LAMK
Lahden ammattikorkeakoulu
Lahti University of Applied Sciences

ENVIRONMENTAL SUSTAINABILITY OF A NEW RESIDENTIAL AREA

LAHTI UNIVERSITY OF APPLIED SCIENCES
Master of Engineering
Urban Sustainability
Autumn 2019
Heta Tuunanen

Abstract

Author	Type of publication	Published
Tuunanen, Heta	Master's thesis	Autumn 2019
	Number of pages 88 pages	

Title of publication

Environmental sustainability of a new residential area

Name of Degree

Master of Engineering

Abstract

The built environment has a crucial role in the mitigation of climate change. A significant part of the energy consumption and emissions arise from the built environment. The European Union and Finland have set many targets to decrease greenhouse gas emissions, to improve energy efficiency and to increase the usage of renewable energy. Urban planning has an impact on the sustainability of urban structure that is essential from the viewpoint of the reduction of energy consumption and emissions. From the point of view of the mitigation of climate change, the aim of urban planning is to create a framework for low-emission life.

This thesis represents environmentally sustainable aspects for planning of a new residential area. The aim of this thesis is to consider how urban planning can affect environmental sustainability of urban structure. The object is to recognise practices that have on impact on environmental sustainability of a new residential area. This thesis concentrates on environmental sustainability excluding economic sustainability and social sustainability.

This study is a theoretical research which has been completed with a literature review. The data collection has been mostly based on online archives and collections. The literature review consists of a review of the sustainable urban structure, the environmental impacts of the built environment, environmental sustainability in urban planning and the practices to increase environmental sustainability of a new residential area with building instructions.

Keywords

environmental sustainability, sustainable urban structure, built environment, urban planning, residential area

Tiivistelmä

Tekijä	Julkaisun laji	Valmistumisaika
Tuunanen, Heta	Opinnäytetyö, YAMK	Syksy 2019
	Sivumäärä 88 sivua	

Työn nimi
Uuden asuinalueen ympäristöllinen kestävyys

Tutkinto
Insinööri (YAMK)

Tiivistelmä

Rakennetulla ympäristöllä on ratkaiseva rooli ilmastonmuutoksen hillinnässä. Merkittävä osuus energiankulutuksesta ja päästöistä syntyy rakennetussa ympäristössä. Euroopan Unioni ja Suomi ovat asettaneet monia tavoitteita vähentääkseen kasvihuonepäästöjä, kehittääkseen energiatehokkuutta ja lisätäkseen uusiutuvan energian käyttöä. Yhdyskuntasuunnittelulla voidaan vaikuttaa yhdyskuntarakenteen kestävyyteen, joka on oleellista energiankulutuksen ja päästöjen vähentämisen kannalta. Ilmastonmuutoksen lieventämisen näkökulmasta yhdyskuntasuunnittelun tavoitteena on luoda puitteet vähäpäästöiselle elämälle.

Tämä opinnäytetyö esittää ympäristöllisesti kestäviä näkökulmia uuden asuinalueen suunnitteluun. Opinnäytetyössä pyritään selvittämään kuinka yhdyskuntasuunnittelulla voidaan vaikuttaa yhdyskuntarakenteen ympäristölliseen kestävyyteen. Tavoitteena on tunnistaa uuden asuinalueen ympäristölliseen kestävyyteen vaikuttavia tekijöitä. Tämä opinnäytetyö keskittyy ympäristölliseen kestävyyteen rajaten pois taloudellisen kestävyyden sekä sosiaalisen kestävyyden.

Tämä työ on teoreettinen tutkimus, joka on suoritettu kirjallisuuskatsauksen avulla. Aineistojen kerääminen on perustunut pääasiassa elektronisiin arkistoihin ja kokoelmiin. Kirjallisuuskatsauksessa tarkastellaan kestävää yhdyskuntarakennetta, rakennetun ympäristön ympäristövaikutuksia, ympäristöllistä kestävyyttä yhdyskuntasuunnittelussa ja tapoja lisätä uuden asuinalueen ympäristöllistä kestävyyttä rakennustapaohjeiden avulla.

Asiasanat

ympäristöllinen kestävyys, kestävä yhdyskuntarakenne, rakennettu ympäristö, yhdyskuntasuunnittelu, asuinalue

CONTENTS

1 INTRODUCTION

Sustainability and sustainable development have many definitions. The most well-known definition is probably from the year 1987 in the report Our Common Future by the United Nations:

> *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*

Commonly, sustainable development is conceived to has three dimensions: environmental sustainability, economic sustainability and socio-political sustainability. This thesis concentrates on environmental sustainability, but because all the dimensions of sustainability are represented in urban planning and construction, this thesis touches economic sustainability and socio-political sustainability as well.

The main goal of this thesis is to discover environmentally sustainable aspects when planning a new residential area. This study is a literature review about environmental aspects of urban planning and construction. The aim of the literature review is to consider environmental impacts of the built environment and construction and to examine how to affect environmental sustainability with urban planning.

The main research questions are the following:

- How to affect environmental sustainability with urban planning?
- What aspects have an impact on environmental sustainability of a new residential area?
- What kind of instructions, that affect environmental sustainability of a planning area can be included in building instructions?

The client of this thesis is Arkkitehtitoimisto Havas Rosberg Oy. The aim of this thesis is to discover the manners how to affect environmental sustainability of a new residential area. The main goal is to find the means for the execution of environmental sustainability through urban planning. The intention is to utilise these findings in future land use projects. The significance of this thesis is to serve as background information for new planning projects and bring an aspect of environmental sustainability to urban planning.

This thesis contains ten major parts. Part I introduces the topic of the thesis. The background of the thesis, the purpose of the study and used research methods and research materials are discuss in parts II and III. Parts IV, V, VI and VII provide the literature overview. These parts discuss the sustainable urban structure and urban planning, environmental impacts of the built environment and practices to increase environmental sustainability in a new residential area through building instructions. Finally, based on all the gathered data, this thesis assembles results in part VIII, and last part IX contain discussion.

2 BACKROUND OF THE RESEARCH AND DEVELOPMENT PROJECT

The idea for this thesis came from author's personal interest and working background. The need for this kind of study existed in Arkkitehtitoimisto Havas Rosberg, which has long-term experience in land use planning. The future land use planning is firmly related to environmental issues, and (environmental) sustainability will be one of the main targets of urban planning and construction.

Climate change has been a topic in the last decades and is still a current megatrend. Improvement of the built environment has a crucial significance when mitigating climate change and creating a sustainable society. Buildings and construction contribute about 40 % of all the energy consumption and emissions (Sitra 2019). The amount will increase when including emissions of transport. The notable part of emissions of transport is derived from the urban structure. Furthermore political decisions, people have an important role in mitigation to climate change. It is more likely to make sustainable choices relating to the housing, transport and consumption if people are aware of environmental impacts.

The concept climate awareness is related to climate change. Climate aware planning is a current topic. In Finland, the Building Information Foundation RTS sr, that is a private, non-profitmaking foundation whose purpose is to advance desirable manners in zoning, construction and building management, is currently composing the RT Building Information File about the climate, climate change and climate aware planning both of land use and buildings (Rakennustieto 2019). The RT file is directed to all parties of planning of land use and buildings. The RT file will be ready by the end of the year 2019. Climate aware planning is a large entirety whose purpose is the reduction of emissions, carbon sequestration and adaptation to future changes. In addition of adaptation to the future, it is also essential to understand the prevalent climate and local impacts of changes in land use and construction. Climate aware planning allows the reduction of the energy consumption and emissions of the buildings and the urban structure, the mitigation and anticipation to the extreme phenomena of weather, the reduction of air pollutants and the creation of a comfortable and safe living environment.

3 PURPOSE OF THE RESEARCH AND DEVELOPMENT PROJECT

3.1 Purpose of the study

The main objective of this thesis is to consider the aspects that affect environmental sustainability of a new residential area. The purpose of the study is to find matters that are related to the sustainable urban structure and sustainable construction. The objective is to utilise the findings in the future planning process. This thesis concentrates on environmental sustainability excluding economic sustainability and social-political sustainability. The main focus is in new construction and in the built environments. The significance is to serve the future land use planning projects of the client.

3.2 Research methods and material

The thesis is a literature review which examines the main factors of sustainable urban planning. The research strategy of this thesis is a theoretical research. The used research method is qualitative. The selected research method is based on an analytical review of the literature available. The thesis was carried out in the following phases:

- Definition of the problem
- Identification of research questions
- Data collection
- Elaboration of the collected data
- Results
- Conclusion and discussion

The used initial data of the literature review are existing researches and reports about the eco-efficiency and resource-efficiency of the urban structure, sustainability in urban planning, environmental impacts of built environment and the energy-efficiency and sustainability of construction.

4 SUSTAINABLE URBAN STRUCTURE

4.1 Concept of sustainability

Sustainable development has four scopes: environmental sustainability, economic sustainability, social sustainability and cultural sustainability. In the built environment sustainability means a balance between ecological, social and economic components in a living environment. In residential areas all the dimensions of sustainability are represented. The environmental dimension is frequently one of the main targets concerning residential areas. Energy efficiency and the preservation of biodiversity and ecosystems are matters that are of close concern to all housing districts. The societal side of sustainability can contain issues such as social equity, a sense of community and wellbeing of inhabitants. The economic side of sustainability is represented as well, as sustainable solutions are generally supposed to be cost-effective. Things related to the environment and humans, that are wanted to be protected, are the shape of natural environment, financial and cultural values of the built environment, human health and welfare and equal chances to use the built environment. If there are fundamental lacks in one of those fields, construction is not sustainable. (Modarres-Sadeghi & Konstari 2015, 11; Vares, Häkkinen & Shemeikka 2011, 13.)

4.2 Concept of sustainable construction

The terms related to sustainable construction have various different definitions. How the parties comprise a meaning of various terms can lead to remarkably different problem settings and conflicting solutions. Public operators can be seen as informants of the usage and as coordinators of consistent terminology. The aim of sustainable construction should be expressed unambiguously and clearly from the outset. The planning of sustainable construction should be done with adequate know-how, and a set of the designers should be led with the skill. Sustainable construction requires an integrated planning process where all the parties of the project, the owner, the real estate developer, designers, the constructor, users and maintenance personnel, would be a part of a planning process from the very beginning. The typical hindrance to sustainable construction is a lack of knowledge or know-how related to sustainable construction. (Häkkinen 2011, 22.)

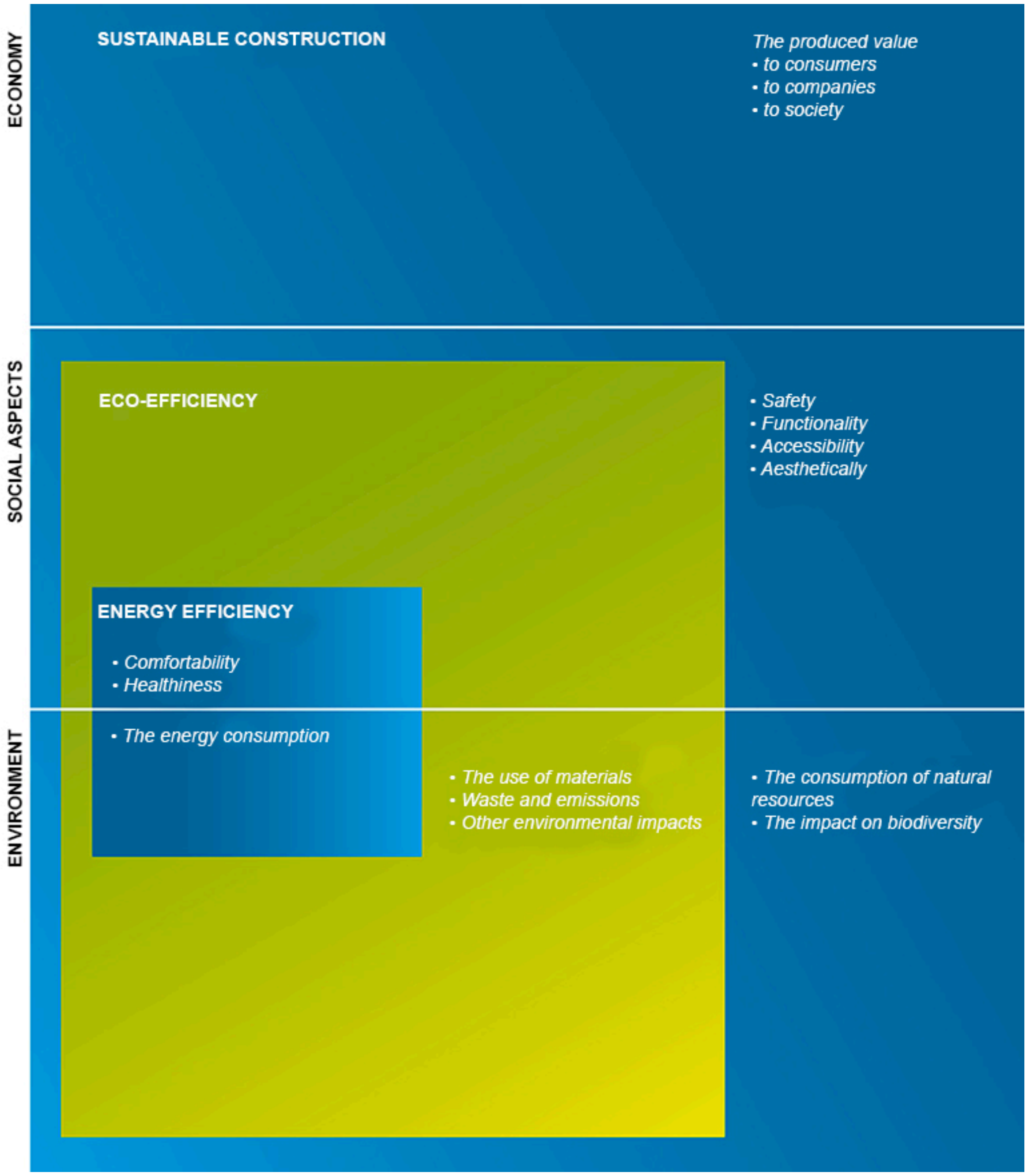

FIGURE 1. The interrelationship of sustainable construction, eco-efficiency and energy efficiency. (ROTI 2011, 28; translation by the author.)

Sustainable construction is a wide and elusive term. Sustainable construction means construction that is compatible with sustainable development. Sustainable development of construction means achieving the aim with the minimum environmental impacts, simultaneously advancing economic and social enhancements at the local, regional and global level. Eco-efficient or energy-efficient construction does not mean the same as sustainable construction. When examining eco-efficiency, the benefits and the quality of the habitat that building is causing are made proportional to caused environmental impacts. When examining energy-efficiency, the results of construction are made proportional to the energy consumption. The concept energy-efficient is also used when the computational energy consumption is compared to an area unit of building. Also the quality of used energy is included in energy-efficiency. (Lylykangas 2013, 1.) Figure 1 represents the interrelationship of sustainable construction, eco-efficiency and energy efficiency.

4.3 Sustainability of a residential area

To increase sustainability of the living environment and to mitigate the impacts of climate change, a reduction of the energy consumption and greenhouse gas emissions is not the only goal. Healthiness, attractiveness and economic efficiency are as well significant in the sustainable areas. To create a functional and sustainable residential area, there are many themes that should be considered. The governance should be well managed and there should be a powerful level of participation. To reduce private motoring, there should be as many services located at a walking and cycling distance as possible, a good public transport system and working transport connections. The functions of the area should be mixed, and there should be living, working, recreational and commercial elements. The environmental themes that should be focused on, are: a decrease of the energy consumption, the minimisation of waste, recycling, the usage of environmental friendly materials and the optimisation of the water consumption. The local economy should be profitable. To achieve equity, all the services (public, private, communal and voluntary) should be accessible to all the inhabitants. The services and dwellings should be advantageous. A sustainable residential area is diverse, it is a blend of social categories and generations. From the point of view of the identity of the district, there should be a clear centre in the district, a strong local culture and a sense of community. Using sustainable development strategies and investing in green practices in energy, transport, building, technology and water and waste management systems, it is possible to reduce the ecological footprint and create a more sustainable local economy in both the existing areas and in greenfield areas. (Modarres-Sadeghi & Konstari 2015, 12-13.)

The aim of urban planning is a socially balanced urban structure. To achieve this, the areas need to be planned so that they mix functions and demographic groups. Children and older people should not be separated from living and working. Also, the traffic planning should be carried out according to the terms of the frailest inhabitants. Urban planning should be based on the future vision and the collaboration with the local stakeholders and crossing administrative borders. Urban planning is a main component for the increase of density of urban areas, for the improvement of mixed land use, for the avoidance of needless uptake of land and soil sealing, for the reduction of automobile dependency and for the encouragement of the usage of public transport, walking and cycling. (European Environmental Agency 2015, 11; Walhgren, Kuismanen & Makkonen 2008, 63)

4.4 City growth strategies

According to Lehtovuori et al. (2017) the three main types of city growth strategies are: the compact city model, the dispersed city model and the controlled expansion of the city. The compact city model increases the intensiveness of land use. The aim is to decrease the amount of journeys and the consumption of resources and at the same time to increase social cohesion and liveliness. The compact city structure is assumed to cause less emissions, but it is also proposed that the compact structure does not reduce emissions per se. An urban lifestyle increases the consumption and causes more emissions because of the economic activity and because of the incremental outbound tourism, for instance. The computation of emissions is challenging, because the communities are complex and unpredictable, and the impact assessment is a relative matter, depending on the point of view and the scale. It is challenging to control emissions directly with the implements of land use. (Lehtovuori, Vanhatalo, Rantanen & Viri 2017, 24-26.)

The dispersed city model decreases the intensiveness of land use, and the aim of it is to decrease the expenses of habitation and production. The dispersed city model corresponds with the necessity of living sparsely with an inexpensive cost of living. It decreases congestions and allows environmentally sustainable choices to be made. The conciseness of the supply in the city centres raises the cost of land and premises, and that raises the cost of production and habitation. The dispersed model has been seen to cause many financial, environmental and social disadvantages. The divergent infrastructure demands investments and the citizens demand services. On the other hand, construction costs and other costs are more inexpensive than in the city centres. All the expansion of the city structure is not adverse dispersal, the difference should be estimated through the evaluation of comprehensive impacts. (Lehtovuori, Vanhatalo, Rantanen & Viri 2017, 24-25.)

The controlled expansion of the city is placed between the former strategies. The aim is to find a balance between compact and congested models and to save open landscapes. In this model, the possible growing parts of the city are the peripheral areas, the corridors and the individually evolving village-like areas. From each growth strategy can be recognised financial, social and environmentally sustainable impacts in addition to the consumption of resources. (Lehtovuori, Vanhatalo, Rantanen & Viri 2017, 24.) Figure 2 represents a summary of the three main types of city growth strategies and their influence on sustainability.

Type	Economic	Social	Environmental	Resources
Compaction	Reduce the cost of travel by reducing the need to travel	Social cohesion Vitality	Reduce CO2 emissions Protect natural landscape	Reduce urban land use Reduce energy use
Dispersal	Reduce cost of living and production	Increase affordability Reduce crowding	Reduce impermeability of land Less exposure to noise and pollution	Potential use of renewable resources
Expansion	Reduce travel cost through balanced communities	Reduce cramming Social cohesion	Some protection of landscape	Greater potential for using renewable resources

FIGURE 2. Alternative urban forms and their influences on sustainability. (SOLUTIONS 2010, 34.)

Impacts of urbanisation are different in different levels of the scale and impacts depends on the definition of the urban area. The social and financial dimensions of sustainability are related to the urban compaction. The compactness offers the potential to reduce urban flows, as the urban structure shapes how people live, move and work in urban areas. The most advantageous impacts of compactness are reduced needs of the land and energy of transport. The urban compaction enables such resource-wise practices as the transition of consumption from products to services, low-carbon consumption choices, a sharing economy and new forms of working. These practices decrease systematically emissions and energy consumption caused by the expenditure and movement, and thus urban compaction has a positive influence in the mitigation to climate change. On the other hand, the compactness leads to significant vulnerability at the same time. Networks that are closely interrelated enable social interaction, the accumulation of economy and the spreading of the promotive development of regeneration, but they also enable the increase of disruption and the accumulation to the wider area. (Lehtovuori, Vanhatalo, Rantanen & Viri 2017, 26; European Environmental Agency 2015, 11.)

