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Dept. of Process and Environmental Engineering

Master's Thesis

Resource efficiency in an urban context: Defining the framework of eco-municipalities

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UNIVERSITY OF OULU **Abstract of thesis**
Faculty of technology

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Abstract

Human settlements are spaces for the exchange of goods, money and ideas; however, their present resource use patterns are unsustainable. Urbanization, urban sprawl, the use of non-renewable resources and the accumulation of wastes create economic, social and environmental challenges. Sustainability can be achieved through action towards resource efficiency, sustainable consumption and production.

This study reviews the concept of human settlements, the dimensions of the eco-cities and case studies of eco-city initiatives. The concept of eco-municipality is endorsed, indicating strategic sustainability objectives for rural and urban settlements. Eco-municipalities follow the principles of eco-cities in their financial and technical decisions regarding the use of local resources, as well as in their communication strategies among municipal officials and residents.

Resource efficiency in an urban context is achieved when synergies among the energy-water-air-waste networks are realized and the boundary conditions are optimized. To this end, environmental technologies for urban development, transportation, heat and electrical energy, municipal solid waste management, water resources and sanitation are proposed.

The Ecological Footprint, The Natural Step Framework and participatory planning were reviewed as instruments of eco-city evaluation. In this work, the ABCD Method of The Natural Step Framework was applied to the municipality of Kostomuksha, Republic of Karelia, Russian Federation. A set of actions toward developing eco-cities has been suggested for the municipal authorities. The actions include urban planning as well as energy-water-air-waste management techniques. The authorities prioritized these techniques using the action priority matrix, which is rooted in environmental economic and social impact assessment. Based on their priorities, a qualitative future scenario has been developed as a target for retro-fit development. Additionally, a timeline of the selected actions has been suggested. The timeline prescribes a path toward sustainability aiming at improving the quality of life and wellbeing of residents.

This work has been conducted under the Green Cities and Settlements (GREENSETTLE) project, co-funded by the European Union, the Russian Federation and the Republic of Finland. It is expected that this study will provide the project participants with the foundation for defining the framework of eco-municipalities.

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OULU YLIOPISTO **Tiivistelmä opinnäytetyöstä**

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Tiivistelmä

Asutukset ovat tiloja, missä tavaroiden, rahan ja ideoiden vaihto tapahtuu, mutta tapa, joilla ne nykyisin käyttävät luonnonvaroja, ei ole kestävällä pohjalla. Kaupungistuminen, kaupunkirakenteiden hajautuminen, uusiutumattomien luonnonvarojen käyttö ja jätteiden kertymät luovat taloudellisia, sosiaalisia ja ympäristöön liittyviä haasteita. Kestävä kehitys voidaan saavuttaa lisäämällä resurssitehokkuutta, sekä kestävää kulutusta ja tuotantoa.

Tässä työssä tarkastellaan asutuksien käsitteitä, eko-kaupunkien dimensioita ja perehdytään eko-kaupunkialoitteisiin. Työssä määritellään eko-kunnan käsite, jolla tarkoitetaan asuinalueita, joissa on hyväksytty kestävän kehityksen strategisia tavoitteita. Eko-kunnissa noudatetaan eko-kaupunkien tapaan samoja periaatteita paikallisten resurssien käytössä ja myös virkamiesten ja asukkaiden välisissä viestintästrategioissa.

Luonnonvarojen käytön tehokkuus kaupungeissa voidaan saavuttaa, kun sähkö ja lämpöenergian-, vesihuollon-, ilmapäästöjen hallinnan sekä jätteiden käsittelyverkot on optimoitu ja saatu synergiaetuja. Näiden tavoitteisiin yltäminen edellyttää kuitenkin erilaisten ympäristötekniikan menetelmien käyttöä, joita on esitelty tässä työssä.

Tässä työssä tarkastellaan ekologista jalanjälkeä, The Natural Step (TNS) -kehysohjelmaa ja osallistavan suunnittelun käsitteitä ja työkaluja eko-kaupunkien arvioinnin välineinä. TNS-kehysohjelman ABCD -metodologiaa sovelletaan tässä työssä erääseen todelliseen asutuskohteeseen, Venäjän Karjalassa sijaitsevaan Kostamuksen kuntaan. Kunnalle laadittiin toimenpidekokonaisuuksia, joita käyttäen kunta voi edetä kohti eko-kaupunkia. Näihin toimiin kuuluvat yhdyskuntasuunnittelu sekä kestävä energia, vesihuolto, ilmanpäästöjen hallinta ja jätehuoltotekniikat. Kaupunkiviranomaisia on pyydetty priorisoimaan näiden osa-alueiden teknillisiä ratkaisuja käyttämällä toiminta-prioriteetti matriisia, joka perustuu ympäristö-, taloudellis- ja sosiaalisten vaikutusten arviointiin. Näiden painopisteiden pohjalta kaupungille on laadittu laadullinen kehitysskenaario. Lisäksi on tehty valittujen toimien aikajana, jolla määritellään kestävän kehityksen polku, jolla voidaan saavuttaa asukkaiden hyvinvoinnin ja parannetun elämänlaadun.

Työ on toteutettu osana Vihreät kaupungit ja asuinalueet (GREENSETTLE) -hanketta, jonka rahoittajia ovat olleet Euroopan unionin ENPI-CBC -ohjelma, Venäjän federaatio sekä Suomen tasavalta. Tässä työssä on määritelty puitteet eko-kunnille, joka tarjoaa hankepartnereille ja muille projektiin osallistuville tahoille perustan eko-kuntien kehittämiseksi.

Säilytyspaikka
Tiedekirjasto Tellus
Muita tietoja

Contents

Forewords

This work has been funded by the Green Cities and Settlements (GREENSETTLE) project, co-funded by the European Union, the Russian Federation and the Republic of Finland. The research work was conducted at the NorTech Oulu unit of Thule Institute, University of Oulu.

I would like to express my gratitude to my supervisor Docent, Dr. Eva Pongrácz for her guidance, support, trust and wisdom that helped me to fulfil this task. My gratitude also goes to my advisor Professor Helka-Liisa Hentilä for the productive contribution in this work.

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Oulu, November 2011

Ioannis Chamilos

1 Introduction

Wellbeing is commonly described in terms of health, happiness and comfort. Humans spend 80-90% of their life indoors (Steemers & Manchanda, 2007). At the same time, a comfortable built environment is a resource-intensive one. According to the estimates of the World Resources Institute, commercial and residential buildings use 25% of total world energy consumption and generate 20% of CO_2 emissions (World Resources Institute, 2007). Energy and water are some of the most important resources consumed in human settlements. At the same, waste and air emission are the results of our everyday life. To find a balance between resource efficiency and a comfortable physical environment, we need cross-cutting technological solutions. In particular, this thesis promotes the use of environmental technologies to achieve resource efficiency in an urban context.

This work is conducted as part of the Green Cities and Settlements ENPI-CBC project. The project aims at improving the quality of life by encouraging a sustainable urban and rural development in remote border areas, reducing environmental loads to promote functionality on urban infrastructure. The objective is to introduce strategic plans and sustainable solutions through collaboration between research institutes and regional authorities.

A key role is to tackle environmental challenges and address the environmental and economic impacts of cities. In this study, the general framework and a sustainable planning method for municipality development is described through the concept of eco-municipalities.

Resource efficiency refers to the reduction of environmental impacts from the production and consumption of raw materials and services supporting the physical environments. The concept addresses the role of raw materials in urban functions, throughout their life-cycle from their extraction through use and final disposal (UNEP, n.d).

Urbanization, inefficiency in resource use and climate change have created environmental stress. Societies need to be aware of the impacts of climate changes and the limitation provided by the scarcity of resources in order to overcome the imminent difficulties and gradually adapt cross-cutting sustainable solutions (Millennium Ecosystem Assessment, 2005). Since resources are the main drivers of economic activities (Fischer-Kowalski, 2009), a resource efficient built environment will positively contribute to energy security, to the reduction of greenhouse gas emissions and to soil pollution, as well as to the conservation of non-renewable resources.

Practitioners, disciplinary scientists and non-governmental organizations have introduced concepts under sustainable development to promote technologies and strategic plans for developing cities authorities towards retrofit development. Retro-fit development refers to refurbishments of the city physical structure and the adaptation of sustainability principles in the local regulatory body.

Nevertheless, the different spatial levels (Bio-region, the city level, the community level and the building level approach) of the society, which describe the different urban forms, show that there is no common conceptual framework to compare these concepts in an urban context (Jabareen, 2006). In that context, the perception of the eco-city concept is challenging.

This work attempts to bridge the approaches describing the Eco-City concept through system thinking. This will be achieved by introducing a process to build a scenario for the target area which is Kostomuksha municipality, located in the Republic of Karelia, Russian Federation.

The structure of the thesis is as follows:

1. Reviewing policy objectives under the framework of Eco-Cities(Chapter 2)
2. Describing the Energy-Water-Waste-Air boundary in an urban context (Chapter 3)
3. Reviewing eco-initiatives and sustainable practices in cities(Chapter 3)
4. Introducing The Natural Step Framework (TNSF) as the underlying theoretical concept (Chapter 4)
5. Performing a case study in which a TNSF tool is applied to the municipality of Kostomuksha (Chapter 5)

THEORY PART

2 The characteristics of an eco-municipality

2.1 The urban functions

There are several approaches that attempt to define what a city consists of. Ekistics was introduced as the science of human settlements (Doxiades, 1968). Ekistics studies how human settlements were inhabited by humans and provides a conceptual framework for a better understanding of human settlements. The foundation of the concept is in nature, which contains ecological systems, within which humans form social network and societies and build the 'shells' which are the physical structures providing comfortable living conditions.

The basic elements of human settlements in the ekistics studies are described below (Doxiades, 1968, p.12):

1. *"Nature, providing the foundation upon which the settlements are created and the frame within which they can function"*
2. *"Human"*
3. *"Society"*
4. *"Shells, or the structures within which humans lives and carry out his different functions"*
5. *"Networks, or the natural and human-made systems which facilitate the functioning of the settlements, as for example roads, cycling corridors and infrastructure in general."*

The basic difference between shells and networks is that shells provide the physical interface between humans and nature, and the network is supporting the urban functions. Urban function are complex systems including processes between private and public sectors in relation to the components of energy, water & sanitation, traffic & transportation, urban development and socioeconomic services.

In an attempt to understand human settlements, it is advisable to review the ekistics classification. The types of classification are (Doxiades, 1968):

(i) ekistics units,
(ii) ekistics elements,
(iii) ekistics functions,
(iv) evolutionary phases and
(v) factors and disciplines.

In this work, the focus is on units, elements and functions. The idea is to describe the dimensions to consider when a strategic planning of city characteristics is undertaken.

The ekistics units describe the levels of the built environment. They are categorized based on population size, to provide an understanding of urban functions. **Figure 1** lists the units of human settlements in the order of population size and magnitude.

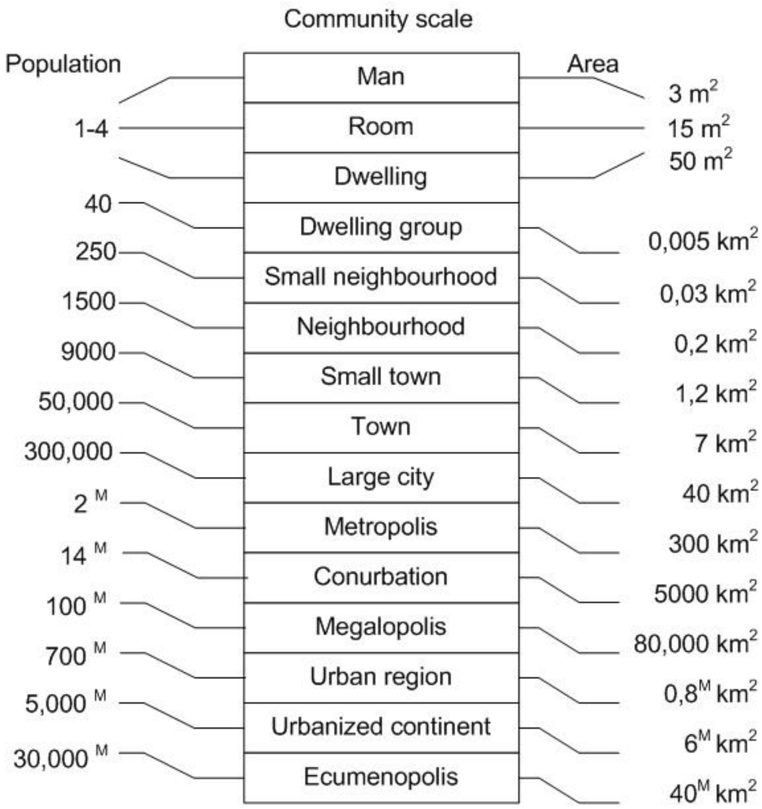

Figure 1. The ekistics logarithmic scale of human settlement units based on population size and density, (Adapted from Dioxiades, 1968).

The subcategories of ekistics give a holistic understanding of the key topics in understanding city functions. **Figure 2**, illustrates the interrelation between ekistics elements and scientific disciplines, and the subcategories of ekistics elements.

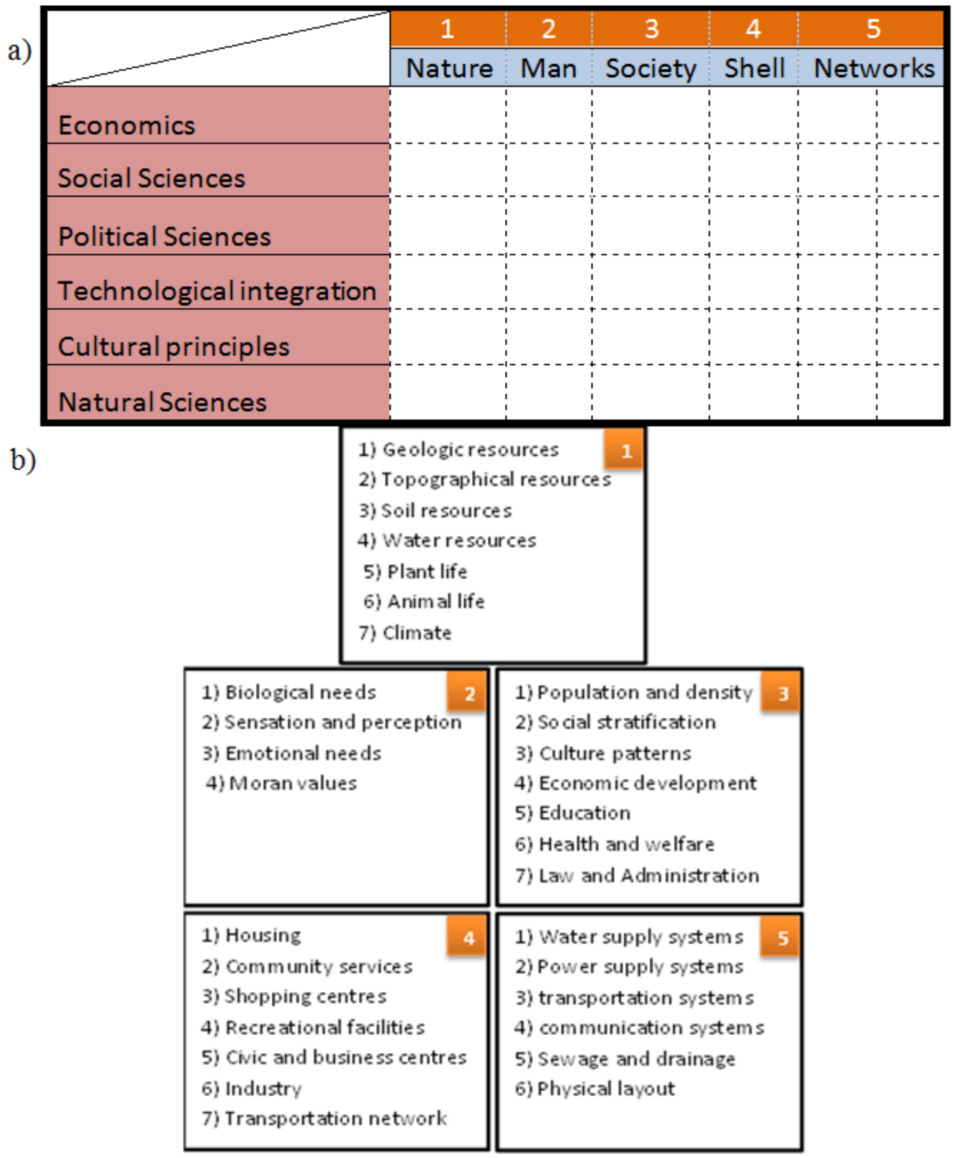

Figure 2. a) Elements and sciences in the study of human settlements, b) Subcategories of the five ekistics elements, (adapted from Doxiades, 1968).

