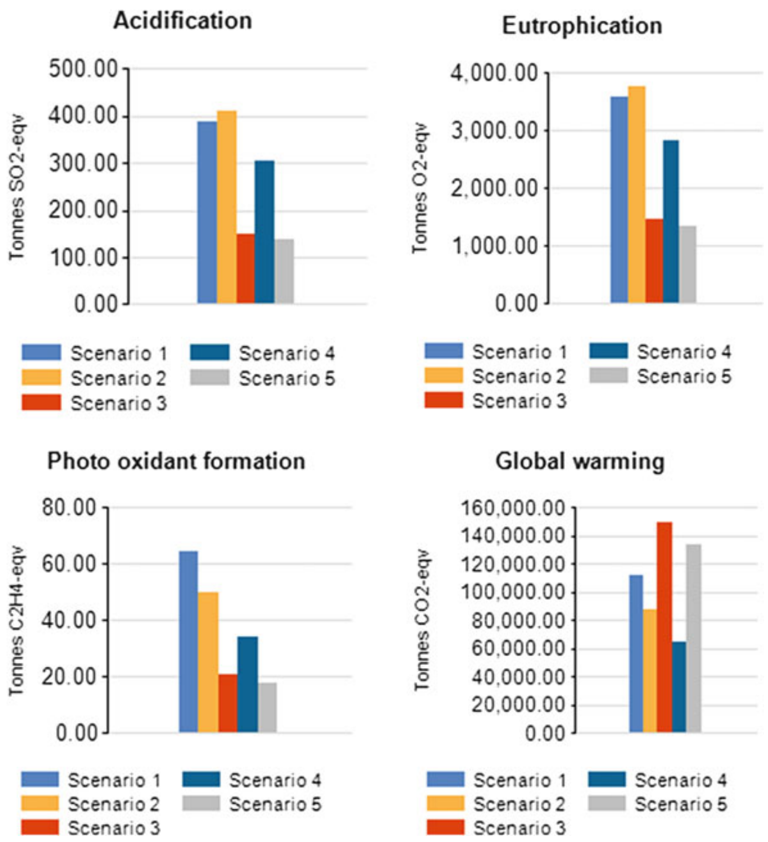


Fig. 3 Impact on environment of waste management planning scenarios at the Piejura region

be 47 %, institutions and small enterprises—40 %, and mixed waste from manufacturing enterprises—13 %. It is also assumed that recyclable waste materials, such as paper, glass, plastic, metal packaging, and biomass, diverted from disposal in the landfill by households and institutions and small enterprises would gradually increase to 5 and 26 % in 2013; 10 and 50 % in 2015; 20 % (except for only 15 % of bio-waste) and 80 % in 2020.

Generation of GHG emissions from unsorted refuse will be limited by pretreatment the biomass being used for compost and biogas production, paper and wood—by recycling. By sorting automatically the municipal waste before disposal in the landfill and stabilising the biomass at the bio cell it can be used as the covering material while the burnable fractions (wood, paper, etc.)—for RDF production. Environmental impacts from municipal waste management scenarios are shown in Fig. 4.

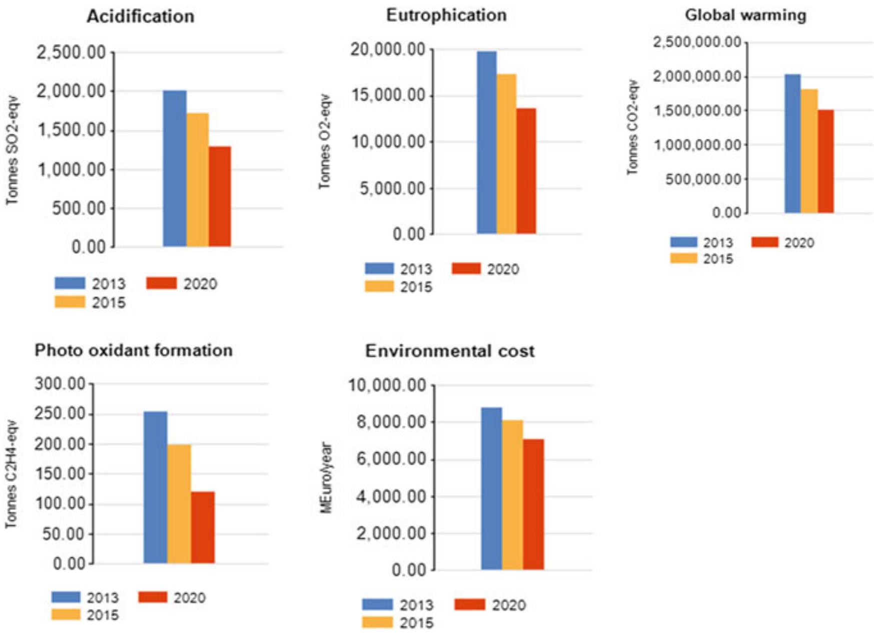


Fig. 4 Impact on environment of waste management planning scenarios in Latvia

8 Conclusions

According to calculations the major impacts on global warming and high environmental costs arise from waste disposed in sanitary landfills, even if well-constructed. Recycling of the waste material sorted by residents at the source is one of best waste management scenarios.

The elaborated Waste Manage Plan where waste material will be treated for RDF production, saving fossil resources, will minimise the impact from waste. Implementation of the plan depends on our practical activities providing the planned actions.

References

Arina D, Bendere R, Teibe I (2012) Pre-treatment processes of waste reducing the disposed amount of organic waste and greenhouse gas emission. In: The ISWA World Solid Waste Congress 2012, congress proceedings, Florence, Italy, p 517

Bendere R, Smigins R, Arina D, Teibe I (2012) Bioreactor cells as waste pre-treatment method—starting statements, maintenance, final recovery and landfilling. In: 18th international conference Linnaeus ECO-TECH 2012, proceedings, Kalmar, Sweden, pp 260–267

IPCC (2006) Guidelines for National Greenhouse Gas Inventories. Revised 1996, IPCC guidelines for National Greenhouse Gas Inventories: reference manual. http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch6wb1.pdf

Latvian Environment, Geology and Meteorology Centre (LEGMC) (2012) Annual GHG inventory report under the Decision No 280/2004/EC for 1990–2010, Latvia. http://rod.eionet.europa.eu/countrydeliveries. 11 Sept 2012)

Teibe I, Bendere R, Perova L, Arina D (2012) Mathematical models for regional solid waste management development. In: 18th international conference Linnaeus ECO-TECH 2012, proceedings, posters, Kalmar, Sweden, pp 598–608

Virsma Ltd. (2011) Degradējamā organiskā oglekļa daļas noteikšana apglabātos atkritumos. Report of Latvia's national greenhouse gas emission inventory, Riga (in Latvian)

Utilisation of Thermoplastic Polymer Waste for Nanofiber Air Filter Production

Jonas Matulevicius, Edvinas Krugly and Linas Kliucininkas

Abstract

Thermoplastic polymers serving numerous practical applications are widely used in modern societies. For example, thermoplastic polystyrene is used as packaging and building insulation material, while thermoplastic nylon due to its extreme durability and strength is widely used to manufacture textile articles. However, disposal or recycling of used thermoplastic polymer items is problematic and expensive. Thermoplastic polymer waste can be successfully transformed into nano-fibres by electro-spinning. Electro-spinning is an inexpensive method where nano-fibres are generated by a charged jet of polymeric solution in a high-voltage electric field. When the jet travels in the air the solvent evaporates and charged fibres are collected on a grounded rotating drum. The diameter of nano-fibres ranges from 100 to 2000 nm and depends on the appropriate polymer solvent system, technological parameters, and environmental conditions. Due to low basis weight, large surface area to volume ratio, high pore volume, tight pore size and relatively uniform fibre size, utilised polystyrene waste could be used in nano- fibre air filters. The experimental results show that nano-fibre air filters meet High-Efficiency Particulate Air (HEPA) filtration standard, where filtration efficiency of the most penetrating particles (0.3 μm) is >85 %, and can be used to filter hazardous chemicals, biological and radioactive particles from air streams.

Keywords

Polymer waste · Nanofiber · Air filter · Electrospinning

J. Matulevicius (✉) · E. Krugly · L. Kliucininkas
Department of Environmental Technology, Kaunas University of Technology,
Radvilenu pl. 19, 50254 Kaunas, Lithuania
e-mail: jonas.matulevicius@gmail.com

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_21

1 Introduction

According to the definition provided by the International Standardisation Organisation (ISO 2008) nano-fibre is nano-object with two similar nano-scale external dimensions the third dimension being significantly larger. The size of nano-scale objects range from approximately 1–100 nm. However, the size mentioned above is very difficult to achieve in the electro-spinning process, so many researchers working with electro-spinning operate with nano-fibre dimension below 1 μm.

Currently, there are three main techniques for nano-fibre production: electro-spinning, multi-component fibre spinning and modular melt-blown techniques (Ward 2005). Due to simplicity and inexpensive setup electro-spinning is the most popular among the three methods (Pham et al. 2006; Barhate and Ramakrishna 2007; Petrik and Maly 2009; Lin et al. 2012).

Aerosol filtration media is one of the potential nano-fibre application areas. Due to their unique characteristics such as large surface area to volume ratio, low basis weight, small pore size and relatively uniform fibre size (Leung et al. 2010; Wu et al. 2010; Okuyama et al. 2010), nano-fibres can be used in air filters. Nano-fibre filters produced by electro-spinning could achieve filtration efficiencies as high as that of the conventional HEPA (high efficiency particulate air) filters (Podgorski et al. 2006; Wang et al. 2008; Wu et al. 2010). However, the pressure drop across a nano-fibre filter increases with the efficiency and sometimes outweighs the increasing efficiency, especially when filtering ultrafine particles (<100 nm) (Wang et al. 2008; Leung et al. 2010). The ratio between filtration efficiency and pressure drop is defined by the quality factor (*QF*) representing the benefit-to-cost ratio (Leung and Hung 2011). Several recent studies (Wang et al. 2008; Leung et al. 2010; Wu et al. 2010) showed that some parameters of nano-fibre media could be used to predict filter efficiency and pressure drop. A higher efficiency of nano-fibre mats is characterised by higher packing density, basis weight and thickness (i.e., a longer time of collecting fibres); however, it also causes a higher pressure drop and, respectively, lowers the value of *QF*. The pressure drop also increases significantly when fibre diameter decreases even at a constant basis weight (Leung and Hung 2011).

Presently, most of the electro-spinning techniques used for production of nano-fibrous materials are based on needle electro-spinning. The needle electro-spinning has a small fibre production rate, typically less than 0.3 g/hr per needle, which is enough on the laboratory scale (Lin et al. 2012).

The goal of this study was to use thermoplastic polymer waste, such as polystyrene and nylon, to produce nano-fibre filter mats. The nano-fibre mats were produced by needle electro-spinning system developed at the Department of Environmental Technology at the Kaunas University of Technology. The nano-fibre mats were formed by coating a non-woven micro-fibre medium by nano-fibres at a negligible pressure drop. The authors examined diameter and basis weight of the electro-spun fibrous mats, measured the pressure drop across the nano-fibre mats and penetration of aerosol particles.

2 Experiment and Methodology

2.1 Electrospinning

The fibre mats were produced from nylon (N) and polystyrene (PS) waste. Nylon pellets were dissolved in formic acid (FA, 85 %, JSC "Eurochemicals") to obtain a 10 w/w solution. The PS pellets were dissolved in *N,N*-dimethylformamide (DMF, 98 %, JSC "Eurochemicals") to obtain 15 and 18 w/v solutions. Solutions were prepared at room temperature after mechanical stirring of the respective waste pellets. A schematic view of the electro-spinning system used in the experiment is shown in Fig. 1. The polymer solutions were loaded into a glass pipette of 0.7 mm inner diameter and volume of 15 mL. A copper electrode immersed in the pipette provides contact to a high-voltage source. Another electrode of high-voltage supply is connected to the drum rotating with linear velocity of 150 cm/min. During the process of electro-spinning, a jet of polymer solution is sprayed out of the pipette nozzle onto the rotating drum collector, and, as the solvent evaporates, a thin fibre is deposited on the drum surface. The distance between the two electrodes was 10 cm and the applied voltage—12 kV. The electro-spinning was carried out at ambient conditions of relative humidity of 36–39 % and the temperature of 25–27 °C.

The spinning being completed, the fibre mats were dried for several hours under vacuum conditions at room temperature to remove residual solvents.

Morphologies of the mats were observed under an Optika M-699, Ponteranica, BG (Italy) optical microscope.

2.2 Filtration

To determine the quality factors of the filters filtration efficiency and the pressure drop were measured. As shown in Fig. 2, the experimental set-up comprises two sub-systems: aerosol generator with filter holder (left in Fig. 2) and a diluting and

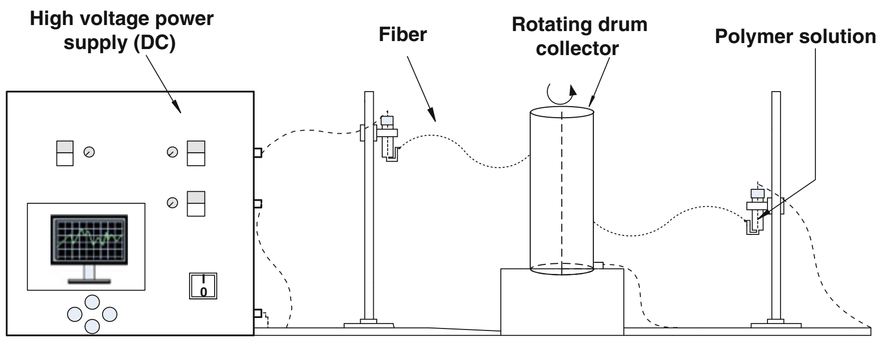


Fig. 1 Schematic diagram of the electro-spinning system used in the experiment

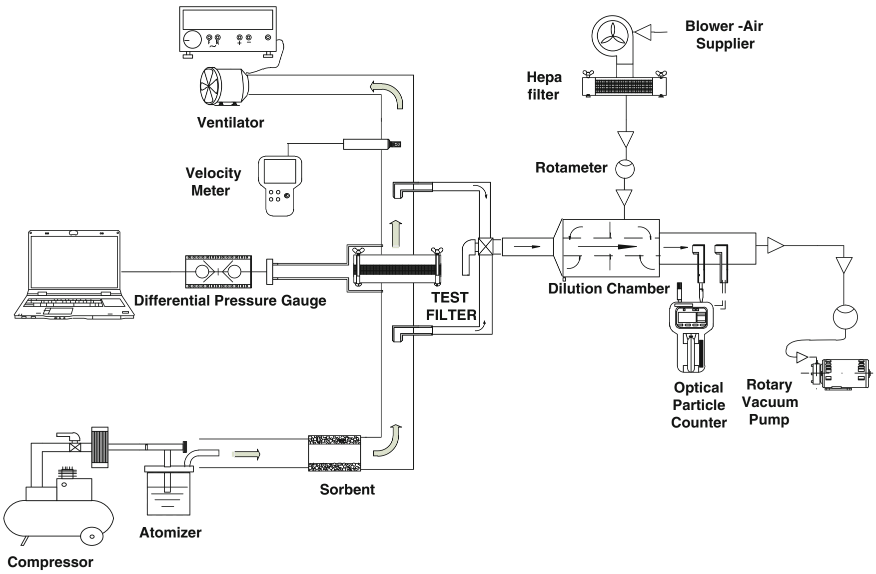


Fig. 2 Experimental set-up for testing filtration efficiency and pressure drop

particle counting system for measurement of particle penetration (the right side in Fig. 2). Compressor provided dry air to a CN 24 J, BGI Inc. (MA, USA) Collison nebuliser. The nebuliser (atomiser) was used to spray 0.05 % NaCl aerosol. To ensure a flow of dry solid particles it was directed through an extended tube. The aerosol flow intensity from the nebuliser varied from 7.65 to 9.25 lpm. The filters were tested under face velocity of 5.3 cm s^{-1} (the required minimum standard face velocity for testing HEPA filters) measured by a mobile Testo 425, Inc. (Lenzkirch, Germany) air flow meter. The pressure drop across the filter being tested was measured by a P300-5-in-D, Inc. pressure sensor (Mooresville, USA). The Diluting system consisted of an air mixing chamber reducing the sample concentration by adding fresh air. To ensure supply of clean air, the ambient air was filtered by a dual HEPA (H11) filter. The air mixture was sucked into the aerosol measurement chamber, where the aerosol concentration was measured by a 3016 IAQ, Inc. (Fremont, USA) optical particle counter operating at flow rate of 2.8 L min^{-1}. An isokinetic sampling tube was used to indicate representative readings of particle concentrations.

Filtration efficiency η (%) was determined by particle concentrations measured downstream (C_{down}) and upstream (C_{up}) of the filter and calculated as:

$$\eta = 1 - \frac{C_{down}}{C_{up}} \tag{1}$$

The quality factor QF (Pa^{-1}) is represented by the filtration efficiency η and pressure drop ΔP:

$$QF = \frac{-\ln(1-\eta)}{\Delta P} \tag{2}$$

A filter with higher filtration efficiency and/or lower pressure drop will have a higher QF. Thus, a filter of better performance should have a high efficiency and a high QF (Leung et al. 2011).