4.5 Population density

Population density has an impact on how large a supply of utilities there are in the area. This also concerns technical services, such as the transport network, the energy network, the water supply and sewerage system, waste management and the IT network, as well social services, such as schools, libraries, kindergartens, health-care centres, shops and other public and private services. If the settlement and positions are situated too sparsely, there are not enough customers for services. The increase of the service level means as well an increase of eco-efficiency and an increase in the quality of life. Population density in Finland is sparse internationally measured, which means correspondingly large consumption levels of material and energy, and a large amount of emissions, especially regarding transport. The urban sprawl and the dispersal of the urban structure increase further oriented passenger traffic, the energy consumption of traffic, emissions of traffic and other adverse effects. It also deteriorates the eco-efficiency of the urban structure. Greenhouse gas emissions in the fringe areas of the cities and in urban areas are relatively high per capita, compared to the city centres and other densely built areas. The emissions are larger in sparsely built areas, or in areas with a low supply of employments. (Lahti, Nieminen & Virtanen 2008, 42.)

4.6 Ratio of residential buildings and business premises

In theory, a land use plan that arranges residences and workplaces close to each other causes less commuter transport. It is called *workplace self-sufficiency*. In practice, people who are living in the area, do not work in the same area, because workplace supplies rarely corresponds with the demands of residents. Even so, it is better that there is a workplace supply in the area than that there is not one, because in the latter case the length of the commutes would increase even more. For that reason, the aim is generally to mix the residency and workplaces. (Lahti, Nieminen & Virtanen 2008, 61.)

With theoretical urban structure models it can be roughly estimated how the functionalistic separation of different functions (workplaces, residency, services and recreation in their own areas) affect the amount of transport. In theory, the most advantageous is the model where all the workplaces and services are located in the city centre so that, there is the shortest distance from all the other parts of the area. In practice, the structures are more complex and the growth of the city affects the increase of the area efficiency. When the main centre increases, a lack of space arises in the centre areas, the traffic gets jammed and the value of land increases. Consequently sub-centres begin to form and some services are situated there. (Lahti, Nieminen & Virtanen 2008, 61-62.)

The main traffic routes and traffic hubs attract workplaces and services. Functions begin to diverge to their own areas and the dispersed centring is strengthened. The formation of sub-centres has a certain positive influence on the eco-efficiency, because all the inhabitants of neighbourhoods do not need to travel to the main centre every time, often travel to the sub-centre is enough. The grocery store and other neighbourhood services increase the eco-efficiency of the area in two ways. The shopping trips are shorter and could be carried out by walking or cycling, or by using public transport, instead of a car. Nevertheless, that concerns only some of the commuters and trips for running errands. When estimating total impacts, the journeys outside of sub-centres should be considered as well. (Lahti, Nieminen & Virtanen 2008, 61-62, 76.)

4.7 Resource efficiency in urban areas

Resource efficiency means using the resources available in a sustainable manner. The insufficiency of natural resources and the impact of overuse of natural resources has led to a promotion of resource efficiency. Urbanisation and the growth of population has accelerated to the usage of resources even more. Urban structure and the various functions of cities, including transport, are notable consumers of the material and energy resources. Resource efficiency of the urban structure is defined as, besides aiming at the conservation and the rotation of resources, aiming at the regeneration of resources as well. Resource efficiency is an essential part of sustainable development. (Lahti, Nieminen & Virtanen 2008, 2, 13-14.)

Urban areas are crucial when pursuing resource efficiency. Urban areas are growing really fast and more than a half of the world’s population is living in urban areas. When trying to become a sustainable city, the usage of resources has to be minimised. The urban system is dependent on its surroundings, and to maintain the daily life of residents and economic activities, the cities require natural resources, energy, raw materials, groceries and utilities outside of the cities. The urban areas’ need for material and energy, and also the emissions, the congestion and the waste production, are related to the components of the urban system. The shortened commuting distances, a minor spatial footprint, an optimised infrastructure and the new innovations are all advantages that the density and the closeness of the population and the business brings. Compact urban structure enables utilities, such as public transport, water and sanitation services, waste management and district heating. The usage of resources is shaped by the urban management and planning, but factors such as the compactness, urban morphology and urban form, affect it as well. (European Environmental Agency 2015, 8-9.)

Urban sustainability requires resource efficiency. The challenge, when pursuing the resource efficient city, is to modify interdependent parts of the urban system at the same time. The factors of the urban system are: society, which includes the lifestyle, governance, economy and future vision; the grey infrastructure, which includes the urban technical systems such as buildings, transport, water and sewage; and green infrastructure, which includes green areas inside the cities, as well around the cities. The nature of the city is determined by the society through its behaviour, ways of life and values. The capability to achieve efficient and comprehensive urban planning and the future vision of the city are defined by the governance and the policy-making process. The spatial dimension of the city and the urban pattern is defined by the grey infrastructure system, that determines how people are living, working and moving. The green infrastructure system enables social, ecological and economic advantages, such as an improvement of air quality, the regulation of temperatures, flood protection and the recreational areas. (European Environmental Agency 2015, 9-10.)

4.8 Significance of green infrastructure for sustainability of urban structure

Green infrastructure is a network of green (land) and blue (water) and its activity is based on its parts, interrelated to the each other and the surrounding environment. Green structure in a city can be almost untouched forests, but as well it can be a green roof, a block yard on the top of underground parking lots, or weeds growing through the asphalt. All of this has a significant contribution to the diversity of the environment, well-being of residents, the production of ecosystem services and the resilience of urban area. A single park is a part of green infrastructure in terms of how it upholds the various features in the socio-ecological system. For example, via the water circulation and supply of the habitats, a park can be connected to the surrounding environment and infrastructure. The parts of a network can be connected functionally even if they are not directly interrelated physically. (European Commission 2019; VirMa 2016; Ariluoma, Kalliala & Lähde 2015.)

Green infrastructure is associated with a variety of environmental, economic and human health benefits, many of which go hand in hand with one another. Green infrastructure produces ecosystem services, such as water purification, air quality and climate mitigation and adaptation. In addition, it supports many other services and mobility. The benefits of green infrastructure are particularly accentuated in urban and suburban areas, where green space is limited, and the environmental damage is wider. When creating a resilience city, the meaning of green infrastructure is emphasised. Nature is a renewable and flexible element, so it is less vulnerable to external irritants than the present, quite stable, built environment. Green infrastructure indicates the possibilities to combine compact building and nature in a sustainable way. (European Commission 2019; VirMa 2016; Ariluoma, Kalliala & Lähde 2015; United States Environmental Protection Agency 2015.) Figure 3 represent a summary about the benefits and practices of green infrastructure.

Benefit	Reduces Stormwater Runoff											Improves Community Livability					
	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding	Increases Available Water Supply	Increases Groundwater Recharge	Reduces Salt Use	Reduces Energy Use	Improves Air Quality	Reduces Atmospheric CO_2	Reduces Urban Heat Island	Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture	Improves Habitat	Cultivates Public Education Opportunities
Practice										CO_2								
Green Roofs	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes	Yes
Tree Planting	Yes	Yes	Yes	Yes	No	Maybe	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Bioretention & Infiltration	Yes	Yes	Yes	Yes	Maybe	Maybe	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe	No	Yes	Yes
Permeable Pavement	Yes	Yes	Yes	Yes	No	Maybe	Yes	Maybe	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes
Water Harvesting	Yes	Yes	Yes	Yes	Yes	Maybe	No	Maybe	Maybe	Maybe	No	No	No	No	No	No	No	Yes

Yes Maybe No

FIGURE 3. An illustrative summary about the benefits and practices of green infrastructure. (CNT 2011, 3.)

Green infrastructure in the cities is easily planned only from the recreation point of view, and its multifunctionality is not sufficiently taken into account. Considering the green areas and green infrastructure more widely, the key position is to recognise its multifunctionality. For example, if the planning areas are favourable only for recreation, the possibility to miss out on other nature values along with planning and construction, increases. Often even a separate green area can manage many different missions and produce various ecosystem services both to humans and animals that exploit the urban nature as a habitat. When considering the diversity of functions as early as possible, it is more likely that the most valuable areas are going to be saved successfully. (Hirvensalo 2015, 25-27.)

Green infrastructure is one approach for a design. The fundamental principles of green infrastructure are a holistic manner of approach: systematical, sector crossing thinking; an endeavour to produce several benefits at the same time; and a long-sighted strategic viewpoint to manage the urban habitat. The operability of green infrastructure is dependent on the purpose for which it is planned, so planning of green infrastructure should be strategic. Often in practice, green and grey infrastructure operates hand in hand, in which case these infrastructures should be planned alongside each other. For instance, the infrastructure of urban runoff can be based partly on the traditional system with the pipes and partly on the open urban runoff system. To find the most functional and the most sustainable solution, both of these systems should be planned as an entirety, in which case it is possible to optimise potential benefits of the green infrastructure. (European Commission 2019; VirMa 2016.) Figure 4 expresses the connection of green infrastructure and other infrastructures.

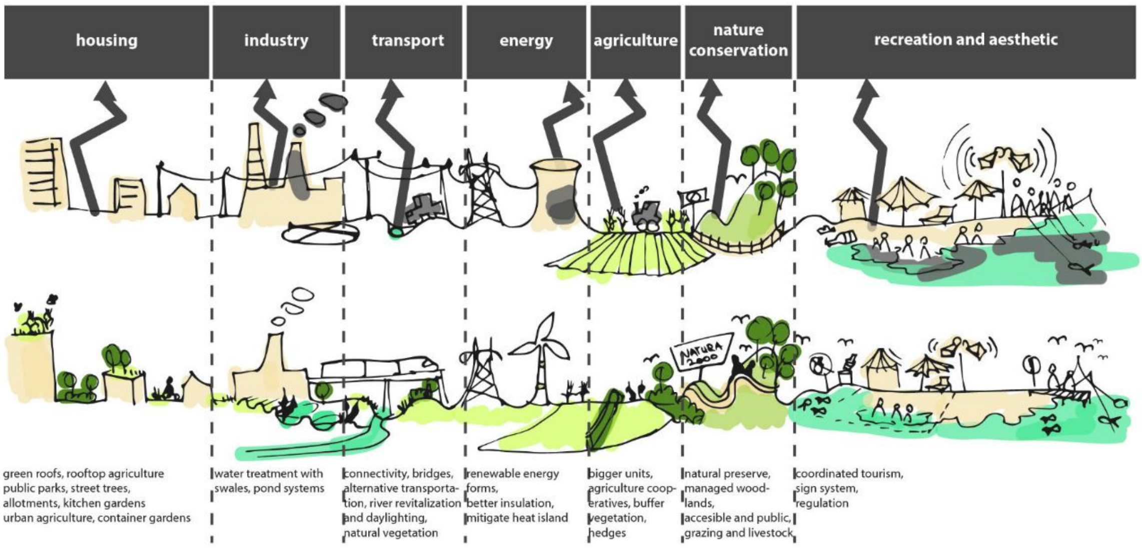

FIGURE 4. Green infrastructure is connected functionally to other infrastructures. (VirMa 2016.)

4.9 Impact of urban structure on mobility and transport

The urban structure of the city determines the functions (mixed land use, patterns of spatial behaviour) and the flows (travel, energy) of the cities. Urban structure contributes to the reduced energy use of transport by decreasing the travel demand (distance) and by promoting more sustainable travel modes, such as public transport, cycling and walking. The travel patterns are substantially affected by the distance and time, accessibility, flexibility, cost and possibilities to combine different modes of transport. To reduce travel distances and journeys by car, the key factors are the size of the city, the compactness and concentration of the city, the mixed land use, accessibility and concepts of self-management. The location inevitably affects the mobility possibilities of inhabitants or other operators of the area. Public transport systems are the most preferable in the city centres and in the corridors of rail transport, such as the undergrounds and local trains. Car ownership is more extensive in the areas where the selection of public transport is minor, because of a low density of residents and workplaces. The location, the density of inhabitants, the transport system, travel habits and energy and carbon dioxide emissions of transport have a clear causal connection. (Große 2017, 18-19, 26; Lahti, Nieminen & Virtanen 2008, 38.)

The urban structure, the location of the settlement, the lifestyle of the residents and related features and the travel behaviour are firmly interrelated. Objective parameters, such as urban structure, and subjective parameters, such as residential preferences, the availability of a car, the attitudes related to travel and lifestyle, and their interrelations, need to be included when considering travel behaviour. The linkage of the travel behaviour, the urban structure, and the lifestyle and related attributes, and the links between these components is expressed in the figure 5. (Große 2017, 33.)

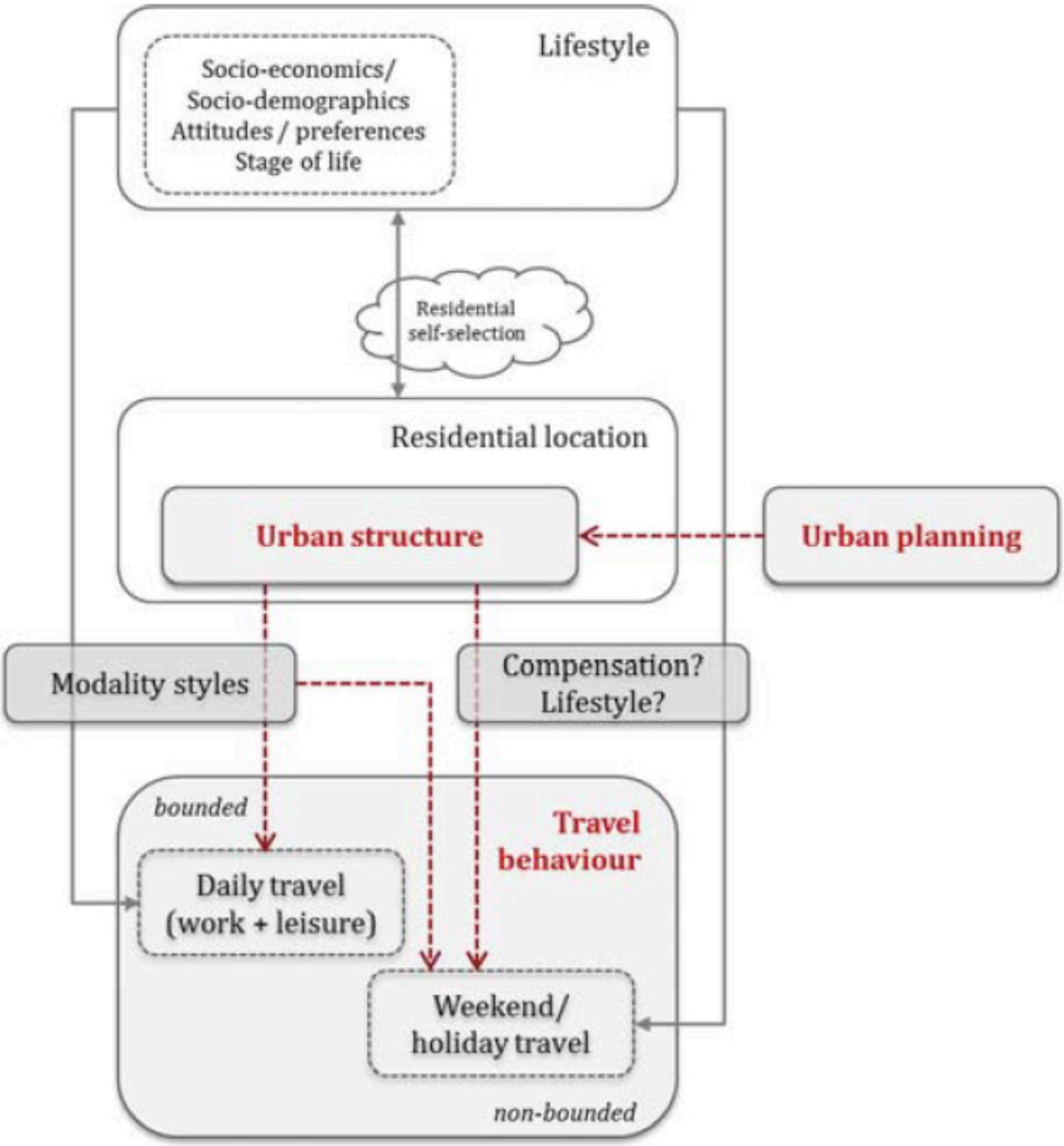

FIGURE 5. Linked concepts that explain travel behaviour. (Große 2017, 34.)

Automobile dependency means a high rate of journeys by automobile per capita. Automobile dependency leads to the transport and land use patterns, that favour automobile access and reduce the alternatives of transport modes. People experience that it is challenging to reach the services and activities without using an automobile. Automobile dependency raises many expenses, such as the higher costs of vehicles, reduced travel options, increased costs of road and parking facilities, congestion, accidents and various environmental impacts. The urban form should be developed so, that its services and workplaces are easily accessible by all the different demographic groups. The need for automobile transport is lower if the services and workplaces are located close to the residential areas. The uniform structure depends on the private motoring and does not offer opportunities for the other forms of mobility, such as public transport, cycling or walking. Mixed urban structure is a requirement for a minor amount of private motoring but does not guarantee the reduction of it. Living in the centre of urban structure secures short distances between activities, and that is a requirement for a lower amount of private motoring. The spatial location of activities such as the residence, work, shopping, and production and consumption give some indications of the required travel demand and average distances between the activities. It is possible to increase the levels of accessibility without necessarily increasing the need for automobile travel, with a higher level of an integration between transport and land use. (Victoria Transport Policy Institute 2016; Rodrigue, Comtois & Slack 2013, 198-199, Kanninen, Kontio, Mäntysalo & Ristimäki 2010, 12-13, 117.)

5 ENVIRONMENTAL IMPACTS OF BUILT ENVIRONMENT

5.1 Greenhouse gas emissions of the built environment

The built environment has a crucial significance in influencing climate change. From the point of view of the mitigation of climate change, the amount of greenhouse gases should decrease from the present level. In Finland, buildings cause over 30 % of the greenhouse gas emissions. The emissions of the built environment, including transport, account for 40 %. In the urban environment, the significant air pollutants that affect the quality of life are also particulates arising, for example, from road dust. These air pollutants and particulates cause health hazards and both of these originate from the features of the built environment. In Finland, people are living mostly in heated houses and partly in air-conditioned interiors, and houses are accessible by versatile, mostly motorised, transportation. Improvement of holistic energy efficiency and the reduction of greenhouse gas emissions is essential. To reduce emission demands it is needed to increase the energy efficiency of production and consumption of energy. (Modarres-Sadeghi & Konstari 2015, 12; Rakennusteollisuus RT ry 2010, 5; Lahti, Nieminen & Virtanen 2008, 33.)

Construction causes a lot of emissions to the environment compared to the other fields of industry. Construction consumes natural resources and has an effect on the environment starting from the planning stage and right through to the deconstruction of the building. The environmental impacts of construction consist of various components in the construction industry, in building and in the utilisation of buildings. The energy consumption, dust and greenhouse gas emissions, waste formation, water contamination, the usage of water reserves, the emissions caused by construction materials, land use, and the consumption of natural resources are viewpoints, from which to examine the environmental impacts of construction. The intake of raw materials, the production of materials and building blocks, construction and the usage of buildings, all cause stress to the environment because they produce harmful emissions and utilise raw materials. In construction, the usage period of a building causes most impacts on the environment. When comparing environmental impacts of the construction period and the usage period of the building, impacts are notably greater during the construction period. The construction period is brief compared to the usage period of the building. (Hämäläinen & Teriö, 2011, 11.)

The emissions concerning the built environment are mostly related to energy, but also construction itself causes carbon dioxide emissions. The promotion of a low-carbon built environment is possible by improving energy efficiency of the built environment and the logistic network related to it, by reducing greenhouse gas emissions of used energy, and by improving the usage of low-carbon materials. Also quality factors, such as attractiveness of walking and cycling environments, affect the consumption choices. The emissions related to energy mostly originate from the energy production plants, from the production of electricity, district heating and district cooling. These are physically located in different places where energy is consumed. The decrease of greenhouse gas emissions is largely related to what kind of combination of energy sources is utilised in its entirety. Utilisation of the carbon sinks to bind carbon is a way to decelerate the concentration of carbon dioxide to the atmosphere. (Lehtovuori, Vanhatalo, Rantanen & Viri 2017, 39.)

5.2 Energy consumption of the built environment

5.2.1 The role of the built environment in energy consumption

The world is still urbanising rapidly, so that sustainable development in urban areas will be even more crucial in the future. In the European Union 70 % of the population and globally over 50 % of the world's population is living in urban areas. In Finland the level of urbanisation was 84 % in the year 2015 (Lehtovuori, Vanhatalo, Rantanen & Viri 2017, 9). Cities are responsible for the major part of energy use and greenhouse gas emissions. That is why the cities are in a key position regarding reducing the consumption of resources. 73 % of the world's energy consumption is resulting in the cities and 69 % of carbon dioxide emissions are produced in urban environments. The energy consumption in cities is mainly composed of the energy usage in buildings (heating, cooling and electricity) and the energy usage in transport. Innovations of the newest sustainable implementations are often developed in the cities, and cities also have the financial opportunities to create and develop sustainable solutions and investments. (Große 2017, 17-18; Modarres-Sadeghi & Konstari 2015, 12.)

