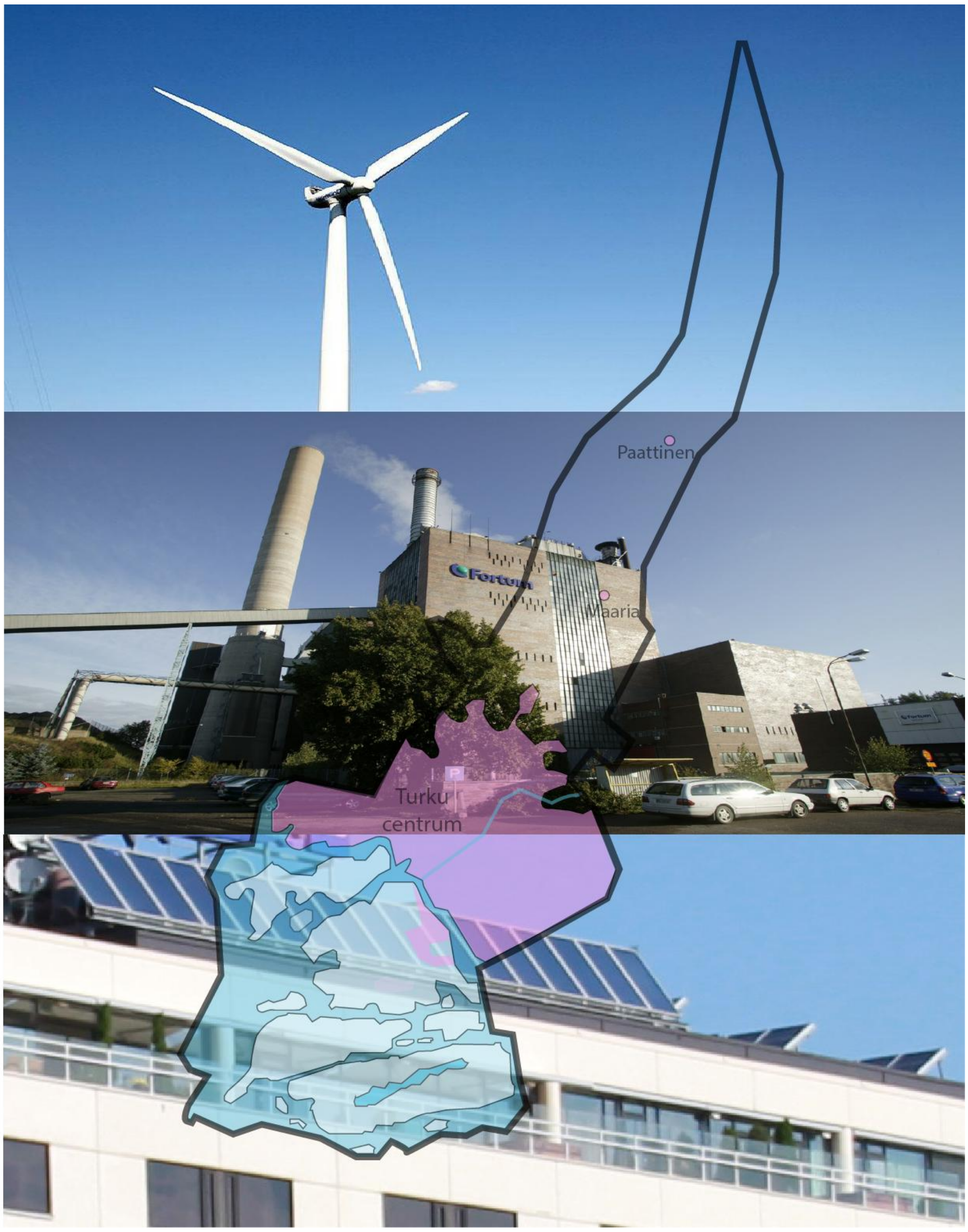
Scenario of a renewable energy system in 2030 for Turku Finland



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Scenario of a renewable energy system in 2030 for Turku Finland

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Preface

This thesis was done in order to complete my Master's degree in Industrial Ecology at the Leiden University and at the Delft University of Technology. The subject of this thesis is about achieving a fully renewable energy system in Turku Finland. I am interested in this topic, because Turku is my home town and because I have been following the progress of implementing renewable energy systems in Finland for several years now. I am also interested in general about renewable energy technology and what solutions it can bring for the future energy systems and what kind of constraints it has. This study is seen as a highly useful source of information for the build up of the future renewable energy system in Turku and offers a roadmap towards a renewable energy system for the stakeholders in Turku.

Although this thesis was an individual project I would like to say thank you to some people who supported me during this thesis. First, many thanks to my supervisors Jaco Quist and Siebe Broersma for supporting me and adding value to my thesis through their experience and feedback. I would also like to say thank you to the people who I interviewed for this thesis and to other people who provided me important information. A special thank you to my contact in the Turku municipality Risto Veivo who enabled my research start up in Turku and who provided me important information during my research. Finally, I want to say a very special thank you to my family for supporting me during the whole course of my studies. Without their support I could not have achieved this.

Summary

This research determines how the change towards a completely renewable energy system inside Turku could be realised and what are the potentials, barriers and possibilities of the transition to this system.

The methodological basis for my thesis comes from the Master's thesis *"Scenarios for Sustainable Energy on Texel"* by Ricken (2012), which researches how to develop and implement locally a sustainable and self-sufficient energy system. The Ricken methodology combined the participatory backcasting and sustainable energy landscape methods in order to explore the subject. However, Ricken (2012) explored the Wadden island Texel in the Netherlands, which cannot be considered as an urban area like the city of Turku in Finland. Therefore, the literature review of my thesis will offer insight to the research that is currently taking place in an urban environment and which bears immediate relevance to my thesis. Furthermore, the literature review will present developments concerning the methods of backcasting and sustainable energy landscape in order to elaborate the Ricken methodology and show shortcomings to these methods. Hence, the methodology will be strengthened and guided towards an exploration of a more populous area.

The objective of this Master's thesis is to find out the potentials, barriers and possibilities for developing and implementing a renewable energy system that can make the city of Turku energy independent by 2030 and to give recommendations concerning the steps that need to be taken in order to develop and implement this renewable energy system. The research will be done by gaining insight to the technological, economic, cultural, institutional and spatial aspects of the case study and by finding recommendations from other case studies already conducted for this subject.