The spatial patterns of a city cover the physical environment (Shells + Nature), and two-dimensional maps give the characteristics showing the spatial distribution of people, built environment and their attributes. Topographic maps, land use maps, street maps with notations, utilities (power, water, sewage) - networks maps, maps of housing condition, weather maps and geographical information files of preserved natural areas give the first overview of a city form (Lynch, 1980, p. 677). Historical and cultural elements are also combined with the information of the spatial patterns. Analyzing the quantitative indicators of ekistics elements (e.g. sewage network), using the tools provided by the listed scientific principles, criteria for city development can be devised. The key is to understand how the ekistics elements (e.g. nature, man, society, shells, and networks) influence each other.

2.2 The concepts and the dimensions of the eco-cities

Eco-cities date back to 1975 when a group of visionary architects and activists created a non-profit organization called Urban Ecology. The mission of Urban Ecology was urban planning, ecology and public participation in order to rebuild the cities in balance with nature. In 1985, the Urban Ecology team collaborated with citizens of Berkeley California, to redesign a street for bicyclists, safe to walk and slow down the speed of cars. The name of this effort was "slow street" and the mission was to raise awareness on our dependence on fossil fuels (Urban Ecology, 2010). Such actions soon started to interest more people and, in 1990, Urban Ecology hosted the first International Eco-City conference in Berkeley CA, with the main criteria to discuss about ecosystems, alternative transportation, environmental justice and urban design in modern cities (Urban Ecology, 2010). The second International eco-city conference was held in Adelaide, Australia, in 1992, the third one in Yoff, Senegal, in 1996. Further on, countless of eco-city initiatives have commenced worldwide. These initiatives defined a common framework of ecological cities.

The Urban Ecology organization envisioned that cities would become ecological by adopting the following 10 principles (As quoted by Roseland, 1997):

1. *"Revise land-use priorities to create compact, diverse, green, safe, pleasant and vital mixed-use of communities near transit nodes and other transportation facilities"*
2. *"Revise transportation priorities to favour foot, bicycle, cart and transt over autos, and to emphasize access by proximity"*
3. *"Restore damaged urban environments, especially creeks, shore lines, ridgelines and wetlands;"*
4. *"Create decent, affordable, safe, convenient, racially and economically mixed housing;"*
5. *"Nurture social justice and create improved opportunities for women, people of colour and the disabled;"*
6. *"Support local agriculture, urban greening projects and community gardening;"*
7. *"Promote recycling, innovative appropriate technology, and resource conservation while reducing pollution and hazardous wastes;"*
8. *"Work with businesses to support ecologically sound economic activity while discouraging pollution, waste, and the use and production of hazardous materials;"*
9. *"Promote voluntary simplicity and discourage excessive consumption of material goods;"*
10. *"Increase awareness of the local environment and bioregion through activist and educational projects that increase public awareness of ecological sustainability issues"*

While these efforts emphasize the significance of environmentally conscious behaviour and the role of appropriate technologies, the key element of eco-cities is the well-being of humans.

Similar actions but on a smaller scale and related with sustainability planning have addressed the eco-city concept. An example is Suomussalmi, Finland, were the first eco-municipality concept introduced in 1980. Later on in, 1983, the municipality council of Övertorneå, Sweden where adopted the eco-municipality concept, rooted in urban ecology principles. The eco-municipality model spread out to other communities in Sweden. Ultimately, a network was created to provide support cities undertaking ecological community planning (SEkom, 2011).

Engwitch, an Australian community activist also criticized city planners and engineers for having eliminated effective human exchange by taking commerce out of the cities into shopping malls, which also increased traffic. A city for Engwitch should be “an invention for maximizing exchange and minimizing travel”. By exchange he meant goods, money, ideas and emotions. He advocates eco-cities where people can safely move and interact without fear of traffic and toxins (Engwitch, 1993, as quoted by Roseland, 1997).

Figure 3 illustrates the dimensions of eco-cities. The figure includes the concepts in which the ideology of eco-cities in rooted in, such as green movements, Community Economic Development (CED), social ecology and bioregionalism. The ultimate aim is sustainable development, to which end, appropriate technologies are used. The goal is also to provide for capacity building by promoting communication and participation, the outcome of which is a set of actions improving the interactions of urban functions (Energy-Water-Waste-Air).

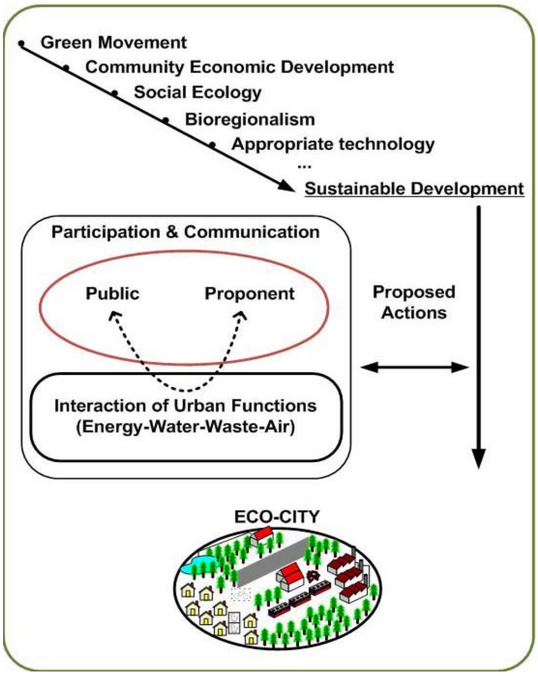

Figure 3. Dimensions and actions towards eco-cities (Based on Roseland, 1997)

In the following, the concepts illustrated in Figure 3 are elaborated.

2.2.1 Green movement

The main pillars of the Green movement are (i) The environmentalism, (ii) social liberalism and (iii) Grassroots democracy (Dereck, 2010). The Green movement has evolved to a political ideology that aims at the creation of economically sustainable society. The roots are in the 1970's, since then Green parties have been established in many countries (Bomberg, 2002).

2.2.2 Community Economic Development

Community Economic Development (CED) is an approach based on the process of localized development by involving stakeholders and decision makers to structure communities, industries, and markets. The mission is to support and use local resources and build an economy with common conceptual benchmarks (Roseland, 1997).

The approach encourages local resource use while improving social, economic and environmental conditions of communities. The CED principles recognize the economical capacity of the region and give a holistic understanding towards a community based development. The principle of CED is to engage community members to create sustainable practices while serving the needs of the region. By engaging the community, barriers arising from unilateral decisions can be avoided (Markey & Sean, 2004). The framework of the CED principles is (Ibid.):

- A community based approach, specifying needs and barriers;
- A meaningful participation of local community;
- An implementation of sustainable development;
- A development based on the strengths and resources of communities, which describe the assets of the community;
- Achieving self-reliance by appropriate technology and respecting bioregionalism;

In order to adapt the above principles, real participation in the planning processes of the community is essential for development. This, in some respect, follows the principles of the green movement, where the general trend is to respect the ecological elements in order to achieve economic development, plan actions under a participatory framework respecting the social networks and promoting safe environments rooted to democracy (Markey & Sean, 2004).

2.2.3 Social Ecology

Murray Bookchin was an American libertarian, socialist, and pioneer of the ecology movement and the founder of social ecology. Social ecology is the study of human and natural ecosystems. In particular, it emphasizes social relations and interactions between the society and nature, and how they function together. Social ecology advances respect global sustainability, appropriate technologies, reconstructions of damaged ecosystems and creative human enterprise targeting an ecological society in harmony with nature (Roseland, 1997).

The ecological society is an eco-community that preserves human assets for (Ibid.):

- Sustainable settlement based on ecological balance
- Community self-reliance, and
- Participatory democracy

Social ecology envisions committed citizens who gather together and create common goals (brainstorming). The purpose is to foster meaningful communication, cooperation, and collaboration for the everyday practices between communities and avoid destruction from political actions, while supporting transparency on those actions (Roseland, 1997).

2.2.4 Bioregionalism

Bioregionalism is an environmental movement to make political boundaries overlap with places or regions, whose limits are naturally defined by topographic and biological features (Roseland, 1997). Region is a place defined from its landscape, climate, ethnic origin, shared history and language. The practices of bioregionalism concentrate on natural resources and the adaptation of appropriate technologies avoiding destruction of the local environment such as forest, rivers, lakes etc. The tools are related to bioregional mapping covering the history and the theory of an ecological mapping while introducing a planning methodology, which preserves the nature and aware the local community. The Ecological footprint (EF) (section 4.2) introduced by Wackernagel and Rees in 1996 is considered as a bioregional tool (Roseland, 1997).

2.2.5 Appropriate Technology

The ideological movement of Appropriate Technology (AT), founded by E.F. Schumacher in 1973 is also known as alternative or intermediate technology. Technologies described in this context have been used in developed and developing countries assisting the needs of the society. AT methodologies, strategies and practices are related to economic development, environmental and social sustainability. The goal is to utilize local resources for common benefits of the society and to introduce technologies compatible with local settings. Some of these technologies are (Roseland, 1997):

- *Passive solar design*
- *Solar collectors for heating and cooling*
- *Roof-top gardens*
- *Hydroponic greenhouses*

The main goal of using AT is to promote self-reliance of people on a local level. Available resources are important to select appropriate technology in a community. In this thesis, the term environmental technologies are used as an upgraded concept of appropriate technologies. These technologies are environmentally sound technologies, are less polluting and promote the use of renewable resources and waste-to-energy technologies. Some of these technologies promoted in this thesis are:

- Passive housing (energy balance, bioclimatic comfort etc.)
- Solar, photovoltaic (PV) and solar thermal panels
- Windmills
- Heat pumps
- Waste and biomass to energy technologies (Anaerobic digestion, pelletization, gasification, alcohol fermentation etc.)
- Solid state (e.g. led) urban lighting

2.2.6 Sustainable Development

The development of the sustainable development (SD) concept has a long timeline with key meetings, environmental events, publications and other milestones paving the path towards sustainability (IISD, 2010).

The term SD was first popularized by the Brundtland report to the Word Commission on Environment and Development, *"Our Common Future"*, and published in 1987. It has been defined as (WCED, 1987):

> *"Development that can meet the needs of the present generation without compromising the ability of future generations to meet their own needs"*

The phrase covers a complex range of meaning and ideas and it is a top priority of strategic plans. In **Figure 4,** the concept is illustrated as economic, environmental and social sustainability being the three pillars of SD, the target being to keep the balance between the three development goals.

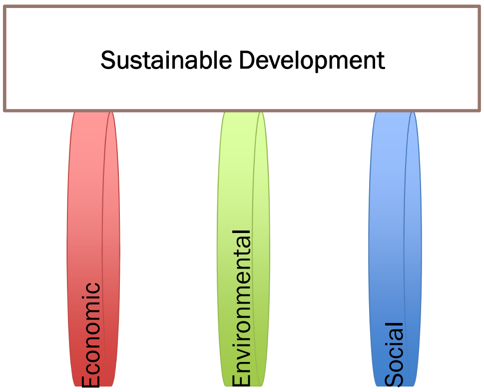

Figure 4. Graphic representation of the three pillars of sustainable development, (as quoted from Adams, 2006).

If Sustainable Development is considered as a process, sustainability refers to the end result of this process Moles et al. distinguish the difference as (2007):

Sustainable development can be defined as: "*a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspiration*"

"Sustainability is considered as a dynamic balance among three mutually interdependent elements*:*

1) *protection and enhancement of natural ecosystems and resources*

2) *economic productivity, and*

3) provision of social infrastructure such as jobs, housing, education, medical care and cultural opportunities"

2.3 The criteria of eco-cities

Bhatnagar (2010, as quoted by Dijk, 2011) defines eco-cities as:

> *"City accessibly to everyone; in balance with nature; reducing, re-using, recycling waste; and contributing to a close water cycle, integrating to the surrounding region"*

The UNESCO-IHE Institute had suggested an inventory of ten criteria to define ecological cities. The ten criteria are how the city deals with the following issues (Dijk, 2011):

1. *Energy*
2. *Solid - waste*
3. *Transport*
4. *Pollutions*
5. *Water related*
6. *Sanitation s*
7. *Climate change*
8. *Housing*
9. *Sustainable urban development*
10. *Integrated approaches*

For each of these indicators, sub-indicators have been suggested (Ibid.). They are listed in Appendix 1.

3 Resource supply and demand in cities

3.1 Urban metabolism

International actions and scientific assessments such as the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2005), the Global Environmental Outlook and the 4th Assessment Report of the Intergovernmental panel on Climate Change (Metz, 2007) are making increasingly evident that the world cannot achieve economic growth without significant innovation in both supply and demand of resources (UNEP, n.d).

Abel Wolman in 1965 developed the concept of the urban metabolism while studying the input and output of 1 million inhabitants of an American city. The focus from his first publications was mainly in water and air quality issues. Furthermore, he studied fluxes of energy, materials, nutrients, water and waste. Wolman analyzed how the physical structure of a city changed depending on the industrial activities, the technological waves, and the cultural characteristics. (Kennedy et al. 2007, p.44). As a conclusion, the context of urban metabolism in his work was summarized (Ibid.):

> "*The sum total of the technical and socioeconomic processes that occur in cities, resulting in growth, production of energy, and elimination of waste"*

Urban metabolism gives an understanding of how cities move towards sustainable development. It quantifies the input-process-output fluxes that take place in cities. During the process evaluation, the storage of energy, water, nutrients and wastes is also taken into account. Decker et al. (2000) synthesize the urban metabolism concept in the definition:

> *"Cities transform raw materials, fuel, and water into the urban built environment, human biomass and waste."* (Decker et al. 2000)

The practical reason to study urban metabolism is to understand the elements of the urban system and the metabolic parameters of the city. These parameters can be used as indicators of improvements and create a variety of different development scenarios.