In Finland, the energy consumption of buildings accounts for 40 % of consumed energy. The energy consumption of the built environment, including transport, is 60 %. (Rakennusteollisuus RT ry 2010, 5.) The size of the building stock in Finland 2017 was 1.5 million buildings. The building stock does not include free-time residences and farm buildings. The floor area of the building stock was over 482 million square metres in total. (SVT 2017.) An increase of the building stock and the amount and quality of the electric equipment increase buildings' energy consumption. On the other hand, the requirements for energy saving and the development of technology have decreased consumption so that the total consumption of heating energy has been reduced by 30 % from the level of the 1970s. The energy consumption of a building depends on the energy efficiency of the building, the quality of maintenance, and the consumption habits of people who are using the building. Architecture has an influence on the energy efficiency of the buildings. Architecture allows the utilisation of renewable energy. From the built environment point of view, the energy consumption is related to the location of the building. Most of the emissions originate from the energy consumption from the usage of premises. The construction period and construction materials are causing a minor part of the emissions, less than 10 %. (Lappalainen 2010, 15; Martinkauppi 2010, 21)

5.2.2 Energy consumption of buildings during construction and usage

Construction uses a lot of fossil fuels compared with other industries. Energy that is used in construction is usually in the form of electricity, fuel oil, natural gas or petrol. On the worksite the energy consumption derives from heating the buildings during the framework and interior periods, for the usage of construction machines, the usage of social premises, and from other activities. Heating and drying of structures constitute the most energy consumption of worksites. Paying attention to humidity control during the construction process receives savings when heating energy is required less and construction is running faster. (Hämäläinen & Teriö, 2011, 17-18.)

The heating of buildings accounts for 27 % of the whole energy consumption in Finland. Residential buildings use 20 % of the final energy consumption, and most of it, 66 %, is consumed in heating. In dwellings, the heating of water consumes 20

% of the energy and the heating of saunas uses 5 % of the energy. In new energy efficient buildings, the portion of heating energy is less, in which case the heating of water, electronic devices and lighting can consume over half of the consumed energy. (Ilmasto-opas 2018.) The specific heat consumption of a building depends on the building's location (macro and micro climate), the quality of insulation structures; the structure, size and orientation of windows; the condensation of the building; the heating system; the type and size of the building; the utilisation habits, such as a room temperature, ventilation and hot water; and the effectiveness of a heat recovery. (Lappalainen 2010, 46.) The main concepts of the energy use of the buildings and the linkages between those are represented in the figure 6.

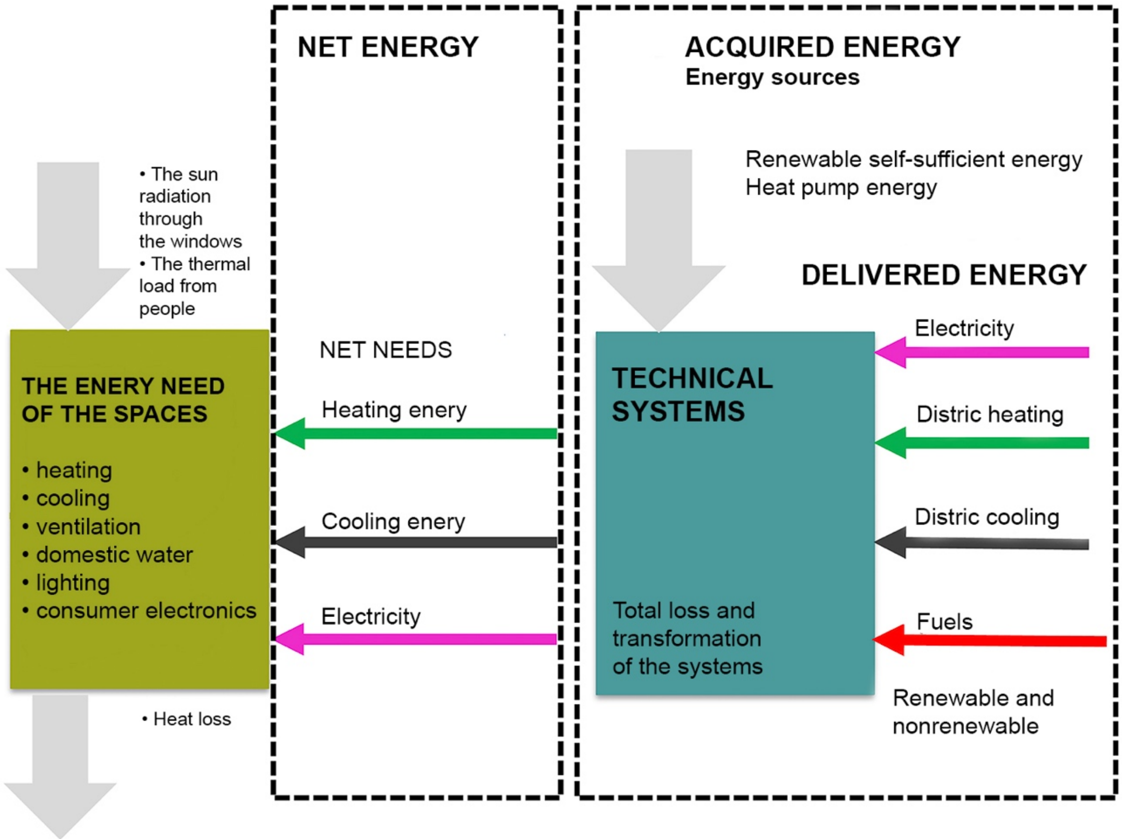

FIGURE 6. The main concepts of the energy use of buildings. (Mattinen, Heljo & Savinlahti 2016, 12; translation by the author.)

5.3 Energy efficiency

5.3.1 Focuses of energy efficiency

The climate political functions that are directed to buildings and the usage of buildings, strive to the improvement of energy efficiency, the reduction of emissions, the increase of renewable energy and the consideration of environmental impacts of construction. The statutes, financial control and information control are ways to influence. Measures are targeted to new construction, repair construction and the usage and maintenance of the building stock. When improving energy efficiency, it is relevant to concentrate on the energy consumption that is generated by non-renewable (fossil) sources and that produce harmful impacts on humans. The reduction of all material consumption and energy consumption is not desirable. Non-renewable natural resources can be consumed only in limits that do not destabilise local, regional or global natural processes. When measuring eco-efficiency of the usage of natural resources, it should be taken into account if it is relevant from the global or local point of view. (Suomen ympäristö 2014, 127; Lahti, Nieminen & Virtanen 2008, 10.)

Used structures and equipment system solutions have an impact on energy efficiency of the building. More attention should be paid to the structure of the area overall, beginning from land use planning, such as what kind of requirements for energy efficient construction there are inside of the area. This includes, for example, the location of buildings and from where the geothermal heating or cooling systems extract the heat. Also, it should be examined how energy efficient construction impacts on the infrastructure of the area. From the point of view of natural resources, the aim is to plan the whole residential area as a nearly zero energy area. Energy efficiency should be planned as an integrated part of the area and its image and structure. That requires the balance and optimisation between the different parts of the area. The aim of the areal energy plan is an optimal overall solution, where non-renewable natural resources are used as little as possible and advantageously from the life cycle point of view. For example, the availability of the waste energy from the industry buildings and service buildings, and the utilisation of ground heat, can have an effect on where to locate buildings in the area. (Lahti, Nieminen & Virtanen 2008, 73-74.)

5.3.2 Low energy areas

A low energy area means a construction area, where the energy need of the whole area is lower than that is in an ordinary corresponding area. In that case, the energy need of a single house can vary and energy efficiency can be improved where it is reasonable technically and economically. Decentralised energy solutions could be utilised in low energy areas. When the energy efficiency of the area is good, it is possible to reach a lower peak power than otherwise. In a residential area the energy need of hot water determines the dimensioning of the network and for this reason there should be attention paid to energy via choices involved with hot water. (Lahti, Nieminen & Virtanen 2008, 71-72.)

5.3.3 Types of energy efficient buildings

Energy efficient buildings can be divided into three types: *low energy buildings, passive buildings and zero energy buildings*. *A low energy building* means a building for which the energy need for heating is less than a half of a building compatible with The National Building Code of Finland. According to The National Building Code, a low energy building is defined as one with a specific heat loss of 60 % of a comparison house specific heat loss. Specific heat loss does not describe the energy need of the building, but rather its purpose is to compare planning solutions and comparison buildings. The definition of *a passive building* is given based on the heating energy need of spaces and the total energy need in terms of primary energy. In the Finnish climate, the heating energy need of spaces is 20-30 kWh/m^2 depending on location and the primary energy need is 130-140 kWh/m^2. Additionally, the air leakage value of the envelope of the building should be n_{50} < 0,6 l/h. *A zero energy building* means a building for which the purchased energy need is 0 kWh per annum. The building produces as much energy as much it consumes external energy per annum. Solutions for zero energy building are based on solutions that are typical for passive building so that a zero level can be reached in a cold climate without notable additional costs. *A plus energy building* means a building that produce more energy than it consumes. This can be reached by utilising local energy sources such as sun and wind, efficiently. (Lahti, Nieminen & Virtanen 2008, 52.)

5.3.4 Energy systems

With the exception of district heating and electrical heating, other forms of heating energy usage are based on building specific production (Ilmasto-opas 2018). The lower the energy need of a separate house or a set of houses is, the more of it is possible to cover with renewable energy sources. The direct solar heat, wind energy, and heat energy that is collected with heat pumps from natural environment (soil, water and air), are the area’s own energy supply. The attainment of energy self-sufficiency requires an availability of energy sources all year round, and for example in terms of bioenergy, an adequate storage system for the fuel. The lower is the relative energy consumption of the area (kWh / floor area square meter), the easier it is to reach self-sufficiency. (Lahti, Nieminen & Virtanen 2008, 27, 67.)

A decentralised energy system means an energy solution that serves a relatively minor area or a section of houses. That kind of energy solution can be a block heating plant, a geothermal heating network, local wind turbines or a solar photovoltaic solution that can serve a single house or multiple houses. The block heating plant could utilise solar thermal that is produced in a house-specific- or in a decentralised way. The benefit of house-specific production is lower distribution loss. Decentralised systems could be attached in an interrelated way when the partition of energy resources is possible. (Lahti, Nieminen & Virtanen 2008, 69, 71.)

A centralised energy system serves a large group of premises. Co-generation of heat and energy is a typical centralised energy solution in cities. The distribution of district heating is not economical for a small group of premises because large investments are involved. The basic difference between centralised and decentralised systems is that energy producers in the decentralised system are independent. This protects the energy supply of houses or sets of houses even if there are malfunctions in other decentralised systems. The problem is that if the decentralised system is connected as a local electricity network, the whole system needs to be shut down if there are problems in a single producer of a system. Decentralised heat production suits best areas where it is not possibility to provide district heating. Also in the premises, where the energy need is low, decentralised production is justifiable at least until the cost structure does not support the connection of an energy efficient house to the district heating network. (Lahti, Nieminen & Virtanen 2008, 71.)

The usage of fuels (coal, natural gas, bio fuel), the delivery and storage of fuels that involve space requirements, the traffic volume and its impacts on energy and emissions, have an effect on eco-efficiency of centralised energy systems. Regional networks, that are based on renewable energy, can be developed. Regional networks can utilise the main network. (Lahti, Nieminen & Virtanen 2008, 77.)

5.3.5 Heating forms

Energy spent on heating varies depending on the outside temperature. The higher the outside temperature is, the smaller is the amount of heat requirement, which means the lower energy needs. In Finland, the most general sources of heating energy in dwelling houses are district heating, wood and electric, that make up 83 % of heating energy of buildings. After these, the most common source of heating energy is heat pump energy. The clearest changes in heating forms have been the decrease of oil heating and the increase of ground-source heat pumps. The size of the building, the habits of residents, the building site, the financial situation of users, and environmental effects of heating are all considered aspects when choosing a heating system. (Ilmasto-opas 2018.) Capital costs of heating systems in detached houses are notable because energy consumption is relatively minor (Mattinen, Heljo & Savolahti 2016, 14).

District heating is a good heating form in the cities and in urban settlements where consumers are near each other. The areas outside of the district heating network can use various geothermal heating and cooling solutions. The more sparse is the urban structure of the area and the further from the core network the area is situated (for example in the Finnish Archipelago), the more inexpensive are heat pumps that utilise energy from the ground or the seafloor. Based on life cycle examinations, the cost of energy (price/kWh), that is based on geothermal heating, is cheaper than district heating or electric heating. District cooling suits large air conditioning needs such as those for office premises. Incorporating of district cooling as a part of the district heating system would improve the profitability of the system. (Lahti, Nieminen & Virtanen 2008, 68-69.)

District heating is the most common heating form when including all the new buildings. Electric heating is decreasing in new buildings, but a notable portion of the whole building stock is still using electric heating. The emissions produced from the consumption of electric heating depends on the production manner. The consumption amounts of electric heating can be decreased with the use of supplementary heating sources, like wood. Wood burning causes the production of particulates, which causes negative health impacts. From the climate point of view, it is more crucial to decrease the energy necessity of the buildings than to increase the usage of wood fuels in fireplaces and stoves in buildings. (Ilmasto-opas 2018.)

The production of district heating uses biomass, waste heat of industry and coal. The greenhouse gas emissions of district heating are dependent on the type of power plant and the fuel used. The cogeneration of heat and electricity have very high efficiency. The greenhouse gas emissions are the lowest in cogeneration, that use renewable energy sources like wood, woodchips, pellets or bio gas. (Ilmasto-opas 2018.)

5.3.6 Emissions of energy production

Energy production is still the most significant source of greenhouse gas emissions. From the point of view of the causation of emissions, the most significant things are how the needed energy is produced and how much energy is used. The energy related choices of consumption and energy sources are guided by taxation, emissions trading regulations and regulations for minimum requirements of options that are permissible on the market, such as the emission limits of new cars or the energy regulations that concern new construction. (Lehtovuori, Vanhatalo, Rantanen & Viri 2017, 40.)

The most emissions originate from the usage of fuels in various types of technical equipment that is used in energy production. Most of these emissions are transferred almost entirely to the atmosphere, from where they pass into the drainage system, into soil and throughout to the Plantae and Animalia kingdoms. The emissions of energy production are mostly carbon dioxide CO_2, when measured by weight. The other significant emissions caused by fuels are nitrogen oxides NO_x, sulphur dioxide SO_2, carbon monoxide CO, hydro carbons CH and particulates. The range of fuel selection is significance from the point of view of the formation of greenhouses gases. Coal causes approximately twice as much carbon dioxide equivalent kilogrammes as natural gas does, and approximately 20 % more than heavy fuel oil per single produced energy unit (kWh). (Lahti, Nieminen & Virtanen 2008, 31-33, 67.

5.4 Environmental impacts of construction materials

The improvement of energy efficiency of new construction means that the significance of the environmental impacts of construction materials is emphasised. Greenhouse gas emissions that are related to construction materials, can also increase in absolute terms because of an increase of the envelope's thermal insulation, choses related to cooling and the utilisation of solar energy, quality of building site and other factors. In new construction, recyclable material should be used as much as possible. Buildings should be planned so that the different materials, especially wood and metals, are as easily separable as possible in repair construction and in demolition. From the perspective of resource efficiency, the improvement of building products made from recycled materials, the compilation of user experiences about the usage of recycled raw material and the issues related to the quality assurance of construction materials based on recycling, are the topics of the future. (Ruuska, Häkkinen, Vares, Korhonen & Myllymaa 2013, 33-34.)

Construction consumes a notable amount of non-renewable natural resources. Annually construction consumes over 100 million tons of natural resources. The loss of materials used in construction is about 10 %. By the reduction of material loss, the environmental impacts decrease. (Hämäläinen & Teriö, 2011, 16.)

Urban planning indirectly affects the construction materials. The area density, functions of the area and the building types (multi-story building or detached house, habitation or office premises etc.) affect the distribution of the materials. The proportion of concrete, steel, glass and aluminium is greater in areas of multi-story buildings and office premises than in detached house areas, where the proportion of wood is greater instead. The amount of energy that is used in the production of different types of building materials varies greatly. The production of construction materials use other natural resources as well. From the Global Warming Potential (GWP) point of view (how much greenhouse gas emissions the production of the material is producing), there are clear differences between the different materials and between the various building blocks. Wood as a raw material is advantageous from the restriction of greenhouse gas emissions point of view, because growing trees bind carbon dioxide and deliver oxygen so, that its greenhouse effect is negative. Wood material is a carbon sink that is adhered to the building. (Lahti, Nieminen & Virtanen 2008, 23-25.)

5.5 Construction waste

Construction and demolition waste accounts for approximately 25 % - 30 % of all the waste streams in the EU, and therefore it is one of the most significant waste streams. The construction of the buildings and infrastructure, the complete or incomplete demolition of the buildings, and the infrastructure and the construction and maintenance of the roads, give rise to construction and demolition waste. The construction and demolition waste comprises various materials, including concrete, bricks, gypsum, wood, metals, glass, plastic, solvents, asbestos and soil. A large part of the construction and demolition waste is possible to recycle. Some of the components of the construction and demolition waste have a large resource ranking, so there is a high potential for recycling and re-use of the construction and demolition waste. The sorting and re-utilisation of the construction and demolition waste is well established, readily accessible and advantageous in general. The level of recycling and material recovery varies widely from less than 10 % to over 90 % across the European Union. The sorting of the construction and demolition waste is important, otherwise it can include the hazardous waste, which can comprise the risks to the environment and complicate recycling. (European Commission, 2019.)

In Finland, construction waste is the second largest waste faction, only the mining industry cause more waste than construction (Hämäläinen & Teriö, 2011, 12). The annual construction waste in Finland is about 26 % (24.6 million tons) of all the waste, when counting all the waste in house building, earthworks and hydraulic construction. 94 % of the total amount of the construction waste is different soil materials. House building causes less than 2 % (about 2 million tons) of the Finland’s total waste amount. (Ruuska, Häkkinen, Vares, Korhonen & Myllymaa 2013, 18.)

The construction waste is divided into production waste and packaging waste. The production waste includes waste material and accessory material. The primary way to decrease the waste in the construction site is to reduce the loss. The planning solutions and the worksite process have the biggest impact on the waste origin. By the reduction of the waste it is possible to achieve major benefits. The most important matters in systematical waste reduction are reuse, recycling and reduction (abbreviation 3Rs). It is possible to utilise most of the construction waste as a raw material or energy. (Hämäläinen & Teriö, 2011, 12-14.)

The sorting of the house building waste in the construction site or in a separate waste treatment plant produces the five main waste flows: wood, metal, concrete and minerals, mixed waste and untreated waste. The total utilising grade of the house building waste, without the land masses, is estimated to be 73 %, including the utilisation of the waste as material or as energy. Utilisation of the waste means restoration of the waste to the circulation of consumption and production. The materials could be utilised by reusing, recycling, utilising it other ways as material or utilising it for energy. The challenge in the future is to improve the material efficiency of the construction industry. With effective recycling, it is possible to achieve both the material and the emission advantages. There is a requirement in the Waste Decree in Finland that in 2020 at least 70 % of the weight of construction and demolition waste will be utilised as an energy or fuel. (Ruuska, Häkkinen, Vares, Korhonen & Myllymaa 2013, 18, 33-34.) Figure 7 represents the utilisation of construction waste.

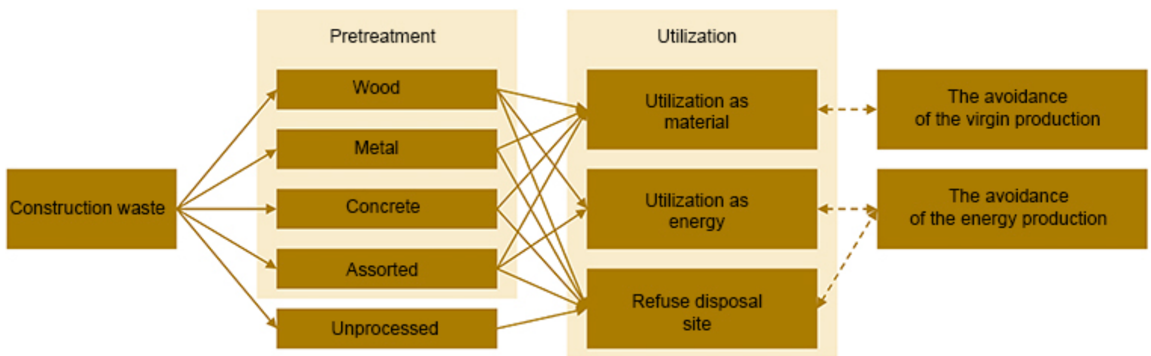

FIGURE 7. The utilisation of construction waste. (Ruuska et al. 2013, 20; translation by the author)

In Finland, construction delivers 400000 tons of hazardous waste per annum. Most of it is contaminated landmass. Impregnated wood, asbestos, paints, PCB and heavy metals are the hazardous waste types from house-building. The duty of the contractor or the owner of the real estate is to compile a survey of the hazardous and dangerous materials in the demolition or in repair construction. The plan how to remove the hazardous substance or how to make it non-hazardous, should be based on that survey. The demolition waste that contains hazardous substances, is always collected apart from the other waste. (Hämäläinen & Teriö, 2011, 15.)