The municipality of Turku will be the research area and only the energy demand of Turku's premises and technical structure (public lighting) will be taken into account. This study encompasses the energy production, distribution, storage and the energy efficiency of the RES.

The main research question of this research is:

What are the potentials, barriers and possibilities for developing and implementing a renewable energy system that can make the municipality of Turku energy independent by 2030 and what steps need to be taken to achieve this?

In the research part of this thesis, first the present conditions in the municipality of Turku were identified. This included aspects like landscape characteristics, climate conditions, employment and economical situation, education, present energy system and renewable energy potentials in Turku. The landscape characteristics indicated that Turku has a very diverse landscape and many protected areas and protected buildings. The present energy system analysis showed that the transition towards renewable energy production is well on its way due to the large investments made in the municipality, but due to Turku's high energy demand there is still considerable amount of further actions to be taken. Furthermore, the energy potentials evaluation revealed that solar and biomass energy have a big potential in Turku but also potentials of other forms of renewable energy production should be still studied. Moreover, energy saving potential of premises in Turku was found to be moderate.

Also the current developments related to the renewable energy system in Turku were presented. This included political, economic, social, technological and regulatory developments. Also the motives for developing a renewable energy system were indicated. One important motive was found out to be positive economical effect that building a renewable energy system would give to Turku. Finally, this part presented the initiatives and projects related to the renewable energy system in Turku. One very important project is the Skanssi project, where it is studied how a two way low temperature district heating network can be built for the area of Skanssi in Turku.

Furthermore, the most important stakeholders and their power interest grid were presented in order to find out which actors are most crucial in reaching the objective of this thesis. This part revealed that the municipality of Turku, Turku Energia and Turun Seudun Energiantuotanto are the key players in the build up of a renewable energy system in Turku.

Next, the energy demand in Turku in 2030 and the exogenous variables were determined. This study assumed that the energy demand will be the same in 2030 as currently. Then, based on the present conditions, developments and exogenous variables, a vision and scenario was built that presents the different aspects of Turku in 2030 related to its renewable energy system. Only one scenario was built, because it was seen that several different actions are together needed in order to build energy independence in Turku. In this scenario there are centralized and decentralized renewable energy production, moderate energy savings and high importance is put to energy storage, smart grid and heating network. Furthermore, important in this scenario is that the residents of Turku have a positive attitude towards the renewable energy system and that they are willing to pay a higher energy price.

Based on the built scenario the spatial interventions, needed changes for the vision and drivers and barriers of the vision were determined. The spatial interventions part showed suitable areas of renewable energy technologies in Turku. The changes, drivers and barriers were divided into political, economic, socio-cultural, organizational, technological, regulatory and spatial aspects. Many needed changes, drivers and barriers of the formed vision were indentified and presented in this thesis. Finally, the pathway and follow up agenda towards reaching the formed vision were presented. Important aspects of these sections are the need to create clearer governance of energy matters in the municipality, orient policies towards energy conservation and centralized and decentralized energy production, improve and increase the cooperation among the stakeholders, increase investments and the implementation of renewable energy technologies.

This thesis also highlights the shortcomings and weaknesses of this study and the subjects for future study. One important subject for future study is to thoroughly evaluate the possibilities of energy storage and smart grid in Turku and the evaluation of the energy storage potential.

To conclude this research it can be said that the energy independence with renewable energy sources in Turku was not able to be achieved in this study. The electricity demand of the city can be supplied fully from renewable sources, but this includes some external sources. This means that if the renewable electricity independence in Turku is wanted to be achieved, additional renewable electricity production technologies need to be implemented inside of the municipal boundaries. Furthermore, the heat demand cannot be fully supplied with renewable sources. This means that if the renewable heat independence is wanted to be achieved, additional renewable heat production technologies need to be implemented inside of the municipal boundaries. Indications for additional renewable energy sources and additional renewable energy production technologies were given in this thesis. One potential source in the future could be the deep geothermal heat.

This study also revealed that motivation for building the RES in Turku is high and the reasons for the motivation were explained. It is highly recommended that the determined potentials, barriers, possibilities and steps towards the RES in Turku are taken into account when building this RES. This thesis is seen as a highly useful source of information for the build up of the future renewable energy system in Turku.

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1. Introduction

1.1 Background and context of the report

Environmental problems like global warming have high interest on the political agenda in the world. Governments in different parts of the world are trying to come up with policies and legislation that would enhance the sustainable development in the society and stop the global warming. Cities around the world are crucial players in this sustainable development, because in the cities the three aspects of sustainable development – people, planet and profit – meet (van Bueren et al. 2012) (del P. Pablo-Romero et al. 2015). In 2014 54% of world's population lived in the cities (WHO 2015) and they are responsible for almost 80% of the world's greenhouse gas emissions, while occupying only 2% of the world's surface (van den Berg et al. 2015) Therefore, it is important to involve the institutions in the city (e.g. municipalities) to reduce emissions and to turn the general determination into operative policies (Schenone et al. 2015) (del P. Pablo-Romero et al. 2015) (Heinbach et al. 2014)

In the year 2008 the European Union (EU) set its 20-20-20 climate and energy target, which included a 20% reduction of greenhouse gas emissions (compared to the year 1990 level), 20% increase in renewable energy production and 20% increase in energy efficiency. This was set to be achieved in the year 2020. Furthermore, EU's long term goal is to decrease its greenhouse gas emissions with 60-80% by 2050. (Ulkoasiainministeriö 2015) In order to achieve the EU's climate and energy targets, the membering countries need to find ways to lower their greenhouse gas emissions. The EU and other major international institutes (e.g. OECD and World Bank) recognize the cities as major environmental externality producers but at the same time EU considers them to be important players in reducing these externalities. (Schenone et al. 2015) (del P. Pablo-Romero et al. 2015) The most important actors in this process are seen to be the public administrators and citizens. Therefore, national governments in all the OECD countries have increased cities' autonomy in political decisions concerning sustainability (Schönberger 2013) (Schenone et al. 2015). This has left the cities with difficult decisions and conflicting views. (Schenone et al. 2015) In Finland, one important initiative that helps cities with these difficulties is the FISU (Finnish Sustainable Communities) network and its goal is to help Finnish municipalities in becoming coal and waste free. This target will be achieved with the cooperation of the different municipalities and other actors in the network. (FISU 2015)