3 Results and Discussion

Three types of electro-spun fibre filter mats from solutions of N 10 w/v, PS 15 and PS 18 v/v were examined under an optical microscope to find out morphology and fibre diameter. All mats had the same electro-spinning collection time on the drum—10 min. The experimental results are presented in Table 1. Figure 3 illustrates typical morphologies and the size of PS 15 and PS 18 filter mats. The increase of polymer concentration increases the mean fibre diameter; in the PS case it also affects morphology changing from an irregular to a uniform fibre diameter. Both PS fibrous mats had weak mechanical properties and were not applicable for filtration and, therefore, the quantitative filtration characteristics were not estimated. In order to improve poor mechanical properties the PS mats could be incorporated with other polymers, such as polyacrylonitrile (PAN) or isoprene. Due to strong intra-chain and inter-chain secondary bonding interactions PAN is an ideal reinforcing material (Ding et al. 2010).

For further assessment of quantitative filtration characteristics only the thermoplastic nylon nano-fibre mats were selected. Filtration properties of the electro-spun nylon nano-fibre filters were compared to the properties of standard HEPA H11. The efficiencies of particle removal (in the size range from 0.3 to 10 μm) passing through filters at face velocity of 5.3 cm/s are shown in Fig. 4. Filtration efficiency of both filters increases with increasing particle diameter with the exception of nylon filter of particles size between 1 and 2.5 μm. This could occur due to the bias of operating with an optical counter. The nylon nano-fibre filter shows better filtration efficiency for particles ranging from 0.3 to 0.5 μm compared to HEPA H11 filter where a low filtration efficiency is observed for particles ranging in size between 1 and 2.5 μm. The highest filtration efficiency of both filters was observed for particle diameters between 5 and 10 μm.

Table 1 Experimental parameters and properties of fibre filters

Filter	Mean fibre diameter, nm	Morphology	Basis weight, g m^{-2}
N 10	300	Nano-fibre	0.35
PS 15	900	Beaded nano-micro-fibre	0.55
PS 18	1300	Micro-fibre	0.68

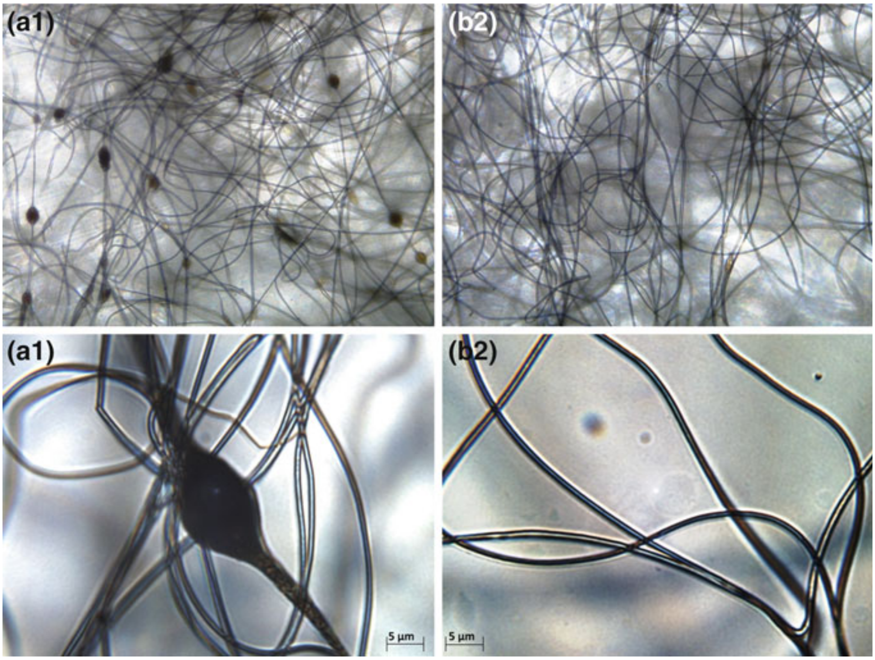


Fig. 3 The optical microscope images of PS 15 (A1, A2) and PS 18 (B1, B2)

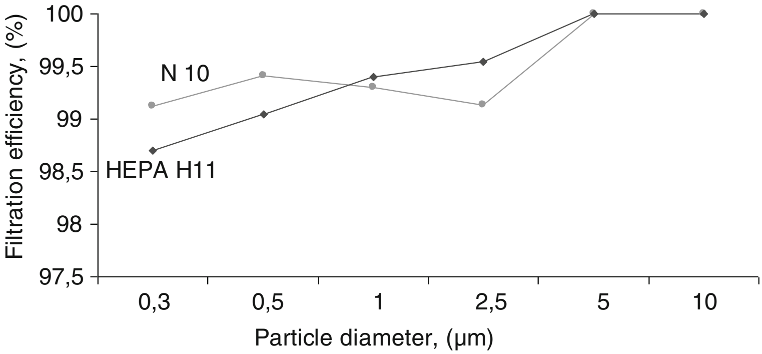


Fig. 4 Filtration efficiencies at face velocity of 5.3 cm/s

The results of pressure drop and calculated quality factors for 0.3 µm particles are presented in Table 2. Unsurprisingly, the H11 filter characterised by a lower pressure drop has a higher quality factor. As mentioned in the introduction, the pressure drop across the nano-fibre filters increases with increasing efficiency. There are several ways to solve this problem in practice. Okuyama et al. (2010) found that usage of nano-fibres with specific morphology, i.e. beaded nano-fibre,

Table 2 Pressure drop and quality factors of filters for 0.3 μm particles

Filter	Filtration efficiency, %	Pressure drop, Pa	Quality factor, Pa^{-1}
N 10	99.12	244.2 ± 4.7	0.0194
HEPA H11	98.70	142.4 ± 1.2	0.0305

results in a slightly higher separation of the nano-fibre layers providing a higher quality factor. A possible reason for the increase of the quality factor and decrease of pressure drop might have been improved volume fraction and the increment of effective fibre surface area. Zhang et al. 2010 show that the quality factor of nano-fibre filters could be improved by use of multiple layers of the nano-fibre mats. Stacking of shorter collection time nano-fibre layers together has a better quality factor compared to single-layer nano-fibres due to a lower pressure drop in case of stacked multiple nano-fibre layers. Therefore, the multiple nano-fibre mats allow for adjusting the packing density and thickness of nano-fibre layer under a fixed basis weight while yielding higher efficiency and lower pressure drop (Leung et al. 2010).

4 Conclusions

The utilisation of thermoplastic waste can be seen as one of the strategies for sustainable material flows in societies. Nano-fibre production from polymer waste due to its simplicity and low price is suitable for a number of applications. For example, nano-fibre mats for air filters is one of the areas of potential development.

Formation of nano-fibre mats is achieved by electro-spinning of thermoplastic polystyrene and nylon waste. Because of poor mechanical properties the fibrous PS mats are not applicable for filtration, only nylon as a polymeric source has been utilised for further characterisation. Filtration characteristics of electro-spun nylon nano-fibre filter have been tested by measuring the penetration of NaCl aerosol particles and by indicating the pressure drop. Filtration efficiency as high as that of conventional HEPA filter has been achieved by nylon nano-fibre filter mat at collection time of 10 min. Filtration efficiency of nylon nano-fibre filter has exceeded efficiency of HEPA H11 filter in the range of particle diameter from 0.3 to 0.5 μm. However, the nylon filter exhibits a higher pressure drop and, respectively, a lower quality factor compared to the HEPA filter. As a result, further research should be focused on decreasing the pressure drop of nylon nano-fibre filters.

References

Barhate RS, Ramakrishna S (2007) Nanofibrous filtering media: filtration problems and solutions from tiny materials. J Membr Sci 296:1–8

ISO (2008) Nanotechnologies—Terminology and Definitions for Nano-objects—Nanoparticles, Nanofibre and Nanoplate, ISO/TS 27687

Leung WWF, Hung CH, Yuen PT (2010) Effect of face velocity, nanofiber packing density and thickness on filtration performance of filters with nanofibers coated on a substrate. Sep Purif Technol 71:30–37

Leung WWF, Hung CH (2011) Filtration of nano-aerosol using nanofiber filter under low Peclet number and transitional flow regime. Sep Purif Technol 79:34–42

Okuyama K, Yun KM, Suryamas AB, Iskandar F, Bao L, Niinuma H (2010) Morphology optimization of polymer nanofiber for applications in aerosol particle filtration. Sep Purif Technol 75:340–345

Petrik S, Maly M (2009) Production nozzle-less electrospinning nanofiber technology. In: Proceedings of 2009 fall MRS symposium, Boston, Nov 30–Dec 4

Pham PQ, Sharma U, Mikos GA (2006) Electrospinning of polymeric nanofibers for tissue engineering applications: a review. Tissue Eng 12(5):1197–1211

Podgórski A, Bałazy A, Gradon L (2006) Application of nanofibers to improve the filtration efficiency of the most penetrating aerosol particles in fibrous filters. Chem Eng Sci 61: 6804–6815

Sun M, Li X, Ding B, Yu J, Sun G (2010) Mechanical and wettable behavior of polyacrylonitrile reinforced fibrous polystyrene mats. J Colloid Interface Sci 347:147–152

Wang J, Seong CK, Pui DYH (2008) Investigation of the figure of merit for filters with a single nanofiber layer on a substrate. J Aerosol Sci 39:323–334

Wang X, Niu H, Wang X, Lin T (2012) Needleless electrospinning of fine and uniform nanofibers using spiral coil spinnerets. J Nanomaterials doi:10.1155/2012/785920

Ward G (2005) Nanofibres: media at the nanoscale. Filtr Sep 42(7):22–24

Wu CY, Zhang Q, Welch J, Park H, Sigmund W, Marijnissen JCM (2010) Improvement in nanofiber filtration by multiple thin layers of nanofiber mats. J Aerosol Sci 41:230–236

Hemp Fibres and Shives, Nano- and Micro-Composites

Silvija Kukle, Anna Putnina and Janis Gravitis

Abstract
Hemp as natural plant is essentially a composite in which rigid cellulose micro-fibrils are embedded in a soft matrix composed of lignin and hemicellulose. Hemicelluloses and, to some extent, pectin are the primary components of the binding substance of the elementary bast and shive fibres, while lignin plays the part of stabilizer and screen for other fibrogenous substances. Practically all the production of hemp-based chemical pulps are still using the sulphite and sulphate processes not very friendly to environment. Specifics of the physical and chemical structure of hemp plant components are discussed in details in the introduction part of the paper. Experimental investigation of the environmentally friendly steam explosion method applied to disperse the hemp fibres into smaller bundles and individual elementary fibres is carried out, analysis of residuals after every stage of the process, effect of the pressure, and distinction between non-retted and dew-retted fibres are qualified. The effects of the content of hemp fibres on linear low-density polyethylene matrix composites are illustrated.

Keywords
Hemp fibres · Steam explosion · Cellulose · Alkali treatment · Composites

S. Kukle · A. Putnina
Department of Design and Material Technologies, Riga Technical University, Azenes 18, Riga LV-1048, Latvia

J. Gravitis (✉)
Laboratory of Eco-Efficient Conversion of Biomass, Latvian State Institute of Wood Chemistry, 27 Dzerbenes Street, Riga 1006, Latvia
e-mail: jgravit@edi.lv

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_22

1 Introduction

Natural fibres as a renewable resource attract the attention of scientists and practitioners spreading the applications to different branches of industry. Since cellulose is the most abundant natural component of biomass and has a very high theoretical strength of 15 GPa and obtainable strength of 8 GPa, an increasing number of studies are devoted to inventory and specifics of local resources, understanding, and potential applications (Lilholt et al. 2000).

Bast fibres are rich in cellulose. Hemp has been cultivated for fibres and seed since prehistoric times (∼8000 BC). A comparison of 26 different indicators of cultivated crops shows that oilseed and fibre hemp refer to an environmentally friendly group of six crops (Montford et al. 1999).

Growing practice confirms high yields of biomass from hemp in addition to improved soil structure (Bois 1982). The tall plant stems of hemp effectively suppress weeds, while diseases and pests are rarely recorded. Thereby the use of pesticides is not needed (Robinson 1996). It has also been reported that hemp produces several times more of fibre cellulose compared to other crops such as corn, kenaf (Werf 1996), or cotton. Therefore, it is of interest to determine the potential for hemp as a source of raw material and to find appropriate solutions for sustainable systems.

Hemp seeds are used to produce edible oil and are also used for fuel, paint solvents, cosmetics, etc. Seeds contain 25–35 % of oil holding 8 essential proteins and 3 essential fatty acids. Whole seed is also used as food (in soups, hemp butter) and animal feed. The oil is very low in saturated fats and contains linoleic acids (approximately 55 % omega 6 and 25 % omega3, considered to be a very good proportion) (BCMAF 1999).

The products made of hemp fibres range from canvas shoes to quality shirts and dresses. The total number of products obtained worldwide from hemp fibres and seeds is estimated to be around 50,000. Hemp ropes for ships is one of the oldest uses. Ropes and sail canvas of hemp fibres being resistant to the effects of salt water have been long since used in shipping. Varieties and the time of harvest determine the properties of fibres, from very fine to thick. Hurds are used for paper, rayon, fuel, cellophane, food additives, animal bedding, and building materials. The whole plant can also be used for fuel, i.e., production of alcohol, although this is not common at this time (BCMAF 1999).

Some newer promising industrial uses of plant cellulose have been developed. The degree of crystallinity of the stem-based xyloid viscose fibre of hemp is found to be better than regular staple viscose fibre containing the same monoclinic crystal type of cellulose. Also the elongation property is somewhat better, and hemp fibres have good antibacterial properties (Zhou et al. 2008).

The usage of cellulose nanoparticles and nano-fibres as filters and fillers to improve mechanical and barrier properties of bio-composites is a fast-developing branch of biotechnology (Putnina et al. 2011).

The cross section of hemp stem is seen to contain bark and wood-like tissues. Figures 1 and 2 show layers of epidermis, bast fibre, cambium, xylem and the core of the stem.

A closer look reveals the fresh hemp stem consisting of a hollow cylinder of 1–5 mm thick xylem covered by 10–50 μm cambium, 100–300 μm cortex, 20–100 μm epidermis and 2–5 μm cuticles (Garcia-Jaldon et al. 1998).

The bast tissue forms the exterior layer of the stalk and is composed of phloem, bast parenchyma, bast radial parenchyma, and bast fibres (Fig. 3a). Bast tissues function as the plants' transport system carrying the products of photosynthesis from leaves to the roots and nutrients taken up by the roots back to the leaves. However, the main function of the bast cells is not transportation of nutrients, but rather strengthening of the stalk. The strong outer walls of the groups of fibre cells have thick layers of cellulose and are formed in the bast tissue containing 65 % of

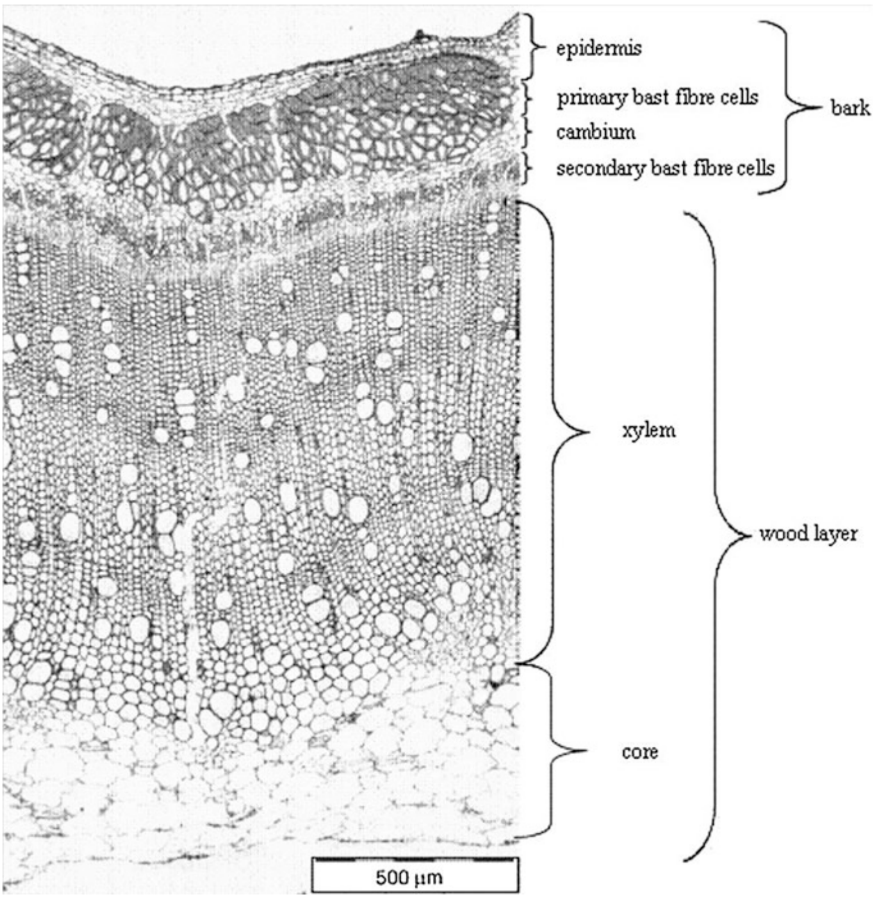


Fig. 1 Cross sections of hemp stem (Kukle et al. 2011)

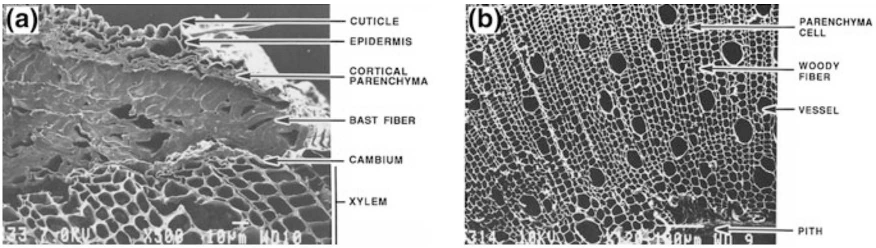


Fig. 2 Layers of epidermis, bast fibre, cambium, xylem and core of stem (Garcia-Jaldon et al. 1998)

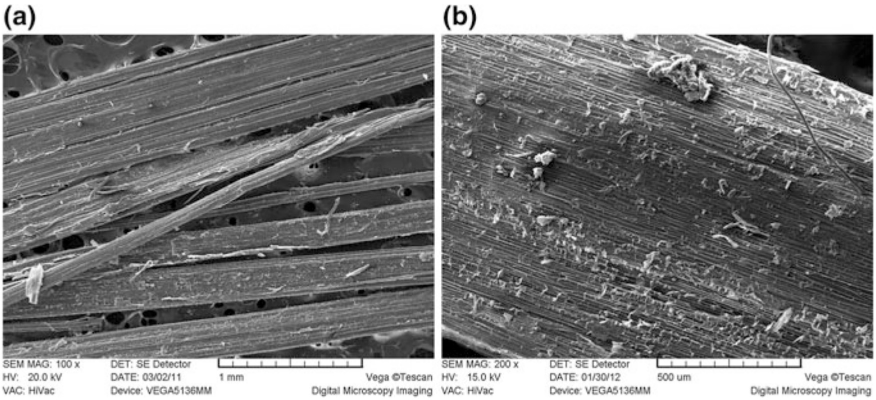


Fig. 3 SEM image of dew-retted hemp fibres **a** (Putnina et al. 2011) and shives (Putnina et al. 2012a) **b** without pre-treatment

cellulose, 15 % hemicellulose, and 4 % lignin and are the most important for hemp cultivation and processing.