5.6 Environmental impacts of transport

The personal and freight mobility has grown in recent decades. Transport relays the notable socioeconomic advantages, but simultaneously, transport systems cause a lot of environmental impacts which are connected with transport modes themselves, the energy supply systems of transport, the emissions of transport and those infrastructures over which they operate. Transport uses a lot of energy, particularly oil, and releases several pollutants and noise. In addition, transport infrastructures have negatively affected many ecological systems. Transport is also considered to be one of the main causes of global warming. Private cars cause most of the emissions. Private motoring causes over 60 % of the emissions in road traffic and road traffic causes 90 % of all the emissions of transport. The most important way, in consideration of the climate effects in planning, is to attempt to reduce the usage of private cars. (Rodrigue, Comtois & Slack 2013, 255; Touru 2011, 3, 108.)

In the European Union, transport accounts for one third of the energy consumption and causes one quarter of the greenhouse gas emissions (Große 2017, 17). Passenger transport causes 60-70 % of the energy consumption of the transport activities. The prevalent mode of passenger transport is private motoring. Rising earnings, the ownership of a private car and the distance travelled by a vehicle, are closely linked. (Rodrigue, Comtois & Slack 2013, 265.) The advanced technology of cars has decreased the specific consumption and carbon dioxide emissions of the cars. The increase of the traffic performance and the increase of the average size of the cars have, after all, taken a part of the benefit by increasing the consumption of fuels, that causes a standard amount of CO_2 emissions. (Toru 2011, 15-16). Of all the transport modes, air traffic and private motoring consume the most energy. The emissions of transport could be decreased by increasing walking and cycling, by preferring rail cargo and by developing low emission vehicles. The growing demand of transport sets a specific challenge to cut the emissions. All forms of transport have an influence on humans and on the environment. The transport mode affects the scope of impacts. Part of the impacts are local or regional, but a part is also global. It is possible to decrease the impacts by decreasing the amount of transport. The most serious environmental problems of transport are a decline in the air quality and the impacts on global warming. These impacts have an effect on the well-being of people and these impacts also change our living environment. (af Hällström 2016, 8.)

Especially in urban areas, transport activities lead to the increase of mobility demands of passenger and freight. Transport activities have also led to increasing levels of motorisation and congestion, and as a result, transport is becoming more and more linked to environmental problems. The most significant causations of the increase of transport activities are climate change, the deterioration of air quality, noise pollution, impacts on water quality and soil quality, the decline of the biodiversity and uptake of land. The structure of the transport network, used transport modes and the volume of traffic are the main factors of environmental impacts of transport. Networks influence on the spatial distribution of emissions, transport modes are characterised with specific emissions and the traffic is related to the intensity of these emissions. Also economical and industrial processes have to be considered, because these maintain the transport system. These include the origin and manufacture of the fuels, the vehicles, the construction materials, the disposal of vehicles, the parts and the provision of infrastructure. (Rodrigue, Comtois & Slack 2013, 257-260.)

5.7 Climate targets and the urban environment

Carbon dioxide is the most significant greenhouse gas emission from the climate impact point of view. Low-carbon means evidently lower greenhouse gas emissions which are related to humans action. There is not a globally unified policy about the amount of emissions, but the European Commission has expressed the goal that greenhouse gas emissions should be at least 80 percent lower than in the year 1990, when pursuing a low-carbon economy by the year 2050. In Finland, the corresponding target for cutting of greenhouse gas emissions is registered in the Climate Change Act (Ministry of the Environment 2019). The European Union's target for 2020 is the cutting of 20 % of greenhouse gas emissions relative to the year 1990 level, improving energy efficiency by 20 % and raising the proportion of renewable energy up to 20 percent. The normative instruction in the EU is to decrease 20 percent of energy consumption by 2020 by enhancing energy efficiency. The low-carbon target for the year 2050 means significant cuts in carbon dioxide emissions from 2020 target. (Lehtovuori, Vanhatalo, Rantanen & Viri 2017, 37.) Finland's commitment to the EU's inner burden sharing is to raise the part of renewable energy of final consumption to 38 % by the year 2020. According to the burden sharing proposal, Finland needs to decrease 16 % of greenhouse gas emissions from the fields outside of those subject emission trading permits. Fields outside of emission permit trading are, inter alia, transport, construction, land use and waste management. (Lylykangas, Lahti & Vainio 2013, 6.)

Finland has committed itself to enhancing a low-carbon society. Also, Finland has signed the Paris Agreement. This will affect decisions related to urban planning and construction in the near future. The aims of the Paris Agreement have affected the National Energy and Climate Strategy for 2030, where there are aligned, inter alia, the improvements of energy efficiency of the old building stock and promotion of the usage of renewable energy. The aims of the National Energy and Climate Strategy, that concretely affect the urban environment, are to halve the mineral-based imported oil that is used as energy, from 2005 level by the year 2030, stop the usage of coal as energy by 2030, and endeavour to raise the proportion of wood-based energy. In transport, the main objective is the consolidation between transport and land use. The aim is to raise the amount of journeys made by walking or cycling to 30 % by the year 2030. Another aim is that there will be 250000 electric cars and 50000 gas-fuelled cars by 2030. Achieving these aims require the improvement of energy efficiency and a change in the division of energy forms in construction and transport. (Lehtovuori, Vanhatalo, Rantanen & Viri 2017, 38-39; Ministry of Economic Affairs and Employment of Finland 2013.)

6 ENVIRONMENTAL SUSTAINABILITY IN URBAN PLANNING

6.1 Impacts of climate change on construction

In Finland, climate change is raising the temperature of air and fresh waters. Because of the rise in temperature, it rains more often than it snows, and the period of snow cover is shortened. The intensity of the rains is growing and the amount of rainstorms is increasing. The solidity of soil is decreasing and the bearing capacity is becoming lower as the water content of the soil increases. The erosion risk grows along with incremental rains, and the flood risk grows in many inhabited areas because of incremental rainstorms. The cooling need of buildings is estimated to increase. The humidity load of the exterior surface of a building is growing and the corrosion risk is increasing. The facades and covers of buildings are loaded because of the slanting rains, and the freeze and melt cycle is becoming more frequent. The need for maintenance and caretaking is emphasising. On the other hand, the structures of buildings may remain drier because of the warmer climate and damage that winter causes may decrease. The operability of the electric power distribution system is threatened by extreme phenomena that climate change is causing. From the point of view of transport, the mode of transport affects the significance of the impacts of climate change. Circumstances for cycling and walking are estimated to improve on average, but occasionally circumstances may be challenging because of windiness, heavy rains or slipperiness. Extreme phenomena of weather increase the damage risk of the infrastructure and the vulnerability to disturbance of transport. (Lylykangas, Lahti & Vainio 2013, 23-24.)

Measures for the mitigation of climate change from the point of view of the built environment are the land use, new construction and repair construction, the maintenance of buildings and the utilisation of renewable energy. The mitigation of climate change modifies the operational environment of construction and land use, for example, from the point of view of the energy regulation, energy production and transport. Instead of zoning new areas, the infill construction is emphasised. The infrastructure changes slowly and the decisions that are made in land use and construction have an effect far into the future. In land use and construction, the most significant impacts that need adaptation are related to the changes in flood hazard areas, an increase of rainfalls, an increase of extreme weather phenomena and features of soil. The increase of rains, winds and temperature changes are straining the weatherboards and the exterior envelopes of buildings. Probably all the climate scenarios are forecasting on increase of floods and rainstorms, though the estimation of the magnitude of those is uncertain. Estimations become more exact as time passes, so it is important to find sustainable solutions that enable resiliency. The climate circumstances vary regionally, which requires flexibility of the environment. (Suomen ympäristö 2014, 124.)

6.2 Mitigation of climate change with urban planning

6.2.1 Planning levels

From the point of view of the mitigation of climate change, the aim of areal planning is to create a framework for low-emission life. Planning solutions that strive for the reduction of climate emissions should be executed in all zoning levels whereupon the effectivity of actions is as great as possible. Various emphasis could be used in many fields when striving towards the reduction of emissions. Finland's National Land Use Guidelines is a starting point to the zoning that executes the climate objectives. When the strategic aim is executed in all zoning levels, any zoning level does not necessarily need the ultimate measures of the reduction of emissions, that could complicate the execution of other aims of the plan or increase the costs of construction unduly. The upper zoning level creates a basis for preferences of the next zoning level. Detailed planning guides mainly construction planning. In the end, the user of the building affects significantly the level of CO_2 emissions. From the point of view of the mitigation of climate change, the role of detailed planning is supportive and enabling for the other means. (Lylykangas, Lahti & Vainio 2013, 16-18.) Figure 8 represents how to achieve the best level in the reduction of CO_2 emissions.

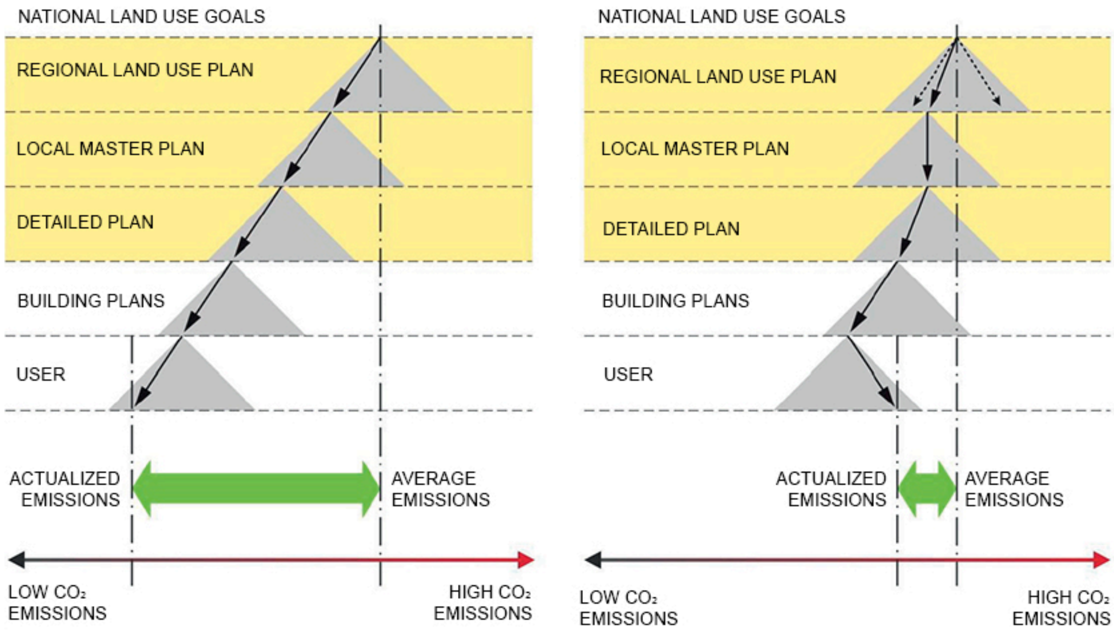

FIGURE 8. The best effectivity (on the left) will be achieved when the strategic aim is executed at all planning levels. (Lylykangas et al. 2013, 17; translation by the author)

The nature of a detailed plan should be a plan of future building, that is understanding of the regional characteristics and coordinating for various aims of land use. A detailed plan should enable low-emission solutions and sustain other means that execute climate targets. Means for the execution and focuses of climate targets can vary regionally. The desirable effectiveness could be achieved when the regional strategy for the emission reduction is fulfilled coherently in land policy, in all levels of planning and in civil engineering. The mitigation to climate change, with the means of detailed planning, requires untraditional practices and disambiguation of means of detailed planning, especially regarding the written plan regulation. From the point of view of opportunities to have an effect on detailed planning, relevant examinations are related to private transport, building materials, emissions from the energy use of buildings and the transformation of land use. (Lylykangas, Lahti & Vainio 2013, summary, 111.)

6.2.2 Climate aware urban planning

Climate aware urban planning means the mitigation and adaptation of climate change. The measures for the mitigation and adaptation of climate change can be, for example, the recognition of the local basis and a change of stress circumstances in planning, the definition of flood risk areas, the investigation of floodwater routes and an adequate dimension of stormwater drain. The possible growth of windiness can be taken into account with the placing of buildings, with the shape of buildings and with the orientation of buildings. The transport network can be protected from extreme circumstances by replacing aerial wires with ground cables, by sheltering from the erosion and by preventing slipperiness. Because of climate change, particularly in zoning should be prepared to floods, the increase of windiness, pouring rains and storms, the increase of precipitation and transitions of the humidity of soil and circumstances of groundwater. The preparation for changes needs to be done. Flood risk areas need to be examined and limited outside of construction. The limitation of construction in risk areas by defining the minimum building level for buildings and streets based on the water level is needed. Temporary and permanent flood protection structures in risk areas are needed. In flood risk areas, the green protection and vegetation should be noticed. Special attention need to be paid to the microclimate, terrain and soil. Windiness can be minimised with the placement of buildings. Placing buildings and networks on unfavourable soil should be avoided. (Lylykangas, Lahti & Vainio 2013, 24-25.)

Climate aware urban planning can utilise climate circumstances when placing the buildings with regard to the terrain shapes, growing stock, sunlight and prevalent wind direction. The key factor is the location of a building site. City quarters should be planned so that they receive cover from the cold air currents and excess insolation. The usage of solar energy and the ventilation of buildings with wind solutions should be advanced. Green zones protect buildings from winds, overheating and horizontal humidity. The canals, ponds and green corridors store water helping to control the floods by slowing down the surface water. Also, coatings that penetrate water, should be preferred. The increase of the average sea level height and flooding have an impact on the planning of shore areas, the arrangement of spaces that require shelter zones or other structures and the erection of equipment systems that might be needed in a case of an emergency. (Lappalainen 2010, 103-104; Lahti, Nieminen & Virtanen 2008, 40-41.) Figure 9 represents the manners to execute climate aware urban planning.

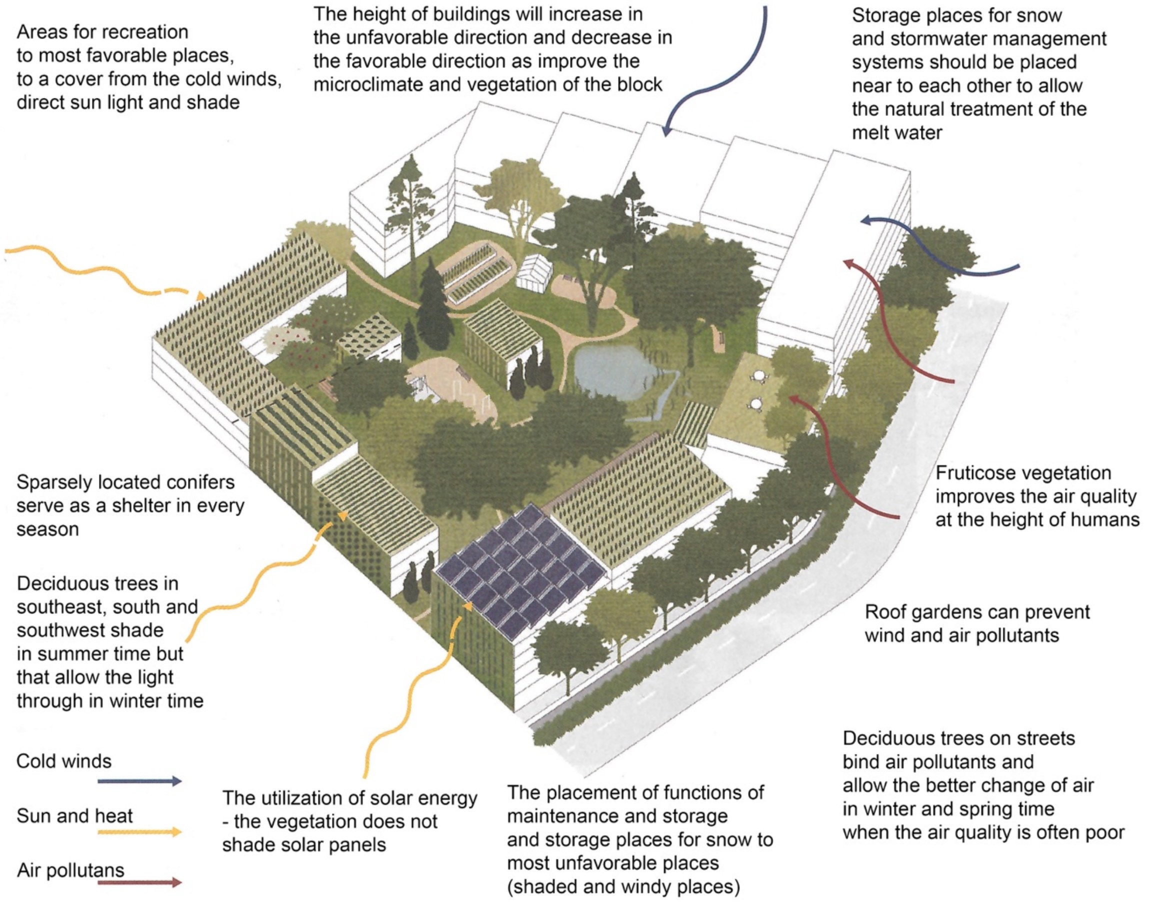

FIGURE 9. Climate aware urban planning observe climate circumstances in the planning area and changes of the microclimate that building will cause. (Sinkkilä et al. 2019, 62; translation by the author)

The specification of the construction material in a detailed plan risks limiting free competition of the producer of materials. To avoid problems in the competition, the written plan regulation is not appropriate to be written so that it fixes the planning solution later in construction planning, such as to use wood as the main construction material, the connection of buildings to the district heating network or to use a passive house as a type of building. The written plan regulation could require the usage of low-carbon construction materials or the usage of a low-carbon heating form or set a requirement for the specific energy consumption of the building. The requirement can be clarified in a plan report or in the building instructions by examples and numerical values. Numerical values should be based on the emission computation of the detailed plan. This kind of requirement would permit various alternative planning solutions and would create an incentive to the construction industry to develop new, low-carbon solutions. (Lylykangas, Lahti & Vainio 2013, 21-22.)

Even though materials, energy efficiency or a heating form of a separate building would not be determined in a detailed plan, it is still possible to make essential and irreversible planning solutions that have a straight impact on total emissions. The placing of residential buildings close to workplaces and services decisively affects the CO_2 emissions of transport. The building type and housing density have an impact on the need of heating energy, and thus on the emissions of energy consumptions of buildings. Building streets on soil that needs stabilisation leads to high CO_2 emissions of the construction of infrastructure. The execution of the minimum requirement of the building regulations after the year 2020, is the production of renewable energy in the sites or regionally. Requirements for the profitable implementation of the production of renewable energy is created in a local master plan and in a detailed plan. (Lylykangas, Lahti & Vainio 2013, 22.)

With urban planning it is possible to affect energy consumption in every sector in the community. Urban planning has an impact on the community's energy consumption in the three main fields: in construction, in the usage of buildings and in transport. The dispersed urban structure results in high energy consumption per inhabitant. The energy management system should be adjusted to the urban structure and hence strive towards an overall positive economic result. (Lappalainen 2010, 103.)

6.2.3 Significance of urban planning to sustainable transport

The automatism between land use and transport has been long the same. The increase of the capacity of routes and improvements of the fluent transport head to the accretion and congestion of traffic again. Transport strives to take over all the space that has organised for it. The increase of incomes and property of people in a respect of fares and costs of cars, and the hedonism related to traveling, lead to the increase of the usage of automobiles. To manage the mobility more eco-efficient way, the prioritised action is needed. The first thing is to control the necessity of transport (for example land use planning, logistics, telecommuting). The second thing is to affect the travel habits (park-and-ride, carpool etc.). The third thing is enhance the usage of transport infrastructure (for example the mobile tickets, telematics etc.). (Lahti, Nieminen & Virtanen 2008, 62-63.)