The municipality of Turku in Finland is one of these members in the FISU network. Turku wants to be a frontrunner of the green economy and also to be recognised internationally. The municipality is planning to enhance circular economy in the area and become a coal neutral city by 2040. (Sitra 2015) This will be achieved by becoming energy efficient, increasing the share of renewable energies in the energy production and by becoming a resource wise city. (Turku 2015) Turku wants that its energy will be produce completely with renewable energies. Currently, about 30% of the energy in Turku is produced with renewable energy and 50% in the year 2020. (Sitra 2015)

Turku has started a cooperation with Sitra (a public innovation fund aimed at building a successful Finland for tomorrow) in order to improve this development towards a renewable and smart energy system. The cooperation with Sitra includes projects that concern the circular economy, renewable energies, water conservation and enhancement of green entrepreneurship. (Sitra 2015) One of the projects that these two parties will start together in 2015 is to find out how the municipality's energy production could be realised fully with renewable energies. Furthermore, this project will study how the change to renewable energy production will influence (circular) economy, employment, innovation activities and greenhouse gas emissions. (Turku 2015)

This is where my thesis comes into the picture. With my thesis I want to determine how the change to a complete renewable energy system in Turku could be realised and can the energy independence be achieved in Turku, as well as what are the potentials, barriers and possibilities of the transition to this system. The current goal of Turku is not to achieve energy independence in their area, but this thesis wants to go a step further and explore this possibility as well. This is due to the positive effects that energy independence can give to Turku (e.g. energy security and positive image). The purpose of this thesis report is to explore the subject of renewable energy and energy efficiency implementation in cities and turn it into a research proposal for a graduation thesis of the MSc Industrial Ecology. Furthermore, the 2nd purpose of this report is to give an answer to the research questions determined in this research.

My contact person in Turku will be the development manager of the municipality of Turku who will support me and give me information during this thesis process. With the help of this thesis Turku will become aware of the potentials, barriers and possibilities of the transition to this renewable energy system. Furthermore, with the help of this thesis Turku can define needed actions to be taken in order to build this system in Turku.

The methodological basis for my thesis comes from the Master's thesis "*Scenarios for Sustainable Energy on Texel"* by Ricken (2012), which researches how to develop and implement locally a sustainable and self-sufficient energy system. The Ricken methodology combined the participatory backcasting and sustainable energy landscape methods in order explore the subject. However, Ricken (2012) explored the Wadden island Texel in the Netherlands, which cannot be considered as an urban area like the city of Turku in Finland. Therefore, the literature review of my thesis will offer insight to the research that is currently taking place in an urban environment and which bears immediate relevance to my thesis. Furthermore, the literature review will present developments concerning the methods of backcasting and sustainable energy landscape in order to elaborate the Ricken methodology and show shortcomings to these methods. Hence, the methodology will be strengthened and guided towards an exploration of a more populous area.

1.2 Research objective

Based on the text above the research objective of this Master's thesis is to find out the potentials, barriers and possibilities for developing and implementing a renewable energy system (RES) that can make the city of Turku energy independent by 2030 and to give recommendations concerning the steps that need to be taken in order to develop and implement this renewable energy system. The research will be done by gaining insight to the technological, economic, cultural, institutional and spatial aspects of the case study and by finding recommendations from other case-studies already conducted for this subject. Pathways towards a renewable energy system and energy independence will be constructed based on these insights and recommendations. These pathways will describe the short-, mid and long term measures that need to be taken towards the objective of 2030.

Furthermore, the research will also give ideas on how to stimulate stakeholders to perform these measures.

1.3 Research boundaries

The following will help to explain the boundaries of this thesis and also in the end help to determine the success of this research. These boundaries have been set in order to be able to conduct this research in its limited timespan and resources and so that the objective of this study could be followed.

- The municipality of Turku is starting projects with Sitra, which concern circular economy, renewable energies, water conservation and enhancement of green entrepreneurship. However, my study will explore only the renewable energy aspect by concentrating only on the RES and making Turku energy independent. Furthermore, this study won't explore how the change to renewable energy system will influence (circular) economy, employment, innovation activities and greenhouse gas emissions, which is also a goal of the cooperation between Sitra and the municipality of Turku.

- Only the suitability of the municipality area of Turku for producing, distributing and storing renewable energy and saving energy will be explored. This is due to the energy independence goal of this thesis and because it is seen that expanding the area outside of Turku would have been too broad for the set timespan of this study.

- Only the energy demand of Turku's premises and public lighting will be taken into account. This study encompasses the energy production, distribution, storage and the energy efficiency of the RES. This means that energy demand and supply for transportation won't be taken into account. These boundary choices are due to the time and resource constraints of this thesis and based on the information availability. Furthermore, a distinction will be made between direct and indirect energy consumption. The intention is to measure only the direct energy consumption. Direct energy consumption means in this case the energy consumption of the premises and technical structure excluding the energy consumption for producing goods in the area of Turku. Including the energy consumption for producing goods would be indirect energy consumption.

- The energy forms of heat, electricity and cooling are taken into account in this study.

- A renewable energy system means that no fossil fuels can be used for energy production.

- The timespan of this thesis will be from the current time until the year 2030. The year 2030 is set to be a goal for the RES build up, because it is seen as a suitable transitory goal for the full coal neutrality of Turku by 2040. Turku will also have its 800th anniversary in 2029.

1.4 Outline of the report

Concerning the research proposal the next section presents the literature review that was conducted related to this subject. The chapter 3 will explain the methodological development for the case of Turku by presenting the research framework and the methodological framework and how these were constructed. Part 3.3 will present the research questions and how they are linked with the methodological framework. Finally, the chapter 4 will present some key definitions of this research and the chapter 5 the guidelines of this report.

Concerning the research part the chapter 6 will explain the present conditions in the municipality of Turku. Furthermore, the chapter 7 will highlight the current developments related to RES in Turku and the chapter 8 will analyse its stakeholders. Moreover, the chapter 9 will describe the vision and scenarios for achieving the objective of this study and chapter 10 will present the needed interventions for the scenario and changes, drivers and barriers of the formed vision. Based on the chapter 10 the pathways for reaching the vision will be presented in the chapter 11 and the follow-up agenda will be created (chapter 12). Finally, this thesis will end with the discussion, conclusions and recommendations.