Wood tissue consists of tracheids, wood parenchyma cells, and wood fibres transporting water and nutrients. The hurds containing 37 % cellulose, 35 % hemicellulose, and 21 % lignin are formed of wood tissue—the wood fibres being responsible for the vertical strength of the stalk. The length of hemp wood fibre cells with diameter in the 10–30 μm range does not exceed 0.55 mm. Wood fibres are loosely packed (Fig. 3b) and significantly stiffer and less flexible than bast fibres.

Historical reviews testify the long bast fibres being used as a source for paper for at least 2000 years, while use of the woody part of the stem is mentioned seldomly.

Hemp fibres are built of micro-fibrils as the basic units comprising different hierarchical microstructures and are embedded in a matrix of hemicelluloses and/or lignin forming the different cell wall layers of an elementary fibre of the average diameter ranging from 10 to 50 μm (Candilo et al. 2003).

Elementary fibres are bonded together with pectin and small amounts of lignin framing the next level of the microstructure (Figs. 4, 5)—technical fibres (filaments) of diameters ranging from 50 to 100 μm (Bhuvan et al. 2003). Filaments are fixed

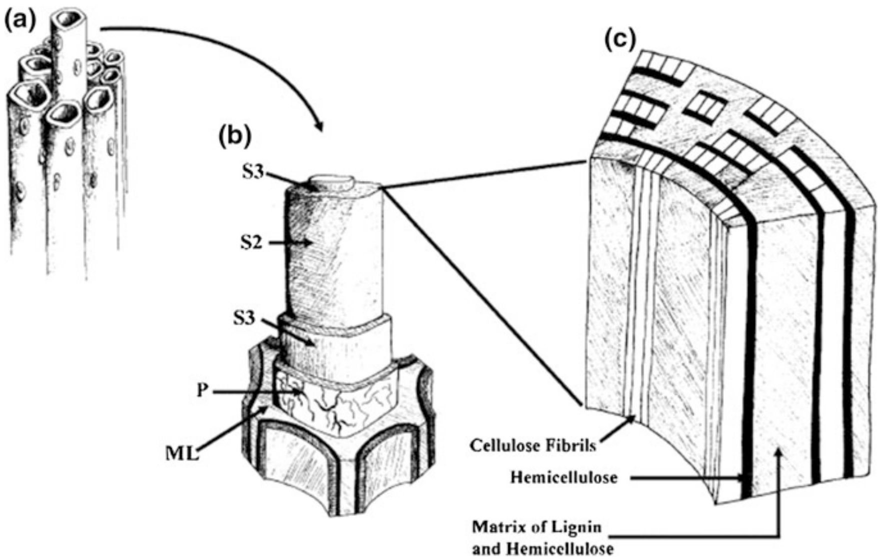


Fig. 4 Cell wall of plant **a** adjacent cells; **b** cell wall layers: S1, S2, and S3 secondary wall layers, *P* primary wall, *ML* middle lamella; **c** distribution of lignin, hemicellulose and cellulose in the secondary walls (Zimnievska et al. 2011)

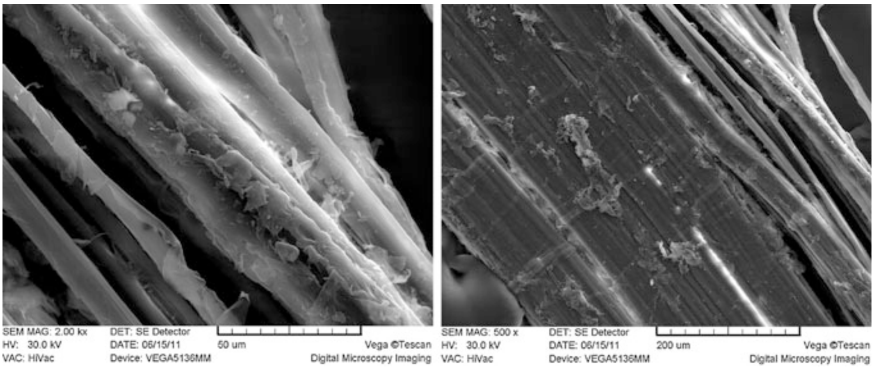


Fig. 5 SEM micrograph of bundles of the hemp fibres (Putnina et al. 2012a, b, c)

together with a pectin-lignin matrix to form bundles of fibres in the cortex of plant stems—the bast fibres. A high content of lignin—from 3.7 to 8 % depending on the origin, variety, and growing conditions of the plant (Sedelnik 2004) is characteristic to bundles of hemp fibres (Fig. 6).

The cortex part of hemp stems contains bundles of 100–300 primary and secondary single fibres of 4–6 sides. The length of a single fibre varies from 5 to 55 mm. Primary fibres, the nearest to stem surface, are formed at the early stage of

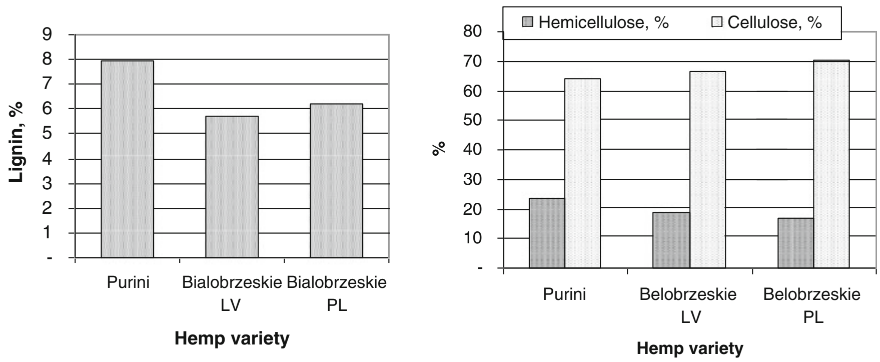


Fig. 6 Main chemical constituents of fibres of two hemp varieties. *LV* grown in Latvia; *PL* grown in North part of Poland (Kukle et al. 2012)

growth during the phase of rapid elongation and contribute up to 92–95 % of the cortex bast fibres (Thygesen 2006). The cell walls of primary fibres are 7–13 μm thick and 20 mm long. The secondary fibres near the cambium layer are smaller (cell walls 3–6 μm thick, length 2 mm) and located only in the thick part of the stem. The average cross-section of a fibre is ~780 μm^2, lumen fraction—9 % ±7 %. Therefore, the load-carrying capacity of a single fibre is high (91 %) compared with wood fibres of larger lumens (flax fibres also have small lumens) (Thygesen 2006).

Micro-fibrils run roughly parallel to each other, following a steep helix around the cell (Bos et al. 1999). Micro-fibrils are composed of alternating crystalline and amorphous regions and contain a large quantity of cellulose molecules (Fig. 7). Individual cellulose micro-fibrils have diameters from 2 to 20 nm (Lu et al. 2008) and could be considered as a string of cellulose crystals linked along the axis of the micro-fibril by disordered amorphous domains (Azizi et al. 2005) as twists and kinks (Montari et al. 2005). Amorphous regions of cellulose are randomly oriented in spaghetti-like arrangement leading to a lower density compared to nano-crystalline regions (Siqueira et al. 2010).

Each type of cellulose has its own degree of polymerization and crystalline organisation determining the properties of the particular fibre. Preliminary investigations show the degree of polymerisation of purified raw hemp fibre cellulose being equal to 7000 (Thygesen et al. 2002). The glucose monomers in the cellulose polymer form intramolecular and intermolecular hydrogen bonds, the intramolecular bonds forming fibrils within its own chain, the intermolecular—microfibrils with the neighbouring chains. The hydrogen bonding facilitates formation of linear crystalline structure of high calculated tensile strength (Atalla et al. 1984).

The properties of cellulose fibres are strongly influenced by factors such as chemical composition, cellulose type, internal fibre structure, microfibrils angle, cell dimensions, and defects of micro-fibrils specific to different parts of the plant and different plant varieties. The low overall angle (4°) of micro-fibrils in hemp fibres

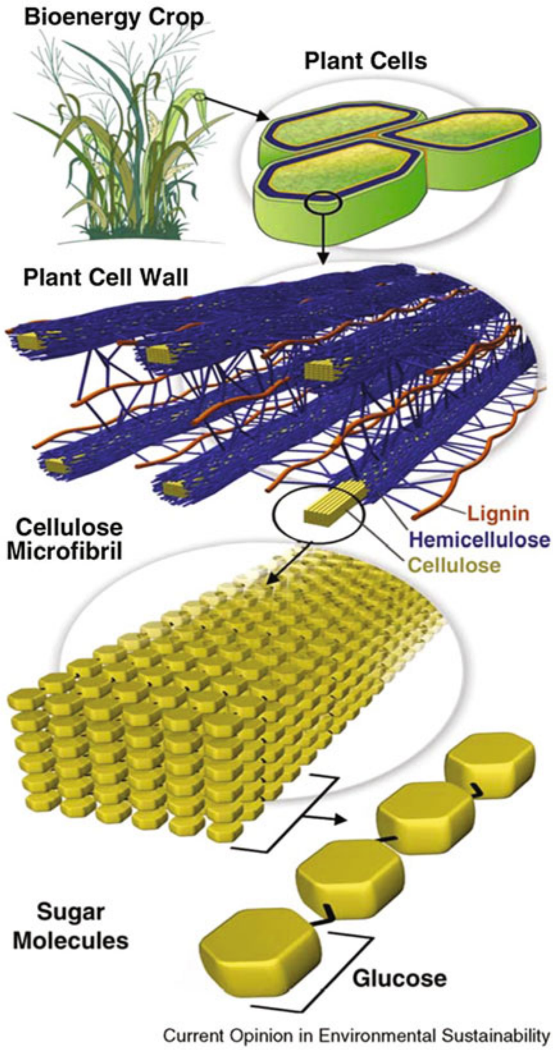


Fig. 7 Schematic plant cell wall (lignin, hemicellulose and cellulose) (Sannigrahi et al. 2010)

explains the high stiffness in the 50–80 MPa range (MFA in flax fibres equals 10°) (Thygesen 2006). As a result, technical hemp fibres are coarser, stiffer and more susceptible to damage in mechanical processing compared with technical flax fibres.

Most native celluloses are mixtures of cellulose I_a and $I_ß$ (Atalla et al. 1984). Cellulose I_a is a metastable form and can be converted into the $I_ß$ by annealing (Sahena et al. 2005). In these forms the polysaccharide chains are similar although the pattern of hydrogen bonding is different (Souza et al. 2004). The $I_ß$ form is present in the typical cellulose of annual plants. Some physical properties of cellulose fibres depend on the ratio between the two allomorphs.

There are several different crystalline arrangements of cellulose labelled as cellulose I, II, III_1, III_2, IV_1, and IV_2 and they can be inter-converted depending on chemical treatment and source (Dufresne 2010). Cellulose has outstanding properties at the crystal level. The elasticity modulus of crystalline cellulose-I has been reported being as high as 138 GPa mm^{-2}, cellulose-II—88 GPa mm^{-2}, cellulose-III—73 GPa mm^{-2}, and cellulose IV—75 GPa mm^{-2} (Nishino 2004). Hemp and other plant fibres, including wood fibres contain mainly cellulose I (Fan 2010).

2 Materials and Methods

Any natural fibre is essentially a composite in which the rigid cellulose micro-fibrils are embedded in a soft matrix composed of lignin and hemicellulose (Gravitis et al. 2006). Hemicelluloses and, to some extent, pectin are the primary components of the binding substance of elementary bast fibres while lignin plays the part of stabilizer and screen for other fibrogenous substances (Szalkowski 1967). The degree of polymerisation ranging from 20 to 300 in hemicellulose is much lower compared with cellulose. Ferulic acid and *p*-coumaric residues attached to hemicellulose enable covalent bonding to lignin (Bjerre et al. 1997). Hydrogen bonds are formed between xylan and cellulose. Degradation of hemicellulose proceeds as disintegration of fibres into cellulose micro-fibrils reducing the bundle strength (Morvan et al. 1990). Mainly the acid residues attached to hemicellulose make it highly hydrophilic increasing the uptake of water and the risk of fibre degradation. Hemicellulose is thermally degraded by wet oxidation at a lower temperature (150–180 °C) than cellulose (200–230 °C) (Bjerre et al. 1996) and composites (Madsen 2004). The amorphous regions are susceptible to acid attack and, under controlled conditions, can be removed leaving the crystalline regions intact. Since hemp belongs to the *Angiosperm* phylum, its lignin composed of coniferyl alcohol, sinapyl alcohol and a minor part of p-coumaryl alcohol is typical to hardwood (Thygesen et al. 2005). Studies show that hemp lignin comprises 12, 8 %H; 53 % G (guacil lignin units) and 34, 2 % S (syringil lignin units) with the ratio S/G = 0.64 (Gutiea et al. 2006).

Modifications of the main cellulose-based structures and non-cellulose compounds are identified in Furrier Transform Infrared (FTIR) spectra of carboxyl acids and esters found in pectin, lignin, and waxes not found in cellulose (Wang et al. 2006). The IR bands of hemp lignin are found in the frequency range from 1034 to 1616 cm^{-1} (Souza Lima 2004). Intensity of the 1035 cm^{-1} band is reduced after treatments decreasing the lignin content (Fig. 8) (Jose et al. 2007).

Different technologies are used to prepare harvested hemp for further processing. By water retting or dew-retting the hemp bast is divided into large bundles of fibres. Additional treatment is required to isolate smaller bundles and single fibres for which purpose the middle lamellae holding the fibres together need to be disrupted. Enzyme treatment (Yan 2009; Thygesen 2003; Madsen et al. 2003; Brühlmann et al. 2000), wet oxidation (Thomsen et al. 2005; Mwaikambo et al. 1999), and NaOH

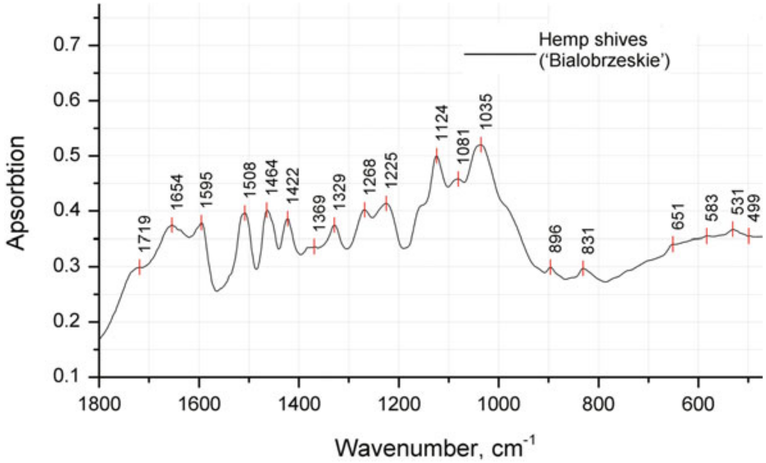


Fig. 8 FTIR spectra of untreated hemp shives (Putnina et al. 2012a, b, c)

treatment (Wang et al. 2003; Garacia-Jaldon et al. 1998) degrade pectin and lignin in the middle lamellae between the single fibres. Physical defibrillation includes treatments by steam explosion (Vignon et al. 1995; Zimmer et al. 1995) and ultrasound (Klinke et al. 2002).