The metabolic parameters show the magnitudes of some indicated problems. For example, studying the resource intensity of a region through indicators such as, the amount of waste generated and disposed, as well as electric consumption in public infrastructure, and heat losses, the metabolism of the city can be modelled in order to further build a quantitative scenario (The Encyclopedia of Earth, 2007).

Some factors influencing the metabolism of the city are as follow (Kennedy et al. 2007):

1. Physical structure
2. Density and morphology
3. Transportation patterns
4. Climate conditions
5. Anthropogenic impact
6. Age of built environment

The above six characteristics give the first impression to draw a baseline scenario about the needs of the specific area. In particular the age of the city built environment indicates roughly the infrastructure and physical conditions. The population density and the morphology of the physical structure provide socio-economic implications, and indicate the demand for resources and waste intensity. The patterns and the technology used in transportation are indicators of fuel consumption and emissions into the air. The climatic conditions create the limitations and standardization of any action in the physical structure and the anthropogenic impact refers to the magnitude of natural distraction and living standards (The Encyclopedia of Earth, 2007).

When the metabolism increases, the consumption of natural resources increases; the magnitude of traffic and pollution increases, which inversely, involves losses of farmland and, forest areas, as well as species diversity. The metabolism can be affected through policies and instruments such as building codes, water and waste fees (Kennedy et al. 2007).

Other critical impacts can be also groundwater failing, the heat island effect, the accumulation of nutrients in water bodies as well as hazardous materials stored in building stocks. All these indicators give a deeper understanding to decision makers for choosing appropriate strategies to meet sustainability. Additionally, using tools such as ecological footprints, Life Cycle Assessment, Environmental Management Systems, Material Flow Analysis and The Natural Step Framework allows to identify synergies between the different city characteristics, which they are analysing the urban functions (Churkina, 2008, p. 110, James & Lahti 2008).

Traditionally, the design of cities levels (Ekistics units, section 2.1) had the tendency to be linear, input versus output. Efficiency is commonly described as a ratio between the input and the output, recognizing losses or waste outputs. The Input Process Output model identifies use of resources and creates indicators per ekistic units (building, neighbourhoods, city, region etc.).

The interactions of the resources used between the different units cannot be identified through linear models, because waste fraction (heat losses, materials etc.) and inefficient processes act dynamically. New models for retrofitting cities follow dynamics models, which attempt to identify and quantify interactions between the different elements and improve resource efficiency (Gafron et al. 2005).

The new sustainable planning method, show in **Figure 5**, should follow a cyclical approach, indicating that urban functions should be analysed not only from their individual inputs-outputs but in interrelation with each other (Gafron et al. 2005).

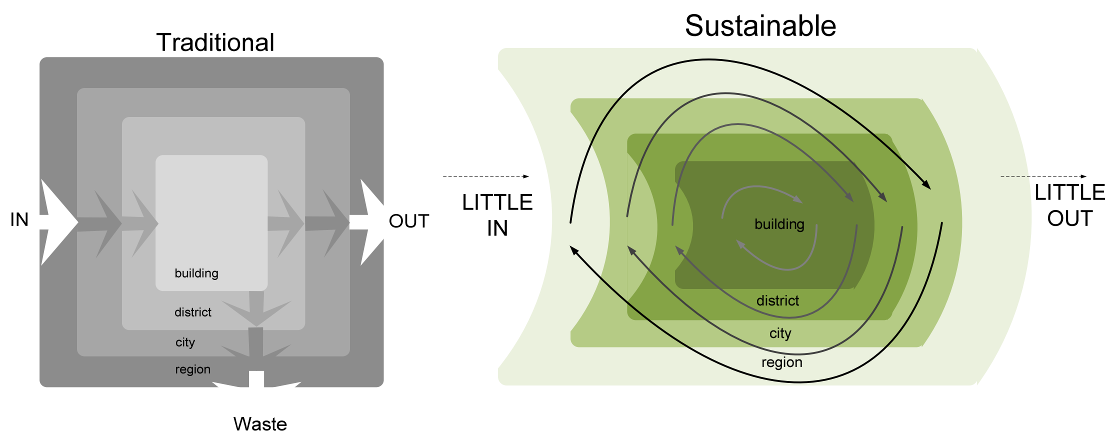

Figure 5. Illustration showing the difference between traditional and sustainable planning (Gafron et al. 2005, p. 22).

3.2 Comfort conditions and Design

Climate conditions are setting the limits for comfort function and design specification. The geographical location, year-round solar radiation, humidity, precipitation and wind are important climate data to factor in (Hegger et al. 2008)**.**

Comfort is a subjective concept, as the user defines the level of comfort. This needs to be understood when comfort factors are included in calculations for retrofit development. The comfort conditions, for indoor and outdoor built environments are categorized in **Table 1**.

Table 1. Representation of the comfort conditions based on the Energy Manual (Hegger et al. 2008, p.55).

Categories 1.Physical Conditions	Subcategories	Indicators of improvement
1. Thermal	Interior air temperature	
	Mean Enclosing surfaces temperature	Building Insulation (U-values)
	Interior air humidity	Ventilation system
	Air movements	avoid sick buildings syndrome
2. Acoustic	Frequencies	Electrical installations and appliances
	Noise level	Traffic Arteries and roads
	Reverberation times	Interior Space design
3. Visual	Lighting, contrast, angle of light	Demand for electricity
	Glare, luminance distribution	Natural light
	Colours, scheme, colour rendering	
	Safety luminance	
4. Olfactory	Unpleasant smells	Waste accumulation
	Carbon dioxide and GHG in general	Emission from traffic/industry
	Dust	Construction site
5. Common	Air pressure	Inversion and smog phenomena
	Static charge of interior air	

To maintain well-being and hence a comfortable indoor and outdoor environment, the collected climate data should be taken into account and the design pattern shall meet specific limits based on standards.

3.3 Energy-Water-Air-Waste boundary

In nature, the biogeochemical cycles are closed. Biogeochemical cycles in ecology and earth science refer to the movements of substances, such as chemical elements or molecules, which move from biotic and abiotic compartments of the earth. Those cycles critical for life are nitrogen cycle, water cycle, carbon cycle, oxygen cycle and phosphorus cycle. The interaction of the biogeochemical cycles, the energy and water cycles and that of human activity can be considered as the functioning of the global Earth System. (Groisman & Bartalev, 2007)

From a regional level to a city, town, village, neighbourhood level and, ultimately, to a building, the borders between these urban units create boundaries of interactions. Within the concept of eco-city a key activity is to control the waste flows across these boundaries.

The mind-map in **Figure 6** depicts the core areas of interest which define an eco-city.

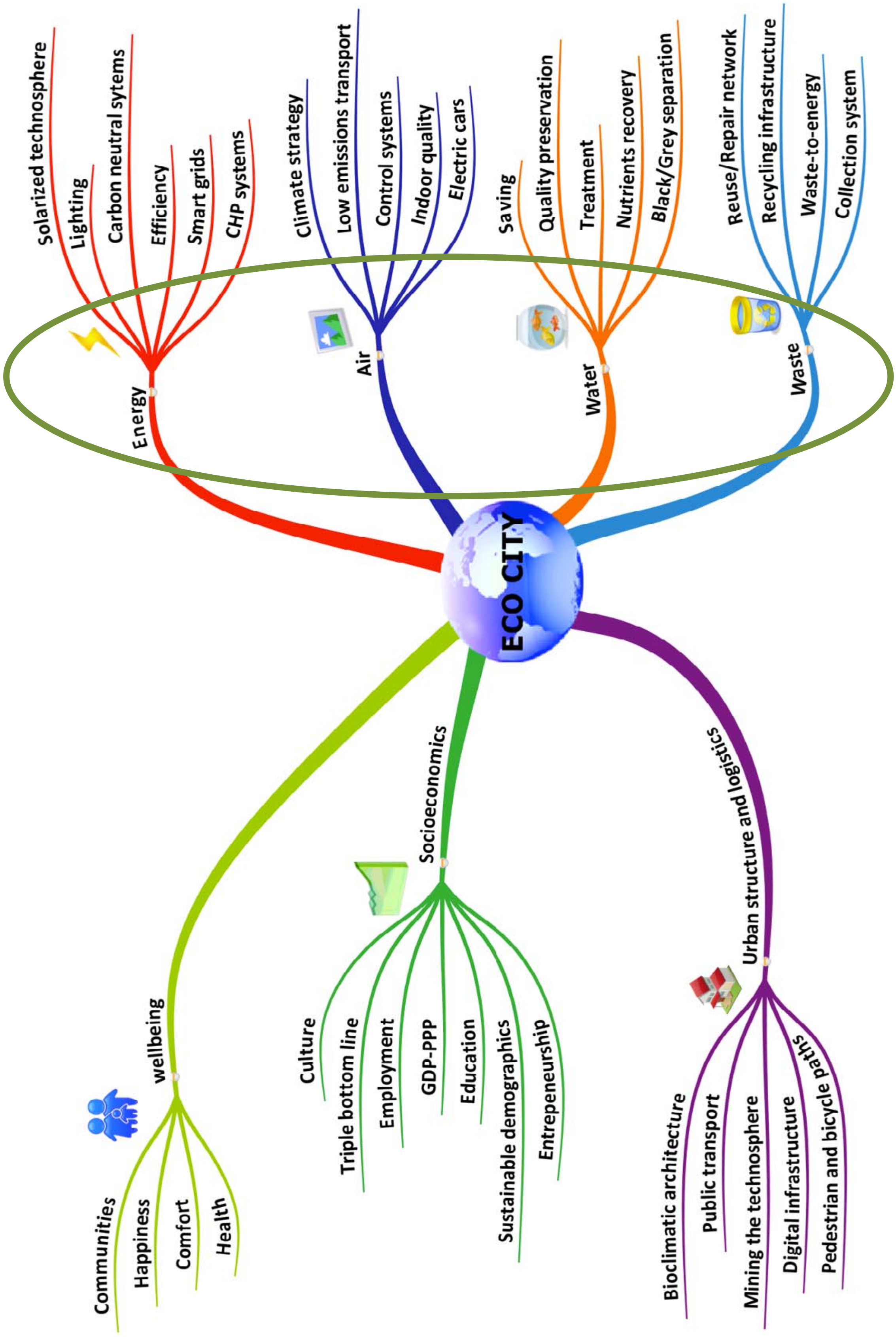

Figure 6.The core area of interest which defines an eco-city.

In this work the focus is to describe the Energy-Air-Water-Waste boundary and the selection of environmental sound technologies.

Figure 7 shows, the core issues related to impact analysis and optimization of the boundaries conditions.

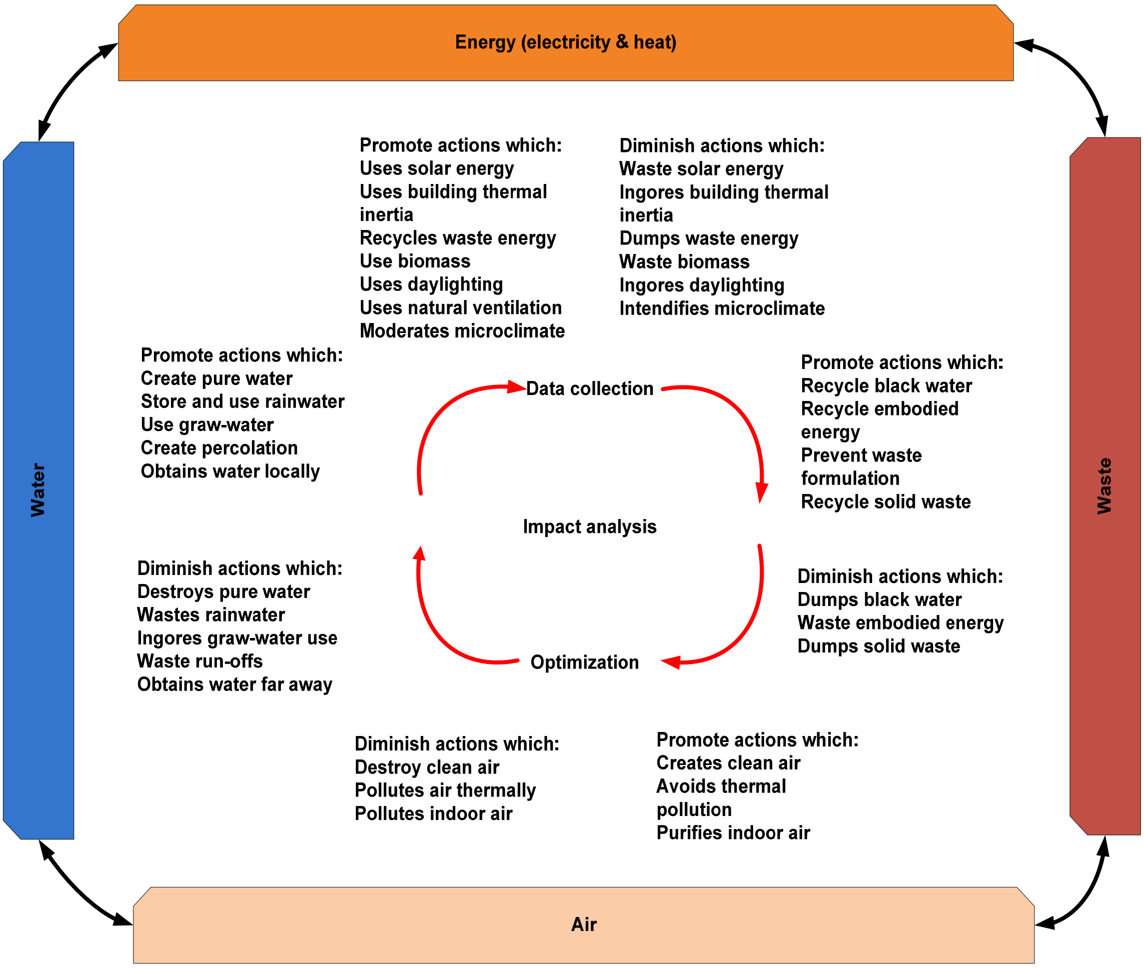

Figure 7. The Hannover principles of sustainability within the Energy-Water-Air-Waste boundary;

The process should move through a concession of data selection processes of qualitative and quantitative scenarios, to assessing environmental load (impact analysis) and, finally, performance optimization. The data collection refers to the quantifying requirements of resources, the impact analysis refers to the environmental load of the actions and optimization refers to the systematic evaluation of the needs and opportunities (McDonough, 1992). The actions listed in **Figure 7** are from the Hannover principles' matrix of sustainability (Ibid).

3.4 Eco-city initiatives

The University of Westminster from United Kingdom published a survey in 2009 on eco-cities initiatives. The aim was to map actions, which cover a broad field of innovations. The survey excluded initiatives that did not go beyond conceptual stage, and of which no English language literature existed. As of autumn 2009, they identified 79 eco-cities initiatives around the world (Joss, 2010, p.15). The majority of the initiatives, 39 are located in Europe, with Scandinavian countries, the United Kingdom and Germany in top three (Joss, 2010). Based on the survey, a typology of eco-cities was presented (**Table 2**).