Sustainable transport means the capacity to advance the mobility needs of people, freight and information in a manner that is the most environmental friendly. Sustainable transport is linked with the development of sustainable transport modes, infrastructures and logistics. A strategy for sustainable transport is the reduction of the environmental impacts of transport. Land use has an impact on transport, particularly the impacts of the construction and maintenance of the infrastructure. Transport has an impact on economic growth and development. A sustainable strategy strives towards the usage of transport for the object of growth and for the creation of jobs. Transport has to be cost-efficient and able to adapt to changing demands. Sustainable transport is safe, does not have an effect on human health, minimise the disturbance on communities and benefit society. Figure 10 represents sustainable development applied to transport systems. The sustainable transport system advance the links between the environmental protection, economic efficiency and social improvement. (Rodrigue, Comtois & Slack 2013, 272-273.)

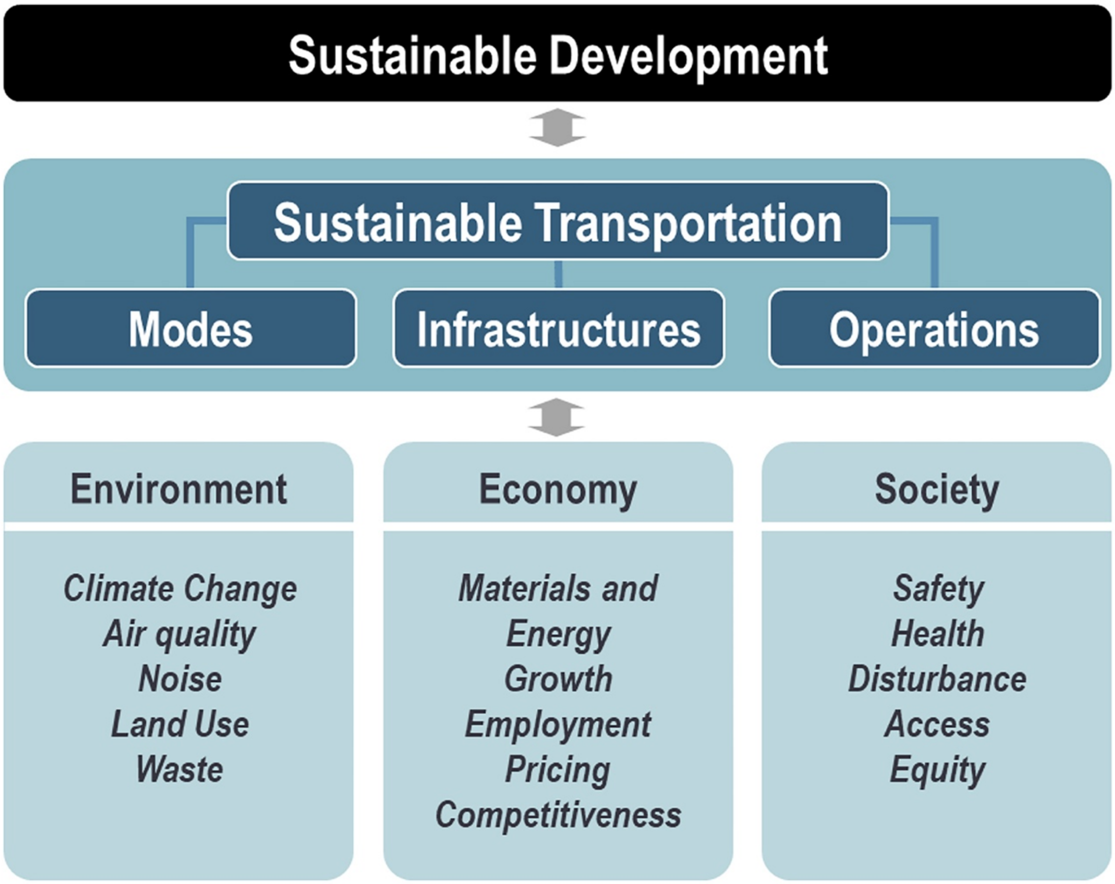

FIGURE 10. Sustainable transport is linked with the development of sustainable transport modes, infrastructures and logistics. (Rodrique 2013, 272.)

Urban planning is a mean to affect the tendency of urban development and how sustainable it is. Urban planning can change the travel behaviour with the interaction of urban structure (compactness, mixed functions) and with supplemental measures (for instance, by preferring public and non-motorised transport). (Große 2017, 19.) As the population is concentrated in urban centres, current transport systems have to adapt to the changes of the urban structure, including the growing and socioeconomically diverse population, and at the same time seeking to minimise the environmental pollution and urban congestion. Sustainable transport approaches, such as the public transit and comprehensive bicycle and pedestrian networks, to become a critical part of a city growth strategy and its ability to effectively meet the needs of its residents. (National League of Cities 2013.) The challenge in urban areas is to expand and improve the transport supply in order that there are alternatives to automobile and trucking. For the passengers, this can be fulfilled by expanding the public transit infrastructure, by improving the existing public transit services and by making the cities friendly to pedestrians and non-motorised vehicles. (Rodrigue, Comtois & Slack 2013, 273.)

When developing sustainable transport, the most significant activity is to control automobile transport. The most important way to decrease private motoring is increase the amount of alternative transport modes, such as public transport and non-motorised transport. The land use is a key position when improving those. The alternative transport modes should be competitive compared to automobile transport. It could be achieved by improving the service level and the selection of transport modes. The mobility habits can be changed by the mobility management. There are various means to control the carbon dioxide emissions. The urban form can be compressed. The use of public transport can be advanced, for example by preferring the investments of rail transport. The part of renewable energy sources should be increased. The new vehicle technology can be utilised. The pricing of transport and the attitudes have an effect on used transport modes. The increase of the amount of walking and cycling supports directly the reduction of environmental hazards. The increase of public transport as a transport mode cuts the amount of private motoring and supports the reduction of environmental hazards as well. In the cities, where there is an advanced network of public transport, there is remarkably less congestions and emissions, and the mobility of all social classes is better. All modes of public transport in regions consume less energy and cause less emissions than automobiles. (Touru 2011, 35-38.)

6.3 Urban planning as an instrument

6.3.1 Significance of urban planning for possibilities to influence on sustainability

A general feature in all planning options is, that the earlier the selections and conclusions are made, the greater are the opportunities to have an effect. This requires that the decisions are compulsory. When the planning proceeds, the opportunities to influence usually decreases. General planning defines roughly the location, usage and effectivity of new areas, as well when planning the transition areas. The traditional financial feature of the land use planning is, that probably over a half of the upcoming expenses is formed before the general planning is completed. That is also valid for other impacts, such as the demand of materials, the energy consumption and emissions. The main conclusion is the location, because that defines how new construction can utilise the existing infrastructure, the soil of a building site and distances to other functions. (Lahti, Nieminen & Virtanen 2008, 35-36.) The possibilities to influence CO_2 emissions with planning are represented in figure 11 below.

Zoning and urban planning have a great potential in sustainable construction because they affect the availability of transport, energy supply, water supply and waste management of complete residential areas. To support sustainable construction, there should be an interaction with the potential clients already in the zoning period. This requires the research work of what kind of sustainable construction solutions the clients appreciate. The aims of sustainable construction should be included in the construction scheme as early point as possible. The aims should be set so that they support the features of the construction site, aims of the project and the intended usage of the building. The recognition of the features of the construction site is essential, because the construction site can limit or even prevent the inclusion of some sustainable elements. (Häkkinen 2011,19-20.)

	LOCAL MASTER PLAN	DETAILED PLAN	BUILDING PLANS PLANS OF INFRASTRUCTURE
CARBON FOOTPRINT OF INFRASTRUCTURE		amounts	strutures and materials
streets, roads, pedestrian- bicycle ways		amounts	strutures and materials
squares and open areas		amounts	strutures and materials
the network of water and sewerage		amounts	strutures and materials
district heating network		amounts	strutures and materials
carbon footprint of street lightning			
TRANSPORT			
ratio of construction and services		mostly in the local master plan	
the network of pedestrian- and bicycle ways			
the connections of public transport	the local master plan and the detailed plan create the conditions		
the energy consumption of lightning		the amount of lightened streets	the type of lighting
CARBON FOOTPRINT OF THE BUILDINGS			
the materials of the frameworks of buildings			
the materials of the weatherboards of buildings			
the foundation type of the buildings	circumstances of the foundation	the location	strutures and materials
other materials of the buildings		controversial	
THE ENERGY CONSUMPTION OF THE BUILIDNGS			
the consumption of the delivered energy		building regulations	
connecting the building to district heating network	the local master plan create the conditions		
other heating forms			
the consumption electrical energy			
the energy consumption of yards and utility buildings		minor control is possible	
the production of the renewable energy in the building		the detailed plan creates the conditions	
the production of the renewable energy in the planning area		the detailed plan creates the conditions	
OTHER IMPACTS ON CO2 EMISSIONS			
the transformation of the land use			

FIGURE 11. The possibilities to influence on CO2 emissions with planning. The dark green colour indicates great possibilities to influence. The light green colour indicates that the planning level in question, can influence on the emissions to

some extent or create conditions for the execution of the low-emission solution. (Lylykangas et al. 2013, 15; translation by the author.)

6.3.2 Detailed planning and building regulations

The low-carbon built-up environment is an acknowledged aim of land use planning. The majority of new buildings and complementary construction are executed guided by a detailed plan or a local master plan. The emission control, that is occurred by zoning, differs decisively from the control that is occurred by building regulations. Building regulations are targeted towards new construction and it sets the minimum requirements for buildings. Zoning should create the opportunities for a low-carbon life throughout all the others decisions that concern the physical environment. The examination of emissions in detailed planning is focused an entire area instead of a single building, and includes the examination from various points of view than just the energy consumption of the building. To control energy efficiency in building regulations is emphasis is put on the technical features of a building, and for example the geographical position does not affect the requirements. In zoning, it is possible to take into account the areal characteristics, such as a geographical position, urban structure, demographic development, regeneration of the building stock; various strategies of the cities and municipalities and the emphases in the reduction of emissions; and the emissions of district heating that is produced in various ways. (Lylykangas, Lahti & Vainio 2013, 14.)

In detailed planning, the goal is not to prevent disadvantageous solutions in the building. Instead of that, the goal is to illustrate possible implementations that guide towards a more low-carbon built-up environment and creates the conditions for subsequent actions that strive towards the reduction of emissions in the future, such as additional and complementary construction or the production of decentralised renewable energy. The implementation of the area does not necessarily follow all the visions of a detailed plan or the visions will be fulfilled only partly. On the other hand, a detailed plan needs to enable the executions of other means, such as the building regulation that controls energy efficiency. Detailed planning has an important role as an enabler of the production of renewable energy in the sites or in the vicinity of buildings. (Lylykangas, Lahti & Vainio 2013, 15.)

6.3.3 Building instructions

Building instructions are a statement by the authority, that define an advisable building manner at the certain area, that have local characteristics. Building instructions are composed either at the same time as the building regulations or at the same time as zoning. Building instructions can be binding if they are attached to the terms of the site alienation conditions. Building instructions can be accepted as a part of a detailed plan, in which case the instructions are binding. In that case, the instructions are registered to the written plan regulation of the detailed plan. The municipality is able to give instructions for areas which do not have any plans as well as for areas which have a detailed plan. A level of binding of building instructions is set in the documents. (Suomen Kuntaliitto 2013, 12, 21.)

Detailed planning regulations, that limit the decisions of a building design, have been criticised to be too restrictive, for example in a case of the heating form or the main construction material. The detailed planning regulation can be set as a functional regulation. This kind of functional detailed planning regulation means setting a functional target level without the individualisation of a planning solution. In the building instructions it can be described in more detail, how to execute the regulation and alternative solutions for the execution. For example, a detailed plan regulation can define that the load-bearing frames and the envelope of a building should be executed with low-carbon construction materials. In addition, it should be defined there what the low-carbon construction material means. The requirement expresses the maximum permissible value of a carbon footprint of the production of a material per each square metre of a building element. Building instructions can describe the low-carbon structure types that fulfil the requirements and explain the acceptable values, as well giving instructions to pass the building permit procedure. In the building instructions could also be set an operational requirement for the CO_2 emissions without a specification of a planning solution. (Lylykangas, Lahti & Vainio 2013, 107.)

6.3.4 Indicators of sustainable construction according to ISO 21929

The content of sustainable construction is defined in the international standards by ISO (International Organization for Standardization). The aim of the standardisation work is the common terminology, parse and procedure for the evaluation of sustainable construction. Along with the standardisation work, the concept of sustainable construction develops from the abstract and nonspecific to the exact framework that includes various viewpoints. The fulfilment of viewpoints is evaluated with measurable or qualitative indicators. (Lylykangas 2013, 1, 3.)

In the ISO 21929 standard, the areas of the protection of sustainable development which it is possible to affect with construction, are identified. Those areas are the form of natural environment, economic and cultural values of the built environment, healthiness and satisfaction of people and equal opportunities to use the built environment. Based on these, the standard defines the fourteen crucial aspects of sustainable construction that are related to the areas of protection. In addition, the standard describes the core indicators, with which it is possible to estimate or measure the fulfilment of different components in a building. The evaluation, based on the ISO standard, leads to a comprehensive examination where various viewpoints of sustainability are taken into account. The priority of the viewpoints varies in different situations. According the ISO standards, the environmental impacts should be estimated based on the life cycle estimation method. (Lylykangas 2013, 3; Vares, Häkkinen & Shemeikka 2011; 13-15.)

According to ISO 21929, the crucial aspects and core indicators of sustainable construction are:

Emissions to air. The estimation of emissions that cause environmental impacts and affect climate change and ozone depletion. Core areas of the protection are ecosystem, health and well-being, social equity (global warming) and economic prosperity.

Use of non-renewable resources. The estimation of the amount of consumption of non-renewable resources of material and energy categorised by sorts. Core areas of the protection are ecosystem, natural resources and economic prosperity.

Fresh water consumption. The estimation of the usage of fresh water that has an effect on the resources of fresh water and its depletion. Core areas of the protection are ecosystem, natural resources, social equity and economic prosperity.

Waste generation. The estimation of the amount of waste sorted for waste components, that arise during construction and demolition and that is not reutilised or recycled. The waste affects the formation of greenhouse gases, the usage of resources directly and indirectly, and harmful emissions that originate from the produce and the delivery of the material that get wasted. Core areas of the protection are ecosystem, natural resources and health and well-being.

Change of land use. The estimation of changes in land use caused by the development of the built environment. Also, the exploitation of the existing infrastructure and networks is measured. The impacts of sustainable development of land use are the spent resources (land), the impact of land use and fragmentation to the diversity, and the impact of water impervious surfaces on flooding. Core areas of the protection are ecosystem, natural resources and cultural heritage.

Access to services. The estimation of the access to services by type. The types are public transport, individual transport modes, basic public services and green and open areas. A short walking distance (for example, 15 minutes or 300-500 metres) indicates an easy access. In terms of public transport, the amount of connections and the service intervals indicate accessibility. In terms of individual transport modes, the parking facilities and for example, the scope and quality of pedestrian and bicycle networks, indicates accessibility. Regarding basic public services, relevant services should be examined from the point of view of users of a building. Green and open areas, such as nature areas, parks, gardens and areas that are intended for walking, cycling or exercising, are the areas that are open to everyone. The access to services affects the mobility necessities of users and based on that, environmental impacts of the usage of premises. The access to services affects also equal possibilities of users of premises to move and achieve needed services, and opportunities to enjoy and spend a healthy life by exploiting green and open spaces freely. Core areas of the protection are ecosystem, health and well-being, social equity and economic capital.

Accessibility. The estimation of possibilities of all the relevant groups of users for accessibility in the site and in the building. The significance of accessibility is related to users equal possibilities to use the built environment. The core area of the protection is social equity.

Indoor conditions and air quality. The estimation of air quality and sub-aspects of indoor conditions. All components affect the contentment of users and the productivity of employees. The air quality has direct health impacts as well. Core areas of the protection are health and well-being and economic prosperity.

Adaptability. The estimation of flexibility, convertibility and adaptability to climate change. Adaptability means a possibility to make changes to the purposed use of a building. Adaptability is measured from the basis of spatial planning, openings, capacity and building services engineering. The adaptability of a building affect its economic value. Successfully adaptable solutions can be resource efficient. Core areas of the protection are natural resources, health and well-being and economic capital.

Costs. The estimation of the life cycle cost and the value of a building. The significance as a component of sustainable construction is related to the economic value of a building. The reasonable price of a building has a social effect as well. Core areas of the protection are economic prosperity and economic capital.

Maintainability. To estimate the maintainability against the results of service life assessment. The maintainability means the possibility to maintain a building in such shape that it will fulfil it required function, and a possibility to repair a building if it loses its operability after being damaged. The maintainability affects the contentment of users, economic value of a building, the productivity of employees and indirectly the usage of natural resources. Core areas of the protection are natural resources, cultural heritage and economic capital.

Safety. To estimate sub-aspects of safety against the results of simulations or fulfilment of the safety related to building regulations. Sub-aspects are the stability of structures, the tolerance of exceptional but relevant weather conditions, fire safety and safe usage. All components can grievously affect healthiness of users if there are shortages in the issues mentioned. These shortages have an effect on the economic value of the building as well. Core areas of the protection are health and well-being and economic capital.

Serviceability. The estimation of serviceability with the help of a list of criteria or with the help of a post-occupancy evaluation. The purpose is to measure the feasibility of a building proposed use. The operability of a building affects contentment and productivity of the employees. The core area of the protection is economic prosperity.

Aesthetic quality. The estimation of the aesthetic quality against the fulfilment of local requirements or with the help of a stakeholder judgement. The aesthetic quality measures the involvement and harmony related to the built environment, the effect of a new building related to old buildings nearby and the preservation of cultural values of the built environment and cultural heritage, and the aesthetic quality related to the needs of stakeholders. The significance of aesthetic quality is based on the effect that aesthetic quality affects the contentment of people, the equal opportunities to live and move in the environment that satisfies aesthetic needs and the effect of the aesthetic quality to the cultural and economic value. The core area of the protection is cultural heritage. (Lylykangas 2013, 4; Vares, Häkkinen & Shemeikka 2011; 16-24.)

6.3.5 Impacts of the user behaviour in sustainability of the building

The effectivity of the buildings' operation mostly depends on the habits and behaviours of its residents. It is not automatic that a building will act effectively and environmental friendly, even though it would have been planned according to sustainable principles. The environmental benefit that is incorporated in a building, does not necessarily become actualised, if the manner in which residents use the building differs from that planned. The requirement for the efficient and ecological operation of a building is that users of the building understand how their action affects the capacity of the building. The guidance, related to a building commissioning and instructions of the building, is essential from the viewpoint of sustainable operation of the building. The buildings should be planned and executed in a manner that takes into account the needs and preferences of users.

That requires a stronger interaction between planners and users than at present. (Häkkinen 2011, 21)

6.4 Means to increase eco-efficiency in urban areas

General planning of urban areas impacts where the future construction will be placed in the urban area, what kind of functions there will be, how efficiently the area will be built, what kind of public transport system there will be and how the residents will be able to utilise it, what kind of prerequisites for the operation of transport and energy infrastructure there will be, and what kind of network of non-motorised transport there will be. General planning also affects where the focuses of new construction will be, the order of construction and how much complementary building there will be. (Lahti, Nieminen & Virtanen 2008, 5.)

Lahti, Nieminen and Virtanen (2008, 5) had examined in their research how to estimate and increase eco-efficiency in Helsinki. In the research, eco-efficiency of the urban structure is defined to be the quality of life that is produced by the urban environment (the physical structure of the city), in respect of the used materials and (non-renewable) energy resources that were needed for the execution, and the emissions and waste that were caused. Eco-efficiency can be regarded as a measure of ecological development. The increase of eco-efficiency lead the development to the direction that is desirable from the environmental sustainability point of view. (Lahti, Nieminen & Virtanen 2008, 5, 11.)

According to Lahti, Nieminen and Virtanen (2008, 83-85), there are eight rules of thumb to the increase of eco-efficiency in urban areas. The increase of eco-efficiency increases environmental sustainability, so these rules are good guidelines for planning a new residential area.

Do not waste land. The area density should be at least e_e=0,3 (the area density rate indicates the ratio of built-up or planned building volume relatively to the square area of land). With less than 0,3 density expenses of the basic structure of the area will increase steeply. With the 0,3 density, it is still possible to build low and compact urban structure. Between construction areas and peripherals of construction areas, useless waste land should not be left.

Compress and complete existing urban structure. The opportunities to increase the permitted building volume and the utilisation of the existing infrastructure should be surveyed. The addition of the granted building permit, the temporary reduction of the real estate tax or the scaling of the real estate tax along the done action could be inducements for the complementary construction.