Since the cellulose content of retted hemp fibres increases after steam explosion from 73 % to 85–90 % while only from 60–64 % to 73–75 % found in raw hemp fibres (Thygesen 2006), it is obvious that retting should precede steam explosion. Results of other studies show that most of the lignin is removed by being decomposed to phenolic compounds of low molecular-mass and oxidised to carboxylic acids under oxidative conditions (Gravitis et al. 2011).

3 Results and Discussion

Disintegration of hemp fibres separated from dried non-retted or dew-retted stems of hemp plants of Latvian local genotype 'Purini' (Putnina et al. 2012a, b, c) grown at the Agricultural Science Centre of Latgale (Kraslava) during the 2010 vegetation season and of the 'Bialobrzeskie' variety (Kukle et al. 2012) by alkali treatment (4 wt% NaOH during 1 h at temperature of 80 °C) and by steam explosion (SE) (200–235 °C, 16–23 bar) were examined (Table 1). Results show that SE treatment at severity of log R_0 = 3.97 followed by treatment in hot water and NaOH solution allow to remove practically all hemicellulose and non-cellulose compounds from the hemp fibres (Table 1; Fig. 6).

Evaporation intensities corresponding to the pressure range of 16–23 bar are at the same level (7 %) (Table 1) and increase with the pressure. The dry residue of 'Purini' and 'Bialobrzeskie' after SE followed by water and alkali treatments is 68.3, and 73.4 %, respectively. Part of the components soluble in NaOH are

Table 1 Steam explosion treatment parameters of hemp fibres (Putnina et al. 2012a, b, c; Kukle et al. 2012)

Volatile fractions, %	STEX parameters				Residue, %	Water solub., %	Resid. after wat., %	Alk. solub., %	Resid. afteralk. extr., %
	Time, s	T, °C	Pressure, bar	$\log R_0$					
'Purini'									
0	0	0	0	0	100	7.3	92.7	4.5	88.2
7	60	200	16	2.94	93.3	5	88.4	2.8	85.5
7	60	220	23	3.53	92.5	10.7	81.6	4.5	77.3
14	60	235	32	3.97	86.2	10.9	75.3	7.1	68.3
'Bialobrzeskie'									
0	0	0	0	0	100	4.4	95.6	13.4	82.2
7	60	180	10	2.36	93	6.4	86.5	10.9	75.7
7	60	200	16	2.94	93	9.1	83.9	8.8	75.1
8.4	60	220	23	3.42	91.6	10.6	81	7.6	73.4

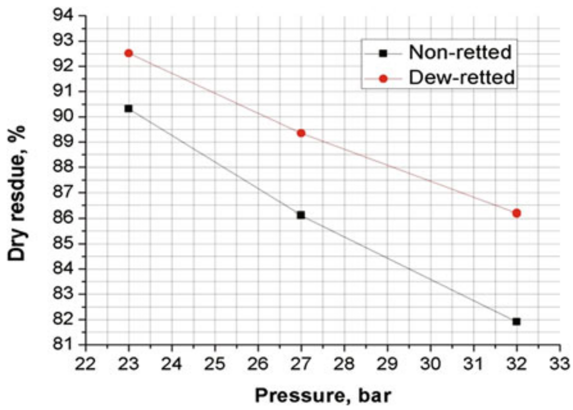


Fig. 9 Dry residue after SE treatments (Putnina et al. 2012a, b, c)

converted in evaporable and water-soluble substances by SE treatment and removed during the first water treatment.

Partly the volatile substances are released in the retting process. Therefore, the amount of volatile substances at SE of dew-retted fibres is smaller (Fig. 9). Weight loss of the dew-retted fibres at alkali pre-treatment and 16 bar SE treatment is approximately the same as in the case without the alkali pre-treatment while subjected to SE at a higher temperature (220 °C) and pressure (23 bar). Weight loss increases rapidly with the severity of SE (32 bar, 235 °C), especially in case of non-retted fibres (Table 1).

SEM images of the fibres (Fig. 10, 11) of both hemp varieties show that after alkali treatment (4 wt% NaOH, 1 h, T = 80 °C) smaller bundles of elementary fibres are separated from a part of larger bundles. After 4wt% NaOH pre-treatment, SE, water extraction and 0.4 % NaOH extraction (Figs. 10b and 11b) elementary hemp

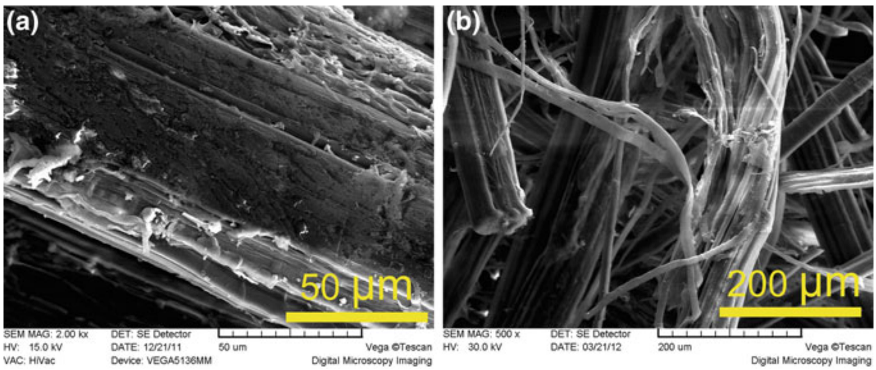


Fig. 10 SEM images of hemp fibres ('Purini') without pre-treatment (**a**), dew-retted and treated by alkali (4 wt%NaOH) (**b**) (Putnina et al. 2012a)

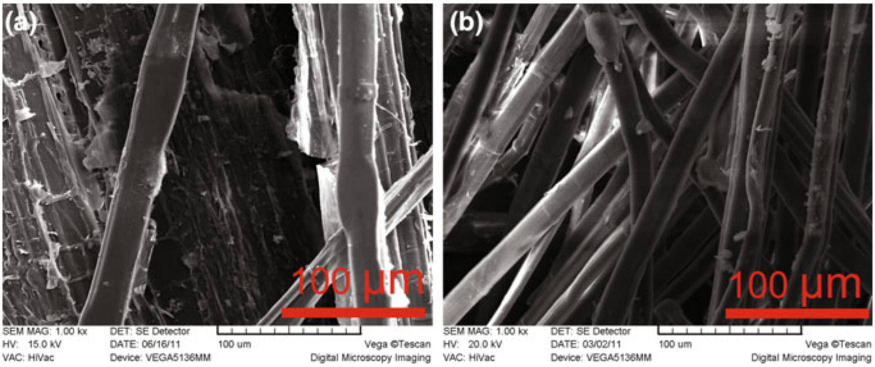
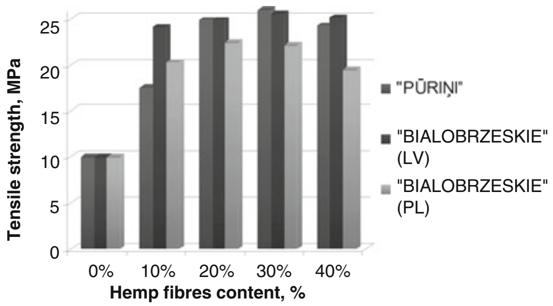


Fig. 11 SEM images of hemp fibres ('Bialobrzeskie') without pre-treatment (**a**), dew-retted and treated in alkali (4 wt%NaOH) (**b**) (Kukle et al. 2012)

Fig. 12 LLDPE-hemp fibre composite tensile strength as function of fibre content (Solizenko et al. 2012)



fibres are isolated, the surface is cleaned, the insoluble substances being removed by 0.4 wt% NaOH after-treatment. An average severity SE in combination with hydrothermal and alkali after-treatments allows the decrease of the diameter of hemp fibres from 10–20 μm and reducing the amount of non-cellulose components—hemicelluloses, pectin, waxes, and water, by ~26 % (Putnina et al. 2012a, b, c; Kukle et al. 2012).

Also the treatment by 4 % NaOH and medium severity SE conditions increases the crystalline cellulose index by 28 and 47 %, respectively. Depolymerisation of pure cellulose I forming small crystallites occurs as a result of both treatments (Kukle et al. 2012).

Hemp fibres substantially improve mechanical properties of the Linear Low Density Polyethylene (LLDPE) composites (Fig. 12). As seen from the graph in Fig. 12 the highest tensile strength is achieved at hemp fibre content of 30 % composite mass.

References

Atalla RH, Vander Hart LD (1984) Native cellulose: a composite of two distinct crystaline forms. Science 223:283–285

Azizi Samir MAS, Alloin F, Dufresne A (2005) A review of recent research into cellulosic whiskers, their properties and their applications in nanocomposite field. Biomacromolecules 6:612–626

BCMAF (1999) Industrial hemp factsheet—Sept 1999. http://www.agf.gov.bc.ca/speccrop/publications/documents/hempinfo.pdf

Bhuvan M, Mohini P, Sain M (2003) Mechanical properties of thermally treated hemp fibres. J. Mater Res Innov 7(4):231–238

Bjerre AB, Olesen AB, Fernqvist T, Plöger A, Schmidt AS (1996) Pretreatment of wheat straw using combined wet oxidation and alkaline hydrolysis resulting in convertible cellulose and hemicellulose. Biotechnol Bioeng 49:568–577

Bjerre AB, Schmidt AS (1997) Development of chemical and biological processes for production of bioethanol: optimization of the wet oxidation process and characterization of products, Riso-R-967(EN). Riso National Laboratory, Roskilde, pp 5–9

Bois WF (1982) Hemp as a raw material for the paper industry. Bedrijfsontwikkeling 13:851–856

Bos HL, Donald AM (1999) In situ ESEM study of the deformation of elementary flax fibres. J Mater Sci 34:3029–3034

Brühlmann F, Leupin M, Erismann KH, Fiechter A (2000) Enzymatic degumming of ramie bast fibers. J Biotechnol 76:43–50

Candilo M, Ranalli P, Bozzi C (2003) Preliminary results of tests facing with the controlled retting of hemp. Ind Crops Prod 11:197–203

Dufresne A (2010) Polymer nanocomposites from biological sources. In: Nalwa HS (ed) Encyclopedia of nanoscience and nanotechnology, American scientific Publisher, USA

Fan M (2010) Characterization and performance of elementary hemp fibres: factors influencing tensile strength. BioResources 5(4):2307–2322

Garcia-Jaldon C, Dupeyere D, Vignon MR (1998) Fibres from semi-retted hemp bundles by steam explosion treatment. Biomass Bioenergy 14(3):251–260

Gravitis J (2006) Nano level structures in wood cell wall composites. Cell Chem Technol 40(5):291–298

Gravitis J, Dobele G, Abolins J, Tupciauskas R, Veveris A (2011) Non-sulphur lignin studies under biorefinery concept and evaluation of energy consumption by steam explosion. Presentation, Paris

Gutiea Rez AM, Rodriaguez I, Del Riao JC (2006) Chemical characterization of lignin and lipid fractions in industrial hemp bast fibers used for manufacturing high-quality paper pulps. J Agric Food Chem 54(6):2138–2144

Jose´ C, del Rı´o, Gutie´rrez A, Rodrı´guez IM, Ibarr D, A´ngel TM (2007) Composition of non-woody plant lignins and cinnamic acids by Py-GC/MS, Py/TMAH and FT-IR. J Anal Appl Pyrol 79(1–2):39–46

Klinke HB, Ahring BK, Schmidt AS, Thomsen AB (2002) Characterization of degradation products from alkaline wet oxidation of wheat straw. Bioresour Technol 82:15–26

Kukle S, Gravitis J, Putnina A (2012) Processing parameters influence on disintegration intensity of technical hemp fibres. J Biobased Mater Bioenergy 6(4):440–448

Kukle S, Gravitis J, Putnina A, Stikute A (2011) The effect of steam explosion treatment on technical hemp fibres. In: Proceedings of the 8th international scientific and practical conference "environment. Technology. Resources". Latvia, Rezekne, vol 20–22, pp 230–238

Kukle S, Stramkale V, Kalnina D, Solizenko R (2012) Comparison of hemp fibre properties. In: Proceedings of the 6th international textile, clothing and design conference. ISSN 1847-7275, Dubrovnik, Croatia, Faculty of Textile Technology, Zagreb, 7–10 Oct 2012, pp 76–80

Lilholt H, Lawther JM (2000) Natural organic fibres. In: Kelly A, Zweben C (ed) Comprehensive composite materials, vol 1. Elsevier, Amsterdam, pp 303–325

Lu J, Askeland P, Drzal LT (2008) Surface modification of microfibrillated cellulose for epoxy composite applications. Polymer 49:1285–1296

Madsen B (2004) Properties of plant fibre yarn polymer composites—An experimental study. Ph. D. thesis, BYG-DTU, Technical University of Denmark. ISBN 87-7877-145-5

Madsen FT, Burgert I, Jungnikl K, Felby C, Thomsen AB (2003) Effect of enzyme treatment and steam explosion on tensile properties of single hemp fiber. In: 12th International symposium on wood and pulping chemistry (ISWPC) Madison, p 80

Montari S, Roumani M, Heux L, Vignon MR (2005) Topochemistry of carbaxylated cellulose nanocrystals resulting from TEMP-mediated oxidation. Maxromolecules 38:1665–1671

Montford SE (1999) Small measuring harm and benefit: the biodiversity friendliness of cannabis sativa. Glob Biodivers 8(4):2–13

Morvan C, Jauneau A, Flaman A, Millet J, Demarty M (1990) Degradation of flax polysaccharides with purified endo-polygalacturonase. Carbohydr Polym 13:149–163

Mwaikambo LY, Ansell MP (1999) The effect of chemical treatment on the properties of hemp, sisal, jute and kapok for composite reinforcement. Die Angewandte Makromolekylare Chemie 272:108–116

Nishino T (2004) Natural fibre resources. In: Baillie C (ed) Green composites. Woodhead Publishing Ltd., England

Putnina A, Kukle S, Gravitis J (2011) STEX treated and untreated hemp fiber comparative structural analysis. Sci J RTU 9 Ser Materiālzinātne 6:36–42

Putnina A, Kukle S, Gravitis J (2012a) Effect of steam explosion treatment on hemp fibres microstructure. In: Book of proceedings 12th world textile conference AUTEX 2012 on innovative textile for high future demands, Croatia, Zadara, vol 13–15, pp 871–874

Putnina A, Kukle S, Gravitis J (2012b) Natural hemp fibre as additives to form polymer composites. In: 17th International conference "mechanics of composite materials-2012": book of abstracts, Latvia, Jurmala, 28 May 1, pp 178–178

Putnina A, Kukle S, Gravitis J (2012c) Innovative technologies for products from renewable resources. In: 3rd international conference on integrative approaches towards sustainability "sustainable development, knowledge society and smart future manufacturing technologies Knowledge": Abstracts, Latvia, Jūrmala, 27–30 June 2012, pp 19–20

Robinson R (1985) The great book of hemp. 1996, Park Street Press, Main; Roe PJ, Ansell MP. Jute-reinforced polyester composites. J Mater Sci 20:4015–4020

Sahena IM, Brown RMJ (2005) Cellulose biosynthesis: current views and envolwing concepts. Ann Bot 96:9–21

Sannigrahi P, Pu Y, Arthur Ragauskas A (2010) Cellulosic biorefineries—unleashing lignin opportunities. Curr Opin Environ Sustain 2(5–6):383–393

Sedelnik N (2004) Properties of hemp fibre cottonised by biological modification of hemp hackling noils. Fibres Text Eastern Eur 12(1) (45)

Siqueira G, Bras J, Dufresne A (2010) Cellulosic bionanocomposites: a review of preparation, properties, applications. Polimers 2:728–765. ISSN 2073-4360

Soliženko R, Kajaks J, Nestore O, Kukle S (2012) Hemp fibres containing linear low density polyethylene composites exploitation properties. In: Abstracts of the Riga Technical University 53rd international scientific conference: dedicated to the 150th anniversary and the 1st congress of world engineers and Riga Polytechnical Institute/RTU Alumni: section: material science and applied chemistry, Latvia, Rīga, 11–12 Oct 2012, pp 18–18

Souza Lima MM, Borsali RMJ (2004) Rodlike cellulose microcrystals: structure, properties and applications. Macromol Rapid Commun 25:771–787

Szalkowski Z (1967) Podstawychemicznejtechnologiisurowcov I wlokeienlykowych, Warszawa

Thomsen AB, Rasmussen S, Bohn V, Nielsen KV, Thygesen A (2005) Hemp raw materials: the effect of cultivar, growth conditions and pretreatment on the chemical composition of the fibres. R-1507, Risø National Laboratory, Denmark