Table 2. Typology of eco-cities (adapted from Joss, 2010).

Type	I New Development	II Expansion of Existing urban area	III retro-fit' development
Phase	1 At planning stage	2 Under construction	3 Implemented
Mode	a Technological innovation	b Integrating sustainability planning	c Civic involvement

Retro-fit development refers to refurbishments of the city physical structure and the adaptation of sustainability principles in the local regulatory body. For the purpose of this study, only the type III initiatives have been evaluated. These retro-fit development efforts are listed in **Table 3**.

Most type III initiatives had their basic goal to decrease vulnerability to climate change, while supporting energy flexibility and resource efficiency of urban functions.

Further to the actions taken in type III eco-initiatives, the Practical Evaluation Tool of Urban Sustainability (PETUS) have been reviewed (PETUS, 2011). As a result of this synthesis effort, a set of actions for retro-fitting (developing) eco-cities is listed in **Table 4**.

It is proposed that these actions, as listed in **Table 4**, are to be used in the Green Cities and Settlements project, for the municipalities to set goals to progress towards eco-cities.

Table 3. Eco-City initiatives for retrofit development (Joss, 2010).

	City	Description	Type	Phase	Mode
1	Curitiba, Brazil	Integrated public transport; waste recycling	III	3	a
2	Erlangen, Germany	Pro-bicycle policy; solar power technology	III	3	a
3	Ferrara, Italy	advanced, city-wide recycling system	III	3	a
4	Freiburg, Germany	'solar city'; renewable energy technologies	III	3	a
5	Glumslov, Sweden	patented 'self-heating house'; recycling system	III	3	a
6	Gothenburg, Sweden	aims to develop into 'super sustainable city'	III	1	a
7	Hamburg-Harburg, Germany	creative-industrial regeneration project	III	1	a
8	Hamm, Germany	government-supported ecological model city	III	3	a
9	Heidelberg, Germany	energy saving measures; 35% CO2 emissions cut	III	3	a
10	Kampala, Uganda	national park zoning in city; public transport	III	3	a
11	Kottayam + 5, India	governmental pilot for six Eco-City initiatives	III	2	b
12	Loja, Ecuador	advanced (organic) waste recycling system	III	3	a
13	*Malmo / BoO1 district, Sweden, augustenborg	600 unit housing & technology centre	III	3	a
14	Oslo, Norway	public transport, waste reduction policies	III	3	a
15	Portland, USA	public transport network; green zones	III	3	a
16	Puerto Princesa, Philippines	reforestation programme; electrical tricycles	III	3	b
17	Reykjavik, Iceland	geothermal energy; hydrogen bus system	III	3	a
18	Sidney, Australia	integrated sustainable development plan	III	2	b
19	St Davids, UK	self-declared first carbon neutral city in UK	III	3	b
20	Tajimi, Japan	renewable energy projects, green roof tops	III	3	c
21	Toronto, Canada	reduced CO2 emission, renewable energy	III	3	a
22	Vancouver, Canada	city council adopted EcoDensity Charter	III	2	a
23	Vaxjo, Sweden	75% CO2 emission cut, bio-energy projects	III	3	a
24	Waitakere, New Zealand	community-based sustainability planning	III	3	c
25	Yokohama + 5, Japan	national, 6 city-initiative to cut CO2 emissions	III	2	a

Table 4. Set of actions towards developing eco-cities.

Urban Development	Traffic & Transportation	Energy (Heat & electricity)	Municipal Waste Management	Water & Sanitation
Prevent ***urban sprawl***[1]	Retrofitting city buses with catalytic converters	Energy saving plan for municipal buildings	Improve present landfills and utilize landfill gas	Harvest rainwater for irrigation purposes
Densification of existing urban structure	Create dedicated bus lines	Energy and environmental inspection to reduce energy losses and pollution	Identify priority waste streams to set up recycling systems	Subsidize water efficient taps and shower nozzles
Plan for mixed uses (better proximity to ***urban function***[2])	Extend roads to improve traffic flow	Pilot investment in small-scale decentralized energy solutions	Set up recyclables collection points (***Ekopoints***[3])	Wastewater sludge utilization (biogas)
Integrate infrastructure planning with service development	Incentives to reduce car use (walking & bicycle lanes)	Subsidize refurbishment of existing buildings for energy saving	Awareness raising for waste prevention and minimization	Improve the efficiency of water purification plant
Plan for the ***recreational aspects***[4] of urban space	Biofuel –run municipal fleet	Energy saving street lighting system	***Wet/dry separation***[5] of waste	Improve the quality of water and sanitation infrastructure
Participatory Planning[6].	Infrastructure supporting the use of electric cars	Promote use of renewable based electricity	Kerbside separate waste collection system	Awareness raising for water saving
Urban interaction (**UBI**[7]) system	Transport ICT systems	Development of **smart grids**[8]	ICT system to optimize waste and management	Pilot areas with grey-water recycling (**living machine**[9])

[1]**Urban sprawl**: spreading outwards of a city to low density, car-dependent areas
[2]**Urban function:** synergies with private and public sector in relation to the components of energy (e.g peak loads, energy efficiency), waste (collection, treatment and utilization of waste), water & sanitation (purification and filtration, phosphorus recovery etc), traffic & transportation, urban development and socioeconomic services supporting the societies.
[3]**Ekopoints:** collection points of waste fractions at areas near markets, shopping centers and small residential areas (Ekorosk, 2011).
[4]**Recreational aspects:** utilization of parks, green spaces and indoors to support leisure activities.
[5]**Wet/dry separation of waste**: segregation of wet organic waste from dry recyclables
[6]**Participatory Planning:** described in section 4.3
[7]**UBI (from ubiquitous):** a concept to develop a monitoring, feedback and information systems for the community. E.g. in the city of Oulu, displays are placed indoor and outdoor in hotspots allowing interactions and sharing of information's between the citizens (UBI, 2010).
[8]**Smart Grids:** Through which suppliers and consumers can have a two-way communication monitoring in real-time the electricity grid condition (small energy production plant, demand respond for lower the consumption and distribution of electricity, electrical car recharging storage).
[9]**Living machine:** is a concept applied to technologies for wastewater treatment and generation of clean water in situ. Its application configures in order to satisfy the needs of the location and the local climate (Living machine, 2011).

4 Tools of eco-city evaluation

4.1 The Natural Step Framework

The Natural Step Framework (TNSF) started in the late 1980's when every environmental problem was handled independently and based on media interest. In 1988, Dr. Karl-Henrik Robèrt, a practicing clinician and specialist in cancer research, approached scientists and professionals and asked them to join in an open dialogue about what was unsustainable in the societies. He asked, to create a framework where human actions would follow a sustainable path regarding the use of local resources. (James & Lahti, 2008)

The framework introduced a set of sustainability principles applying a certain methodology to look at the "big picture" of communities. Communities under this framework set common goals and create the assets for the future generation to inherit and continue to develop. The knowledge to build up TNSF continued by broadening the dialogue and engaging government officials, business leaders, trade union representatives, members of national non-profit organizations, entertainers etc. (James & Lahti, 2008). Dr. Karl-Henrik Robèrt prompted a phrase which was the seed of The Natural Step (TNS) approach-"*Find fundamental principles of indisputable relevance, and thereafter ask the advice of others on how to apply them*" (Robèrt, 2002, p. 32).

To create a common system oriented thinking, Karl-Erik Eriksson, Physics Professor, and the physics doctoral student John Holmerg, have met in 1990 in Orsa, Sweden, for the first conference of eco-municipalities. Combining knowledge and respecting the natural laws physic laws (the Law of conservation of matter, first and second law of thermodynamics etc.) Robèrt, Holmerg and Eriksson developed the conceptual model for a sustainable society that is the basis of the fundamental principles of TNSF or the *system conditions* for a sustainable society. The directions of TNSF for sustainability follow these four system conditions for sustainability planning. The tools to apply the TNSF, which are the ABCD Method and the backcasting approach, are described in the follow sections. The goal of TNSF is to reorient business operations and practices toward the ones that are sustainable. TNSF has a range of action in Canada, Europe, North America and Japan (James & Lahti, 2008, p. 182).

4.1.1 System Conditions for sustainability under TNSF

The Natural Step developed such a framework of complementary, non-overlapping conditions for social and ecological sustainability (Robèrt et al. 2002).

System condition one:

> *1.”In the sustainable society, nature is not subjet to systematically increasing concenstrations of substances extracted from the Earth’s crust”*

Substances extracted from earth such as fossil fuels, minerals and metals have been instrumental in building our physical infrastructure. However, during the combustion fossil fuels emissions such as carbon dioxide and nitrogen oxides are created, and toxins released. Based on the first law of thermodynamics, energy cannot be destroyed neither created but it may only change from one form to another. In chemical reactions matter follows the same principle. These are examples of substances extracted from earth’s crust concentrated in nature (James & Lahti, 2008).

Another essential issue is population growth. The world population is estimated to reach 8 to 10,5 billion by 2050 (Millennium Ecosystem Assessment, 2005). While the number of people and their demand for resources increases, concurrently, the availability of resources and ecosystem services will decline. This is illustrated with the Funnel analogy as presented in **Figure 8.**

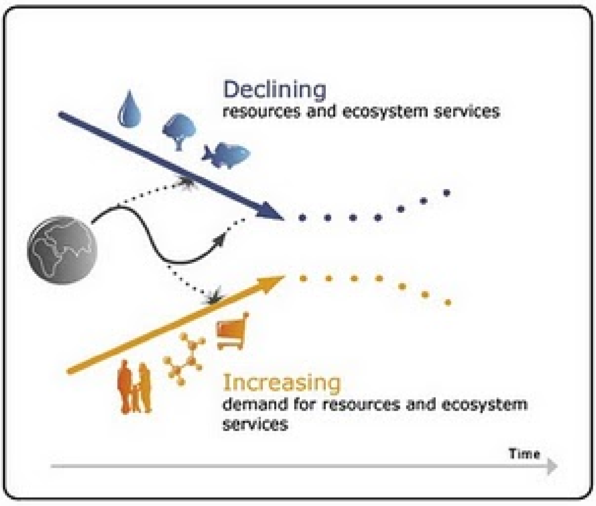

Figure 8. The Natural Step Funnel (Bertner, 2008).

The funnel is a metaphor for the overall problem of non-sustainability. This metaphor is also used to explain the self-benefit that lies in avoiding the walls of the funnel, and directing activities towards its opening (Robèrt, 2000).

System condition two:

2.” in the sustainable society, nature is not subject to systematically increasing concenstrations of substances produced by the society”

It is estimated that there are more than 70.000 chemical substances in commerce and many of those have a negative impact on human health and environment. Many of this are persistent and can spread from one point of origin to another (James & Lahti, 2008).

System condition three:

3.”In the sustainable society, nature is not subject to systematic increasing degradation by physical means”

Anthropogenic activities are causing the breakdown of natural systems, land, water, forests, soil and ecosystem functions. The breakdown rate is faster than what nature can handle and restore. Half of the Earth’s original forest cover has been destroyed to support human and industrial needs. Two of every three species is estimated to be in decline and the demand for fresh water exceeds the world supply by 17%. It is therefore important to stop natural degradation and reconsider the functions and networks of the society (James & Lahti, 2008).

System condition four:

4.”In the sustainable society, people are not subject to conditions that systematically undermine their capacity to meet their needs.”

The fourth system condition is addressing the social and economic objectives of sustainable development (James & Lahti, 2008, p.216). Societies must provide for the basic needs of humans such as air, water, food and shelter (Max-Neef, 2011). While community needs depend on cultural characteristics and livelihoods; human have a need for mobility, equality, safety, public hearing, free access to nature and rights for peaceful life. Additional needs are those for psychological and spiritual connection. Basic needs are not substitutable, for example, the need for a house does not substitute the need for potable water, either the need to heat the building. On the other hand, it is critical to establish a fundamental basis to deliver the basic needs without overconsumption of resources (James & Lahti, 2008).

The basic needs have been defined in numerous prior works (e.g. Maslow', Max-Neef, etc.) (Max-Neef, 1987). Needs are closely related with the quality of life and differ from country to country. For example, the needs of a person living in a third world country can be significantly different of those of a person living in the western world or in a developing country.

The Natural Step's understanding of human needs is based on the work of Chilean economist Manfred Max-Neef. He created a model of human need development that classifies the fundamental basic needs as subsistence, protection, affection, understanding, participation, recreation (in the sense of leisure, time to reflect, or idle), creation, identity and freedom. He supports the human-scale development of needs rather than a hierarchical setting of needs (Max-Neef, 2011).

Societies should carefully examine and understand the system conditions of TNSF to avoid impacts that will affect overall wellbeing (e.g. fossil fuels use vs. GHG emissions, loss of biodiversity).

Dematerialization and substitution also need to be taken into account when the system conditions of TNS are considered (Robèrt et al. 2002). Dematerialization refers to resource productivity and minimization of waste. Resource productivity means to improve efficiency of urban functions e.g. more efficient buildings, street lighting, reducing waste, or using waste as a resource to find synergies between urban functions. Resources, on the other hand, are classified based on the availability such as abundant (more than 100 yr), plentiful (equal to 50-100 yr), constrained (less than 25-50 yr) and rare (less than 25yr) (Graedel & Allenby, 2003, p.5). Thus substitution of materials in the urban function has an additional role. (Robèrt et al. 2002)

4.1.2 The ABCD Method

The ABCD Method is a strategic planning process, which combines the four sustainability system conditions for organizational changes and decision-making (James & Lahti, 2008). This method is based on describing a desirable on vision of future towards which steps need to be taken.

Figure 9 illustrates the ABCD method.

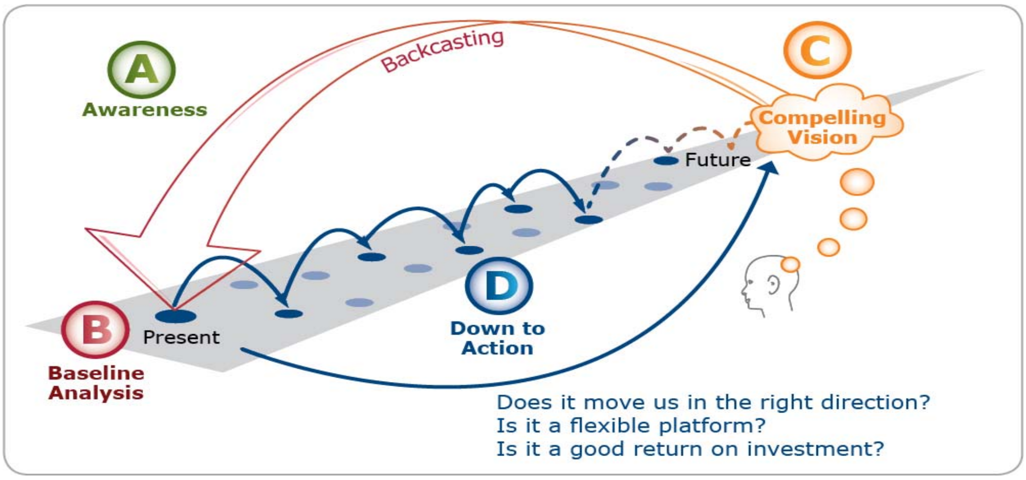

Figure 9. Illustration of the ABCD Method (The Natural Step, 2008)

The ABCD Method consists of the follow steps.