2. Literature review

This review is constructed from two main sections. The first section presents the current state in local energy backcasting (BC) and transition management as well as in sustainable energy landscape design (SELD). The second section presents the current state in local renewable energy and energy efficiency planning in Europe.

In the first section the Master's thesis "*Scenarios for Sustainable Energy on Texel*" by Ricken (2012) will offer an example of a study that researches how to develop and implement locally a sustainable and self-sufficient energy system. This thesis will also offer a methodological starting point for my thesis. The plan for my thesis is to develop and elaborate the Ricken (2012) methodology by looking into the discrepancies of the Ricken methodology and developments that have occurred after Ricken (2012) in BC and transition management as well as in SELD. Furthermore, the current state in local renewable energy and energy efficiency planning in Europe will be presented by looking into current case-studies and used methodologies. This information will further develop and elaborate my methodology and create an atlas of case studies that will indicate the possible actions to be taken in transitioning to renewable energy system.

2.1 Current state in local energy backcasting and sustainable energy landscape design

This section will explain how the methodology of Ricken (2012) thesis was build from the BC and SELD methods. Subsequently, the developments to BC and SELD methods after the Ricken (2012) will be discussed. This section will also describe discrepancies that the author of this thesis found from the Ricken methodology and from the BC framework.

2.1.1 BC, SELD and the methodological framework in Ricken (2012)

The goal of Ricken (2012) is *"to gain insight into the opportunities, potentials and barriers for developing and implementing a sustainable energy system that can make Wadden Island Texel energy self-sufficient in 2020."* In order to gain these insights, the thesis develops a methodology by combining two methodological frameworks of BC and one of SELD. The following text highlights the aspects of BC and SELD presented in Ricken (2012) and shows how these aspects were combined to a methodology for the Texel case-study. This Ricken (2012) methodology will be the starting point in developing my own methodology for the case of Turku in Finland.

Backcasting

In backcasting a desirable future vision is created and then steps are determined from the present to the defined future so that these visions can be achieved. By using backcasting an operational plan can be determined for the pathway and the feasibility of this plan can be determined. (Ricken 2012)

Ricken (2012) presents two important general characteristics of backcasting:

- Backcasting is a very useful methodology for complex, long-term problems where there is a major need for a change and the problem includes dominant trends

- Broad stakeholder involvement is important and possible through backcasting. These stakeholders can be for example companies, governmental authorities, research and knowledge institutes and the public.

The introduction part of my thesis shows that these characteristics are strongly involved also in the case of Turku, which indicates that the methods used in backcasting can be valuable for reaching the objective of my thesis.

Ricken continues by presenting two different backcasting methodologies (Quist & Vergragt 2006; Robinson 1990), which were used in constructing the combined methodology for Texel.

According to Ricken the Quist & Vergragt (2006) methodological framework consists of five main steps. After each step a further elaboration of the step is given in brackets:

1. Strategic problem orientation (specify goals, describe present system, define current developments and involved stakeholders);
2. Develop future visions or scenario;
3. Backcasting analysis (changes needed for the scenarios);
4. Elaborate future alternative & define follow up agenda (define drivers and barriers for achieving the scenarios**,** defining pathways);
5. Embed results and agenda & stimulate follow-up (constructing a follow-up agenda for different actors, implementation of needed actions). (Ricken 2012)

The Robinson (1990) methodological framework consists of six main steps:

1. Determine objectives;
2. Specify goals constraints and targets;
3. Describe present system;
4. Specify exogenous variables (variables not included in the backcast itself but which cause constraints to the scenarios (e.g economic growth));
5. Undertake scenario analysis based on the input developed;
6. Undertake impact analysis (backcasting analysis, comparison of results to the specific targets). (Ricken 2012)

When the two methodological frameworks were presented, Ricken moves on by finding differences in these two frameworks. First difference is that the Robinson framework was not intended for broad stakeholder involvement. Second is that the Robinson framework is more extensive when looking at the problem orientation steps (first four steps in Robinson). Robinson also addresses the importance of expressing qualitative goals or constraints as quantitative, where possible. Finally, the exogenous variables are indicated as a one step of the Robinson framework, which is not included in the steps of Quist & Vergragt. (Ricken 2012) Finding out these differences was important when developing the methodology for Texel.

Sustainable Energy Landscape Design

Ricken (2012) defines the SELD as *"developing a physical environment where energy needs can be optimally fulfilled by locally available renewable energy sources, which can replace the current fossil fuel depending environment."*

Important in a SELD is that the sustainable energy system is well integrated in the landscape design and that it is cost-efficient, reliable, environmentally friendly and that it uses efficiently local resources and networks. (Ricken 2012)

Ricken distinguishes two important concepts that can provide information when designing sustainable energy landscapes and that can also help implementing sustainable energy technologies. These concepts are nature and thermodynamics. Natural ecosystems can provide information about the system size, source and sinks, and ecological strategies as energy cascading and symbiosis. Furthermore, thermodynamics can offer principles that can increase the energy efficiency of the area under study. (Ricken 2012)

Ricken continues by presenting the methodological framework of Stremke et al. (2012), which can be used to design sustainable energy landscapes at regional scale. Nature and thermodynamics can also be taken into account in this framework.

The methodological framework of Stremke et al. (2012) consists of the five following steps. After each step a further elaboration of the step is given in brackets.

1. Present conditions (analyzing the landscape and present energy system, identifying the renewable energy potential);
2. Near future developments (analyzing current trends, projected trends and policies);
3. Possible far futures (using existing national and regional scenario studies);
4. Integrated visions (constructing visions with the help of previous steps);
5. Spatial interventions (identification of interventions and assessing their robustness). (Ricken 2012)

According to Ricken the five steps should be passed through twice when applying the framework. The first round consists of context and scope definition, gathering maps and data and inviting the stakeholders to participate. The second round consists of composing the visions and carrying out the design process. Furthermore, Ricken explains that the robustness of an intervention can be evaluated by finding out in how many visions a certain intervention is appearing. If an intervention appears in multiple created visions its robustness can be considered high. The robust interventions can be implemented in short term because they are less depended on critical uncertainties. The less robust interventions can be seen as chances or opportunities, which can be implemented when certain developments occur. (Ricken 2012)

The SELD framework suits well to the case of Turku, because the city wants to develop and implement a sustainable energy system in its area. The described framework of Stremke et al. can support the design of sustainable landscape in the municipality of Turku and determine the feasibility for Turku becoming a fully energy independent city by using renewable energy.