Thygesen A (2006) Properties of hemp fibre polymer composites. An optimisation of fibre properties using novel defibration methods and fibres characterisation, Ph.D. thesis, The royal agricultural and veterinary University of Denmark, ISBN 87-550-3440-3

Thygesen A, Daniel G, Lilholt H (2005) Hemp fiber microstructure and use of fungal defibration to obtain fibers for composite materials. J Nat Fibers 2(4):19–37

Thygesen A, Thomsen AB, Skammelsen Schmidt A, Jorgensen H, Ahring BK, Olsson L (2003) Production of cellulose and hemicellulose-degrading enzymes by filamentous fungi cultivated on wet-oxidised wheat straw. Enzym Microbial Technol 32(5):606–615

Thygesen A, Madsen FT, Lilholt H, Felby C, Thomsen AB (2002) Changes in chemical composition, degree of crystallisation and polymerisation of cellulose in hemp fibres caused by pre-treatment. In: Lilholt H, Madsen B, Toftegaard H, Cendre E, Megnis M, Mikkelsen LP, Sørensen BF (ed) Sustainable natural and polymeric composites—science and technology

Vignon MR, Garcia-Jaldon C, Dupeyre D (1995) Steam explosion of the woody hemp chénevotte. Int J Biol Macromol 17:395–404

Wang HM, Postle R, Kessler RW, Kessler W (2003) Removing pectin and lignin during chemical processing of hemp for textile applications. Text Res J 73:664–669

Wang Q, Fan XR, Gao WD, Chen J (2006) Characterization of bioscoured cotton fabrics using FT-IR ATR spectroscopy and microscopy techniques. Carbohydr Res 341:2170–2175

Werf HMG, Mathijssen EWJM, Haverkort AJ (1996) The potential of hemp for sustainable fibre production: a crop physiological appraisal. Ann Appl Biol 129:109–123

Yan L (2009) Processing of hemp fibre using enzyme fugal treatment of composites. The University of Waikato, Waikato

Zhou Y, Zhang J (2008) Structure and properties of hemp xyloid stem based viscose fiber. J Text Res 29(4):22–26

Zimmer H, Kloss D (1995) Ultraschallaufschluss von Hanf. Ziele-Technologie-Anwendung-Resultate-Qualita¨tsmanagement. Nova-Institut. In: Proceedings of the bioresource Hemp ’95 symposium, Frankfurt, Germany, 3–5 Mar 1995

Zimnievska M, Wladika-Przybylak M, Makowski J (2011) Cellulosic bast fibres, their structure and properties suitable for composite applications. In: Sushel Kalia B (ed) Cellulosic fibres: bio- and nano-polymer composites. Green Chemistry and Technology, Springer, Berlin, p 98

Part VI
Invited Articles from Contributors to Poster Sessions of the Conference: Sustainable Development Indicators of Knowledge Society and Knowledge Based Economy

Monitoring Regional Land Use and Land Cover Changes in Support of an Environmentally Sound Resource Management

Salvatore Mellino and Sergio Ulgiati

Abstract

The worldwide trend of conversion of forested and wild areas into agricultural and urbanised land under the pressure of increasing population affects the environment in many ways: increases pollution, decreases biodiversity and degrades ecosystems in such a way that they are no longer able to provide their services to humans and other species (e.g. soil formation, photosynthesis, nutrient and water cycling). Scientists and governments are increasingly aware of the negative trends: the urgent need for monitoring and mitigating the negative effects of land use changes requires efforts of environmental protection without decreasing the local carrying capacity for the production of basic resources and services to human society. Such efforts cannot be randomly displayed: it is important to be able to analyse and monitor land use changes, understand the drivers and the impacts, identify the most valuable areas in order to preserve a regional environmental quality. If the integrity of wildlife (forests, water bodies, soil, biodiversity) is not preserved, then, due to urbanisation, agriculturalisation and transport infrastructure implementation, a fragmentation of landscape is likely to occur with the consequent loss of its functionality in providing ecosystem services. This work investigates recent urbanisation processes in the Campania Region and designs maps of impervious surfaces, in order to provide a way to assess the environmental worth and quality of lands. Newly urbanised areas between 1990 and 2006 are about 5200 ha, of which 173 ha have been converted from natural to urban and 5028 ha from agricultural to urban, totally accounting for 0.4 % of the regional area. This recent

S. Mellino (✉) · S. Ulgiati
Department of Science and Technology, Centro Direzionale - Isola C4, Parthenope University of Naples, Naples 80143, Italy
e-mail: salvatore.mellino@uniparthenope.it

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_23

urbanisation adds to the already urbanised 105,000 ha of the regional area, one third of which is concentrated in the Province of Napoli (about 38,000 ha). Reversing this trend, by means of appropriate environmental planning and resource management, would help to reduce environmental problems associated with landscape overbuilding, loss of natural capital and diminished environmental services.

Keywords
Emergy · GIS · Urban sprawl · Impervious surfaces

1 Introduction

Human life and activities continuously affect and shape the biophysical environment of our planet. Humans have been indicated as the most effective geological agents in the last millennium, (Wilkinson 2005) due to the large amount of sediments moved from Earth crust to oceans, about an order of magnitude higher than natural processes, in so denuding and lowering the continental surfaces. Sustainable development requires controlled interactions, and mitigation of the related negative effects. An important role in the human-environment interactions could be played by environmental management, intended as control of human-environment exchanges to protect and improve human wellbeing and environmental quality (Randolph 2004). Planning is a central and essential part of environmental management, namely a problem-solving process, addressing the needs and ways to meet them. Dealing with and understanding the environmental dynamics means dealing with a complex system the analysis and management of which requires a wide diversity of knowledge tools and expertise; therefore, environmental planning and management involves the integration of an extensive and diverse range of qualitative and quantitative information.

The interplay of human society and the environment cannot be represented without a spatial reference, because the environment is described by topological relationships among physical objects, and human activities impact the environment spatially (Batemean et al. 2002). The widespread use of GIS (Geographic Information System) and geospatial data has emerged as an important support in planning and environmental decision-making processes.

In this context, land-use planning deserves a special attention; in fact, human uses of land are a significant driving force of human impact on the environment. Direct and indirect effects of land-use have deeply and irreversibly altered the Earth's surface (topography, surface and ground water, flora and fauna) (Sala et al. 2000). Land in its broader sense is a non-renewable and limited environmental resource that assumes a paramount role in an overpopulated and overloaded world. Land Use and Land Cover Change (LULCC) have been accused of wide-ranging environmental consequences, including climate change, soil degradation, changing hydrology, impacting the global biodiversity and degrading areas important for ecosystem services (Eshleman 2004; MEA 2005; Turner et al. 2007; Gillespie et al. 2008; Sleeter et al. 2012). Within LULCC, deforestation, intensification of agriculture, urbanisation in general and, more recently, urban sprawl have been identified as significant environmental stressors (Marshall and Shortle, 2005; Frenkel and Ashkenazi 2008). Urban sprawl is defined as "dispersed, low density development on the edges of urban areas, characterized by fragmented and ribbon developments" (Gregory et al. 2009). It is characterized by low-density development (Edwin 1997; Arribas-Bel et al. 2011), significant per capita land consumption, and almost a total dependence on car transport. Main consequences include increased energy use, reduction of open spaces, fragmentation of landscape, loss of contiguous habitat, loss of ecosystem services, increased soil erosion, and water and air pollution (Marshall and Shortle 2005). An increase of urban land uses translates into increasing impervious surface areas. Impervious surfaces are constructed surfaces (i.e., roofs, sidewalks, roads and parking) covered by impermeable materials such as asphalt, concrete and stone, that prevent water from infiltrating the soil (Barnes et al. 2002). Changing the amount of impervious surface within a watershed has a variety of environmental impacts such as altering local and regional hydrological cycles, enlarging the volume of surface water runoff, increasing magnitude and frequency of flooding events and decreasing stream flow during dry periods.

Urbanisation processes and, also, conversion of forested land into intensive agricultural land affect the environmental heritage of regional systems, facilitating loss and degradation of natural areas with a high environmental value.

Mellino et al. (2014) assess the amount of environmental services provided to the economy of the Campania Region by natural areas without excess of human presence. Such services occur in the form of water cycling, temperature regulation, CO_2 uptake by photosynthesis, wilderness shelter, and aesthetics, among others. As such, these areas need a careful environmental planning and management to be preserved and to prevent exploitation overload. An energy-based value framework was suggested (Odum 1996; Brown and Ulgiati 2004) in calculating the environmental worth of land in terms of ecosystem development potential on the basis of the convergence of renewable energy resources towards each portion of land considered.

In the present study we investigate the urbanisation of the Campania Region over time (1990–2006) by mapping the evolution of impervious surfaces. Furthermore, the emphasis being laid on relation to the loss of environmental quality and ecosystem services. A focus is placed on the Napoli Province, because it is the most urbanised and densely populated area of the Region (and of Italy as well).

2 Materials and Methods

2.1 Case Study Area

The Campania Region is located in the southern part of the Italian Peninsula, with a population of 5,834,056 people and a total area of 13,595 km^2 (ISTAT 2012). It is the second most populous and the most densely populated region of Italy. It is divided into five administrative provinces: Napoli, Salerno, Benevento, Avellino and Caserta. Napoli is the most densely populated Italian province. In 2011 its population was of 3,080,873 people in an area of 1171 km^2 (ISTAT 2012)—2631 persons per km^2. The environmental quality is certainly affected and damaged by these factors causing problems of urbanisation and overpopulation, and a careful planning is needed to preserve the already shrinking natural resources of this area and the whole region. Other parts of the region, where natural resources are still in a relatively good condition, support and maintain the economy of the Napoli Province, as a *source* of materials, resources and ecosystem services, and as a *sink* and buffer of impacts, emissions, and wastes.

2.2 The Emergy-GIS Framework

The Energy method assesses the environmental support provided by nature to each process or service, expressed as the direct or indirect solar energy required to make them. The solar energy is defined as the total amount of solar available energy (exergy) directly or indirectly required to make a given product, service or to support a given flow, measured in units of solar equivalent Joules (seJ) (Odum, 1996; Brown and Ulgiati 2004, 2010). The amount of energy required to generate one unit of product or service is referred to as its Unit Energy Value (UEV) or Energy Intensity. This value is used to convert the input flows of energy, matter, and money into energy values (seJ J^{-1}, seJ g^{-1}, seJ $€^{-1}$). When the process output is expressed in terms of its available energy (or exergy) content the UEV is named transformity.

Mellino et al. (2014) integrated the energy method into a GIS framework at regional level, in order to assess and quantify the main renewable flows (solar radiation, geothermal heat, wind, evapotranspiration and runoff) that reach the region and their embodiment of environmental work and time for resource generation. The spatial distribution and convergence of these flows, expressed in energy terms, allows one to assign an environmental value to land, different from the market value. The latter is too often affected by factors that have nothing to do with the environmental quality of land: urban development planning, construction of transport infrastructures and distance from city centres assign market value to land based on human preferences, not on the ability to provide ecosystem services. Creating an environmental value map, free from market bias requires the following steps to be performed:

(a) Collection and mapping of raw data about the main natural flows supporting the area (solar radiation, geothermal heat, wind and precipitation, waves and tides if applicable);
(b) Elaboration of available energy maps, generated through the combination of previous resource flows maps with appropriate physical parameters (albedo, elevation, temperature, wind velocity) and specific exergy factors (Szargut et al. 1988);

(c) Characterisation of available energy maps by means of environmental quality factors, the Unit Energy Values (UEV's). At this step, an appropriate UEV is applied to each map depending on the exergy flows considered;
(d) Generation of a summary map (Fig. 1) in which convergence patterns of all renewable flows are mapped and expressed in terms of annual renewable areal empower density (Brown, 2010).

This summary map quantifies the concentration of renewable flows in the different areas of the region, assigning them an environmental value based on the local ability to drive an ecosystem development and the provision of environmental services. In other words, the more renewable flows reach an area, the higher is its intrinsic worth. It must be underlined that the ability of an area to provide environmental services also means an ability to support human economy and society locally and in the surrounding areas.

In the present study the annual renewable areal empower density map of the Campania Region is used to rank the regional surface in four environmental quality zones (score from 1 to 4) as the starting point of an assessment of the environmental value of land. Finally, a correlation is drawn between the highly urbanised area, identified in the impervious surfaces map, and the low environmental worth.

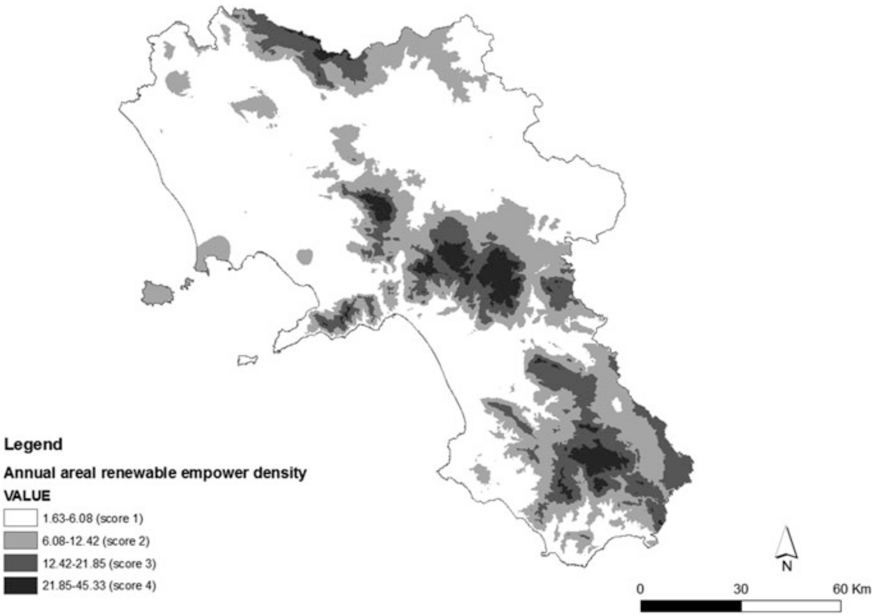


Fig. 1 Annual renewable areal empower density of Campania Region (from Mellino et al. 2014)

2.3 The Urbanisation Over-Time

Conversion of different natural land-uses to artificial ones (urbanisation) was firstly analysed by means of the CORINE Land Cover (CLC) database (EEA 2012). The CLC project developed maps of European land uses for three different years, 1990, 2000 and 2006. The differences and the land use changes were mapped in order to show the evolution of the European landscape. For the study the data for the Campania Region was extracted and the urbanisation over time analysed to show the regional trend. The data has been intersected with the Province of Napoli boundaries and the single Province trend was detected and described.

Limits of the CLC maps are associated with the mapping scale of the project—1:100,000 only. The smallest surface unit mapped is only 25 ha. These limitations do not, however, prevent achieving a sufficiently clear idea and indicative estimates of the phenomenon.

2.4 A Spatial Environmental Quality Indicator from Impervious Surfaces Map

According to Arnold and Gibbons (1996), the impervious surfaces can be defined as any material that prevents the infiltration of water into soil. The presence of impervious surfaces increases the runoff from an area, modifying the water cycle and the natural hydrological balance. Precipitation that runs off results into decreased infiltration and reduced recharge to groundwater reserves. On the other hand, the increase of surface runoff intensifies flooding events and soil erosion. In light of this, impervious land cover could be used as an environmental risk indicator in natural resource planning and water resource protection.

A map of impervious surfaces of the Campania Region was designed in the present study. A layer of urbanised land-uses was extracted from the natural resources and agro-forestry map of the region (PTR 2008). Urbanised areas include continuous and discontinuous urban fabric, transport units, mineral extraction sites, dumps and construction sites. This layer was merged with a detailed map of the main regional roads and railways (PTR 2008). To calculate the area associated with roads, they were divided into highways and primary roads. The assigned width was 25 and 10 m, respectively.

3 Results and Discussion

Results show an upward trend of urbanisation during the investigated period and a related loss of natural and agricultural land throughout the Region. The Napoli Province has a high percentage of imperviousness and its surface is overbuilt and overpopulated, with negative consequences on the environmental quality of this area.

3.1 Urbanisation Over-Time (1990–2006)

Analysis of urban transformation in the Campania Region is made over the time period of 1990–2006. Table 1 displays the obtained results in each Province. More than 5000 ha of newly urbanised areas have replaced agricultural and/or natural land uses. When a portion of land is converted to urban uses, there are impacts from increasing the urban land cover, and there are impacts from decreasing the amount of whatever cover was pre-existing.

Results are confirmed by ISTAT (2012); in fact, from 1995 to 2006 the Campania Region administration issued authorisations for new buildings covering an area of 3709 ha. However, ISTAT data does not account for the high rate of illegal constructions in the region. Moreover, the time series starts from 1995 only, thus ignoring the previous land use change.

Considering the areal extension of each Province, the urbanisation phenomena mainly concern the Provinces of Napoli and Caserta.

Table 2 shows data relative to the all-time period analysed (1990–2006) of urbanisation phenomena disaggregated for 2 categories of land-use transformation from natural to urban land and from agricultural to urban land. The Campania Region has been losing mainly agricultural land and, consequently, farms and agricultural products. From 2000 to 2010 only the number of farms has decreased by 41.7 % and the utilised agricultural area (UAA)—by 6.6 % (INEA 2011).