A = Awareness and Visioning

Step ‘A’ is a common understanding of the organization or community to create a common understanding on how to introduce sustainable practices. The organization sees the ‘whole picture’ together with the practitioners and develops a prosperous development plan. In this step, the System conditions and other models of sustainability principles with basic scientific characteristics give the ability to adhere to facts and visualize the future. The target is to set the actualization of innovative capabilities and the path to follow (The Natural Step, 2008).

B = Baseline Mapping

Step ‘B’, or baseline mapping, is a ‘gap analysis’ to see the major flaws and impacts of the organization and evaluate the present bias in favour of the four system conditions of sustainability. The analysis includes an evaluation of services, utility networks, spatial distribution, capital, human resources, and, in general, what concerns global communities. The focus is on all three pillars of sustainability, especially in the social integration. The mapping processes allow to seeing the existing assets of the community and the possible opportunities for change (The Natural Step, 2008).

C = Creative Solutions

During step ‘C’, potential solutions to the issues recognized during baseline mapping are sought. The philosophical asset is “begin with the end in mind”. From the described vision backwards steps are described to the baseline, which is also called as backasting (to be described in section 4.1.3). Scenarios, which give temporary solution, are to be avoided (The Natural Step, 2008).

D = Decide on Priorities

The final step of the ABCD Method summarizes solutions described in step ‘C’, prioritizing different scenarios and actions, and the systematic step-by-step process is prescribed towards sustainability. Backcasting is used continually to ascertain how the described outcome in step ‘A’ deflects from the desired vision so that the decisions taken will be effective. The decisions reflect investments of sustainable practices where short-term investments are encouraged and long-term ones are retained as a result to give flexibility and optimization to the organization. This is effective to give a rapid return on investments and stimulate other actions. This is implemented applying the backcasting process**.** Meanwhile, experience and awareness is gained applying the ABCD method. The Natural Step Framework is used to map out all the possible sequence of steps that lead to sustainability (The Natural Step, 2008).

Table 5 lists, a set of fundamental questions to aid in the process of using the ABCD Method.

Table 5. List of question to guide through the ABCD process (James & Lahti, 2008).

Using ABCD as a compass	
A: Improve Awareness: • "Describe what sustainability and sustainable development mean." • "A common sustainability language allows municipal officials and community citizens to communicate " • "Explore possibilities for how to proceed." • "Identify present unsustainable practices, developing a sustainable community vision, and creating an action plan to move toward that vision "	**C: Creative solutions :** *Introducing a sustainable community vision asking what will our community look like, When we eliminate:* • *"Wasteful use of fossil fuels, scarce metals and minerals"?* • *"Dependence upon persistent chemicals and wasteful use of synthetics"?* • *"Contribution to violation of nature"?* • *"When we meet human and community needs fairly and efficiently"?* *n*
B: Identifying Present conditions: • "In what ways is our community systematically dependent upon fossil fuels, scarce metals and, minerals"? • "In what ways is our community dependent upon on persistent and wasteful use of synthetics"? • "In what ways is our community causing destruction of the nature at a rate faster that it takes to regenerate"? • "What are the basic needs of our community"? • "In what ways is our community not meeting basic needs fairly and efficiently"?	**D: Setting the priorities of Action:** • *"Which actions meet all four system conditions"?* • *"Which actions provide flexible platforms for future actions"?* • *"Which actions give a good return on investments"?*

4.1.3 The Backcasting approach

Backcasting is an approach formalized by John Robinson (1990) to emphasize future options for planning and management issues. However, a method a kin to backcasting was applied back in 1977 by Amory Lovins in energy futures studies (Dreborg, 1996).

In the field of future oriented studies, a forecasting approach and scenario development are common. In contrast, backcasting identifies the path to the target vision of sustainability. The scenario analysis is used to achieve consistency of a study from a sequence of steps as it permits a broader analysis of topics that allow projections. However, backcasting is an approach of coherent thinking for more complex and long-term projects (James & Lahti, 2008).

The method is central to a strategic approach of sustainable development. It is a planning process with the input of contemporary needs. It starts with answering the question how the future will look like? In that sense, an image of alternative solutions and visions need to be drawn and confined to technical feasibility followed from a sequent of steps from the present to the future (as illustrated in **Figure 9**, section 4.1.2).

Backcasting has found use especially for environmental and socioeconomics studies. A six step procedure to apply backcasting is described by Robinson as follows (1990):

1. *"Determine objectives*
    a. *Describe the purposes of the analysis*
    b. *Determine the temporal, spatial and substantive scope of the analysis*
    c. *Decide number and type of scenarios*
2. *Specify goals, constrains and targets*
    a. *Set goals, constrains and targets for scenario analysis*
    b. *Set goals, constrains and targets for exogenous variables*
3. *Describe present system*
    a. *Outline physical consumption and production processes*
4. *Specify exogenous variables*
    a. *Develop description of exogenous variables*
    b. *Specify external inputs to scenario analysis*
5. *Undertake scenario analysis*
    a. *Choose scenario generation approach*
    b. *Analyse future consumption and production processes at the end-point and mid-points*
    c. *Develop scenario(s)*
    d. *Iterate as required to achieve internal consistency*
6. *Undertake impact analysis*
    a. *Consolidate scenario results*
    b. *Analyse social, economic and environmental impacts*
    c. *Compare results of the last two steps with step 2, above*

Iterate analysis (steps 2, 4 and 5) as required to ensure consistency between goals and results"

Backcasting is expected to solve major societal problems and highlight polarities from different actions. It requires novel ideas and technical knowledge to address multidisciplinary projects (Dreborg 1996, p.816).

Backcasting is recommended to be used for environmental analysis and development problems in cities and organizations (James & Lahti, 2008). The boundary of a scenario analysis follows an Input-Process-Output model. Scenario analysis is an *"effective method for examining future uncertainties and investigating assumptions in organizations"* (Chermack, 2005). The scenario analysis considers several alternatives to create a vision for the future. As backcasting involves a variety of disciplines and scenarios to envision a sustainable future, it requires the participation of regional institutes and experts on the field of urban retrofit development. A step-by-step process of backcasting is illustrated in **Figure 10**.

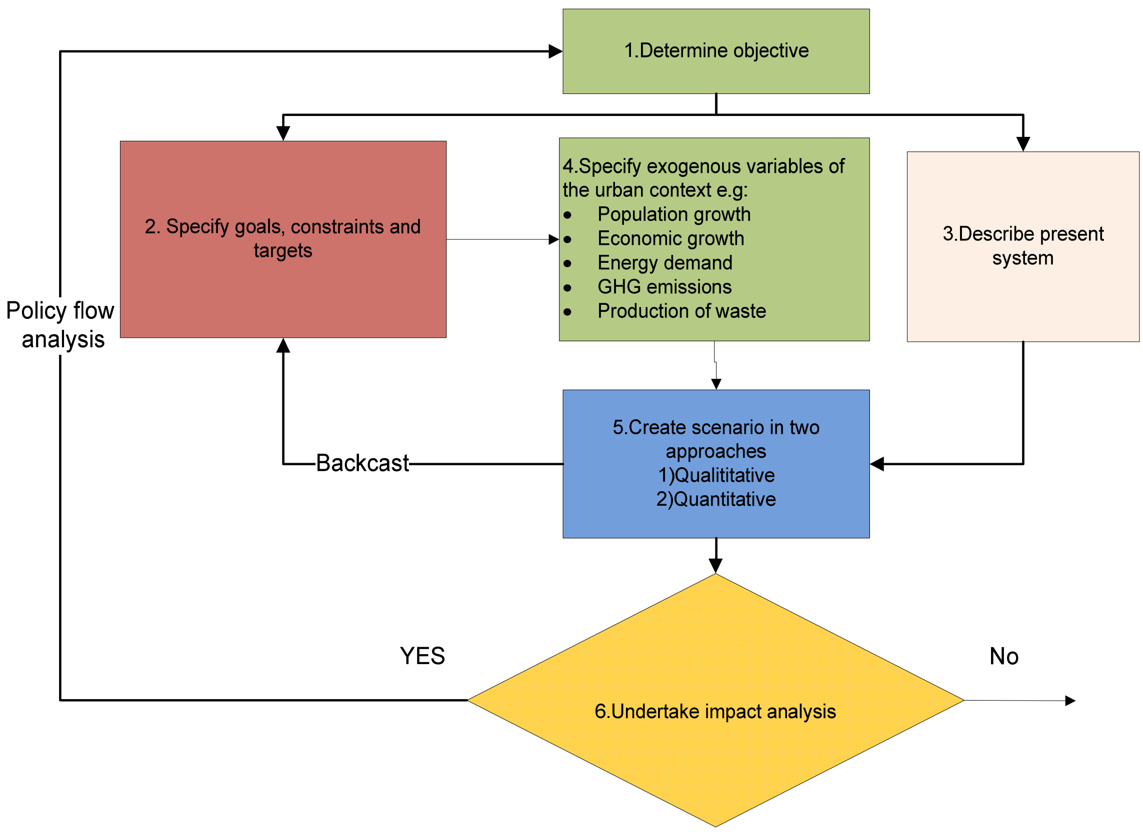

Figure 10. Outline of a backasting process for urban development case study (Adapted from Robinson, 1990 p. 824)

Steps 1 in **Figure 10** (determine objectives) is to describe the overall objectives, which in our case is a path towards developing an Eco-City. The scope of the analysis and the indicators, are listed in Appendix 1.

In ***Step 2,*** (the goals constrains and targets are specified) to create the context for formulating the scenario analysis in the next steps. As well, in this step the exogenous variables are collected to formulate the assumptions based on which the needed data will be collected. For example, population growth and the economy of the region are specified as exogenous variables (Robinson, 1990 p. 828).

Step 3 describes the present system, to which end the topographic and biological features of the case study are mapped and analysed.

In ***step 4*** the data available will be used to carry out the backcasting. For example, if the backcast focus is in energy supply, the exogenous variable will be the energy demand. In order to achieve consistency of scenario analysis, more exogenous variables are needed to minimize uncertainties.

The backcasting unfolds when the context of the model is specified during ***step 5*** (undertake scenario analysis). The scenarios are two types, qualitative and quantitative, which are revised from the goals described in step 2 and from the system conditions for sustainability **(Figure 10**).

A formal quantitative model is advisable to be used in order to keep track of the physical interactions among many variables over a period of time. However qualitative scenarios are also undertaken at this stage to carry out the studies and meet future goals (Robinson, 1990). The outcome of the scenarios is evaluated in ***step 6*** (Undertake impact analysis), which describes the plausibility and impacts of the scenario analysis and introduce the development dimensions to the policy makers.

4.2 Ecological Footprint

Cities, municipalities and local bodies depend on natural resources and ecosystem services. The general trend is to think globally and act locally in terms of resources and planning technics. It is because the annual demand of resources exceeding and the waste generation what earth can regenerate or absorb. The level of resource consumption and waste generation can be calculated as the Ecological Footprint (EF) (Global Footprint Network, 2008). EF is determined by three factors: population, consumption per capita, and the resource and waste intensity. (Ewing et al. 2010)

The main reason for calculating EF is to have a system view of waste and resource intensity. EF is a good monitoring tool for providing snapshots of particular regions, and can be used by local authorities in order to manage the economical assets of the region and protect bio-capacity.

Bio-capacity is an important term to be calculated in relation with EF. Bio-capacity is determined by the area of biologically productive land or water and the productivity of that area. The gap between resources supply (capacity) and demand (Ecological Footprint) define the Overshoot, as illustrated in **Figure 11**. (Ewing et al. 2010, p. 23)

Figure 11. The relation between bio-capacity (global hectares per person) and Ecological Footprint (global hectares per person) (adapted from Ewing et al. 2010**)**

Monitoring the supply and demand of available resources, a feasibility plan can be made prior to any actions and decisions be made, in order to avoid overshoot (Wackernagel et al. 2006).

Societies are aiming at economic growth but growing affluence causes environmental stress. The factors that characterize the anthropogenic stress are Population, Affluence and Technology. The model is known as The IPAT model (**Figure 12**) and it was proposed and developed by Ehrlich, Holdren and Commoner in the early 1970s (Ehrlich & Holdren, 1971). The IPAT model is describing the driving forces determining the Ecological Footprint. (Graedel & Allenby, 2003)

IPAT [Environmental Impact (I) = Population x Affluence (GDP/Person) x Technology (Environmental impact/unit of GDP)]

Figure 12. IPAT model adapted from (Ehrlich & Holdren, 1971).

The IPAT equation is not supposed to be used as a mathematical equation, but rather as a conceptual model and to emphasize the role of technologies. As referred to earlier, population is expected to grow up to 1.5 times in the next 40 years. At the same time, the economic growth is estimated 3% per year, which translated to a factor 3.3 growth. This means that in order to halve global environmental impacts, the unit environmental impact of GDP needs to be reduced by a factor 10. This emphasizes the role of environmental technologies. Such as, waste prevention, energy efficiency, water saving, nutrients recovery, etc.

4.3 Municipal planning instruments

The goal for RIO Summit +20 of the United Nation Conference of Sustainable Development (UNCSD) to be held in 2012 is to create a mechanism for systematic decision making processes which promotes a green economy (UNEP, 2011a). Additionally, it intends to create indicators to measure economy beyond Gross Domestic Product (GDP). The path to succeed includes shifting investments into new directions respecting the sustainable development concept. Cities and its inhabitant have a critical role in green economy (UNEP, 2011a).

Under the framework of eco-municipalities, the planning process includes both stakeholder and sectoral level activities, all illustrated **Figure 13**. Co-operation is necessary on both levels, in a multidisciplinary planning team as well as among all stakeholders, (Gaffron et al. 2008). The ultimate objective is to improve the overall quality of life.

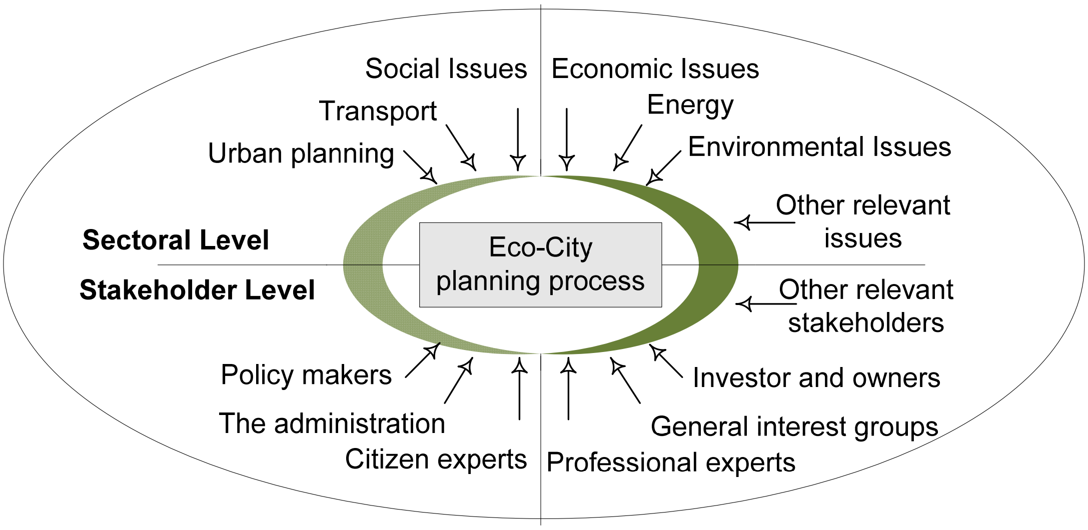

Figure 13. Planning process on stakeholder and sectoral levels (Gaffron et al. 2008).