Methodological framework of Ricken (2012)

After having described how Ricken describes BC and SELD in his thesis, it is time to describe how the methodological framework was constructed in Ricken (2012) for the Texel island. The goal was to combine the frameworks presented above to one methodology.

Ricken decided to use the five steps of Quist & Vergragt (2006) as a basis for developing the methodological framework for the case of Texel. This decision was made based on the fact that the BC methodology is suitable for dealing with complex sustainable issues and that by using BC different kind of methods can be applied and combined. Furthermore, the BC methodology allows the elaboration of certain scenarios and the creation of possible pathways towards a vision. (Ricken 2012)

Furthermore, Ricken pointed out the similarities and differences that BC frameworks and SELD framework have in order to identify steps that needed to be added to the basis. These similarities and differences are:

- First three steps of Stremke et al. are part of the problem orientation step of Quist & Vergragt
- Defining possible far-futures in Stremke et al. can be compared with the step four of Robinson (Specify exogenous variables) and added to the basis framework
- Visions are set in all of the frameworks
- Spatial interventions can be seen as necessary changes and thus be included in the step three of Quist & Vergragt
- Stremke et al. emphasizes that the robustness of the spatial interventions need to be evaluated whereas in Quist & Vergragt this evaluation is not required
- All the frameworks are intended for long time horizon
- The frameworks of Quist & Vergragt and Stremke et al. propose a participation of stakeholders

These differences and similarities allowed the construction of the methodological framework for Texel on the basis of the Quist & Vergragt framework. The Texel framework is presented below in the Table 1. Table 1 also indicates which tasks are related to which described framework. Furthermore, the Table 2 gives further explanations on what is meant with each task.

Table 1. The steps and tasks of the methodological framework for Texel (Ricken 2012)

	Steps	Tasks	Q*	R*	S*
Stakeholder involvement	1. Strategic problem orientation	• Specify goals, constraints and targets	✖	✖	✖
		• Analyze landscape characteristics			✖
		• Analyze present energy system	✖	✖	✖
		• Identify renewable energy potentials			✖
		• Define current developments	✖	✖	✖
		• Identify stakeholders	✖		✖
		• Define exogenous variables		✖	✖
	2. Construction of scenarios	• Construct desirable scenarios	✖	✖	✖
	3. Backcasting analysis	• Identify spatial interventions			✖
		• Define necessary changes	✖	✖	
	4. Elaboration	• Identify drivers and barriers	✖		
		• Define possible pathways	✖		
	5. Implementation	• Construct follow-up agenda	✖		

*Q = Quist and Vergragt (2006), R = Robinson (1990) and S = Stremke et al. (2010a)

Table 2. Description of the tasks that comprises the methodological framework for Texel (Ricken 2012)

Steps	Tasks	Description	Methods	
			BK*	SD*
1	• Specify goals, constraints and targets	Defining goals, constraints and targets of research	✖	✖
	• Analyze landscape characteristics	Analyzing the characteristics of the landscape in the region		✖
	• Analyze present energy system	Determining the current energy supply and energy demand in the region	✖	✖
	• Identify renewable energy potentials	Identifying renewable energy potentials in the region		✖
	• Define current developments	Defining current technical, economic and cultural and spatial trends and policies regarding the region	✖	✖
	• Identify stakeholders	Identifying the stakeholders that are involved and their interests and influences regarding the vision	✖	✖
	• Define exogenous variables	Defining possible far-futures or assumptions that can offer a certain constraint in constructing the scenarios	✖	✖
2	• Construct desirable scenarios	Constructing different scenarios, which take into account the desirable future vision	✖	✖
3	• Identify spatial interventions	Indicating which interventions should be implemented for achieving the constructed desirable scenarios and evaluating the robustness of these possible interventions		✖
	• Define necessary changes	Defining technical, structural, institutional, organizational and cultural changes that are necessary for achieving the constructed desirable scenarios	✖	
4	• Identify drivers and barriers	Identifying the main drivers and barriers for achieving the constructed desirable scenarios and analyze them	✖	
	• Define possible pathways	Defining possible pathways that can lead to achieve the constructed desirable scenarios	✖	
5	• Construct follow-up agenda	Constructing an action agenda in which is described what the stakeholders should do to work towards the desirable future	✖	

*BK = Backcasting and SD = Sustainable energy landscape design

However, some discrepancies were found from the methodological build up of Ricken (2012). A further study to the article of Quist & Vergragt (2006) done in this thesis reveals that defining drivers and barriers in the step 4 is not mention in the article of Quist & Vergragt (2006), although Ricken claims so. However, according to Quist (2013) the drivers and barriers analysis should be done in the step 3 of the backcasting framework. Thus, in this study the drivers and barriers analysis will be done in the step 3. Furthermore, the author of this thesis believes that the step 4 of the framework should be called "Pathways" and the step 5 should be called "Follow-up", because they describe better and more clearly the content of these steps. Thus, the steps 4 and 5 will be called after these terms in the methodological framework of this study.

The methodological framework of Ricken was used for the islands of Texel in the Netherlands, which can be considered as a rural area. The intention in my thesis is to develop this Ricken framework towards a framework, which can be used for an urban area such as the city of Turku in Finland and where the discrepancies of Ricken methodology and BC framework are corrected. The following parts will describe the developments in BC and SELD after Ricken (2012) and describe the current state in local renewable energy and energy efficiency planning in Europe. These parts will guide the methodological development for Turku case towards the desired direction and help to build the atlas of case studies as well as present measures that can be taken towards a sustainable energy system in cities.

2.1.2 Developments in backcasting and transition management (TM)

This part of the literature review will give a short presentation of the BC and TM literature studied for this thesis. Furthermore, this part will discuss the developments made in the BC and TM after Ricken (2012). These developments are divided into the steps of the BC framework, developed in Quist & Vergragt (2006), and further elaborated in Quist (2013). This framework is intended as an overall methodological framework for participatory BC. It can be used when elaborating an operational BC methodology for a specific case (Quist 2013), which was the intention for the case of Texel and is the intention for the case of Turku. Each step will give a short description of the purpose of the step and point out developments in BC and TM in the urban context.