As a consequence of urban transformations, the natural capital and ecosystem services provided by natural ecosystems and agricultural lands are lost and the environmental quality has consequently declined.

The most widely recognised impacts are increased soil erosion and runoff due to loss of vegetative cover. This effect is intensified by soil compaction associated with construction, compromising the ability of soil to absorb water (Barnes et al. 2002; Marshall and Shortle 2005). Figure 2 shows an overview of the territory of Napoli Province; the new urbanised land areas are distributed over the landscape in a patchy way—evidence of the urban sprawl occurring over the region. As a consequence, the random urban development causes fragmentation of the landscape, loss of contiguous habitat and ecosystem services (Marshall and Shortle 2005).

Table 1 Urbanisation over-time for Campania Region

		Time period			
Province	Area	1990–2000	2000–2006	1990–2006	% $_{(1990–2006)/Area}$
Avellino	278,905.77	556.37	169.81	726.18	0.26
Benevento	206,781.37	377.24	116.22	493.45	0.24
Caserta	263,914.68	732.20	745.09	1477.29	0.56
Napoli	117,149.78	755.64	388.44	1144.07	0.98
Salerno	492,033.22	670.27	690.22	1360.51	0.28
Campania Region	1,358,784.82	3091.72	2109.78	5201.50	0.38

Data disaggregated for Province (ha)

Table 2 Urbanisation phenomena between 1990 and 2006 for categories of land-use transformation

Province	Natural to urban (ha)	Agricultural to urban (ha)
Avellino	6.19	719.99
Benevento	5.85	487.6
Caserta	61.95	1415.34
Napoli	22.29	1121.78
Salerno	76.84	1283.67
Campania Region	173.12	5028.38

Data disaggregated for Province

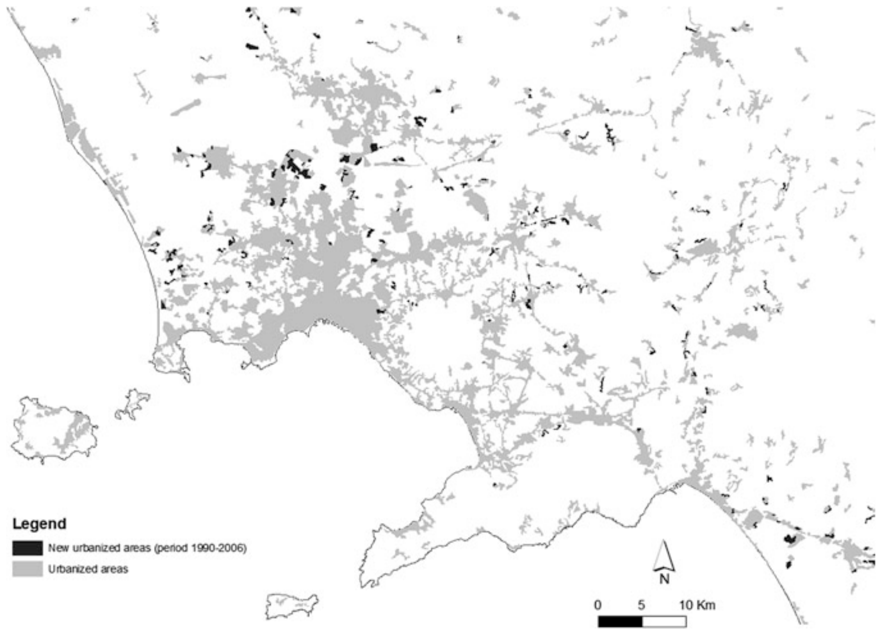


Fig. 2 Urban areas of Napoli Province. The *black spots* are areas urbanized from 1990 to 2006

3.2 Impervious Surfaces of Campania Region

Figure 3 shows the impervious surfaces map of the Campania Region overlaid with categories of the environmental worth. According to renewable energy areal convergence, value 1 corresponds to low environmental quality and value 4—to high environmental quality. Impervious surfaces are mainly concentrated throughout low quality areas (1—white) showing a correlation between low environmental quality and human-built spaces.

Impervious surfaces are an important indicator used to show changes in environmental conditions and to gauge the health of natural resources. Furthermore, the

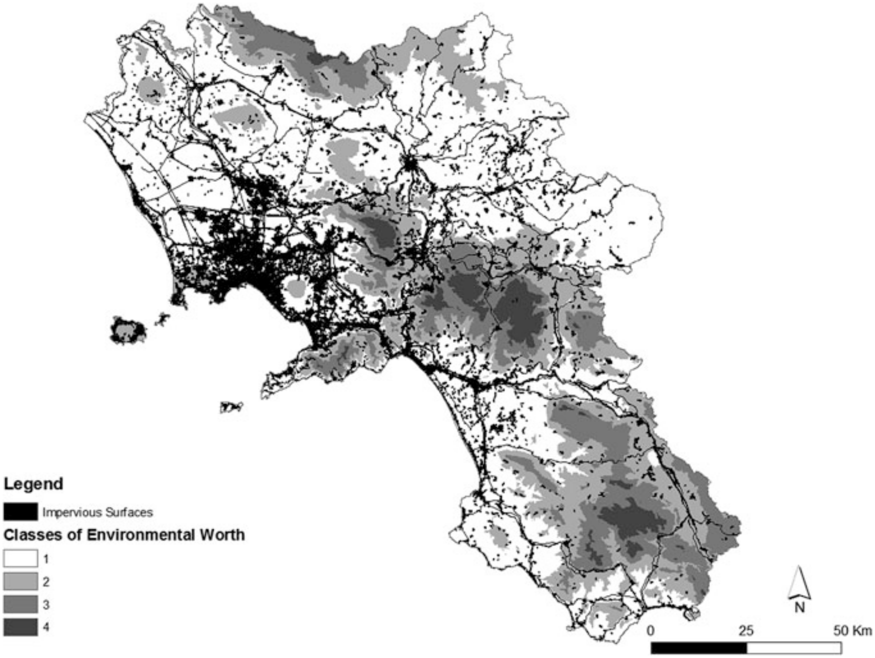


Fig. 3 Impervious surfaces of Campania Region overlaid with categories of environmental worth

amount of impervious surface in a landscape is an important indicator of environmental and habitat quality (Arnold and Gibbons 1996). The percentage of imperviousness could be considered as the first indicator of environmental quality and useful to identify areas exposed to environmental problems that need careful attention in the process of environmental planning.

Table 3 clearly displays this strict relationship. Only 0.04 % of the area of environmental score equal to 4 is impervious while 10.74 %—of the area is of score 1. Impervious surface area of the Campania Region amounts to 7.76 % and the covered area to about 105,000 ha. This value is surely underestimated because only the urban areas exceeding 1 ha and the main roads and railways are considered in the databases.

Table 4 shows impervious surface area of each province of the region. On average, the impervious area of the Napoli Province (32.55 % of the total area) is 3 times larger compared with other provinces. The city of Naples and its suburbs are highly overbuilt, with negative consequences for the environmental quality of the space. Good environmental planning and management is of paramount importance to reducing and mitigating environmental problems of the Napoli Province, caused by over-urbanisation and related over-population. Furthermore, the whole Region

Table 3 Impervious surfaces of the areas of different environmental quality and percentage of the relative imperviousness

Env. quality score	Area (E+03 ha)	Impervious surfaces (E+03 ha)	%
1	814.10	87.41	10.74
2	334.82	16.66	4.98
3	163.28	1.40	0.86
4	46.58	0.02	0.04
Campania Region	1358.78	105.49	7.76

The environmental quality score is generated according to convergence area of renewable emergy

Table 4 Impervious surface area

Province	Area (E+03 ha)	Impervious surface (E+03 ha)	%
Avellino	278.91	15.32	5.49
Benevento	206.69	7.20	3.48
Caserta	263.83	20.58	7.80
Napoli	117.33	38.19	32.55
Salerno	492.02	24.20	4.92
Campania Region	1358.78	105.49	7.76

Data disaggregated for Province

needs planning to preserve areas of concentrated environmental resources supporting the regional economy and providing the ecosystem services crucial for human wellbeing.

Colonising areas rich with resources, over time humans have changed and altered natural ecosystems and their functions such as soil formation, nutrient and water cycling, temperature regulation, photosynthesis and CO_2 uptake. The changes (overbuilding and imperviousness) have degraded the local natural capital causing a loss of ecosystem services necessary for human well-being and survival of the urban environment.

Figure 4 is a detail of impervious surfaces of the Napoli Province. It is evident that a huge part of the provincial surface has been modified by human presence and activities. The two less urbanised zones displayed in Fig. 4 are Sorrento Peninsula and Vesuvius region. A protected park area is located in both regions: the Lattari Mountains Regional Park and the Vesuvius National Park, respectively. As clearly seen from Fig. 1, these regions have a high environmental quality and are zones of convergence of natural flows. Protection of the environmentally valuable areas is of paramount importance for protecting the natural capital and preserving ecosystem services. Financing the nature conservation could translate into preservation of our present wellbeing. If environmental protection is not enforced, the complexity of the area is likely to be lost and so will be the opportunities to benefit from environmental services in support to human societies.

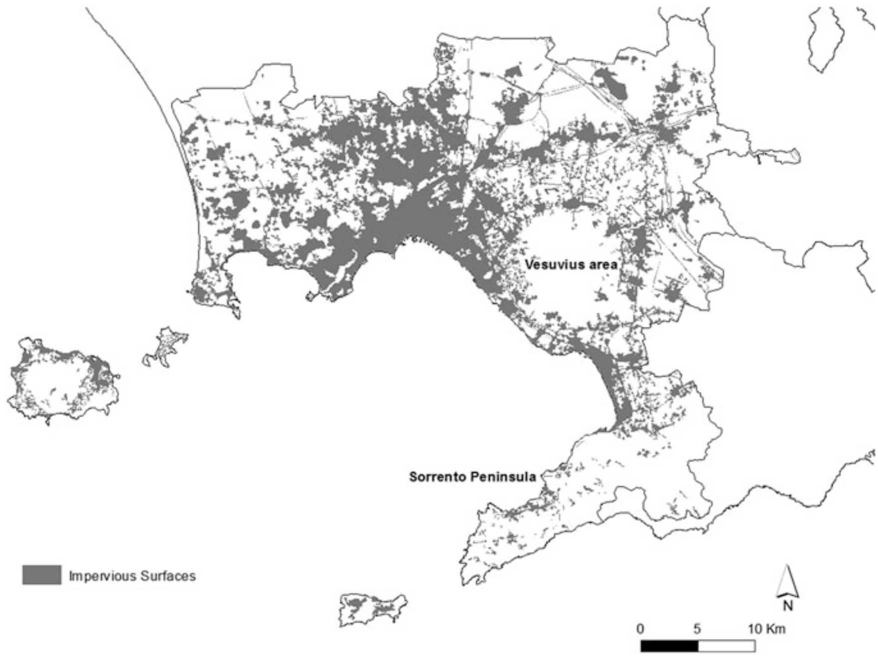


Fig. 4 Impervious surfaces of Napoli Province

4 Conclusion

Based on the methodologies and the approach used in this study, the following conclusions are made:

(a) The analysis of urban transformation in the Campania Region shows an increase by about 5000 ha of the urbanised area between 1990 and 2006.
(b) The newly urbanised sites cover the landscape in a patchy way evidencing an urban sprawl over the region. The irregular urban development causes fragmentation of the landscape and a subsequent loss of contiguous habitat and ecosystem services.
(c) 7.76 % of the area of the Campania Region is of impervious surface. Impervious surface area of the Napoli Province (32.55 % of the total area) is very high compared with other provinces (between 3.48 and 7.80 %).
(d) A strict relationship between impervious surfaces and environmental quality is suggested by the energy concept. Areas of high environmental quality have been converted into impervious surface areas. Therefore, the percentage of the impervious surface area can be considered as an indicator of the environmental quality and used to classify the areas exposed to environmental problems

(air, water and soil pollution, resource depletion, loss of biodiversity and ecosystem services among others).

To preserve areas where environmental resources are concentrated and to recover the natural capital in areas where it has been degraded the Campania Region needs a good environmental planning and management—the only way to preserve the wellbeing of the present and future generations of the region.

References

Arnold CA, Gibbons CJ (1996) Impervious surface coverage: the emergence of a key urban environmental indicator. J Am Plann Assoc 62:243–258

Arribas-Bel D, Nijkamp P, Scholten H (2011) Multidimensional urban sprawl in Europe: a self-organizing map approach. Comput Environ Urban Syst 35(4):263–275

Barnes KB, Morgan III JM, Roberge MC (2002) Impervious surfaces and the quality of natural and build environments. Towson University, Department of Geography and Environmental Planning, URL: http://pages.towson.edu/morgan/files/Impervious.pdf, Towson, Maryland (last accessed on Nov 2012)

Bateman IJ, Jones AP, Lovett AA, Lake IR, Day BH (2002) Applying geographical information systems (GIS) to environmental and resource economics. Environ Resour Econ 22:219–269

Brown MT, Ulgiati S (2004) Energy quality, emergy, and transformity: H.T. Odum's contributions to quantifying and understanding systems. Ecol Model 178(1–2):201–213

Brown MT (2010) Suggestions for an emergy nomenclature (2010) In: Brown MT, Bardi E, Campbell D, Comar V, Huang SL, Rydberg T, Tilley DR, Ulgiati S (eds) Emergy synthesis. Theory and applications of the emergy methodology—5. The Center for Environmental Policy, University of Florida, Gainesville, pp 541–544

Brown MT, Ulgiati S (2010) Updated evaluation of exergy and emergy driving the geobiosphere: a review and refinement of the emergy. Ecol Model 221:2501–2508

Edwin R (1997) Is Los Angeles style sprawl desirable? J Am Plann Assoc 63:107–126

EEA (2012) European Environment Agency—http://www.eea.europa.eu/ (last accessed on Nov 2012)

Eshleman KN (2004) Hydrological consequences of land use change: a review of the state-of-science. Ecosystems and land use change. In: DeFries RS, Asner GP, Houghton RA (eds) Geophysical monograph series, vol 153. American Geophysical Union, Washington, DC, pp 13–29

Frenkel A, Ashkenazi M (2008) Measuring urban sprawl: how can we deal with it? Environ Plann B: Plann Des 35:56–79

Gillespie TW, Foody GM, Rocchini D, Giorgi AP, Saatchi S (2008) Measuring and modelling biodiversity from space. Prog Phys Geogr 32:203–221

Gregory D, Johnston R, Pratt G, Watts M, Whatmore S (2009) The dictionary of human geography. Wiley-Blackwell, New York

INEA (2011) Report on the state of agriculture. National Institute of Agricultural Economics (INEA)—http://www.inea.it/public/pdf_articoli/1616.pdf (In Italian; last accessed on Nov 2012)

ISTAT (2012) Italian National Institute of Statistics—www.istat.it (last accessed on Nov 2012)

Marshall EP, Shortle JS (2005) Urban development impacts on ecosystems. In: Goetz S, Shortle J, Bergstrom J (eds) Land use problems and conflicts: causes, consequences and solutions. Routledge Publishing (Taylor & Francis Group), New York

MEA (2005) Millenium Ecosystem Assessment. Synthesis. Island Press, Washington, DC, Ecosystems and Human Well-being

Mellino S, Ripa M, Zucaro A, Ulgiati S (2014) An Emergy-GIS approach to the evaluation of renewable resource flows: a case study of Campania Region, Italy. Ecol Model 271:103–112
Odum HT (1996) Environmental accounting. Emergy and environmental decision making. Wiley, New York
PTR (2008) Landscape design guidelines for Campania Region—Regional Territorial Plan (PTR). http://www.sito.regione.campania.it/burc/pdf08/burc48bis_08/lr13_08allegati_tomo_II.pdf (In Italian, last accessed on Nov 2012). Data and maps downloaded from http://sit.regione.campania.it/allegati_PTR/ (last accessed on Nov 2012)
Randolph J (2004) Environmental land use planning and management. Island Press, Washington, DC
Sala OE, Chapin SF, Armesto JJ et al (2000) Global biodiversity scenarios for the year 2100. Science 287:1770–1774
Sleeter BM, Sohl TL, Bouchard MA, Reker RR, Soulard CE, Acevedo W, Griffith GE et al (2012) Scenarios of land use and land cover change in the conterminous United States: utilizing the special report on emission scenarios at ecoregional scales. Glob Environ Change 22(4):896–914
Szargut J, Morris DR, Steward FR (1988) Exergy analysis of thermal, chemical and metallurgical processes. Hemisphere Publishing Corporation, London
Turner BL II, Lambin EF, Reenberg A (2007) The emergence of land change science for global environmental change and sustainability. Proc Natl Acad Sci USA 104:20666–20671
Wilkinson BH (2005) Humans as geologic agents: a deeptime perspective. Geology 33:161–164

Is Sustainability Possible in Suburbs of Big Cities?—The Example of Warsaw

Nina Drejerska

Abstract

Warsaw, as the capital of Poland, has relatively good economic and social conditions compared to the rest of the country. It strongly influences neighbouring areas, which are rural, from the administrative point of view. However, they are not like traditionally perceived rural areas with dominating agriculture—they have undergone significant transformations. Development of a big city is a challenge and a chance but, on the other hand, it puts on pressure by the demand for investments of a different nature—for example, the housing or industry and services. All the processes contribute to a very complicated situation connected, for instance, with a necessity of an efficient transport system or respect for protected areas of high quality and importance to the natural environment. The study includes some attempts to determine relationships between social, economic and environmental aspects of the development of rural areas close to Warsaw by use of selected statistical methods and is based on indicators from the public statistics. The second part consists of partial results of research—a questionnaire directed to local authorities and their opinions on the influence of protected areas on the potential of the development of local communities.