Utilise the corridors for rail traffic effectively. Potential corridors and spots for the stations should be surveyed. Enhance the utilisation rate of vicinities of corridors and stations for at least a walking distance of 200 meters. If the district is favourable for cycling, the enhancing area can be 800-1000 meters. The aim is the reduction of automobile dependency and the augmentation of profitable public transport and non-motorised transport so that the part of those will be over 50 % of the total amount of journeys.

Mix residence and working. Workplaces should be placed among residences. Bare residential areas or bare workplace areas should not be built outside of the city centres. The residences and business premises should be built simultaneously in the same area and to the same buildings as well, excluding the heavy construction or the disruptive construction of production and trade. The mixed structure enables working near the habitation and levels the flows of commute.

Limit building of large shopping centres far from residences. Shopping centres cause traffic and energy consumption, and emissions they are caused are directly proportional to the distance from the focus of customers. The low price of the land compensates the excessive cost of traffic only in the distance of few hundred metres. The price of the land does not directly affect eco-efficiency, as supposed the consumption of non-renewable energy and emissions caused by traffic.

Execute public transportation systems before other construction. The new area should be executed so that the public transport system would be completed before the residents move in. Otherwise the residents will assume an automobile dependent behavioural pattern. It is hard to change a habit later.

Do not terminate the realisation of plans that are incomplete. In the middle of the area, there should not be left uncompleted blocks. The area should be fulfilled consistently from the middle to the sides. Otherwise, the uncompleted areas may remain unfinished for a long time, the basic structure of the area will become unnecessarily expensive and ineffective, and the services may not be executed.

Select an energy system on a local basis. The selection of an energy system depends on the size and the energy need of the area, the availability of local fuels, and the prices (including biofuels) and the supply of district heating. When building low-energy houses or passive houses, the regional need of heat is low, and in the best case external energy is not needed. Urban planning that is based on passive houses or on zero-energy houses, requires compact house types. The utilisation of passive solar light requires the appropriate orientation of buildings and openings of a facade in respect to the surrounding terrain, growing stock and prevalent wind directions. The structure of the street network, the types of blocks and buildings and the reciprocal layout of buildings help to prevent cold winds and utilise wind energy. Systems that utilise low exergy (like district heating that arises as a by-product of electricity production and heat that is produced with ground-, air- or water heat pumps) should be used before other systems. In that case, the scope and profitability of centralised systems depends on the adequate effectivity of the area. The systems that utilise decentralised energy production and renewable energy sources, such as solar collectors, solar panels and windmills, can be used beside centralised system to produce hot water and electricity for the area, blocks or houses.

7 PRACTICES TO INCREASE ENVIRONMENTAL SUSTAINABILITY OF A NEW RESIDENTIAL AREA WITH BUILDING INSTRUCTIONS

7.1 Transport network

7.1.1 Ways to influence the traffic performance

There are various areal planning solutions that decrease the necessity of automobile transport and automobile dependence. The most effective way to affect the traffic performance and the energy consumption and greenhouse gas emissions of transport is decrease the amount of journeys by motorised transport. The decrease of average distance of journeys is possible by placing the activities closer to each other, which leads to an increase in areal effectiveness, housing density and mixed functions. In the areas where there are enough residents and workplaces, the public transport supply can be increased so that the amount of the energy consumption and emissions decrease. The amount of cycling and walking can be increased by improving the quality and safety of non-motorised ways. The increase of energy efficiency of motorised transport and technology will decrease the emissions of a passenger-kilometre. (Lylykangas, Lahti & Vainio 2013, 75.)

From the point of view of the promotion of low-carbon society, ways of influencing transport are changes in energy forms, the improvement of energy efficiency and to affect the amount and length of journeys and travel habits. By improving urban structure it is possible to influence the energy consumption of transport and the supply and attractiveness of the different transport modes. From the viewpoint of the comprehensive promotion of the low-carbon society, it is important that various actions support each other. For example, from the point of view of transport, it means that at the same time there is a need for solutions in the urban structure that encourage walking and cycling, an adequate supply of public transport, the taxation and pricing that favour the desired choices, and furthermore, a culture and attitude of the users that supports the desired activity. (Lehtovuori, Vanhatalo, Rantanen & Viri 2017, 46.)

7.1.2 Public transport

Public transport is an ecological solution when there are enough passengers. The significance of public transport to the functionality of transport systems increase continuously when the urban regions and population grow. Especially in the large urban regions, the benefits of public transport systems are extensive. The usage of the public transport system decreases the necessity to build new roads, streets and parking lots. The requirements for the usage of public transport are the fluency of connections and the sufficient capacity also at rush hour. The public transport network should be connected to pedestrian roads and cycling roads so that those create a flexible network of local transport. In the areas where there is a railway track, the train is usually chosen because of the travel comfort and speed. An adequate train supply, the access distances, connections and station facilities are the requirements for its usage. The railroad track requires an adequate area density and density of housing, workplaces and services. The usage of public transport is crucially dependent on the supply of public transport. The more and denser there are inhabitants, the more profitable public transport is. Also the public funding for a private operator of transport has an influence on its profitability. (af Hällström 2016, 15; Lylykangas, Lahti & Vainio 2013, 77-78; Touru 2011, 37-38.)

Alternative solutions to increase the use of public transport and to improve the mobility and accessibility of residents can be developed by using technology and innovations. Intelligent transport system technologies improve the travel efficiency and effectiveness through increased safety and decreased congestions. Some examples of technologies that are meant to enhance the user experience of multi-modal systems, are real-time bus and train information, variable speed limits based on the congestion and the data integration of multiple transport systems between the administrative territory. (National League of Cities 2013.)

7.1.3 Walking and cycling

Walking, cycling and other movement by using muscle power, are particularly sustainable transport. Walking and cycling need less space than other modes of transport and do not cause emissions. Walking is an attractive travel mode when the distance is short enough, the planning rule for it is approximately 400 meters. The walking environment should be agreeable and safe. In the urban environment, walking is also a way to spend time, that requires interesting targets in a landscape or a cityscape and the commercial services. Along with walking, cycling is the most ecological transport mode. Cycling does not use non-renewable energy, does not pollute, needs only a little space and is silent. Over short distances, cycling is competitive with automobile transport. In order for cycling to be an attractive transport mode, the activities should be situated close to each other, and there should be safe cycling roads. Separate cycle paths and parking places for the bicycles encourage cycling. The width of the lane, the cross-sectional geography, coatings, markings of the carriageways, traffic lights and signs, the maintenance et cetera, are features that affect the attractiveness of cycling. Having locked or otherwise safe parking places for bicycles, and also a possibility to take a shower and change the clothes, matters as well. As a planning rule, 800 metres is a distance for the services reached by bicycles. If there are neighbourhood services, such as a grocery store in a block or at a maximum distance of 400 metres, it is more likely that the journey will be fulfilled by walking or cycling. (Lylykangas, Lahti & Vainio 2013, 76-78; Touru 2011, 40.)

7.1.4 Car parking

Car parking can be placed in sites, in blocks, on streets or centralised in ground level car parks, in parking decks or in parking garages. All solutions have impacts on the mobility. Also, all car parking solutions have impacts on energy and emissions of the execution and on the usage of needed structures. Centralised parking solutions increase the walking distance from the home or workplace to the parking place. If the distance is shorter to a public transport stop than to a parking place, the resident might choose a bus, tram or the underground instead of a car. (Lylykangas, Lahti & Vainio 2013, 77-78.)

7.2 Green structure

7.2.1 Significance of green areas

The pressure for effective land use and compact urban structure causes its own challenges of the recognition of green areas and nature. Often, green areas are considered as a reserve area for building and due to this attitude, green areas are commonly used for construction. It would be easier to plan and build the compact urban structure from the scratch, than to compress the existing urban structure and decrease the present recreation areas. Economic values are often a definitiving author in planning. Streets and other infrastructures are often seen as more valuable parts of the infrastructure, and green areas are parts what are left after building. More value to ecosystem services would be brought by a case, where it would be possible to numerate the economic values of nature areas as well, for example savings if there are used other methods used to handle the urban runoff instead of together with sewerage. There are a lot of distinct targets in land use which must be considered in planning. Traditionally, best places are used for building, and if it is intended to leave certain areas untouched or unbuilt, that causes conflicts and differing goals. The major goal of planning is to create a desirable habitat for the residents. If wanted to save nature at the same time, it often causes conflicts and differing aims. The challenge is to design green areas so that those serve the recreational purposes and advance the biodiversity simultaneously. (Hirvensalo 2015, 26-27.)

Impacts of climate change need to be taken into account in urban development and city planning. The amount of green areas decreases due to urban development. In the adaptation of climate change, green areas have a crucial role. Green areas reduce the risk of flooding, serve as a carbon sink, reduce air pollution and mitigate the urban heat island effect of the built environment. When the urban structure becomes denser, the significance of green surfaces is emphasised. (iWater 2019.)

7.2.2 Stormwater management

In the urbanising society, the management of urban runoff is an increasing challenge. Stormwater pollution, flooding and other effects cause threatening impacts on water quality, public health and local environments. Urban areas become denser and areas with coated surfaces increase. The development of cost-effective and integrated strategies is needed to manage the greater amount and flow velocity of stormwater. (iWater 2019.)

Some general principles should be prioritised when planning the stormwater management. The prevention of stormwater is the first principle. The second one is the reduction of the formation of stormwater by handling and utilising stormwater in the place it originates. The management of stormwater with a system that filtrates and decelerates it is the third principle. The fourth one is leading stormwater to deceleration and retention areas that are situated in public areas. The final principle is leading stormwater into wastewater or outside the area. Opportunities for the application of these principles depend on local circumstances, the quality and level of groundwater, the condition and usage of drainage basins and the topography of the area. (Inkiläinen, Tiihonen & Eitsi 2014, 7.)

There are various different techniques for sustainable stormwater management. Techniques can be combined together and realised structures of stormwater management can have features of different solutions. *Green roofs, green walls and pervious surfaces* are source management options. *A green roof* forms a multi-layered system, that covers the roof of a building with vegetation. Green roofs decrease the amount of runoff and mitigates peak flows by retaining water and through evaporation. Additionally, a green roof increases the accessory thermal insulation and reduces the heat reflected from rooftops. Heating and cooling costs of the building are reduced due to the green roof. *Green walls* include green facades where plants are growing onto and over structures designed for that purpose, and living walls, that are distinct wall panels with a growing medium or liquid nutrient. Green walls, as well green roofs, naturally absorb, filter and evaporate stormwater. Green walls can also reduce soundary reflection, air pollution and regulate the microclimate through shading. *Pervious pavements* enable the water to flow vertically through paved surfaces. Pervious pavements decrease the runoff by the retention and infiltration of stormwater. Pervious pavements can be used in areas where hard surfaces are required. (Lähde & Ariluoma 2019.) The green roof, green wall and pervious pavement are represented in pictures 1, 2 and 3.

PICTURES 1, 2 and 3. Examples of a green roof, green wall and pervious pavement. (Lähde & Ariluoma 2019.)

Conveying techniques for stormwater management are *the canals and rills, ditches and streams, and swales*. *The canals and rills* are water channels with open surfaces and hard edges. *Ditches* are dug, narrow channels at the side of a road or field, that hold or convey the water away. *Streams* are wider and more serpentine than the ditches. The stones, vegetation and shallows or other natural elements can be included to the stream for slowing down the stormwater flow. *Swales* are slightly sloped, planted channels for the treatment and conveyance of stormwater. (Lähde & Ariluoma 2019.) The rill, ditch and swale are represented in pictures 4, 5 and 6.

PICTURES 4, 5 and 6. Examples of a rill, ditch and swale. (Lähde & Ariluoma 2019.)

For the detention and infiltration of *stormwater tree trenches, rainwater cisterns, infiltration pits, rain gardens, filter strips, stormwater planters, infiltration basins, detention basins, ponds and wetlands* stormwater can be used. Underground infiltration structures connect stormwater to *tree trenches*. In this case an engineered system to manage the incoming runoff is located under the sidewalk. On the surface, stormwater tree trenches look like a series of street tree pits. *Stormwater planters* manage the runoff of streets and sidewalks by collecting and retaining stormwater runoff. The fabric of the planter is permeable, it is filled with the gravel or stones, and topped off with the soil, plants and perhaps trees. The runoff is infiltrated, biologically treated, and evaporated by trees and other vegetation within cells. *Rainwater cisterns* preserve rainwater from roofs and hard surfaces for a later use as a water supply. Cisterns can be located above or below the ground or sometimes within a building. Collected stormwater can be used, for instance, to flush toilets, thereby reducing the use of fresh water consumed. (Lähde & Ariluoma 2019.) The stormwater tree trench, stormwater planter and rainwater cistern are represented in pictures 7, 8 and 9.

PICTURES 7, 8 and 9. Examples of a stormwater tree trench, stormwater planter and rainwater cistern. (Lähde & Ariluoma 2019.)

An infiltration pit is a system for detention and infiltration of the sub-surface runoff. The infiltration pit collects stormwater in an underground storage space, that is composed of large rocks, geocellular system or other material, that infiltrate and restrain the stormwater. The infiltration pit is usually located close to the downspout from the roof. *The rain garden* collects the runoff from impervious surfaces and allows the water to infiltrate the ground. The garden is lower than the surrounding ground level and the bottom layer is filled with stones, which enables the collection and the pool of the runoff within it. In order for the stormwater to flow into the garden, the site needs to be graded appropriately. Rain gardens reduce the stormwater runoff volume and remove pollutants effectively. *Filter strips* infiltrate and decrease the velocity of stormwater and allow suspended solids to drop out of the stormwater runoff by utilising slightly sloping areas and vegetation. (Lähde & Ariluoma 2019.) The infiltration pit, rain garden and filter strip are represented in pictures 10, 11 and 12.



PICTURES 10, 11 and 12. Examples of an infiltration pit, rain garden and filter strip. (Lähde & Ariluoma 2019.)

Vegetated *detention basins* or *dry ponds* temporarily hold and pre-treat the first flush of stormwater before the regulating discharge to a receiving waterbody. Vegetated detention basins slowly release stormwater further on the management chain, but do not infiltrate it. *Infiltration basins* are very similar to detention basins. Infiltration basins store the runoff on the surface and infiltrate it slowly into the ground. Infiltration basins are dry except during periods of heavy rainfalls. *Wet ponds* are constructed basins designed to retain a permanent pool of stormwater with limited biological treatment. Constructed *wetlands* are shallow and vegetated depressions. Water stands permanently in wetlands and they offer a large amount of ecosystem services to manage and treat stormwater. Evapotranspiration, filtration, and biological and chemical stormwater treatment are enhanced by the high biodiversity of plants, animals, and micro-organisms of wetlands. (Lähde & Ariluoma 2019.) The detention basin, infiltration basin, pond and wetland are represented in pictures 13, 14, 15 and 16.




PICTURES 13, 14, 15 and 16. Examples of a detention basin, infiltration basin, pond and wetland. (Lähde & Ariluoma 2019.)

7.2.3 Green factor

Green factor is a systematic approach to calculate the amount and quality of vegetation as well the stormwater treatment in urban areas. The green factor tool ensures an adequate green infrastructure when building new areas in a dense urban environment. With the green factor tool, the ratio of the scored green area of the plot area is calculated. Aspects that are included in the green factor are ecological and functional viewpoints, the value of landscape and maintenance. Ecological aspects include the binding and cleaning of stormwater, the diversity of species and habitats and stability of the ecologic network. The value of landscape indicates the meaning of vegetation. The maintainability indicates the need of routine maintenance of the element after the foundation period. The green factor can be included in written plan regulations or used for granting concessions during a construction permit application process. With the green factor tool can be created green, agreeable and climate aware plots in a dense urban structure, that advance the adaptation of urban areas to climate change. (Inkiläinen, Tiihonen & Eitsi 2014, 11-13; Ilmastonkestävän kaupungin suunnitteluopas 2019; iWater 2019; Stadin ilmasto 2019.)

7.3 Energy efficiency of buildings

7.3.1 The location of the building

The heat consumption of a building depends on the geographical location as well the local situation. Local factors that affect the heat consumption, are the microclimatic temperature, wind speed and direction, and how much solar energy the building gets. In the disadvantageous situation, these factors can increase even 30 % heat consumption of the building. The building should be placed in the sunniest place in a plot. By utilising terrain shapes, growing stock, plantings or other buildings it is possible to shelter the building from cold winds. Cold outbuildings should be placed on the windy side and deciduous trees should be placed on the sunny side so that they shade the building in hot weather. (Lappalainen 2010, 26.)

Construction in valley dells should be avoided because it leads easily to so-called cold-water lakes in which the water accumulates. Buildings on hillsides should be placed so that cold airmasses could flow easily the downhill. Long building masses, that are located across the hillside, should be disconnected with gaps. The terrain shapes, growing stock, buildings and structures have an impact on the speed, vorticity and direction of wind. Woods that naturally form a shelter against cold winds, should be retained. Buildings should be placed so, that they do not create long and narrow wind gorges. In some cases, the disadvantages of winds could be reduced with embankments and suitable ceiling forms. (Lappalainen 2010, 26.)

The passive utilisation of solar energy means that buildings without technical ancillaries or with simple ancillaries, can utilise solar energy for heating. Manners to utilise passive solar energy are: the placement of a building to the southern hillside; the direction of a window area to the sunny compass point; the circulation of air between southern and northern rooms; the storing of energy in structures; and the utilisation of structures, for example, to circulate air in cavity slabs. Solar energy decreases the need for heating energy when the building place is unshaded enough and the g-value of windows is good enough to get heat energy to interiors. Directing windows to the south may lead to overwarming of interiors during the summer time. The National Building Code of Finland requires the computational inspection of summer time temperatures of all building types excluding detached houses. In building instructions it is possible to demand the computational inspection of summer time temperatures in detached houses as well. (Lylykangas, Lahti & Vainio 2013, 110; Lappalainen 2010, 26.) Figure 12 expresses principles of the location of a building.

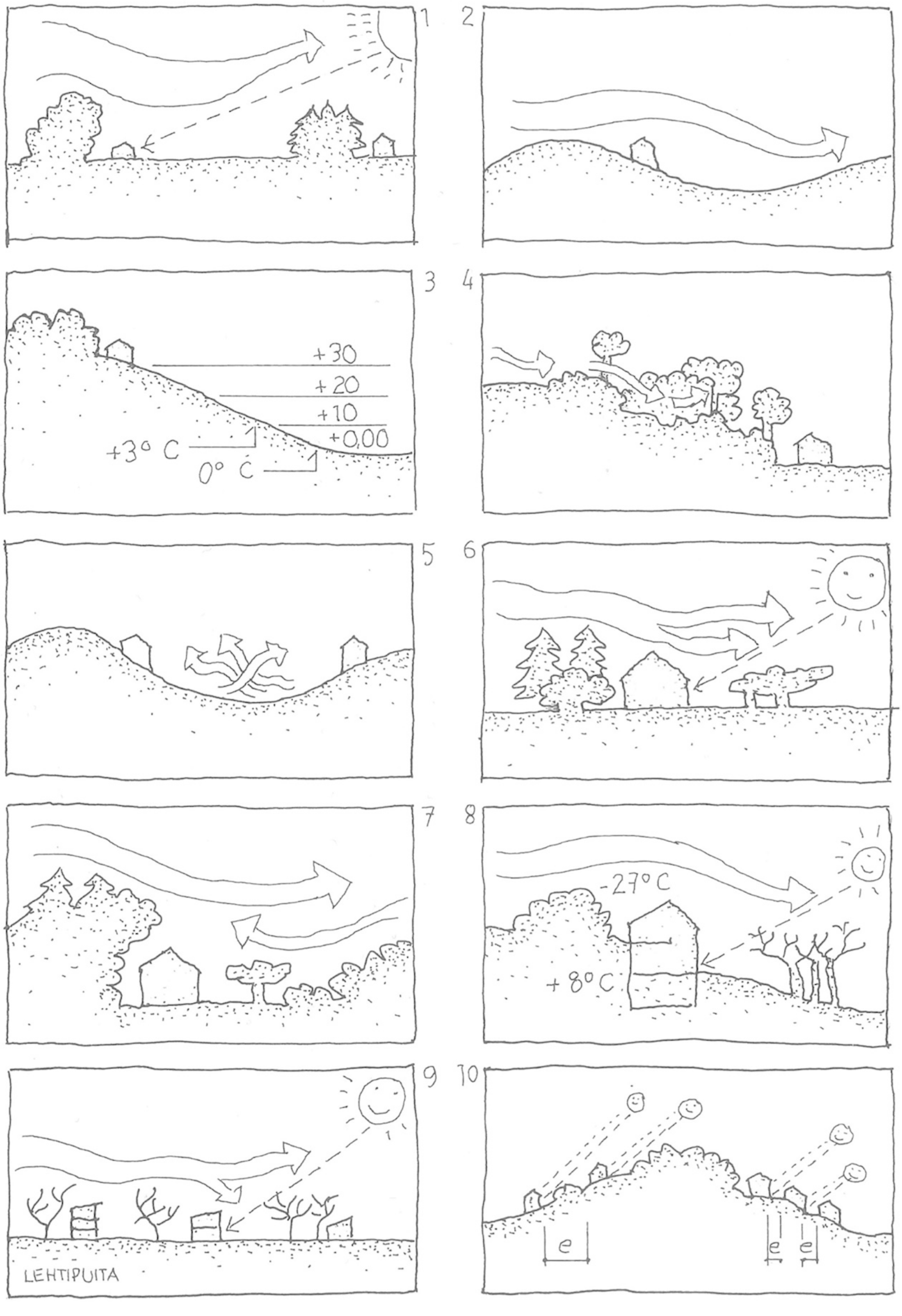

FIGURE 12. Principles of the location of a building. (Erat 1994, 137.)