The literature research on BC and TM showed that the BC framework developed in Quist & Vergragt (2006) and Quist (2013) is often used as a basis when examining a certain case-study. However, for each case this basis has been further elaborated to fit better the characteristics of a certain case. Therefore, the developments are divided into the BC framework steps developed in Quist & Vergragt (2006) and (Quist 2013), and for each step an elaboration is offered according to the information found from the literature and according to what the author of this thesis sees suitable for making the framework stronger. These elaborations will present developments in BC and TM and guide the BC framework towards a methodology that is better adapted to study sustainable energy in the urban environment.

Furthermore, in the end of this part, additional dimensions to the BC framework will be presented in order to answer to its shortcomings mentioned in the literature. Moreover, further research directions for BC and TM in the urban context are given.

Literature on BC and TM

Quist (2013) focuses in his article to the development of a BC framework that is suitable for long term transitions and system innovations and which contributes to sustainable development. Quist (2013) states that this framework is an overall framework for participatory BC and that it can be used as a basis to elaborate an operational BC methodology for a specific case. This article gives examples of methods that can be used for each step of the BC framework and also gives indications on what needs to be taken into account when constructing each step.

Nevens et al. (2013) present an approach called *"Urban Transition Labs".* This approach can be used to support sustainable development in the cities. The article presents the steps of this approach and the essential elements of these steps that will guide the sustainable development in cities. These steps are strongly related to the steps of participatory BC and thus the elements presented in this article can be included to the BC steps below.

McCormick et al. (2013) introduce four themes on advancing sustainable urban transformation. For each theme they indicate what actions are needed for sustainable urban transformation. Therefore, this article can be used in the creation of pathways that presents needed actions towards a set vision(s)/scenario(s). Through these examples, actions can be identified that are relevant for sustainable urban transformation.

Dixon et al. (2014) use participatory BC methodology as a basis in developing their own methodology in order to create visions for city-regional retrofit futures (energy, water, waste and resource efficiency) and to identify key sustaining and disruptive technologies at city level. They also find a shortcoming in the participatory BC methodology, to which they give a solution by expanding the BC methodology with an additional dimension. This additional dimension will be further explained below in the *"Additional dimensions for backcasting and transition management"* part.

Step 1. Strategic problem orientation

The purpose of this step is to examine the problem from a systemic viewpoint (Quist 2013) and to get an integrated perspective of the system under study (e.g. city) (Nevens et al. 2013). This way the multi-scale challenges of urban sustainability transitions can be tackled (Nevens et al. 2013). This step includes determining the possible problem definitions, main unsustainabilities, opportunities, possible solutions and present trends and developments of the system under study. Furthermore, the different stakeholders should be identified and involved in the process and their mind set, values and interests should be evaluated. (Quist 2013)

The system analysis should highlight the current dominant regime, the emerging niche and the landscape pressures and thus the city can be seen in a multi-level perspective (Nevens et al. 2013). Nevens et al. (2014) state that *"essential elements of such a system analysis are the definition of the boundaries (in space, time and themes), a comprehensive yet understandable structure, an overview of the relevant stocks and flows (e.g. labour force, air quality, housing stock) and the data/indicators that illustrate them. "*

Finally, Nevens et al. point out that physical and institutional contexts play a very important role in urban systems. According to this statement these contexts should have a special attention in this stage of the analysis.

Step 2. Develop sustainable future visions/scenarios

Important in this section is to create a vision/scenario in which a societal function (e.g. renewable energy production in urban environment) can be fulfilled in a sustainable way in the far future and where the unsustainabilities and problems defined in the strategic problem orientation step are solved. Furthermore, it is possible to add to this step, first estimates for environmental improvement potential of the societal function. (Quist 2013) Other characteristics that are considered important for the vision/scenario creation in the urban settings are:

- *"Expressing the key priorities (including values and norms) and guiding principles that are considered as the baseline conditions that the future urban system (and the diversity of its subconfigurations) should comply with;*

- *Establishing clear and vivid images (mainly in the form of narratives) of the desirable sustainable future of the city; this vision is meant to have a mobilising and guiding function and to contain 'living' material that can trigger a shift in mind-set. "* (Nevens et al. 2013)

Both Quist and Nevens et al. emphasize the importance of stakeholder participation in the creation of the vision(s)/scenario(s). According to Nevens et al. (2013) community and local change agents should be the involved stakeholders in this envisioning part.

Step 3. Backcasting analysis

In this step the necessary changes needed to be made in order to reach the future vision/scenario are determined (Quist 2013). These changes can be divided into political, economic, socio-cultural, environmental and regulatory changes. One useful tool to determine the needed changes can be expert or stakeholder workshops. The possible drivers and barriers analysis of the created scenarios is also done in this step. (Quist 2013)

McCormick et al. (2013) introduce in their article four themes which can advance sustainable urban transformation. These themes are governance and planning, collaboration and learning, infrastructure and resilience and buildings and precincts.

McCormick et al. continues to explain what kinds of changes and actions are related to each of the themes. In the governance and planning theme new modes of governance connected to strategic planning are needed in order to create room for visionary plans, transition management, disruptive activities and entrepreneurial change agents. Collaborative action and learning from this collaboration are also seen as important for sustainable urban transformation. Collaboration can be for example co-creation through university partnerships or urban transition labs. Furthermore, collaboration with different actors (e.g. universities and municipalities) needs to be increased and diversified, because it can integrate different knowledge to the process and create new ideas for sustainability in the urban environment. Here the documentation of processes, key decisions, mistakes and unexpected results is important for the success of further sustainable urban transformation.

In the infrastructure and resilience theme integrating water, waste and energy infrastructures is a desired action to be taken. These integrations can be for example linking waste management and energy infrastructure.

Next, the buildings and precincts theme explains the importance to drive for sustainability in a well manageable area like precincts. This is because the precinct level can offer room for creative solutions that can be integrated in an area which is well manageable. Furthermore, on a precinct level it is easier to engage communities in collaboration. The lessons learned from the projects on precinct level are valuable when scaling up towards sustainable transformation on a whole city level. In addition, cities are also important players in the global networks and therefore cities have the ability to spread their learned lessons outside their area. (McCormick et al. 2013)

Finally, McCormick et al. address the importance of constructive competition between cities in sustainable development, and also creating evaluations that can measure the cities' sustainable development. Examples of these evaluations are sustainability indicators, assessment frameworks and ranking systems.