Keywords

Sustainability · Rural areas · Suburbs · Warsaw

N. Drejerska (✉)
Department of European Policy, Public Finance and Marketing,
Faculty of Economic Sciences, Warsaw University of Life Sciences—SGGW,
166 Nowoursynowska Street, 02-787 Warsaw, Poland
e-mail: nina_drejerska@sggw.pl

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_24

1 Introduction

A rapid development of cities is usually accompanied by an equally dynamic growth of surrounding areas. The suburban zone is characterised by a considerable diversification and intensity of various socio-economic phenomena. However, the intensity decreases with people moving away from the city boundaries towards rural areas. A distinct identity of suburban areas, to a considerable extent, is manifested, for example, by merging of the contents and forms of urban and rural lifestyles, merging of urban and rural landscapes, intensive pendular migrations, intensity of single-family housing and dynamic functional changes (Bański 2009).

In contemporary Poland, residential migrations of urban population and dynamic development of suburban areas are primarily observed around major cities. Just as it was observed in the case of highly developed countries—where rapid spatial expansion of cities to rural areas took place in the second half of the twentieth century—an increasing inflow of population and a diversification of the functional structure of these areas (Milewska-Osiecka and Ogrodowczyk 2011).

All the processes have contributed to the fact that it is very difficult to ensure the balance between often contradicting requirements to suburbs of big cities. No matter how sustainable development is defined—it is a very complicated issue to implement in the reality of areas surrounding big cities, also in the case of Warsaw—the capital city of Poland. It can be started from one of the most general definitions of sustainable development introduced by the Brundtland Commission in 1987, which assumes that sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987). As this definition can provide some general suggestions, for example, for local authorities or local planners, there exist significantly more specified propositions developed in the process of discussion on sustainability. For instance, some American authors offer 14 principles, which accordingly capture the essential land-use dimensions of sustainability (Jepson and Edwards 2010):

1. jobs–housing balance;
2. spatial integration of employment and transportation;
3. mixed land use;
4. use of locally-produced, clean, and renewable energy sources;
5. energy and resource efficient building and site design;
6. pedestrian access (walking and biking) to work and leisure;
7. housing affordability (for all income groups);
8. housing diversity (of style, type and tenure);
9. higher density residential development;
10. protection of natural and biological functions and processes;
11. resident involvement and empowerment;
12. social spaces (public spaces to encourage social gathering);
13. sense of place;
14. inter-modal transportation connectivity.

Such a comprehensive listing of sustainability aspects can help in implementation, for example, by showing detailed fields for activities. On the other hand, it can be more difficult in general terms for local authorities and planners because it does not allow for flexible interpretation of what is sustainable and what is not sustainable.

2 Material and Method

The question raised in the title resulted from research entitled "Social and economic determinants of development of rural areas in the suburban and external zone of Warsaw". Based on the studies of Polish geographers (Komornicki and Śleszyński 2009) it indicates the functional area of suburbs of Warsaw including rural and urban-rural communes (with towns of less than 5000 inhabitants) (Fig. 1).

Based on the defined area, the study comprises the following steps:

1. selection of statistics from the Local Data Bank of the Polish Central Statistical Office and based on it indicators describing the increasing pressure of urban sprawl on neighbouring rural and urban-rural communes (in Poland, this division is made on the basis on administrational criteria):

   x1—growth of population density in the period 2003–2010
   x2—growth of the number of enterprises (establishment of physical persons conducting economic activity) per km^2 in the period 2003–2010
   x3—growth of commercial law companies per km^2 in the period 2003–2010
   x4—distance from the centre of Warsaw
   x5—proportion of the area covered by local spatial management plans in 2010
   x6—proportion of the area for which the status was changed from agricultural for non-agricultural

Fig. 1 Researched area around Warsaw and its location in Poland. *Source* Author's with use of MapInfo Professional 10.5

2. values of indicators were normalised with zero unitarization method according to the equation

$$z_{ij} = \frac{x_{ij} - \min_i\{x_{ij}\}}{\max_i\{x_{ij}\} - \min_i\{x_{ij}\}}$$

where:

z_{ij}	the normalised value of the ith element of the jth variable
x_{ij}	the actual value of the ith element of the jth variable
$\min(x_{ij})$	minimum of the jth variable
$\max(x_{ij})$	maximum of the jth variable

3. one variable which was a de-stimulant (x4—distance from Warsaw) was transformed into a stimulant according to the formula:

$$x_{ij}^{s} = \max_i\left\{x_{ij}\right\} - x_{ij}$$

where:

x_{ij}^{s} the value of of the ith element of the jth variable after transformation into stimulant

4. to determine homogenous subgroups of communes similar from the perspective of the synthetic aggregated variable (Zeliaś 1991) a taxonomic comparative analysis was conducted by use of the k-means method; the IBM SPSS Statistics 20 and MapInfo Professional 10.5 were used for calculations and display of the results on a map.
5. an attempt was made to investigate relationships between the statistical analysis and partial results of the research—a questionnaire to local authorities asking, for example, opinions on the influence of localisation of protected areas on their development potential; the questionnaire was a part of the research project of "Social and economic determinants of development of rural areas in the sub-urban and external zone of Warsaw" N N114 145240. This part includes some general conclusions from the study visits in the investigated communes.

3 Results

3.1 Statistical Analysis

One of the preliminary tasks in using the k-means method is determining the number of groups the population is divided into. It cannot be very high because it requires much time for analysing without improvement of grouping. On the other

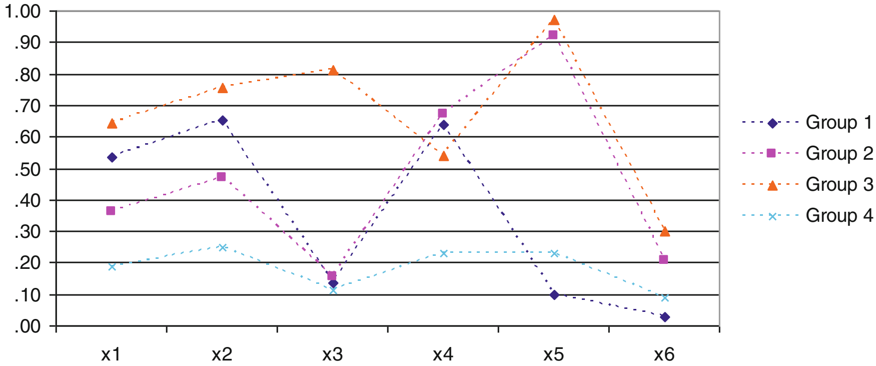


Fig. 2 Average values of normalised variables for groups distinguished by the k-means method. *Source* Author's by use of IBM SPSS Statistics 20

hand, it cannot be too low because the groups are too weak (Najman 2008). Based on the knowledge of the communes examined in previous studies and the results of a different number of groups in different variations of the analysis, four groups were finally selected (Fig. 2).

The analysis of the figure proves that the third group of only two communes—Lesznowola and Radziejowice, is the best; however, they appear to be the most outstanding ones in all the analyses performed so far within the project. The fourth group has the lowest values of variables describing growth of population density (x1) and growth of economic development expressed as growth of the number of enterprises (x2 and x2), and it also has the longest distance from Warsaw. However, the situation in case of spatial planning is not the worst there.

The presentation of grouping results on the map (Fig. 3) is not surprising. Communes closer to Warsaw have better characteristics, whereas representatives of the fourth group are the most distant from the centre.

3.2 Empirical Studies

Unfortunately, the research team has not managed to get answers to the survey from commune offices of the whole investigated population in the suburbs of Warsaw. The survey included one question concerning the issue of the presence of legal protected areas being perceived by the local authorities of the communes. Because of the number of missing answers, they do not provide a comprehensive picture. Taking into account the groups of communes distinguished by the k-means method, the presence of legal protected areas were perceived as:

- a chance for entrepreneurship according to one commune of the 3rd (best) group;
- a chance for two while a barrier for other two communes of the 2nd group;

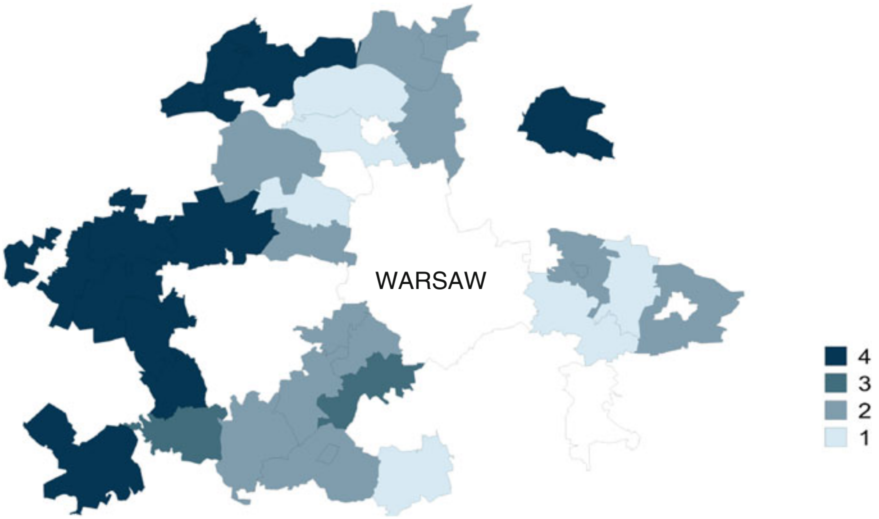


Fig. 3 Communes studied according to grouping with the k-means method (*1* first group, *2* second group, *3* third group, *4* fourth group). *Source* Author's by use of MapInfo Professional 10.5

- a barrier for two and a neutral factor for other two communes of the 4th group (the most remote communes);
- both a chance and a barrier for one commune of the 4th group.

The list does not allow the drawing of any clearly significant conclusions. Apart from the survey of commune offices, the research project included direct questionnaires to inhabitants of the areas. Results of this part is a wide source for further analyses and conclusions. However, direct meetings with inhabitants can be perceived as a kind of study visits in these communes. Personal experience and observations of other investigators provide some general conclusions:

- some examples of the traditional agricultural, especially horticultural, function are still present; a number of orchards are seen in a very good condition; the observations could confirm some elements of the Von Thunen model of agricultural land use with intensive farming, here horticultural production, in the ring closest to the city;
- on the other hand—the horticultural function as a matter of the past; this function was destroyed in many places as proved by ruined greenhouses, completely abandoned or, in some cases, transformed, for example, into places for selling used cars;
- some of the investigated areas do not look like rural areas any more, an example being Dębe Wielkie—an administrational rural commune placed in the 1st group by the k-means method located about 32 km from the centre of Warsaw, in the second circle of communes around Warsaw, with the express road E30 to Terespol (the border crossing with Belarus);

- construction and presence of many industrial buildings is an evidence of the development of industrial functions of the investigated areas;
- development of the function of housing, especially evidenced by the establishment of modern estates or individual houses which are very different from the traditional style of rural housing.

4 Conclusions

There are still many areas in Poland without local spatial management planning. The reason is the existing legal regulations (which oblige to plan for specially defined areas only) and the unwillingness of some local municipalities to make the efforts. Of course, it should be admitted that such planning is a long and expensive process. On the other hand, it is much more difficult to comply with the guiding principles of sustainable development on the local level lacking relevant planning. When decisions concerning permissions of the location of industrial or housing objects are rendered separately of enquiries, it also causes a potential risk of giving a positive answer for investments not friendly to the environment and inhabitants of the particular location.

Communes located in suburbs of big cities and along developed transport corridors are exposed to urban sprawl. In the case of the communes closest to Warsaw, it was demonstrated by pressure of increasing population density or growth of the number of entrepreneurships and the highest proportion of areas for which the agricultural status was changed to non-agricultural. In such situations considerable responsibility for sustainable development, in some cases contradicting with short-term economic interests, lies with local municipalities.

On account of the issues mentioned above, it is nearly impossible to answer the question raised in the title of the study. The pressure of urban sprawl makes sustainable development of the suburban areas a really complex matter. The present study can, at least contribute to finding out the importance of local responses to this pressure in the context of rural areas becoming not so "rural" any longer.

References

Bański J (2009) Odrębność obszaru podmiejskiego w kontinuum miejsko-wiejskim. Czasopismo Geograficzne 80(4):227–228

Jepson EJ Jr, Edwards MM (2010) How possible is sustainable urban development? An analysis of planners' perceptions about new urbanism, smart growth and the ecological city. Plann Pract Res 25(4):421–422

Komornicki T, Śleszyński P (2009) Typologia obszarów wiejskich pod względem powiązań funkcjonalnych i relacji miasto-wieś. In: Bański J (ed) Analiza zróżnicowania i perspektywy rozwoju obszarów wiejskich w Polsce do 2015 roku, Rural Studies, vol 16, PTG, IGIPZ PAN, pp 31–32

Milewska-Osiecka K, Ogrodowczyk A (2011) Development of housing construction in the suburban zone as a result of the stimulating impast of a big city (Lodz agglomeration case study). In: Marszał T (ed) Urban regions as engines of development. Polish Academy of Sciences Committee for Spatial Economy and Regional Planning, p 77

Najman K (2008) Symulacyjna analiza wpływu wyboru kryterium optymalności podziału obiektów na jakość uzyskanej klasyfikacji w algorytmach k-średnich. Taksonomia 15 Klasyfikacja i analiza danych – teoria i zastosowania. Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu, No 7(1207):303

World Commission on Environment and Development (1987) Our common future. United Nations

Zeliaś A (ed) (1991) Ekonometria przestrzenna. PWE, p 86

Sustainability Triple Bottom Line Management Enhancement for Municipal Level: Integrated Governance Environment Dimension

Anita Lontone, Raimonds Ernšteins, Līga Zvirbule, Māra Lubuze and Valdi Antons

Abstract

To ensure sustainable development of a municipality, it is necessary to improve the potential for development of measures of environmental management balancing the economic, social and environmental dimensions. A lot of municipalities having successfully established goals and objectives, tend to sustainable management, evaluate the quality of local governance, including preparation of documents of the environmental policy and setting the administrative tasks and priorities related to assumptions of sustainable development, systemic evaluation, interdisciplinary approach, and implementation of governance as a comprehensive collaborative management. This review article describes the main components of the environment of municipal governance. The study was conducted as a case study of the Salacgrīva municipality. The case study analysis was based on a field research project of the Environmental Management Department of the University of Latvian in cooperation with the municipal council of the Salacgriva region—"Guidelines for environmental management in the coastal municipality of Salacgriva region", the research results being used for spatial sustainable development.

A. Lontone (✉) · R. Ernšteins · L. Zvirbule · M. Lubuze · V. Antons
University of Latvia, Riga, Latvia
e-mail: anitalontone@inbox.lv

R. Ernšteins
e-mail: Raimonds.Ernsteins@lu.lv

W. Leal Filho et al. (eds.), *Sustainable Development, Knowledge Society and Smart Future Manufacturing Technologies*, World Sustainability Series,
DOI 10.1007/978-3-319-14883-0_25

Keywords
Governance environment · Environmental governance · Working environment and collaborative governance · Collaboration and environmental governance processes

1 Introduction

The Department of Environmental Management (DEM) performed a collaboration research project on local municipal environmental management in the coastal municipality in 2011 with partnership of the Municipality of Salacgriva County. The project was realised as a case study research (CSR) of a research and development (R&D) project with the aim of performing an interdisciplinary audit of the local municipal environmental management, conditions of the existing practice and development possibilities, and, as a result, to draft a relevant policy plan (Ernsteins 2012).

In order to ensure sustainable development of the territory and to improve the well-being of people living in the particular territory, especially of the coastal population who are under additional stress by the sea-land processes and nature-socio-economic interaction with particular emphasis on further studies, understanding and subsequently pro-environmental development of governance environment. We need to ensure good governance in the territory that has become an indispensable part of the dimension of sustainable development and ensures a balanced development by interaction between social, economic and environmental dimensions (see Fig. 1).