The benefits of an integrated sustainability planning are, to find solutions in complex systems, and to improve public awareness through the interactions of citizens and experts. The assessment of the impacts is followed by communication techniques, which emphasize the role of the public. The actions should follow a participatory planning process.

Participatory planning is a process through which social, economical and/or environmental goals can be met. During this process, authorities (local, regional, national), developers and citizens communicate and collaborate to find a way to reach the set target. The United Nations Framework Convention on Climate Change also recommends public participation to address climate change and create adequate responses (UNFCCC, 1992).

Through the process of the participatory planning, data is collected by communication techniques, as indicated in **Table 6.**

Table 6. Techniques for public involvement (adapted from Edwards, n.d).

Techniques for public involvement:	Description:	Advantage:	Disadvantage:
Focus groups	Includes small discussion groups to give "typical" reactions of the general public. Normally conducted by a professional facilitator. May be several parallel groups or sessions	Provides in-depth reaction and detailed input; good for predicting emotional reactions	May not be representative of the general public or a specific group. Might be perceived as manipulative
Interviews	Face-to face interviews with key persons or stakeholders	Can be used to anticipate reactions or gain key individual support and provide targeted education	Requires extensive staff time and an effective interviewer
Hearings	Formal meetings where people present formal speeches and presentations	May be used for introductory or "wrap-up" meetings; useful for legal purposes or to handle general emotional public input safely	Can exaggerate differences without opportunity for feedback or rebuttal; does not permit dialogue; requires time to organize and conduct.
Meetings	Less formal meetings of persons to present information, ask questions	Highly legitimate form for public to be heard on issues. May be structured to allow public to be heard on issues and small group interaction	May permit only limited dialogue; may get exaggerated positions or grandstanding; may be dominated by forceful individuals
Workshops	Smaller meeting designed to complete a task or communicate detailed or technical information.	Very useful to handle specific tasks or to communicate, in a hands-on way, technical information; permits maximum use of dialogue and consensus building.	Inappropriate for large audiences; may require several different workshops due to size limitations; requires much staff time in detailed preparations and many meetings.
Survey/Polls	Carefully designed questions are asked of a selected portion of the public	Provides a quantitative estimate of public opinion.	Susceptible to specific wording of questions; provides only a static snapshot of a changing public opinion; can be costly

The proper communication technique is to be selected based on the magnitude of the undertaking. By the use of participatory planning, social conflicts such as NIMBYism (not in my backyard) can be avoided (Fischer, 2000).

To integrate sustainable practices into municipal activities, the municipality planning instruments need to be revised. In **Figure 14**, the key municipal planning instruments are conceptualized. Specific policies refer to those on energy, solid waste, education, elder care and social services (James & Lahti, 2008).

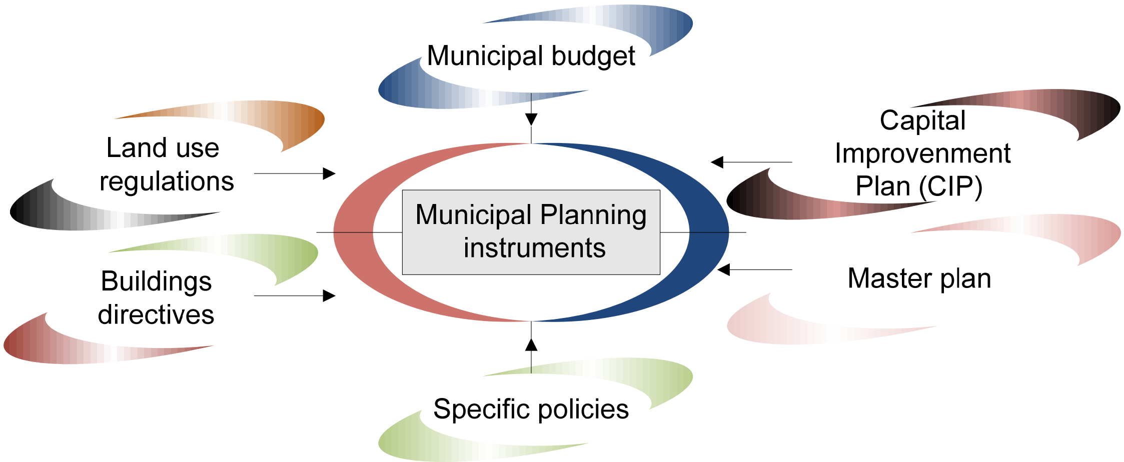

Figure 14. Illustration of the Municipal Planning instruments, (adapted from James & Lahti, 2008).

The instruments mentioned in **Figure 14** needs to be harmonised with the adopted sustainable practices and sustainability objectives. (James & Lahti, 2008) The detailed description of the instruments mentioned is beyond the scope of this work. However, this work takes into account policies about energy, waste management and building directives.

EMPIRICAL PART

5 Case Study: Applying the ABCD Method to Kostomuksha municipality, Republic of Karelia, Russia Federation.

5.1 Step A: Awareness and visioning

The Green Cities and Settlements project (GREENSETTLE), this thesis is part of, aims at encouraging the development of eco-cities in remote border areas. The main target is to contribute to the long-term spatial development of the area by proposing a balanced progress of the economic and social requirements.

The GREENSETTLE project is one of the 11 projects under the European Neighbourhood and Partnership Instrument for Cross Border Cooperation (ENPI-CBC). The project is realized in partnership between academic institutes and administrative bodies in Kainuu, North Karelia and Oulu regions in Finland and in the Republic of Karelia in Russia.

The main goals of the project are:

1. To improve the utilization of the spatial potential in remote border areas
2. To explore the potential of green cities and settlements in the border areas
3. To develop an effective cross-border exchange of best practices in public facilities and services to minimize the environmental impact
4. To identify and address the key challenges of climate change in remote border areas
5. To enhance the role of local business and entrepreneurship
6. To build awareness and sharing information on potentials and possibilities of sustainable spatial development

The **Figure 15** conceptualizes the content of the project. The first two work packages, Spatial planning and Resource management, include the research activities, the outcome of which is a Roadmap towards sustainability. The project is realized through cross-border communication and uses the problem-solving technique of Think tank. Finally, the compiled information is stored in an Internet-based Knowledge bank.

Figure 15. Conceptualization of the Green Cities and Settlements project;

It has been recognized that, in cross-border spatial planning, there is a need for collaboration between administrative, business, civic organizations, and research institutions. The four regions participating in the GREENSETTLE project are border municipalities with previous history in cross-border collaboration. All municipalities have a need for and will benefit from development plans for better natural and spatial resource utilization, as well as implementation of environmentally friendly and energy efficient solutions.

Recommendations on improving the utilization of spatial potential for the specific areas will enhance the attractiveness of the region and promote the capitalization of the territory at a larger extent. With focus on more efficient municipal planning, waste management improvement and waste-to-energy solutions in particular, the project's added value will be a contribution to the development of the region, promoting sustainable spatial management and more efficient utilization of local resources. The cross-border cooperation will also be laying foundation to an urban-rural interaction, that will provide and added value to local self-government reform.

This work is to provide the fundamental theoretical basis of the project. In a multidisciplinary and multisector collaboration a crucial gap often is the lack of common language. It is, therefore, believed that a crucial role to develop eco-cities is to understand and share the main philosophy behind the concept.

Throughout this project, action proposals are formulated by the workshop communication method. To this end, the main subject of the project kick-off meeting (held during June 20-21, 2011) was to define the characteristics of eco-cities and to reach a common understanding of the dimensions of the concept.

The meeting was participated by representatives of Kostomuksha administration, who have described the development needs, actions and objectives of Kostomuksha to reach sustainability. The authorities' plan for Kostomuksha city is:

- Improve the quality of life
- Introduce cross-cutting technological plans for infrastructure development
- Maintain outdoor air quality
- Improve urban development plans
- Reduce energy consumption in the municipality
- Reduce and reuse waste
- Find recovery solutions for problematic waste fractions such as, pneumatics, light bulbs, plastic packaging;
- Improve the water purification system

One of the first actions to this end will be the retro-fitting a kindergarten with an air-to-air heat pump to reduce the energy consumption.

5.2 Step B: Baseline description of Kostomuksha municipality

The Republic of Karelia is a part of the North West Federal district of the Russian Federation. The area of Karelia is 180.5 thousands km^2 and consist of 1.06% the total territory of Russia. Karelia borders Finland in the west, Leningrad in the south and Murmansk and Archangelsk districts in the East. The Karelian region is rich in natural resources and minerals and is considered an important node for tourism and trade between Europe and Russia. However, the prevailing circumstances of the socioeconomic, cultural and other regional disparities between Finland and Russia create a delicate development framework (Liikanen et al. 2007).

The population of the Republic of Karelia is divided into working age (64.5 %), younger working age (15.4%) and elderly people (20.1%) and totals is approximately 684,200 people. The population density is 3.8 persons per km^2 and the gross monthly wage per person is approximately 18,342 RUB (436.8 EUR, September 2011) (The official Karelia, 2009).

The region is a collection of different nationalities with the common language of Russian. The majority of people are Russians (76.6 %) and the others are Karelians (9.2 %), Byelorussians (5.3%), Ukrainians (2.7%), Finnish (2%) and Vespasians (0.7%). The unemployment rate is 3.7% (January 2010). The Karelian region is characterized by a stable economy without debts, nevertheless, urbanization affects the population of region (The official Karelia, 2009).

The natural environment of the Karelian region is rich in biotic and abiotic resources. Forest (pines, fur-trees, elders and aspens trees) cover 49% of the territory and comprise a variety of species (fishes, wild animals etc.). The water deposits, lakes and rivers are vital for the region and, therefore, their need to be protected. The average temperature during winter is -9 to -13 ^{o}C and during the summer +14 to + 16 % ^{o}C, with a precipitation of approximately 500mm per year (The official Karelia, 2009).

The overall goal of the government in the Republic of Karelia is to improve the quality of life by improving the health and financial conditions of the urban and rural districts as well as capacity building by increasing cross-border collaborations (ENPI, 2011). Every municipality has a representative body of local self-government, which allows the municipality administration to adapt innovative plans under the municipality instruments for the benefit of the local community (The official Karelia, 2009).

The Republic of Karelia has two urban districts, the city of Petrozavodsk and the city of Kostomuksha. The city of Kostomuksha is located in the North West part of the Karelian region near the Finnish border, (**Figure 16)**. The city has a crucial industrial role for the region as it has a variety of industries and, especially compared with its size (4.3% of Karelia Rep. pop.), it is a significant supporter of the Karelian regional economy (35%). The main primary and secondary resources, which are underutilized in the city, are mainly round-wood, aluminium, paper sacks, newsprints, cellulose and ferrous metals. The industries around the city employ most of Kostomuksha's 32,000 inhabitants (The official Karelia, 2009).

Figure 16. City of Kostomuksha as indicated with black dot (The official Karelia, 2009).

<u>Urban Development</u>

Ownership is an important factor especially for retrofit development (section 5.1). Most of the land and the high-rise buildings in Kostomuksha belong to the Republic. Today, the land ownership is changing since the administrative authorities decide whether the land is for sale to private companies or to individuals by organizing an auction. Currently, the urban development plans are supporting urban sprawl, by allowing of row houses and villas.

<u>Energy</u>

Energy in Northern territories is vital to sustain well-being and assure an indoor comfort. The city dwellings are heated by district heating. The district heating network is state-owned but the heated water circulated into the network is provided from the mine company. The mine company has a petroleum-fired boiler of 75,000 tons water capacity to support the demand for district heating. The price of the heating per unit is fluctuating due to high petroleum prices and the general instability in the petroleum market. This affects the expenses of the municipality properties. Households, on the other hand, receive 20% discount per unit of their heating.

The electricity grid and supply is public, with the electricity supply transmitted from a hydropower station located 200 km away from the city. The city authority plans the construction of an additional power plant (electricity only or CHP). The fuel to be used in power production is yet undecided. Considering that peat resources are unlikely to be sufficient to support the city's functions, the most feasible fuel considered for power generation is wood. The local wood capacity is enough to support the power production for many years, but the quantity of wood based fuel was not specified.

Traffic and transportation

Traffic congestion it does not often happen in Kostomuksha since the city is rather compact; nevertheless, an average household in Kostomuksha owns two cars, which adds to 16.000 cars registered in the municipality.

The frequency of the public transportation is insufficient and thus citizens prefer to use their own cars or taxis. The municipal fleet has only one bus. The public transportation is organized mostly for the outskirts and peripheral cities. If there is demand for buses they are provided from private companies, which are subcontractors of the municipality.

The bike corridors in the city of Kostomuksha exist to some extent. The illumination of the bike corridors is not satisfactory and the use of bikes is not favoured by the majority of the population. The living conditions, the winter temperature and the snow conditions as well as the absence of infrastructure (shower, dryers etc.) in workplaces, make daily cycling challenging.

Water and sanitation

The wastewater treatment plant, as well as the water network, belong to the state. The water network is 30 years old and attempts to its improvement are priority for the municipality. The potable water has good quality as it derives from the Cardinal Lake, which is located in one of the two natural reserved areas of Karelian Republic.

The wastewater treatment plant is located at the outskirt of the city. The maximum capacity of the plant is 24 km^3/per day and the average wastewater flow is 14 km^3/per day. The wastewater is screened twice before it reaches the plant where the biggest fractions of waste have been removed (screening process). The first two grids are located close to the city and the third one is located at the wastewater plant which is operating under a physical wastewater treatment process. The physical process of wastewater treatment is as follows:

- Initial screening steps prior to the wastewater treatment plant
- Sedimentation tanks
- Aeration tanks
- Retention tanks
- Stabilization of organic matter
- Disposal of dewatered sludge
- Discharge of cleaned water to the lake

The grids during the screening process remove the biggest fractions of waste to the next stage of the sedimentation tanks that allow the suspended solids to precipitate. The aeration tanks are used for the creation of biological-flocs by mixing (wastewater) with air. The sludge is dewatered mechanically and later stored and dried. Some amount of the sludge is composted and used for landfill cover, the rest is left to be dried in an isolated place. The water of the plant is discharged into the lake next to the wastewater plant.

Municipal waste management

The municipal waste collection is organized by the private sector. There is no separation of waste at source. The municipal waste is collected in communal garbage bins. In high-rise buildings the renters dispose their waste bags through a shaft to a tank where all the waste is collected. The private companies are collecting the mixed waste, then separate some fractions of paper or other valuable materials to recycle or deliver to recipient facilities. The recycled waste fraction is mainly paper because of the pulp and paper industries in the area.