Solar energy can be utilised in low-energy houses and in passive houses as well, where the heating period is relatively short. Most of the heating energy is used in the winter time when the sun radiance is low, so it is not possible to get the great energy benefit by utilising passive solar energy. Typically, an attainable energy benefit is 10-15 %. Detailed planning can create requirements for the passive utilisation of solar energy but eventually, the reduction of heating energy need depends on solutions in the building planning. (Lylykangas, Lahti & Vainio 2013, 110; Lappalainen 2010, 26.)

The pile foundation, and the base structure and the surface structure can cause an extensive environmental load. Avoiding building sites that require a pile foundation or a stabilisation is one means to decrease CO_2 emissions. (Lylykangas, Lahti & Vainio 2013, 84.)

7.3.2 The size and the usage of space of the building

Conduction loss and the uncontrollable ventilation are proportional to the area of buildings' lateral surface. When the volume of building is permanent, the addition in a floor count converts the relation of lateral surface of the building. In a detached house, the effect of the floor count is notable. In a semi-detached house, the consumption of heating energy by decreases approximately 15 % when the house is built as a two-story instead of a single-story. In a multi-story building the floor count does not affect the energy consumption that much. The bigger a building, the less it uses heating energy per utility square metre, in the case that other qualities stay unchanged. The impact of size of the building on the total consumption is significant in detached houses when the loss of lateral surface is relatively greater. In multi-story buildings, the impact of size of the building on the total consumption is minor because the lateral surface subject to the heat loss is lower. (Lappalainen 2010, 27-28.)

The most necessary action is to reduce the amount of heated space without complicating technical solutions. In detached houses, long aisles, large stairways, fireplace rooms, some storages and high spaces increase the heated volume. Unnecessary spaces increase the lateral surface and heated spaces. With the placement of living spaces near heat sources and to the southern side, it is possible to decrease the energy consumption. Bedrooms and occasional living spaces should be placed to the northern side and outer zone of the building. Because the warm air rises, spaces where the heating need is continuous, should be placed on the second floor, and spaces that could mainly be cool, should be placed on the ground floor. (Lappalainen 2010, 28-29.)

By installing sunscreens to windows that are directed towards south and west, can be decreased the necessity of cooling. That also helps to avoid unnecessary purchases of accessory air coolers and the addition of energy consumption that they cause. Particularly essential it is in passive houses, where the extra heat that is caused by electronic devices, leads to a need for cooling. The challenge in energy efficient buildings is, that the cooling need usually increases when the heating need decreases. With aid of passive means, such as sunscreens in windows or shadowing southward and westward windows, it is possible to achieve as much as a 50 % decrease in the cooling need. (Lahti, Nieminen & Virtanen 2008, 64, 76.)

Strong winds and rains can cause the destruction of structures and the need fo premature reparation. Strong winds can also cause air flows and leaks to the envelope of the building, that leads to an increase of energy consumption. The thermal insulation, thermal capacity and impermeability of the envelope affect the energy loss throughout the envelope. Also, the form and location of the building have an effect on the energy economic of the building. The tighter the envelope of the building is, including windows and doors, the lower is the impact of winds on air leaks and energy consumption of the building. (Lappalainen 2010, 29; Lahti, Nieminen & Virtanen 2008, 41.)

7.3.3 Heating forms

The heat distribution system of building affects the selection of the method of heating. The heat distribution system transfers the heat energy to where it is needed and releases it there. The heat vector is water or air that circulate in the heat distribution network. Heating options and planning of energy economy affect widely the living comfort and operating costs of a detached house. The heating form of a detached house can be district heating, electric heating, oil heating, natural gas, electric accumulators and boilers, pellet heating, a ground-source heat pump, an air-water heat pump, an exhaust air heat pump and boilers for woodchips, wooden blocks or billets. Ancillary heating systems are complementary systems that can be used to decrease substantially the amount of delivered energy. Covering the whole heating need with ancillary heating systems is challenging or even impossible. Air source heat pumps, solar heating and fireplaces are ancillary heating systems. The climate effects of the electric heating can be decreased by choosing electricity that is produced with renewable energy. (Motiva 2019.)

From the point of view of the development of a low-carbon society, the focus is on the reduction of fossil energy sources as a heat source by guiding heating forms of buildings from the fossil fuel oil to other heating forms and by improving energy efficiency for as long as the usage of fossil energy sources continues. In practice, oil heating systems can be modified to operate by electricity or district heating or to modify the composition of oil to be more organic. In new buildings, it is possible to affect the energy source that the building uses. Urban planning together with the building code and energy pricing, can affect the role of the oil heating in construction. (Lehtovuori, Vanhatalo, Rantanen & Viri 2017, 46.)

7.3.4 Ventilation

Ventilation ensures that the indoor air is fresh and clean. Ventilation removes unclean air from the building and take in fresh air instead. Energy efficient buildings are strived to be built as air-tight as possible. Air leakages through structures increase the unnecessary consumption of energy. Ventilation of an air-tight building is mechanical. In practice, all new buildings are built with the mechanical conditioning with heat recovery. The air is removed from the kitchen, bathroom and walk-in wardrobe. The removed air goes through the heat recovery system that salvages as much of the heat energy as possible. The heat is transferred to the fresh air taken from the out. When planning the ventilation it is relevant to choose a machine that is of suitable size. The conditioning needs to be adjustable according the loading. (Motiva 2018.)

Natural ventilation is based on differences of the pressure and temperature. The supply air comes through the outside air valve or through the air vents of a window to living spaces. The exhaust air moves into the vitiated air duct, for example through the air vent of the kitchen hood or bathroom. (Motiva 2018.)

7.3.5 Electric appliances

The part of electric equipment and lighting of the total energy consumption of the habitation is almost 13 percent. The amount and usage of electric equipment are increasing, but at the same time the energy efficiency of equipment is improving. The energy consumption of lighting has decreased, and the energy consumption of information technology and consumer electronics has increased. Greenhouse gas emissions of electric equipment and lighting can be decreased with energy efficient equipment, with usage habits that save energy and by using renewable electricity. Savings in lighting are possible with the appropriate planning of spaces, by utilising natural light, by controlling the lighting and with the choices of types of lamps. (Ilmasto-opas 2018.)

Using habits affect the electricity consumption significantly. Energy saving is possible in various ways with the usage of refrigeration equipment, in cooking, in laundering, with the usage of consumer electronics and with the heating of stoves. Consideration of the energy efficiency of equipment saves costs during the using period. Besides energy efficiency, the quality, durability and reparability of equipment should be considered. When choosing new domestic appliances their energy efficiency class should be ascertained. An old domestic appliance consumes even twice as much energy as a new, energy efficient appliance. The wrong placement, neglecting the maintenance and standby mode of the appliance can increase the energy consumption by a large amount. (Ilmasto-opas 2018; Energiatehokas koti 2018.)

7.4 Energy supply

7.4.1 Ground source heat pumps

The ground source heat pump utilises the solar heat, that is stored in the ground, bedrock or water. With an effective heat pump is possible to decrease the amount of delivered energy that is used for heating, even though energy that is produced with a heat pump would not be counted as renewable local energy. Pipelines to collect thermal energy are typically installed in a drilled well or in a horizontal pipeline. The horizontal pipeline is a more inexpensive alternative, but it demands an adequate surface area for the installation in a plot. The horizontal pipeline is usually installed approximately to the depth of one meter, depending the climate zone. From the point view of heat production, the most effective ground is clayey soil and the weakest is sandy soil. It is also possible to set pipelines into a lake, the sea or a river. When placing the pipework in water, the instalment depth should be at least two meters. The geothermal heating system can be executed in a block base solution as well. (Lylykangas, Lahti & Vainio 2013, 102.)

7.4.2 Wind turbines

Placing a wind turbine in a residential plot that it is large enough to produce a substantial amount of energy compared to the delivered energy, is rarely possible. Instead, vertical axis wind turbines can be integrated to be a natural part of a building. The estimation of the revenue of a vertical axis wind turbine is challenging, because the amount of produced energy depends on the size of the turbine and the wind conditions of a place. A small turbine that is placed to the roof of a building does not cause disruption to the environment, but the revenue is relatively low in the annual energy balance of a building. (Lylykangas, Lahti & Vainio 2013, 102.) Figure 13 represents the possible placement for wind turbines and solar panels in the urban structure.

FIGURE 13. Examples about the placement of wind turbines and solar panels in the urban structure. (Lylykangas, Lahti & Vainio 2013, 70.)

7.4.3 Solar energy systems

With solar collectors buildings, domestic water for residents or process water of the industry can be heated. Solar thermal can be stored as well, for example, in detached houses to a water accumulator. Solar energy systems are usually placed on the roof of the building. The shape, angle and orientation of the roof affect the revenue of solar energy. Solar panels can also be installed to a facade of a building, which allows the utilisation of solar energy during the winter time as well, when the sun shines from a low angle. In building instructions it should be mentioned that inlets of the building service technology should be placed at the highest point of the building in the case where the solar energy system will be installed. The guidelines regarding the installation angle of the panels on the roof should be followed as much as possible targets of the townscape. However, the revenue of energy does not deteriorate significantly even if the angle and orientation of the roof are not optimum. (Salokoski 2017, 21; Lylykangas, Lahti & Vainio 2013, 103.)

In detailed planning it is possible to create advantageous conditions for the production of solar energy. One recommendation is to face the pane of the roof to the southwest, south or northwest. Another datum is to place a building to the north side of the plot. The owner of the site determines the growing stock and construction of the south side, so there will not be shading factors, such as buildings or growing stock on the sunny side of the building. If building of solar energy systems is one of main aims of detailed planning, the endeavour should be to create advantageous conditions for the production of solar energy. If expected returns stay a long way behind maximum returns of the system, the profitability of the investment declines. (Lylykangas, Lahti & Vainio 2013, 103.) Figure 14 represents the possible placements of solar panels.

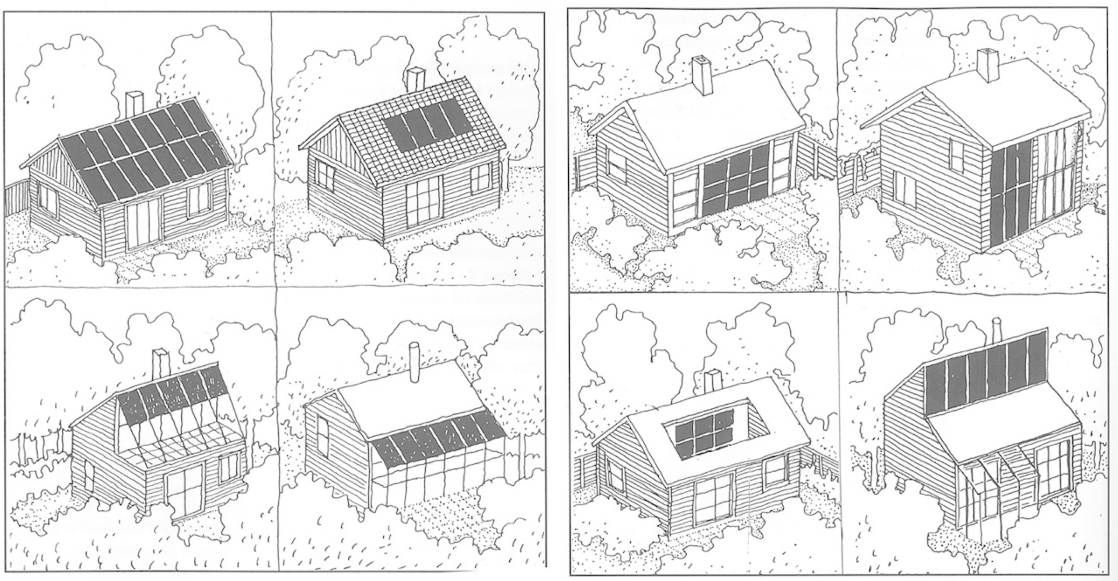

FIGURE 14. The placement of solar panels. (Erat et al. 2008, 137-138.)

7.4.4 Small CHP plants

A small CHP plant (Combined Heat and Power) involves the small-scale cogeneration of heat and electricity, which can be restricted as the plant specific or even a building specific scale. Because energy will be produced despite of the amount of wind or sun, it is possible to execute so-called off-grid solutions, that means buildings or groups of buildings could be executed as the self-sufficient of the electricity or heat networks. Generally, CHP plants have used fossil fuels, but in the Nordic countries there have been built plants that utilise biomass. A CHP plant, that uses the wood pellets or wood chips, produces very low-carbon energy. A small CHP plant that serves a group of detached houses or a block of row houses, can possibly be placed in the same plot as a residential building without the individual detailed plan provision. The chimney flue of a small CHP plant is the same size as the chimney flue of a small fireplace. Together with a small CHP plant there is a woodchip silo, that needs to be filled up at specified intervals. Because the need for heating energy in new buildings has decreased and the price of electricity is low, the cogeneration of heat and energy has become unprofitable. (Salokoski 2017, 28; Lylykangas, Lahti & Vainio 2013, 105.)

7.4.5 Net-zero energy buildings

In a net-zero energy building, annual returns of renewable local energy correspond with the annual delivered energy when calculating in terms of primary energy. In the roof surface area of a single-story detached house is possible to produce enough solar energy enough for the requirement of a net zero-energy building, when the building is moderately energy efficient. In a multi-story building the corresponding production of a solar energy system is not enough to make the building a zero-energy house. (Lylykangas, Lahti & Vainio 2013, 105.)

7.5 Construction materials

Environmental impacts of construction materials are evaluated by life-cycle assessment. Life-cycle assessment is used to examine how much materials and energy are consumed in multiple periods of the production, and how much it generates harmful emissions to the environment. Carbon dioxide and other greenhouse gases are harmful emissions because they have an effect on global warming. Environmental impacts of construction materials should be an expressive factor from the early stage of the planning process. CO_2 emissions of construction materials can be striven to control by setting requirements for the main construction material of the frame and envelope of the building. The major part of environmental impacts of construction materials originate from main structures of the building. In house building, the framework, floors and walls of the building cause about a half of a buildings' carbon footprint. That part is significant from the point of view of decisions at an early stage. (Ruuska, Häkkinen, Vares, Korhonen & Myllymaa 2013, 8, 29, 33; Lylykangas, Lahti & Vainio 2013, 84.)

When choosing construction materials, the energy use of the production and delivery of the material, the impact of the material on the energy consumption of the building and the impact on the safety from the point of view of users, all should be observed. In new construction materials should be used materials that are made from renewable natural resources. If materials are made from the non-renewable resources, recycled or recyclable materials should be preferred. The aim is to use long-lasting, easily maintainable and fixable materials. (Knight 2011, 8-11.)

7.6 Water supply and sewerage

In Finland, fresh water is not a scanty natural resource, and water saving has not become a crucial environmental issue. Globally, fresh water is a waning natural resource. Sustainable water means water self-sufficiency, ensuring that there is enough water for various needs, from agriculture to municipal and industrial needs. On the global scale, each person on the planet should have access to minimum 20 to 50 litres of daily water required to sustain life. Sustainable water also means that water supply will persevere despite climate change impacts, such as heavy rains and floods or a shortage of rainfalls and drought. Economics should be matched with the supply and demand, and the water delivery process should be as effective as possible. The combination of traditional water treatment technologies and renewable energy can enable energy neutrality. (Aquatech 2019; Kuluttajaliitto 2019.)

Saving water has many environmental benefits. The need for the purchase and purification of untreated water decreases, the need for sewage treatment decreases, the amount of energy, that is needed for the pumping of water decreases and the saving of hot water saves energy as well. In Finland, each person consumes approximately 90 to 270 litres of water every day. Most of it is used for showering and water closets. Reasonable using habits and a properly calibrated domestic water system can decrease the water consumption by tens of percent. Changing water taps and showerheads to water saving models, changing toilet seats to seats with the dual flush and exchanging urinals for waterless models in public and commercial buildings, all help to decrease the water consumption of buildings. (Motiva 2019; Knight 2011, 37; Kuluttajaliitto 2019.)

Waste water can be separated to grey and black. Water from water closets is called black water. Grey water is water that originates from kitchen sinks and showers. Rainwaters are also grey. Grey water can be utilised for some purposes without circulation through the wastewater treatment plant. Grey water can be treated in different types of the filtration systems or in small sewage treatment plants. Reuse of grey waters is a good way to reduce the water consumption and the amount of wastewater. (Ympäristö.fi 2019; Knight 2011, 37-38.)

7.7 Waste management

A residential district produces on average 400 kg of household waste per inhabitant per annum. The arrangement of sorting and recycling of waste impacts on the amount of all type of waste. Eco-efficient communities endeavour to recycle and utilise the most of waste arising from construction, housing and transport. The delivery and processing of waste should be as eco-efficiency as possible, so that it will cause as little as possible emissions and disadvantages from transport, noise, smell and other issues that might disturb the community. The mission of urban planning is to facilitate areas and spaces for the eco-efficient waste management (collection and processing site, delivery system, landfills and waste incinerators) so that the amount of negative impacts is as minor as possible. (Lahti, Nieminen & Virtanen 2008, 26-27.)

The waste collection could be organised either so that the waste is collected from waste containers by waste collection vehicles or so, that waste will be sucked through a waste pipe system. The first case requires waste containers and other structures, as well as waste collection vehicles that are proceeding in the road network, also in residence streets and courtyards. That causes negative impacts, such as fuel consumption, emissions and other traffic disadvantages such as noise, smell and accidents. (Lahti, Nieminen & Virtanen 2008, 34, 76.) To decrease negative impacts of the waste collection, it can be organised in a centralised manning using underground waste containers. The shared waste collection point is well suited for detached house areas and small areas with multi-story buildings and row houses. The planning rule for a distance from the residence to the waste collection point is approximately 100 meters. Underground waste containers save space, minimise odours because of the coolness of ground, maximise the amount of waste that fits in the container because the gravity compacts waste, reduce the amount of emptying pick-ups and increase the safety in the area. (Molok 2019.)

In a compact urban structure, the waste management can be developed to be a self-contained system. Waste that has been sorted in the building can be carried to the intake pipe network of compaction place, from where waste will be delivered to the waste management point. Waste collection pipes require investments in the pipe network, mostly the underground space, and structures of pipes from the building as far as the waste collection point. The further processing after the waste collection point, can be the same as waste collected by waste collection vehicles. This solution decreases the traffic of waste collection vehicles and thereby the disadvantages they cause, especially in narrow residence streets. (Lahti, Nieminen & Virtanen 2008, 34, 76.)

8 RESULTS

The aim of this thesis was to discover issues that have an effect on the environmental sustainability of a new residential area. The objective was to recognise manners how to affect environmental sustainability with urban planning and especially with building instructions.

The main research questions in this thesis were the following:

- How to affect environmental sustainability with urban planning?
- What aspects have an impact on environmental sustainability of a new residential area?
- What kind of instructions, that affect environmental sustainability of a planning area can be included in building instructions?

According to the literature study of the subject, urban planning has a great potential to affect environmental sustainability. Urban planning defines where the future construction will be placed, functions there will be, density of the area, public transport system and how residents will be able to utilise it, prerequisites for the operation of transport and energy infrastructures and the network of non-motorised transport. Urban planning creates a framework for low-emission life, that is essential from the point of view of the mitigation to climate change. With urban planning it is possible to affect the energy consumption of communities in construction, in the usage of buildings and in transport. Urban planning affects the arrangement of transport, energy supply, water supply and waste management of residential areas. Urban planning should enable low-emission solutions and sustain other means that execute climate targets. From the point of view of the execution of climate targets in urban planning, relevant examinations are related to private transport, construction materials, emissions of the energy use of buildings and transformation of the land use. Urban planning defines the location, usage and effectivity of new areas, as well when planning transition areas. From the point view of affecting environmental sustainability, the main conclusion is linked to the location of the area, because that defines how new construction can utilise the existing infrastructure, soil of the building site and distances to other functions.