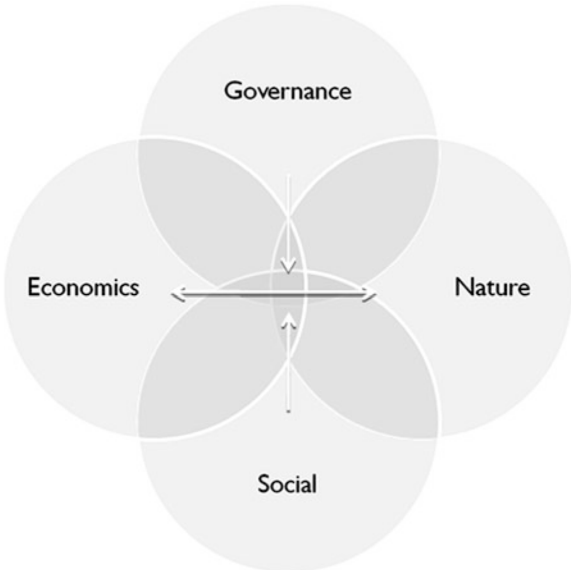


Fig. 1 Sustainable development

The concept of sustainable and good development of governance, the complexity of environmental policy issues, and the outlined governance tasks and priorities related to assumptions of sustainable development requires; systemic evaluation, inter-disciplinary approach and implementation of collaborative governance as the comprehensive governance approach (Zvirbule 2012). This ensures good governance within the public governance system and realisation of the basic principles of good governance in the society (Lontone 2012).

For the decision to be more favorable for all development dimensions, functional efficiency of good governance must be ensured. This includes qualitative governance of environmental processes—the ensuring of institutional capacity, quality governance and qualitative document preparation and policy planning for service rendering to society, communication ensuring inter-structural collaboration and involving society in the processes of decision making. Appropriate public involvement is decisive in governance processes, as stipulated by the UNO Convention on information availability to public and public participation in making decisions, known as the Orhus Convention. The Convention emphasises necessity of public involvement in the decision making process to improve the quality of governance and to provide understanding of environmental issues (Lontone 2012).

2 Research Problem Background

The dilemma of coastal governance and sustainable development is: how to protect the unique and climate-sensitive reactive natural coastal environment, while promoting expansion of the human environment by taking into account the social and economic needs of the local population and preserving the local culture?

The problem of research—in order to ensure the sustainable development for the territory of the municipality, it is necessary to improve the internal development potential of environment of governance activities, balancing the development among economic, social and environmental dimensions. The greatest part of coastal municipalities where goals and tasks have been successfully established, tended towards sustainable governance development. The quality of governance processes of municipality is not assessed, this includes the preparation of documents, mutual collaboration among all the target groups, involving society in decision making process and ensuring the qualitative working environment for the employees.

The development of coastal municipality is restricted by its territorial placement and environmental policy in low-integration of various sectoral policies and lack of governance integration. The failure of environmental governance for sustainable development policy is renewed interest groups which are involved in managing the low level of collaboration and the need to review, re-applied environmental governance approaches, tools, which according to authors, can be solved by putting in order the inside of governance environment, ensuring mutual cooperation with all relevant target groups, coordinate the implementation of actions and decisions affect the implementation of environmental policy and environmental governance process which is the overall focus.

3 Methodology

The chosen area and subject for the research is: the environmental governance in coastal municipality, the working environment and collaborative governance processes in a local level of governance.

The case study analysis was carried out in the municipality of Salacgrīva and was based in the Environmental governance department of Latvia University. It was a field study cooperation project together with municipality council of Salacgrīva region while completing joint course project by Master's degree students of environmental governance in a working group titled "The guidelines of environmental governance in coastal municipality: the region of Salacgrīva" (see Table 1).

The case study analysis was realised according to the case study research (CSR) methodology, traditionally consisting of the list of complementary and integrative selection of traditional sociological research methods:

- document analysis (incl. all procedures, municipal planning and regulatory document studies, work task planning for managers etc.);
- field observations, evaluations/assessments
- sociological research in case territories, including in-depth interviews of experts and municipal officials as well as mandatory representatives of all main target groups, a comprehensive study of all municipal target groups (local administration, regional government institutions etc.), and questionnaires for local residents.

The drafted guidelines of environmental governance in coastal municipality were based on the three pillars of sustainable development (SD)—i.e., natural environment, social environment and economic environment. The case study was based on the key elements of the 4P environmental governance cycle implementation (Ernsteins 2010b; Ernsteins et al. 2012a, b): Pl—problem analysis, P2—policy formulation, P3—policy planning, P4—(action) programming. This strategic governance cycle usually contains the following key components: starting with cross-sectorial/horizontal and vertical thematic and management audit, target group's assessment; policy values and intentions, aim and principles; planning preconditions; objectives, instruments and indicators; implementation and review resource basis (Ernsteins 2010a, b, 2012; Ernsteins et al. 2012a, b).

4 Governance Environment Development

The situation assessment/audit in the Salacgriva coastal municipality as for the municipal case in Latvia has been carried out by applying both sectorial analysis and also their integration attempt in each of the three pillars of sustainable development (SD)—i.e., natural environment, social environment and economic environment. Research approach priority also lies with an additional separate research

Table 1 The guidelines of environmental governance in coastal municipality: the region of Salacgrīva

Key action directions: 16	Action groups: 57
1. Natural resource and landscape ecological management	1. Implementation of landscape ecological planning
	2. Relevant management of SPNA
	3. Ensure water quality of Salaca River Basin
2. Forest resource management	1. Spatial management of forest areas
	2. Management of forest biodiversity resources (SPNA)
	3. Forest territory management to promote county's overall development
3. Ecotourism, nature protection and sustainable development	1. Nature protection (ecotourism)
	2. Society's environmental awareness
	3. Local community's economic development
4. Sustainable water management in coastal municipalities	1. Quality potable water supply
	2. Ensure efficiency and availability of sewage systems
5. Integrated beach and dune area management	1. Preservation and development promotion of local coastal biotope diversity
	2. Efficient use of the potential of coastal material and immaterial cultural and historic heritage
	3. Coastal resource quality management in its functional space for the development of residents' living environment and recreation
6. Household waste management, processing and recycling	1. Facilitate waste sorting in line with national and regional plan requirements
	2. Enhancement of biological processing and recycling in Salacgrīva county on site
	3. Enhancement of waste management infrastructure
7. Ensure sustainable urban environment	1. Improvement of public building environment
	2. Development of industrial areas
	3. Improvement of private building environment and ensuring a healthy living space
	4. Development of interlinkage between communities and development of pubic infrastructure
	5. Integrated management of natural and artificial green territories
	6. Image enhancement of cities and villages
	7. Community building
8. Ensure environmentally friendly mobility	1. Infrastructure improvement and maintenance for environmentally friendly means for transport
	2. Development of a rational internal mobility
	3. Promotion of environmentally friendly means for transport

(continued)

Table 1 (continued)

Key action directions: 16	Action groups: 57
9. Develop an environment promoting sustainable business	1. Stimulating use of county-specific resources for the production and use of environmentally friendly products
	2. Promotion of environmentally friendly business practices
	3. Sales promotion of environmentally friendly produce
10. Sustainable energy management	1. Improvement of heating supply (energy management) management organisation
	2. Promotion of energy efficiency measures
	3. Promotion of renewable energy resource use
11. Sustainable tourism development	1. Development of tourist service packages
	2. Broadening/diversification of the scope of tourist services
	3. Strengthening of county's local identity
	4. Ensuring quality of tourism objects and infrastructure (environmentally friendly)
12. "Green" living	1. Stakeholder collaboration
	2. Development of the "green" infrastructure
	3. "Green" household activities
13. Environmentally friendly and healthy food in Salacgrīva county	1. Environmentally friendly and healthy consumption in catering places
	2. Development of environmentally friendly and healthy consumption and purchase movement
	3. Decrease impact on environment and health
	4. Promote environmentally friendly and healthy everyday food consumption in households
	5. Promote growth, production, processing of "green" food, its distribution locally in the county
	6. Use of natural resources in Salacgrīva county: promote the "green fisheries"
14. Green thinking and everyday action by local administration	1. "The green bureau" in everyday practice of local administration and its structures
	2. Implementation of green procurement in municipal management
	3. Environmentally friendly management of the physical municipal environment
	4. Management of the working environment and environmental health in municipal institutions
15. Ensure good governance in coastal municipal management	1. Environmental policy integration into planning and decision-making processes
	2. Environmental management integration into institutional management

(continued)

Table 1 (continued)

Key action directions: 16	Action groups: 57
	3. Development of co-operation management
	4. Ensuring and development of participation management
16. Environmental communication in Salacgrīva county	1. Environmental communication in municipal management practices
	2. Stakeholder communication
	3. Green county communication

and planning/management area, often in planning processes still being almost not recognized and so not sufficiently studied or forgotten and an additional separate dimension to be managed sustainably as well. This management is to be done both ways—directly disciplinary and integrative crucially interlinked and deciding on three other sustainability dimensions. We are calling this additional and separate sector model (Ernšteins 2008) as the governance environment (parvaldibas vide—in Latvian), which, if summarizing, is to be considered the unifying horizontal element encircling all the three vertical SD sectors and intentionally is to be the called "integrating medium" as well and subsequently separately studied, planned and managed (Ernsteins 2012).

Governance environment is the working conditions for local administration structure and content, which ensures an institutional and processural framework for the coordination of everyday work of administration employees and groups in an adequately organised and equipped working environment. The aim is to develop, adopt and implement- through an internal and external stakeholder communication process—governance services and products required for the development of the public and the territory in line with the municipality's overall development objectives (Ernsteins 2012) (Fig. 2).

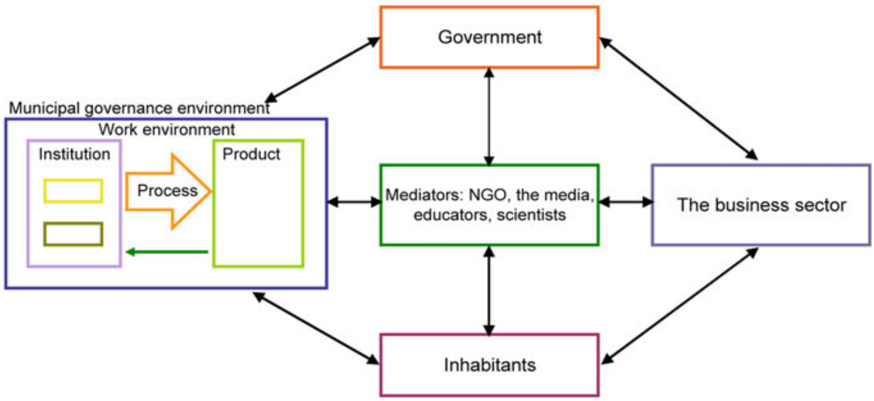


Fig. 2 Municipality governance of the environment and target block diagram

The goal of the governance environment of sustainable coastal development reflects the integration of environmental governance into governance environment of municipality for promotion of sustainable development of coastal governance, which is based on planned and systematic balanced development of governance environment, cooperation and public support and active participation. It is possible to define a couple of other important and useful principles, but these guidelines emphasize the most successful and significant principles for development:

- The integration of environmental governance into procedural environment of coastal municipality—ensuring environmentally friendly governance processes in activities of municipality integrating environmental governance principles and instruments into decision making process and documents produced by municipality ensuring communication for mutual collaboration;
- The integration of environmental governance into institutional environment of coastal municipality—integration of environmental governance into institutional structures and working procedures, ensuring environmentally friendly working environment and services rendered to residents promoting mutual collaboration communication;
- Collaboration of target groups ensuring governance and development of coastal municipality (promotion of establishment of communication and collaboration network of local stakeholders to make complete use of internal collaboration potential of municipality) (Lontone 2012).

5 Salacgriva Coastal Municipality CSR

5.1 Results of the Study

There is a program of action Salacgriva Green region Environmental Governance guidelines block "Governance Environment", which is part of the environmental governance guidelines (16 actions) in coastal municipality: the region of Salacgrīva (see Table 1).

Management environment is based on a pure main and sub-actions, the program is based on four main lines of activities and sub-measures (see Table 1).

Good governance in coastal municipalities in action; integration of environmental policy planning and decision-making, environmental governance integration of the institutional management, target groups cooperation coastal communities and the administration of the development of the population participation in governance in government and development.

Environmental Communication Salacgriva region: Environmental Communication municipal administration—human resource management skills/knowledge building environmental issues, Environmental Communication municipal governance in action—on-site improvement of communication, environmental communication municipal governance in action. It should be stressed that nowadays the governance component—the communication and in both directions as traditionally

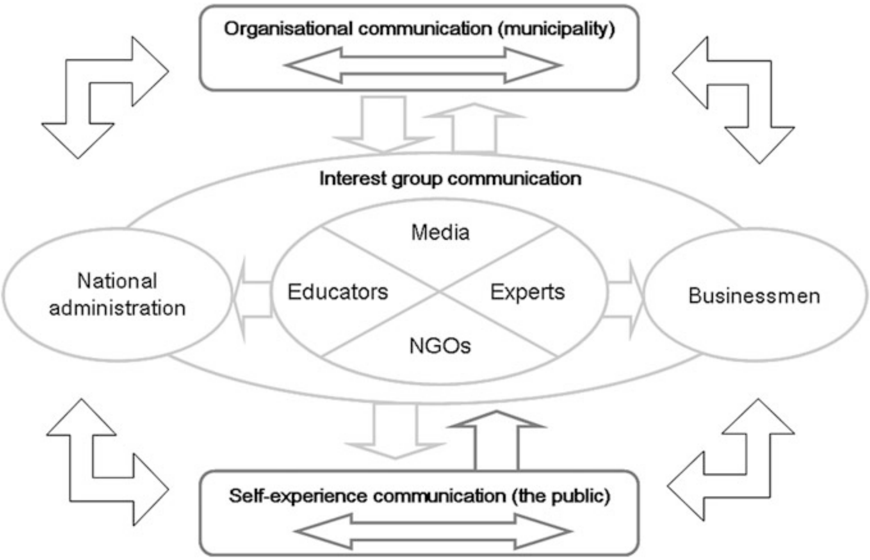


Fig. 3 Interaction of organisational, interest group and self-experience communication for municipal developrnen (Lubuze 2011)

known internal (vertical and horizontal) communication and external all stakeholders communication, self-experience communication, the mutual practical self-experience exchange and learning, and, of course, participating and acting/behaving communication from/between environmentally and sustainable already experienced inhabitants/families, groups/organizations (see Fig. 3).

Municipal governance, departments of green thinking and action in everyday life: "Green Office" local governance council and its structures in practice and daily implementation of green procurement municipal administration, physical facilities more environmentally friendly management of local governance, working environment and environmental health management of municipal institutions.

6 Conclusion

Governance Environment at all levels of governance, particularly at local level of government closest to the community may affect sustainable development. Any economic, social or environmental issue to be addressed so that the decision would be favorable for all dimensions of sustainable development. Sustainable development and environment management provides a logically structured system and governance structure. When all the local government units (institutional, procedural, environmental services) will operate with a common goal, then be able to realise good governance.

The driving forces of collaborative governance development: clearly defined collaborative and environmental governance objectives; clearly defined functions, roles and responsibilities of governance actors; appropriate collaborative and environmental governance capacity of joint action (procedural and institutional arrangements, leadership, knowledge, resources); collaborative initiatives and good experience; governance actors' motivation.

The main conclusions made during the research, including the most significant driving forces and conformities characterizing the successful development of governance environment for realization of sustainable coastal environmental governance.

The guidelines are prepared for integration of environmental governance into governance environment of municipality for promotion of sustainable governance development which consist of essential components of governance environment:

- procedural environment;
- institutional environment;
- service environment;
- communication environment;
- working environment.

Governance environment has the features of public governance activity environment which ensures the institutional and procedural framework for everyday working coordination of employees and groups. In adequately organized and furnished governance environment of municipality it is necessary in the process of communication between external and internal target groups to prepare, accept and carry out decisions made by governance, as well as work out governance services and products for the development of society and territory, according to common development goals of municipality (Lontone 2012).

References

Ernšteins R (2008) Sustainable coastal development in Latvia: collaboration communication and governance imperative. Sustainable coastal development: colaboration governance. University of Latvia Academic Publishing, Rīga, pp 159–178

Ernsteins R (ed) (2010a) Climate change adaptation policy planning for coastal municipalities. Salasgriva Region, University-Municipality project, University of Latvia, Riga, 248 p

Ernsteins R (2010b) Sustainable coastal development and management: Collaboration communication and governance. J Soc Sci 3:247–252

Ernsteins R (ed) (2012) Environmental governance guidelines for coastal municipalities. Salacgriva Region, University-Municipality reasearch project, University of Latvia, Riga, 286 p

Ernsteins R, Lubuze M, Lontone A, Zvirbule L, Antons V, Zilniece I, Kauliņš J, Vasarina L (2012a) Climate change adaptation integration into Coastal Municipal development: governance environment and communication preconditions. University of Latvia, Riga

Ernsteins R, Lubuze M, Lontone A, Zvirbule L, Antons V, Zilniece I, Kauliņš J, Vasarina L (2012b) Climate change adaptation integration into Coastal Municipal Development: governance environment and communication preconditions. University of Latvia, Riga

Lontone A (2012) Sustainable coastal development: governance environment approach. Master thesis (supervised by Ernsteins R.), University of Latvia, Riga, 120 p

Lubuze M (2011) Green region development communication: Salacgrīva Municipality. Master thesis (supervised by Ernsteins R.), University of Latvia, Riga, 158 p

Zvirbule L (2012) Regional environmental governance development: collaborative governance approach. Master thesis (supervised by Ernsteins R.), University of Latvia, Riga, 140 p