Studies to collect and recycle plastic bottles have been made earlier. The initial idea was to collect the bottles and deliver them to recipient facilities in Finland but, due to border bureaucracy and the limited amounts of bottles, such an operation was not deemed unfeasible. Some of the municipal waste, fraction that have been perceived as problem wastes are light bulbs and tires, as there is no recipient facility nearby to utilize these fractions.

5.3 Step C: A future vision for Kostomuksha municipality

As described in section 3.4, a set of actions towards developing eco-cities have been compiled (**Table 4**). The documents provided in Appendix 2, were delivered to municipal officials of Kostomuksha to select their priorities for the future vision. In **Table 7**, the choices of municipal officials are circled with red.

Table 7. Actions preferred by Kostomuksha municipal officials.

	A	B	C	D	E
	Urban Development	**Traffic & Transportation**	**Energy (Heat & electricity)**	**Municipal Waste Management**	**Water & Sanitation**
1	Prevent urban sprawl	Retrofitting city buses with catalytic converters	Energy saving plan for municipal buildings	Improve present landfills and utilize landfill gas	Harvest rainwater for irrigation purposes
2	Densification of existing urban structure	Create dedicated bus lines	Energy and environmental inspection to reduce energy losses and pollution	Identify priority waste streams to set up recycling systems	Subsidize water efficient taps and shower nozzles
3	Plan for mixed uses (better proximity to urban function)	Extend roads to improve traffic flow	Pilot investment in small-scale decentralized energy solutions	Set up recyclables collection points (***Ekopoints***[3])	Wastewater sludge utilization (biogas)
4	Integrate infrastructure planning with service development	Incentives to reduce car use (walking & bicycle lanes)	Subsidize refurbishment of existing buildings for energy saving	Awareness raising for waste prevention and minimization	Improve the efficiency of water purification plant
5	Plan for the recreational aspects of urban space	Biofuel –run municipal fleet	Energy saving street lighting system	Wet/dry separation of waste	Improve the quality of water and sanitation infrastructure
6	Participatory Planning	Infrastructure supporting the use of electric cars	Promote use of renewable based electricity	Kerbside separate waste collection system	Awareness raising for water saving
7	Urban interaction (UBI) system	Transport ICT systems	Development of smart grids	ICT system to optimize waste and management	Pilot areas with grey-water recycling (living machine)

Further to the selection as described in the previous **Table 7**, a qualitative future scenario of Kostomuksha municipality is described below.

<u>Urban Development</u>

Presently urban sprawl is not a priority for Kostomuksha; however, efforts should be made in the future to prevent urban sprawl. In the meantime, efforts need to be made toward the densification of existing urban structure.

Urban sprawl is the result of urban extension and refers to a low-density city, which has mostly villas, houses with their own gardens and large surrounding green areas. Although it has some advantages to citizens, it creates problems in the long term (Jabareen, 2006, p.44). It is because distances to services are longer, which results in more travel, higher consumption of fossil fuels, and more emissions to air. The economic aspect of urban sprawl is the cost involved with infrastructure construction and maintenance of services such as, electricity, telecommunication and district heating.

Densification refers to a strategic decision regarding land use (zoning) characteristics, which aim at increasing population density and improving resource efficiency. The primary effect of the densification is to decrease the use of cars when travelling between places of residence and work (Kamal-Chaoui & Robèrt, 2009, p.66). High density cities conserve energy, materials and land for housing (Jabareen, 2006).

Communication techniques between the public and proponents are critical for urban development to exchange knowledge and expertise. It is recommended to establish an Ecological Information Center (EcoInfo), which would educate about green technologies, promotes environmental actions and provide subsidies for green entrepreneurship.

The EcoInfo Center could also provide information for the rehabilitation of unhealthy buildings. A long-term objective would be to set up an urban interaction system, to provide information to citizens and allow receiving feedback. A system like, called UBI system this is in place in the city of Oulu in Finland. UBI comes from ubiquitous, and refers to a concept to develop monitoring, feedback and information systems for the community (UBI, 2011). Displays are placed indoors and outdoors in hotspots around the city of Oulu allowing interactions and sharing information between the citizens.

Ultimately, the EcoInfo Center would encourage public to become more environmental benign by encouraging resources conservation.

Traffic and transportation

Primarily, Kostomuksha should provide opportunities for pedestrian and bicycle transport. To this end, the safety of pedestrian and cycle paths needs to be ensured by appropriate street lighting and maintaining clean from snow in the winter.

The ultimate vision is of a city where the buses and other vehicles such as taxis, are using biofuels (e.g. methane, ethanol, butanol, synthetic gas). This will decrease fossil CO_2 emissions and overall pollution levels in the city. Additionally, Information and Communication Technologies (ICT) can be applied, to allow monitoring, access and sharing information between the different urban functions. Through such a system, synergy could be developed with smart logistics system (saving space, fuels, electricity and heating), smart energy grids (energy production plant, electric car recharging, energy storage, etc.) smart monitoring for buildings and industries to avoiding peak loads and result in a higher overall resource efficiency. This information and communication systems would provide environmental economic and social benefits.

Energy (heat & electricity)

Nordic climates have a higher demand for heat and electric energy. To lower the demand of electricity and heat, energy efficiency measures need to be implemented in public buildings and infrastructure (electricity grid, pipelines).

The EU Directive 2006/32/EC defines measures of energy end-use efficiency and energy services. The Directive encourages Member States to set up energy efficiency action plans, and define energy saving targets. Similar legislation is in force in Russia as well (Federal Law No.261-FZ, 2009).

Energy efficiency measures can be separated as low-cost and high-cost investments.

Low-cost investments:

- Reduce the use of unnecessary loads by switching off heating, ventilation and lighting in unused spaces
- Raise public awareness about low-cost per kW hours periods and other energy saving measures

High-cost investments:

- Automation control systems or Building Energy Management systems (BEMS) for centralized operative systems (heating, cooling, ventilation)
- Replacement or Improvements of light bulbs and supportive equipment (fluorescent light magnetic ballast with electronic ballast) with more efficient.
- Improvements in U-Values (insulation for building envelope)
- Installation of Combined heat and power (CHP) Units
- Hybrid renewable energy systems
- Heat pumps to utilize geothermal energy

Before any of the high-cost measures are to be implemented, an assessment of energy and environmental impacts is to be undertaken, in order to study the feasibility of the measures. An initial assessment of investment costs, maintenance costs and payback period is critical. In Addition, energy efficiency measures in residential buildings will create new job opportunities and support local economy (Eco-city Builders, 2010).

In the current energy system, energy providers and end-users have different roles. The end-user aims at lowering the energy consumption and expects better energy services. The energy provider's role depends on regional or national legislation. The supply and demand relationship and the choice of the energy provider for the end-user depend on the liberalization of the energy market.

Eventually, in the future, end-users and providers would be connected with a smart energy grid. The expression smart grid refers to a system through which suppliers and consumers can have a two-way communication, monitoring grid condition and electricity prices in real-time. Through a smart grid, small-scale individual energy providers as well as larger scale energy production plants could be connected with potential end-users. The crucial elements of the system are energy storage elements (such as electrical cars) and a smart control system. The smart control system is capable to monitor and optimize heat, electricity and fuel consumption. The envisioned smart grid based system can anticipate and mitigate power peaks and power quality problems. At the same time, it allows for a more prominent position on the market of renewable energy resources, characterized by a discontinuous and irregular power generation (i.e. wind power). This can be achieved strategically from the liberation of the energy market, which will allow smaller producers to enter the energy market and invest in the renovation of the existing infrastructure. (Caló, 2011)

This will provide energy flexibility to unfold more energy efficiency projects and allow small producers of geothermal, waste and biomass based energy to enter in the energy market.

Municipal waste management

In municipal solid waste (MSW) management, authorities and citizens will uphold the waste management hierarchy (reduce-reuse-recycle-dispose). This implies that waste is primarily prevented or, secondarily, used as a resource. Priority MSW streams are identified and recycling systems are in place. The city uses separate waste collection systems to improve the quality of recyclable waste fractions. This includes both kerbside and centralized collection points (e.g. 'Ecopoints'). Landfilling of biodegradable MSW is prohibited, in order to avoid greenhouse gas emissions. Bio-waste recycling (composting) and utilization (waste-to-energy technologies) measures are in place. Further, a synergy between waste and energy flows is realized, partially providing for the heating needs in buildings or industrial processes.

Water and Sanitation

In an eco-city water is potable and preserved for the future needs of the society. Best available technologies are used to treat wastewater and nutrients are recovered from the wastewater sludge and delivered back to the nature. Further, the energy content of the sludge is recovered and utilized. The biogas generated from the sludge can be purified to be used as a transportation fuel, or incinerated to provide energy for the wastewater treatment plant itself. Ultimately, the wastewater treatment plant will be an element of the smart energy grid.

5.4 Step D: Deciding on priorities

Further to the documents delivered (Appendix 2), the representatives of Kostomuksha were also asked to indicate their priorities. The choices of the municipal officials are shown in the action priority matrix of **Table 8**.

Table 8. Sorted actions from Kostomuksha municipality.

	Environmental Economic and Social Impact	
	Low impact	**High Impact**
Easy (short-term investments)	***Fill-Ins***: **C.1:** Energy saving plan for municipal buildings **C.5:** Energy saving street lighting system	***Quick wins***: **A.7:** Urban interaction (UBI) system
Difficult (Long-term investments)	***Hard slogs***: **C.3:** Pilot investment in small-scale decentralized system **B.5:** Biofuel –run municipal fleet	***Major projects***: **A.1:** Prevent urban sprawl **A.3:** Plan for mixed uses **D.2:** Identify priority waste streams **E3:** Wastewater sludge utilization (biogas) **E.4:** Improve the efficiency of water purification plant **E.5:** Improve the quality of water and sanitation infrastructure

In **Table 8**, the terms quick wins, major projects, hard slogs and fill ins, were used based on the action priority matrix which is a diagrammatic technique to illustrate which activities to prioritize accordingly (Time analyzer, 2008).

The term *Quick wins* refers to relatively cheap and easy initiatives or strategic decisions that can be quickly implemented

The term *Major projects* refers to long-term investments which, if broken down to smaller investments, could bring a sequence of quick wins.

The term *Fill-ins* refer to short-term investments, which come after the major projects and quick wins.

Hard slogs refers to actions which have low returns of investments and are time consuming; however, could be used at a different time and in different way to bring quick wins.

Figure 17 illustrates a recommendation for the timeline to implement the selected actions.

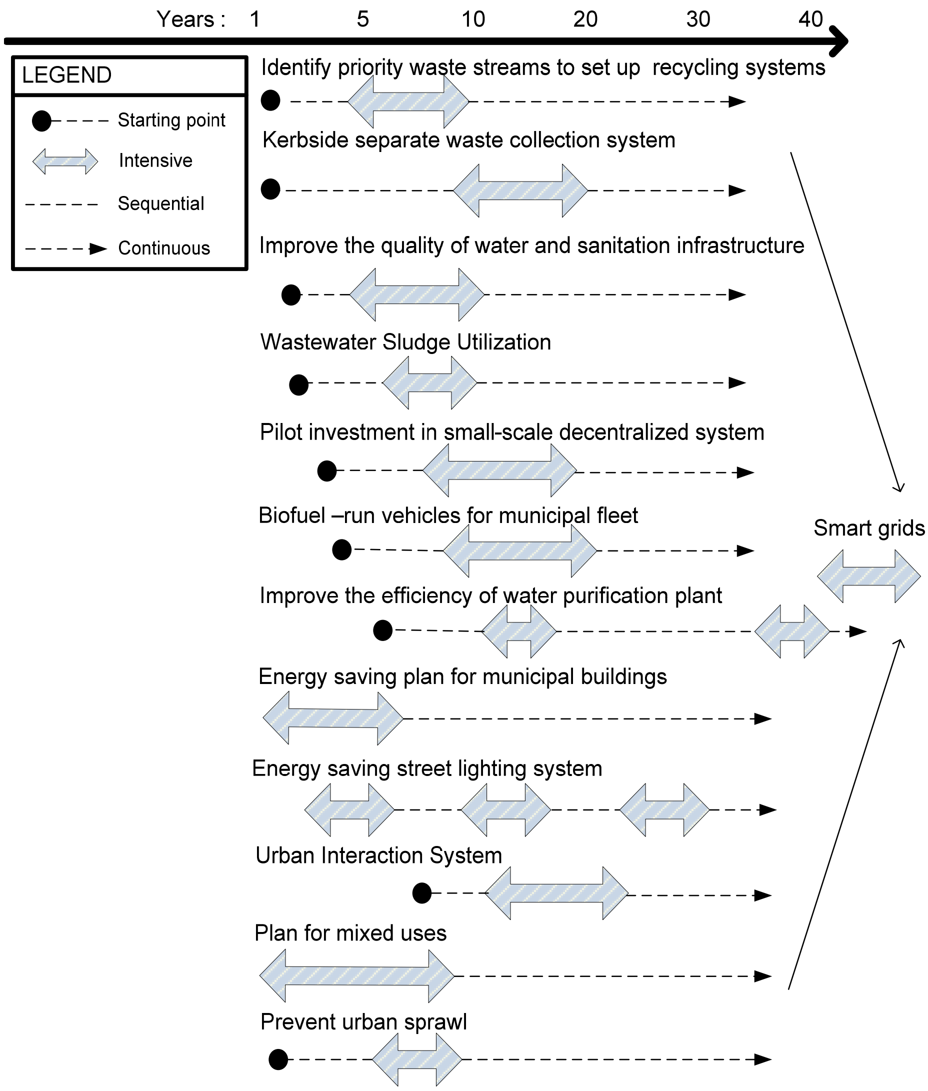

Figure 17. Timeline of selected actions for Kostomuksha municipality.

The timeline presents the actions towards developing an eco-city. One of the key issues in sustainable organic waste management is to divert organic waste from landfills. To this effect, the first strategic decision is to have a wet/dry separation of municipal waste at source. Further, pilot-scale composting facilities can be built to accept organic waste. The compost can be used as a fertilizer for landscaping or in agriculture. Source separation will also improve the quality of dry recyclables. This will provide flexibility to authorities to identify the waste streams to set up recycling systems. If a recipient facility exists, it provides further motivation for citizens to participate in source separation process. Only when there is an existing recyclable recipient infrastructure, can kerbside collection systems or ekopoints be profitable.

Resource efficiency measures for the municipality are critical. By planning for mixed use of urban space, making energy saving plan in buildings and street lighting, maintenance and operational costs can be significant lowered, while also reducing the ecological footprint. These actions need to be undertaken continuously. Urban sprawl is not a phenomenon for the city at the moment; however, prevention of urban sprawl should be on the municipal agenda.

Refurbishment of the water infrastructure is critical to ensure a low operational-cost. Additionally, a synergy could be achieved between the sanitation and energy infrastructure. For example, anaerobic digestion technologies can be used to produce biofuels for municipal sludge or biowaste. It is also recommended that the wastewater treatment facility could utilize sludge for the production of energy.

Biofuels can further find application in transportation to run the municipal fleet. Pilot small-scale decentralized systems will promote the use of renewable energy and municipality will benefit with independence from fossil fuels.

Ultimately, it is recommended that the city consider the development of a smart energy network, which allows for a more efficient energy utilization. The two-way communication system of smart-grid could be combined with the urban interaction system (UBI system), which would provide an added social benefit.