Building instructions guide the execution of buildings, blocks, street environments and green areas. Building instructions define an advisable building manner for a certain area, that has local characteristics. Building instructions can act as a guidance book for designers of different fields as well for constructors and residents. According the literature review, building instructions can complete the climate targets of detailed planning. In detailed planning a target can be set without individualisation of the planning solution. In building instructions it can be described in more detail how to execute that regulation and alternative solutions for the execution. User habits have a significant impact on the energy consumption and sustainability of the building. The environmental benefit that is incorporated in a building, does not necessarily become actualised if the manner in which residents use the building differs from that planned. The guidance is essential from the point of view of the sustainable operation of the building. In building instructions guidance can be given for the sustainable usage of the building.

There are some principles to increase environmental sustainability with urban planning. The area density should be sufficiently high, the existing urban structure should be compressed and completed, and the realisation of plans should also be completed. From the viewpoint of transport, the public transport system should be executed before other construction and corridors for rail traffic should be utilised effectively. In the urban structure, the residency and working should be mixed, large shopping centres should not be built far from the residency and the energy system should be selected on a local basis.

To improve the sustainability of transport, the most significant activity is to control automobile transport by increasing the amount of alternative transport modes, such as public transport and non-motorised transport. The most effective way to affect the traffic performance, is through a decrease in the amount of journeys by motorised transport. Land use is a key factor. The placement of activities closer to each other leads to the increase of the areal effectiveness, housing density and mixed functions. Public transport is an ecological and profitable solution when there is enough passengers. Requirements for the usage of public transport are the fluency of connections and having a sufficient capacity, also at the rush hour. The public transport network should be connected to non-motorised traffic roads so, that those create the flexible network of local transport. Alternative solutions to increase the use of public transport can be developed by using technology and innovations. The improvement of walking and cycling environments and public transport stops, and the arrangement of public transport stops and parking places for cars and bicycles, can increase walking, cycling and public transport as a transport mode.

For the adaptation of climate change, in urban planning floods should be anticipated, as well as the increase of windiness, heavy rains and storms, an overall increase in the precipitation and transitions of the humidity of soil and circumstances of the groundwater. The preparation for these changes requires the examination of flood risk areas and the limitation of flood risk areas outside of construction. Construction in risk areas needs to be limited by defining the minimum building level for buildings and streets based on the water level. The risk areas need the placement of temporary and permanent flood protection structures and to have attention paid to the green protection and vegetation. When placing buildings, special attention needs to be paid to microclimate, terrain and soil. Climate aware urban planning utilises the terrain shapes, growing stock, sunlight and prevalent wind direction in the placing of buildings. City quarters should be planned so that they receive a cover from cold air currents and excess insolation. The usage of solar energy and ventilation of buildings with wind solutions should be advanced. Green zones protect buildings from winds, overheat and horizontal humidity. The canals, ponds and green corridors store water helping to control floods by slowing down the surface water.

Green areas are in the crucial role in the adaptation of climate change. Green areas reduce the risk of flooding, serve as a carbon sink, reduce air pollution and mitigate the urban heat island effect of the built environment. Often even a separate green area can manage many different functions and produce various ecosystem services, both to humans and animals, that exploit the urban nature as a habitat. The urban runoff management is an increasing challenge in an increasingly urbanising environment. Solutions that are integrated to the environment are needed for the sustainable management of stormwater. The green factor tool is a tool that can be used to calculate how much vegetation and solutions, that retain stormwater, there are in a plot with respect to the surface area of the plot.

The energy efficiency of the building can be affected through the placing of the building, the arrangement of spaces in the building, structures of the building, the heating form, by setting a target for the energy efficiency class of the building and by proposing solutions that decrease the energy consumption. The placement of the building on the plot has an impact on opportunities to utilise passive solar energy and on wind circumstances in the plot. The size and the usage of the space of the building have an effect on the needed heating energy. The chosen heating form and technical systems affect emissions of the building. Solutions for energy production in residential areas are ground source heat pumps, solar energy systems, wind turbines and small CHP plants. As ancillary heat systems, air source heat pumps and storing fireplaces can be used.

The improvement of the energy efficiency of new construction means that the significance of environmental impacts of construction materials is emphasised. When choosing construction materials, the energy use of the production and delivery of the material, the impact of the material on the energy consumption of the building and the impact on the safety from the point of view of users should be considered. In new construction materials that are made from renewable natural resources should be used. If materials are made from non-renewable resources, recycled or recyclable materials should be preferred. The aim is to use long-lasting, easily maintainable and fixable materials.

Buildings should be planned and executed in a manner that takes into account needs and preferences of users. That requires a stronger interaction between planners and users than at present. Many decisions that have an impact on the environmentally sustainability of the area, are already carried in the period of detailed planning. One manner to increase environmental sustainability of a new residential area is the involvement of potential future residents in the planning process at an early point as possible.

The general feature in all planning options is, that the earlier selections and conclusions are made, the greater are opportunities to have an impact. This requires that decisions should be binding. The planning solutions that strive towards the reduction of climate emissions, should be executed at all planning levels, whereupon the effectivity of actions is composed as great as possible.

When the strategic aim is executed in all planning levels, any level does not necessarily need ultimate measures for the reduction of emissions, that could complicate the execution of other aims of the plan or increase costs of construction unduly. The traditional financial feature of urban planning is that probably over half of the upcoming expenses are combined before the local master plan is completed. That is also valid for other impacts, such as the demand for materials, the energy consumption and the total emissions.

9 CONCLUSIONS AND DISCUSSION

The literature review forms a general view about the sustainable urban structure and the effect of urban planning to environmental sustainability. The study gives some practices to increase the environmental sustainability of a new residential area. Moreover, the literature review gives a general view about environmental impacts of the built environment.

Consequences of the literature review about impacts of urban planning on environmental sustainability were mostly strategic. The main outcome was that environmentally sustainable aims should be executed at all planning levels so that the best effectivity will be achieved. The study gives viewpoints on how to estimate the sustainability of built areas. Also some practices that can be benefitted in detailed planning given.

The focus of practices to increase the environmental sustainability of a new residential area was on the building instructions. The purpose was to discover means which are feasible to have an impact on building instructions. Results about practices to increase the environmental sustainability of a new residential area, were quite practical, and therefore easy to apply in practice.

The uncertainty factor of the study was that completed areas with similar principles were not examined and reported. Analysis about completed areas with targets of environmentally sustainability involved would have produced useful and essential information about how used practices operate in practice.

Some challenges were met during the thesis process. The case study was left out in the home stretch and the thesis was carried out as a literature review. The reason for the non-appearance of the case study was the nature of the study, which was confidential. The case study would have brought a practical aspect to the study.

Reviewing the target setting of the project, it was entirety too ambitious. The examination about the environmental impacts of the built environment and how to affect environmental sustainability with urban planning and with building instructions was too wide a subject. The concentration on the affect at one planning level, either with a local master plan, a detailed plan or the building instructions, would have led to more exact results. Practices to increase environmental sustainability of a new residential area were now quite superficial. The focus on having an effect via the building instructions supplemented with analysis about completed areas would have given more specific practices.

In future projects, the earlier aspects of environmental sustainability are included in the planning process, the better are possibilities that environmentally sustainable aims will be executed. The sustainable aim should be fulfilled strategically in all planning processes. Future residents of the planning area should be involved in the planning process at as an early stage as possible. Environmental sustainability of residential areas is strongly related to the location of the area. The planning of a new residential area should begin with the recognition of factors that affect the connection of a new area to the existing environment.

REFERENCES

Printed sources:

af Hällström, J. 2016. Arki, valinnat ja tulevaisuus. Kestävä liikkuminen. Helsinki: Suomen luonnonsuojeluliitto ry.

Ariluoma, A., Kalliala, E. & Lähde, E. 2015. Kestävä maisemasuunnittelu – Tiivistä, joustavaa ja monihyödyllistä? Viherympäristö 1/2015, 8-10.

Erat, B. 1994. Ekologia, ihminen, ympäristö. Helsinki: Rakennusalan kustantajat.

Erat, B., Erkkilä, V., Nyman, C., Peippo, K., Peltola, S. & Suokivi H. 2008. Aurinko-opas. Aurinkoenergiaa rakennuksiin. Helsinki: Aurinkoteknillinen Yhdistys ry – Soltekniska Föreningen rf.

Hämäläinen,J. & Teriö, O. 2011. Talonrakentamisen ympäristömittari. Helsinki: Suomen Rakennusmedia Oy.

Knight, R. 2011. Vihreät rakennukset. Helsinki: Perhemediat Oy.

Lappalainen M. 2010. Energia- ja ekologiakäsikirja: suunnittelu ja rakentaminen. Helsinki: Rakennustieto Oy.

Rodrigue, J-P., Comtois, C. & Slack, B. 2013. The Geography of Transport Systems, Third edition. New York: Routledge.

Ruuska, A., Häkkinen, T., Vares, S., Korhonen, M-R. & Myllymaa, T. 2013. Rakennusmateriaalinen ympäristövaikutukset. Selvitys rakennusmateriaalien vaikutuksesta rakentamisen kasvihuonekaasupäästöihin, tiivistelmäraportti. Ympäristöministeriön raportteja 8/2013. Helsinki: Ympäristöministeriö.

Sinkkilä, J., Pihkala, A. & Weckman, E. 2019. Maiseman tekijät. Näkökulmia maisema-arkkitehtuuriin. Helsinki: Aalto-yliopisto.

Suomen ympäristö 2014. Arviointi maankäyttö- ja rakennuslain toimivuudesta 2013. Suomen ympäristö 1/2014. Helsinki: Ympäristöministeriö.

Digital sources:

Ala-Outinen, T., Harmaajärvi, I., Kivikoski, H., Kouhia, I., Makkonen, L., Saarelainen, S., Tuhola, M. & Törnqvist, J. 2004. Ilmastomuutoksen vaikutukset rakennettuun ympäristöön. Helsinki: VTT.

Aquatech 2019. Sustainable water: our essential guide to sustainable water resource management solutions & strategies [accessed 20.11.2019]. Available at: https://www.aquatechtrade.com/news/article/sustainable-water-essential-guide/

CNT 2011. The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits [accessed 7.12.2019]. Available at: https://www.cnt.org/publications/the-value-of-green-infrastructure-a-guide-to-recognizing-its-economic-environmental-and

Energiatehokas koti 2018. Sähkölaitteet [accessed 25.11.2019]. Available at: https://www.energiatehokaskoti.fi/suunnittelu/talotekniikan_suunnittelu/sahkolaitteet

European Commission 2019. Construction and Demolition Waste (CDW) [accessed 7.10.2019]. Available at: https://ec.europa.eu/environment/waste/construction_demolition.htm

European Commission 2019. The forms and functions of green infrastructure [accessed 15.11.2019]. Available at: https://ec.europa.eu/environment/nature/ecosystems/benefits/index_en.htm

European Environment Agency 2015. Urban sustainability issues – What is a resource-efficient city? Technical report No 23/2015.

Große, J. 2017. Urban structure and sustainable transport. Exploring the relationship between urban structure and travel behaviour and the role of urban planning in Northern Europe. Copenhagen: University of Copenhagen.

Hirvensalo, J. 2015. Kaupunkien vihreän infrastruktuurin suunnittelu viheliäisenä ongelmana. Helsinki: Helsingin yliopisto.

Häkkinen, T. (ed.) 2011. Kestävän rakentamisen prosessit. VTT Tiedotteita – Research Notes 2572. Espoo: VTT.

Ilmastonkestävän kaupungin suunnitteluopas 2019. Viherkerroinmenetelmällä vihreitä ja viihtyisiä pihoja [accessed 24.11.2019]. Available at: https://ilmastotyokalut.fi/vihrea-infrastruktuuri/viherkerroinmenetelma/

Ilmasto-opas 2018. Rakennusten lämmitys kuluttaa runsaasti energiaa [accessed 11.2.2019]. Helsinki: SYKE, Aalto-Yliopisto YTK, Ilmatieteen laitos. Available at: https://ilmasto-opas.fi/fi/ilmastonmuutos/hillinta/-/artikkeli/73fa2827-42d1-4fd7-a757-175aca58b441/rakennusten-lammitys-kuluttaa-runsaasti-energiaa.html

Ilmasto-opas 2018. Sähkölaitteet ja valaistus [accessed 25.11.2019]. Helsinki: SYKE, Aalto-Yliopisto YTK, Ilmatieteen laitos. Available at: https://ilmasto-opas.fi/fi/ilmastonmuutos/hillinta/-/artikkeli/5fbaa6aa-f525-4cdd-9699-23d415815ae5/sahkolaitteissa-ja-valaistuksessa-on-merkittavia-energiansaastomahdollisuuksia.html

Inkiläinen, E., Tiihonen, T. & Eitsi, E. 2014. Viherkerroinmenetelmän kehittäminen Helsingin kaupungille. Helsingin kaupungin ympäristökeskuksen julkaisuja (8/2014). Helsinki: Helsingin kaupungin ympäristökeskus

International Energy Agency 2013. Transition to Sustainable Buildings. Strategies and Oppurtunities to 2050. Paris: OECD/IEA.

iWater 2019. Stormwaters: From waste to resource! [accessed 24.11.2019]. Available at: https://www.integratedstormwater.eu/

Kanninen, V., Kontio, P., Mäntysalo, R., Ristimäki, M. 2010. Autoriippuvainen yhdyskunta ja sen vaihtoehdot. Espoo: Aalto-Yliopisto.

Kuluttajaliitto 2019. Vastuullinen vedenkulutus [accessed 20.11.2019]. Available at: https://www.kuluttajaliitto.fi/tietopankki/vastuullinenkuluttaminen/sahko-vesi-lampo-ja-vastuullinen-kuluttaminen/vedenkulutus/

Lahti, P. & Moilanen, K. 2010. Kaupunkiseutujen yhdyskuntarakenne ja kasvihuonekaasupäästöt. Kehitysvertailuja 2005–2050. Suomen ympäristö 12/2010. Helsinki: Suomen ympäristökeskus.

Lahti, P., Nieminen, J. & Virtanen, M. 2008. Ekotehokkuuden arviointi ja lisääminen Helsingissä. Helsinki: Helsingin kaupunkisuunnitteluvirasto ja VTT.

Lehtovuori, P., Vanhatalo, J., Rantanen, A. & Viri, R. (eds.) 2017. Kaupunkirakenteen kokonaisvaltainen resurssitehokkuus. Valtioneuvoston selvitys- ja tutkimustoiminta: Valtioneuvoston selvitys- ja tutkimustoiminnan julkaisusarja 65/2017.

Lylykangas, K. 2013. Kestävä rakentaminen. Helsinki: Helsingin kaupunki, rakennusvirasto & Arkkitehtuuritoimisto Kimmo Lylykangas Oy.

Lylykangas, K., Lahti, P. & Vainio, T. 2013. Ilmastotavoitteita toteuttava asemakaavoitus. Aalto-yliopiston julkaisusarja Tiede + teknologia 13/2013. Helsinki: Aalto-yliopisto, Sitra & Ympäristöministeriö.

Lähde, E. & Ariluoma, M. 2019. Sustainable stormwater management solutions [accessed 24.11.2019]. Available at: https://www.integratedstormwater.eu/sites/www.integratedstormwater.eu/files/toolsheet_descriptions_of_swm_solutions.pdf

Martinkauppi, K. (ed.) 2010. ERA17 Energiaviisaan rakennetun ympäristön aika 2017. Helsinki: Ympäristöministeriö, Sitra ja Tekes.

Mattinen, M., Heljo, J. & Savolahti, M. 2016, Rakennusten energiankulutuksen perusskenaario Suomessa 2015-2050. Suomen ympäristökeskuksen raportteja 35/2016.

Ministry of Economic Affairs and Employment of Finland 2013. Energy and climate strategy [accessed 15.11.2019]. Available at: https://tem.fi/en/energy-and-climate-strategy

Ministry of the Environment 2019. National climate change policy [accessed 15.11.2019]. Available at: https://www.ym.fi/en-US/The_environment/Climate_and_air/Mitigation_of_climate_change/National_climate_policy

Modarres-Sadeghi M. & Konstari, T. 2015. Study on Sustainable City Districts. Good Practice From Ten European Reference Cases. Turku: City of Turku Environmental Publications 1/2015.

Molok 2019. Molok-syväkeräysjärjestelmän edut ja toimintaperiaate. [accessed 20.11.2019]. Available at: https://www.molok.com/fi/edut-ja-toimintaperiaate

Motiva 2019. Lämmitysjärjestelmän valinta [accessed 25.11.2019]. Available at: https://www.motiva.fi/koti_ja_asuminen/rakentaminen/lammitysjarjestelman_valinta

Motiva 2019. Vedenkulutus [accessed 20.11.2019]. Available at: https://www.motiva.fi/koti_ja_asuminen/hyva_arki_kotona/vedenkulutus

Motiva 2018. Ilmanvaihto [accessed 3.12.2019]. Available at: https://www.motiva.fi/koti_ja_asuminen/rakentaminen/rakentajan_ohjeet/hyva_talo/ilmanvaihto

National League of Cities. 2013. Transportation. [accessed 13.8.2018]. Available at: https://www.nlc.org/topics/transportation.

Rakennusteollisuus RT ry. 2010. Rakennettu ympäristö ratkaisee energiatehokkuuden [accessed 29.8.2018]. Available at: https://www.rakennusteollisuus.fi/globalassets/julkaisuja/rakennettu-ymparisto-ratkaisee-energiatehokkuuden.pdf

Rakennustieto 2019. [accessed 20.11.2019]. Available at: https://www.rakennustieto.fi/index/rakennustieto.html

ROTI 2011. Rakennetun omaisuuden tila 2011. Helsinki: Suomen Rakennusinsinöörien liitto RIL.

Salokoski, P. 2017. Tulevaisuuden energia 2030...2050. Taustaraportti. Helsinki: Tekes.

Sitra 2019. Climate change [accessed 20.11.2019]. Available at: https://www.sitra.fi/en/topics/climate-change/

SOLUTIONS 2010. Solutions - Sustainability of Land Use and Transport in Outer Neighbourhoods. Final Report, EPSRC.

Stadin ilmasto 2019. Helsingin viherkerroin [accessed 24.11.2019]. Available at: https://www.stadinilmasto.fi/viherkerroin/

Suomen Kuntaliitto 2013. Opas rakennusjärjestyksen laatimiseen. Helsinki: Suomen Kuntaliitto.

Suomen virallinen tilasto (SVT): Rakennukset ja kesämökit [verkkojulkaisu]. ISSN=1798-677X. 2017, Rakennuskanta 2017. Helsinki: Tilastokeskus [accessed 11.2.2019]. Available at: http://www.stat.fi/til/rakke/2017/rakke_2017_2018-05-25_kat_002_fi.html

Touru, T. 2011. Ilmastovaikutusten huomioon ottaminen liikennejärjestelmäsuunnittelussa. Liikenneviraston tutkimuksia ja selvityksiä 20/2011. Helsinki: Liikennevirasto.

The United Nations 1987. Our Common Future. Report of the World Commission on Environment and Development. Oxford: Oxford University Press.

United States Environmental Protection Agency 2015. Green Infrastructure Opportunities that Arise During Municipal Operation [accessed 9.8.2018]. Available at: https://www.epa.gov/nep/green-infrastructure-opportunities-arise-during-municipal-operations

Vares, S., Häkkinen, T. & Shemeikka, J. 2011. Kestävän rakentamisen tavoitteet ja niiden toteutuminen. Espoon Suurpellon päiväkodin arvio. VTT Tiedotteita 2573. Espoo: VTT.

VirMa – Vihreä infrastruktuuri ja maisema 2016. Maisema-arkkitehtuurin tutkijaryhmän blogi. Helsinki: Aalto University [accessed 9.8.2018]. Available at: https://blogs.aalto.fi/virma/.

Wahlgren, I., Kuismanen, K. & Makkonen, L. 2008. Ilmastonmuutoksen huomioinen kaavoituksessa – tapauskohtaisia tarkasteluja. Tutkimusraportti Nro VTT-R-03986-08. Espoo: VTT.

Ympäristö.fi 2019. Harmaiden jätevesien käsittely [accessed 20.11.2019]. Available at: https://www.ymparisto.fi/fi-FI/Rakentaminen/Rakennushanke/Talotekniset_jarjestelmat_LVI/Kiinteiston_jatevesien_kasittely/Syventavaa_tietoa/Puhdistamosivusto_jatevesien_kasittelymenetelmista/Harmaiden_jatevesien_kasittely