Step 4. Elaboration and definition of a follow-up agenda

The results of the previous step are elaborated here and based on this elaboration a pathway is constructed that will lead to the formed vision. Also the follow-up agenda is defined in this step, which will enable the long-term implementation and realization of actions (Quist 2013).

Elaboration part is done by assessing and analysing the changes described and the visions/scenarios developed in the previous steps. The purpose of the pathway creation is to describe a possible trajectory in which the future vision can be realized (Quist 2013). In the pathway creation, the vision is linked with the presented actions, which were determined in the previous step (Nevens et al. 2013). However, the author of this thesis believes that an elaborate determination of actions in the previous step (Step 3) shouldn't take place, because this will cause unnecessary repetition of action determination in the following steps. Instead emphasis on the needed changes should be taken in the Step 3 and an elaborate determination of actions should only take place in Step 4.

After the elaboration and pathway creation, the follow-up agenda can be defined. This agenda will describe what different stakeholders could do and what should be on their action agenda (Ricken 2012).

Step 5. Embedding of action agenda and stimulating follow-up

At this stage the results of the study are articulated. The last step is to embed the results in the city system and to stimulate follow-up so that the different stakeholders would use these results to further develop the sustainability in the city. This means translating the learned lessons to change-inducing actions. By doing this the city will start its actual and dynamic transformation process. (Nevens et al. 2013)

One example of this change-inducing action is the city transition experiments. Nevens et al (2013) describe the city transition experiment as a "*real-life scale realisations that illustrate the envisaged transition pathways and the way they link with the envisaged desirable future images.*" Important to take into account in these experiments is that it follows the previously defined follow-up agenda and that not only new experiments are started, but also ongoing experiments are connected to the created pathways. (Nevens et al. 2013)

Additional dimensions for backcasting and transition management

The first aim of this part is to bring to the readers' knowledge a BC and roadmapping study, where the methodological framework of BC was developed further by adding additional dimensions to the framework. Here the article Dixon et al. (2014) will be used as an example study to describe what additional dimensions were used and how they were used. The second aim of this part is to highlight further research directions for TM in an urban context. This information was presented in the article of Nevens et al. (2013).

Dixon et al. (2014) are arguing that in "performative" consensus based techniques, such as participatory BC and roadmapping, sustaining technologies and social innovations are commonly identified but identifying and foreseeing disruptive technologies and social innovations is considered less common. Therefore, there is a need to add additional dimensions to the frameworks of these techniques in order to help in the identification of disruptive technologies and social innovations.

According to Dixon et al. (2014) the disruptive technologies and social innovations involve *"new knowledge bases that replace existing ways of doing things, but do not require significant regime change (for example, replacing petrol with biofuels would disrupt business models based on petrol but would have minimal effect on social practices)."* On the other hand, sustaining innovations are described as innovations that "*are based on discoveries which occur within existing technology paradigms which do not significantly alter them (for example, increasing wind turbine efficiency through longer blades).* " (Dixon et al. 2014)

In the article of Dixon et al. participatory BC and roadmapping techniques were used as a basis for the methodology of the study. This basis was connected to urban foresight oriented activities, which focuses on the information from foresight based expert reviews, disruptive and sustaining technologies and developments of national roadmaps for urban retrofit. Furthermore, the foresight based activities included doing an online survey work ("horizon scanning") in order to identify further disruptive and sustaining technologies. The respondents to this survey came from the private sector, local government, other public sector/NGOs and academics. (Dixon et al. 2014)

This article revealed that some disruptive technologies were found by using the participatory BC and roadmapping techniques, but the "horizon scanning" helped to identify more of these disruptive technologies. Dixon et al. conclude that using appropriate techniques, like "horizon scanning", to identify disruptive technologies and linking these techniques back to a transitions-based framework is important from a methodological viewpoint. (Dixon et al. 2014) Figure 1 below presents the methodological framework used in this study.

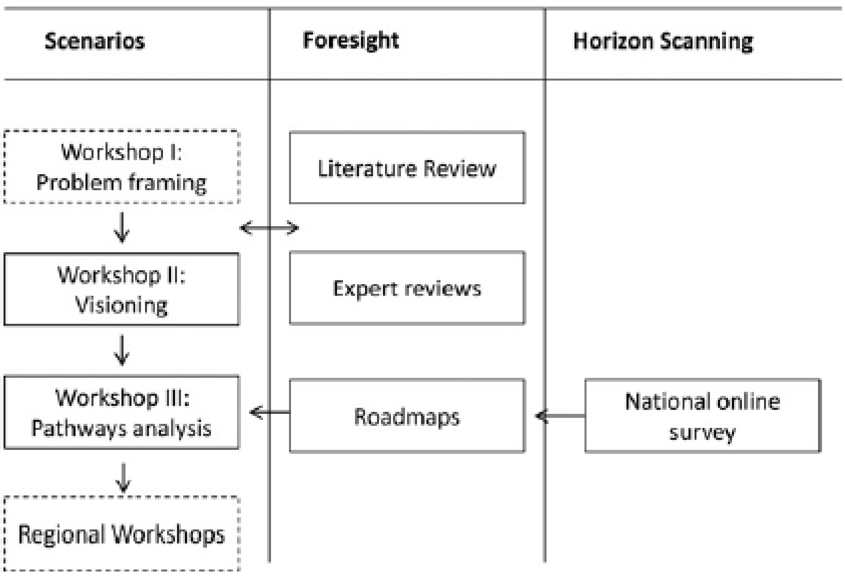


Figure 1. Overview of the methodology of Dixon et al. (2014)

Note: Boxes with solid lines indicate the primary source of methods and results covered in Dixon et al. (2014). Dotted lines indicate supporting methods and results which are not discussed in detail in Dixon et al. (2014).

Finally, Nevens et al. (2013) indicate in their article three further research directions for TM in an urban context. First they address the need for new engagement and planning tools to enable and steer urban transitions towards multiple sustainabilities (e.g. social sustainability, economic sustainability, environmental sustainability). Secondly, it would be important to monitor and evaluate urban transition processes against sustainability criteria and not against city-led targets, which often concern city-marketing or promoting agendas. Third, it is important to examine how agency dynamics affect the urban sustainability transition. This kind of research should take into consideration the dynamics of politics and power and how these dynamics negatively or positively affect the urban transition process.