6 Discussion

As a result of a rapid economic and technological growth, human settlements and, especially cities in the industrialized world have substantially changed their face and the way they interact with their inhabitants and the natural environment. The challenges (e.g. urbanization, urban sprawl, non-renewable resource use), presented in this work are sizeable contributors to environmental degradation as well as deteriorated public health. Eco-city initiatives introduce activities to build scenarios and unfold a sustainable vision. To this end, actions towards sustainability need to be implemented, in order to improve resource efficiency in the framework of eco-municipalities.

The pattern of raw material consumption in building the physical environment and providing materials goods and services is currently unsustainable. The key element of resource efficiency is decoupling resource use intensity from providing economic growth and human wellbeing. The OECD organization describes Resource Decoupling as breaking the link between environmental "bads" and economic goods (as quoted by UNEP, 2011b). Resource efficiency can be rephrased as minimization of negative environmental impacts, from using less energy-water-air-waste resources in order to improve economic activities and wellbeing. In this respect, resource efficiency can be achieved by optimizing the energy-water-air-waste networks and realizing synergies between these networks.

Cities and ecosystems are systemically interrelated. As **Figure 18** illustrates, cities bring in energy and materials and process them through the system. (Eco-city Builders, 2011) In this work, this is expressed as the interface of the energy-water-air-waste boundary. Urban economy is realized by the urban functions, which is described as the shells and networks ekistics elements in human settlements studies of Doxiades (1968). Additionally, a city can be viewed as an "invention for maximizing exchange and minimizing travel" (Engwitch 1993, as quoted by Roseland, 1997). To this end, Urban Ecology has created 10 principles for ecological cities in the same conceptual framework. Based on these, the follow definition of eco-municipality is proposed: *Eco-municipality is an urban or rural space, where exchange is maximized and throughput is minimized and, at the same time, resource and impact decoupling is achieved.*

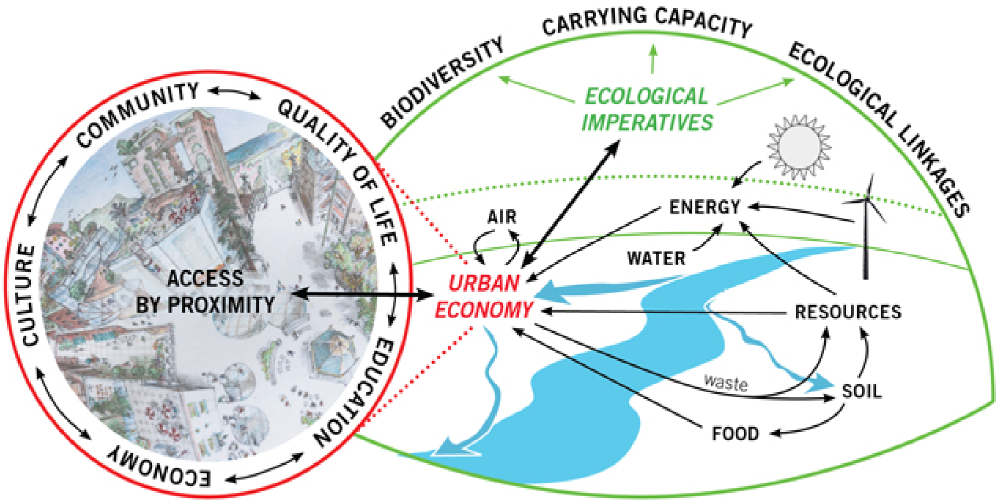

Figure 18. Cities and urban ecosystems (Eco-city Builders, 2011).

Environmental technologies such as sustainable energy systems, water treatment technologies, air pollution control and waste management have a key role to achieve resource efficiency in cities. On the other hand, human wellbeing is described in terms of comfort, happiness and health. Environmental technologies can assure comfortable and healthy living conditions. However, technologies alone cannot support the emotional needs of people. Therefore, communication techniques and participatory planning methods are relevant elements in eco-municipalities.

In this work, the ABCD Method and communication techniques of The Natural Step (TNS) organization were used. The TNS had gained global interest due to publicizing case studies performed under the framework in Canada, Europe, North America and Japan. In their understanding, an eco-municipality is one that has adopted a particular set of sustainability principles guiding municipal policy and has committed to a bottom-up, participatory approach for implementing them. (IEMEA, 2011) In Sweden, the Sveriges Ekokommuner organization has adopted the same principles in their efforts to develop eco-municipalities (SEkom, 2011).

Unfolding the legal basis of municipality planning instruments, solutions can be found to solve economic, social and environmental problems. There are still many open questions on how cities could be developed. The main concern in this work is how to best apply environmental technologies under the process of sustainable development. It is hoped that this work would serve as a framework for more comprehensive studies.

7 Conclusions

The purpose of this work was to raise awareness of the resource use intensity of human settlements and promote the concept of eco-municipalities. The study begins by reviewing the concept of human settlements, dimensions of the eco-cities and case studies of eco-city initiatives.

In this study, the concept eco-municipality refers to strategic sustainability objectives for rural and urban settlements. Eco-municipalities follow the principles of eco-cities in their financial and technical decisions regarding the use of local resources, as well as in their communication strategies among municipal officials and residents.

The general objectives and case studies of existing eco-cities are described. Based on this, it is concluded that communities could successfully apply environmental technologies to achieve resource efficiency, social stability and community economic development.

In the experimental part strategies for the retro-fit development of Kostomuksha municipality are proposed. For this, the ABCD Method of The Natural Step framework has been used as a participatory planning tool. The method encourages authorities to generate targets for sustainability and apply integrated sustainability planning. The method also fosters communication between public authorities and proponents to achieve resource efficiency.

Resource efficiency in an urban context is achieved when the synergy among the energy-water-air-waste networks is realized and the boundary conditions are optimized. To achieve this, a set of environmental technologies for urban development, transportation, heat and electrical energy, municipal solid waste management, water resources and sanitation are proposed. Based on these technologies, a set of actions toward developing eco-cities has been compiled, to be used together with the Action Priority Matrix to rank their impacts and priorities. Kostomuksha municipal officials have applied the matrices to select their preferences. Finally, a timeline for the implementation of selected actions is suggested.

This study has been conducted under the Green Cities and Settlements (GREENSETTLE) project and it is expected that this study will provide the foundation for defining the framework of eco-municipalities.

A. Appendices

1 Eco-city indicators

A.1 (1/3)

Criteria and sub-criteria with indicators for the classification of Ecological Cities. (Dijk, 2011)

1	Energy	Efforts to limit emissions Stimulate energy management Reducing GHG emissions from transportation Promoting Energy Saving Public transport on LNG Promoting Solar energy (PV, Thermal) Promoting Use of wind energy Allowing generated energy to be ploughed back in the network Promote city heating based on excess industrial heat Promoting heating and cooling based on underground water
2	Water	Efforts to close the water cycle Dealing with flooding Separate drainage and sanitation Integrated waste resource management City promotes water demand management Promoting rain water harvesting Using sustainable Urban drains (SUD) Separate Brown and Grey water Re-use of grey water on the spot Promoting urban agriculture
3	Sanitation	Efforts to promote eco-sanitation Produce energy out of sewer Promote decentralized waste water treatment Use of environmental technologies for water treatment Appropriate sanitation solution Developing sanitation value chain Central treatment systems Using Biogas Collective facilities

A.1 (2/3)

4	Integrated approach	Policy document developing an integrated approach Integrated into the surrounding region Formulating objectives concerning justice and equality Emphasize the need to involve all stakeholder Planning for the future of cities is a visionary debate Promoting biodiversity Promoting wild life Accountability towards stakeholders Urban Management philosophy Quality of life
5	Solid waste	Efforts to limit production of solid waste (Reduce) Waste collection Re-using Recycling waste Go for waste minimization in production Constructing waste collection points Policies on hazardous waste Policies on toxic chemicals Involvement of private sector in waste collection Integrated waste management
6	Transport	Efforts to limit the use of cars City accessible for everyone Road infrastructure deemphasized Promoting the use of bicycles Promoting modal split (transit) Policies to limit congestion Physical planning to take transport issues into account Integrated Urban Design Develop integrated transport policies

A.1 (3/3)

7	Sustainable Urban Development	Efforts to promote sustainable urban development In balance with Nature Apply the Brundtland definition of sustainability Protecting the natural environment City with high quality public culture Try to change attitudes of actors Promote ecological production Use zoning policies Reserve green areas Ecosystem rehabilitation activities
8	Pollution	Efforts to limit air pollution (dealing with smog) Efforts to limit water pollution Efforts to limit soil pollution Efforts to limit industrial pollution Efforts to limit noise pollution Efforts to limit other types of pollution Reducing intensive agriculture Reduce the city's footprint Liveable city
9	Housing	Efforts to promote isolation Reduction emissions from home heating City has eco houses and neighbourhood Reduction the GHG emissions from the construction industry Compact urban form The natural environment permeates the city's scape Introduce context for a green or Eco-City/neighbourhood Space for recreational purpose's
10	Climate Change	Efforts to limit CO2 emissions Policy of climate mitigation Policy of adaptation Resources Fair governance structure Available Technology Adaptive capacity Leadership Autonomy Acting according to plan

2. Set of actions towards developing eco-cities

Table 1. Set of actions towards developing eco-cities

	A	B	C	D	E
	Urban Development	**Traffic & Transportation**	**Energy (Heat & electricity)**	**Municipal Waste Management**	**Water & Sanitation**
1	Prevent ***urban sprawl***	Retrofitting city buses with catalytic converters	Energy saving plan for municipal buildings (using energy saving equipment and smart monitoring)	Improve present landfills and utilize landfill gas	Harvest rainwater for irrigation purposes
2	Densification of existing urban structure	Create dedicated bus lines	Energy and environmental inspection of public infrastructure to reduce energy losses and pollution	Identify priority waste streams to set up recycling systems	Subsidize water efficient taps and shower nozzles
3	Plan for mixed uses (better proximity to ***urban functions***)	Extend roads to improve traffic flow	Pilot investment in small-scale decentralized system (e.g. waste-to-energy or bioenergy)	Set up recyclables collection points for citizens (such as ***Ekopoints***)	Wastewater sludge utilization system (e.g. biogas production)
4	Integrate infrastructure planning with service development	Incentives to reduce car use (walking & bicycle lanes)	Subsidize refurbishment of existing buildings for energy saving (energy saving equipment and monitoring)	Awareness raising campaign for waste prevention and minimization	Improve the efficiency of water purification plant
5	Plan for the ***recreational aspects*** of urban space	Biofuel –run vehicles for municipal fleet (buses, trucks…)	Energy saving street lighting system	***Wet/dry separation*** of waste & organic waste collection	Improve the quality of water and sanitation infrastructure
6	***Participatory Planning***.	Plan for an infrastructure to support the use of electric cars	Promote use of renewable based electricity	Kerbside separate waste collection system	Awareness raising for water saving
7	Urban interaction (***UBI***) system	Transport ***ICT*** systems (logistics, timetables, etc.)	Development of ***smart grids***	ICT system to optimize waste collection and transportation efficiency	Pilot areas/buildings with grey-water recycling system (***living machine***)

Select those actions from this **Table 1** that you would like to see been implemented in Kostomuksha, and rank the actions based on their impact and difficulty of implementation. Please mark your choices (such as D.1 or E.4) to **Table 2**. Concepts highlighted with bold and italics font are explained in **Table 3**.

Table 2. Action priority matrix

Rank the actions selected from **Table 1** according to low or high impact, easy or difficult to implementation. Additional information for the meaning of the boxes can be found in **Table 3.**

	Environmental Economic and Social Impact	
	Low impact	**High Impact**
Easy (short-term investments)	***Fill Ins***:	***Quick wins***:
Difficult (Long-term investments)	***Hard slogs***:	***Major projects***:

Comments and any other actions you plan to implement

Name of respondent:
Position:

Table 3. Additional Information for Tables 1 & 2

ACTIONS
Urban Function refers to all possible synergies with private and public sector in relation to the components of energy (e.g. peak loads, energy efficiency), waste (collection, treatment and utilization of waste), water & sanitation (purification and filtration, phosphorus recovery etc.), traffic & transportation, urban development and socioeconomic services supporting the societies.
Recreational aspects refer to utilization of parks, green spaces and indoors comfort to support leisure activities.
Urban sprawl refers to spreading outwards of a city to low density, car-dependent areas which has mostly detached houses with their own gardens, or row houses and large surrounding green areas.
Participatory Planning refers to a community strategic planning where knowledge/data is sharing between professionals, stakeholders and citizens combining the boundaries of sectorial and stakeholder levels. Interviews, public hearings, meetings, workshops and surveys are actions for gathering the data.
UBI[1] (from ubiquitous) refers to a concept which has as a goal to develop a monitoring, feedback and information systems for the community. Displays are placed indoor and outdoor in hotspots around the city of Oulu allowing interactions and sharing of information's between the citizens.
ICT (Information and communication technology) Systems allow to monitor, access and sharing information between the urban systems, which is result of the urban functions. A system like that allow gradually synergy between the components and development related with smart logistics system (Saving space, fuels, electricity and heating), Smart power grids (energy production plant, electrical car recharging storage etc.) Smart monitoring (etc. avoiding peak loads) for buildings and industries which result to a higher overall energy efficiency for the city. Design information and communication systems which will use the available technology integrated with social indicators. This will provide more information to Majors and will improve the overall decision making process for the city functions.
Smart Grids refers to suppliers and consumers to have a two-way communication monitoring in real-time the electricity grid condition (small energy production plant, demand respond for lower the consumption and distribution of electricity, electrical car recharging storage).
Ecopoints[2] (Ekopiste) refers to collection points of waste fractions at areas near markets, shopping centres and small residential areas.
Wet/dry separation of waste refers to the segregation of organic waste from municipal waste fractions. Wet waste refers to the waste fractions produced from organic materials (fruits, vegetables etc.). Dry waste refers to waste fractions of paper, cardboard, glass, metal etc.
Living machine[3] is a concept refers to applied technologies for wastewater treatment and generation of clean water in situ. Its application configures in order to satisfy the needs of the location and the local climate.

PRIORITIES
Quick wins[4]: A term used in the regeneration sector to refer to relatively cheap and easy initiatives or strategic decisions that can be quickly implemented in an attempt to secure a community support for a regeneration scheme.
Major projects[5]: Projects with long time invest of return the investments and bring a sequent of quick wins
Fill Ins[5]: List of actions need to be done, but always come after the major projects and quick wins.
Hard slogs[5]: Actions with low returns of investment and time consuming; however would be used at a different time and in different way to bring quick wins.

1 UBI [web document],[accessed 17.09.2011], available at: http://www.ubioulu.fi/

2 Ekorosk [web document],[accessed 17.09.2011], available at: http://www.ekorosk.fi/en/ekopunkter.html

3 Living Machine [web document],[accessed 17.09.2011],available at: http://www.livingmachines.com/about/how_it_works/

4 ENCYCLO [web document],[accessed 17.09.2011],available at: http://www.encyclo.co.uk/define/Quick%20wins

5 Time analyser [web document],[accessed 17.09.2011],available at: http://www.timeanalyzer.com/lib/priority.htm

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