2.1.3 Developments in the sustainable energy landscape design

Based on the literature research on the developments in SELD, the improvements to its methods concern the creation of the criteria for the evaluation of SELD's sustainability in specific location as well as the creation of key renewable energy science strategies in order to evaluate to what extent and how is renewable energy science incorporated in SELD. This part of the literature review will explain these two aspects found from the literature.

Important when implementing renewable energy interventions to a specific location is to evaluate the sustainability of those spatial interventions. Implementing renewable energy to a specific location can not necessarily be considered as a sustainable intervention. For example, a renewable energy technology can destroy the ecosystem of a specific location or decrease the aesthetic value of the landscape and thus the intervention cannot be considered sustainable (Stremke 2015).

Stremke (2015) develops a conceptual framework in his article through which the sustainability of a possible renewable energy intervention to a specific location can be evaluated. The framework consists of technical, environmental, sociocultural and economic criteria that can inform a sustainable implementation of energy transition in the physical realm. These criteria were derived from the ecosystem services theory. Table 3 below presents some of those selected criteria.

Table 3. List of selected sustainability criteria for sustainable energy landscapes (Stremke 2015)

Criterion		Description
1. Sustainable technical criteria		
1.1	Safety and health issues	Consider safety and health regulations to reduce risk and minimize impacts for humans
1.2	Renewable energy sources	Make us of energy sources that can be replenished and do not deplete
…	*Total of 9 criteria*	
2. Environmental criteria		
2.1	Reversibility	Precautionary principle of sustainable development: All actions and interventions must be reversible
2.2	Emission reduction/carbon footprint	Renewable energy should contribute to the reduction of greenhouse gas emissions and have a smaller carbon footprint than fossil fuels
2.3	Hazardous materials/pollution	Energy technologies should not make use of harmful materials and minimize pollution
…	*Total of 10 criteria*	
3. Socio-cultural criteria		
3.1	Aesthetic values/landscape experience*	Maintain (or improve) "innovatory" aesthetic value that is not limited to visual landscape experience[a]
3.2	Sensual experiences	Maintain (or improve) positive sensual experience of landscapes
3.3	Sense of place and belonging*	Maintain (or improve) sense of place and enable belonging to community
…	*Total of 11 criteria*	
4. Economical criteria		
4.1	Affordable energy	Ensure inhabitants have access to affordable energy also in the future
4.2	Land use competition	Minimize land use competition due to renewable energy provision
4.3	Distribution of benefits and drawbacks (energy equity)	Enable fair distribution of benefits and drawbacks between all involved
…	*Total of 7 criteria*	

Criteria Marked with "*" are linked to the ESS Framework.
[a]The criterion of aesthetic values/landscape quality is, by definition, of core interests to landscape architects and other environmental designers. Due to constraints of this entry, I can only refer to some key authors: Thayer,[36] Thompson & Steiner,[37] Belanger,[38] Barrett et al.[39] and Selman.[40]

By taking into consideration these presented criteria in the decisions concerning the design of renewable energy interventions for a certain area, the energy transition in a specific location (e.g. urban area) can be guided towards a more sustainable implementation.

Moving to the second development of this part, de Waal et al. (2015) study in their article to what extent and how renewable energy science is incorporated in SELD. This is done by creating a theoretical framework, based on renewable energy science, that is used to analyse the participants' entries of *"The Ninth Eo Wijers Regional Landscape Design Competition"* in the Netherlands during the years 2011-2012. The goal of this analysis was to find out to what extent and how is renewable energy science incorporated in SELD. The information for the framework creation was derived from the renewable energy science and the framework consisted of key strategies for renewable energy transition. These key strategies are reduction in energy demand, diversity of energy supply, reduction of fossil fuel emissions and consideration of the energy system components. (de Waal 2015) Table 4 below presents these strategies and their dimensions, which further explains what is meant by the strategy and what is considered important in the design of a sustainable energy landscape.

Table 4. Important strategies and dimensions in SELD (de Waal et al. 2015)

<table>
<tr><th>Origin</th><th>Strategy</th><th>Dimension Present in the Entries</th></tr>
<tr><td rowspan="9">Renewable energy science</td><td rowspan="2">Reductions in energy demand</td><td>Proposals for improving energy efficiency, e.g., by energy saving measures</td></tr>
<tr><td>Reference to goals for energy efficiency and/or renewable energy generation in specific, quantitative terms</td></tr>
<tr><td rowspan="4">Diversity of supply</td><td>Catering for the regional energy demand using at least two options derived from electricity, heat, and (transport) fuels</td></tr>
<tr><td>Making use of at least one renewable energy source and/or conversion technology</td></tr>
<tr><td>Making use of more than one kind of renewable energy source and/or conversion technology and in this way acknowledging the need for a diversified energy mix</td></tr>
<tr><td>Calculations indicating the contribution of proposed energy-conscious interventions</td></tr>
<tr><td>Reduction of fossil fuel emissions</td><td>Proposals for the use of CCS (Carbon Capture and Storage) and/or alternative solutions for reducing fossil fuel emissions</td></tr>
<tr><td rowspan="2">Consideration of the energy system components</td><td>Proposals for at least two of the following: energy generation, energy distribution, and energy storage</td></tr>
<tr><td>Proposals for energy generation, energy distribution and energy storage that acknowledging the fact that energy-conscious interventions should be seen as components of a larger energy system</td></tr>
</table>

The results of the analysis revealed that the application of these four key strategies, and thus the application of renewable energy science, in SELD was insufficient in *"The Ninth Eo Wijers Regional Landscape Design Competition."* Furthermore, de Waal et al. conclude that it would be important to use *"evidence-based approaches to landscape design, in terms of enhancing its development as a socially relevant academic discipline and one that has important implications for sustainable energy transitions."* This can be done by implementing these key strategies from renewable energy science to the design of sustainable energy landscapes. Indeed, these strategies and dimensions could be used as a checklist when planning renewable energy interventions for a specific location (e.g. urban area). This checklist could inform the designer important aspects that need to be taken into consideration in order to design a sustainable energy landscape.

2.2 Current state in local renewable energy and energy efficiency planning in Europe

This section will discuss the current state in local renewable energy and energy efficiency planning in Europe by first presenting three European Union (EU) projects (Covenant of Mayors, City-zen and Transform) related to this subject and their processes and results. This section will end by presenting the measures that certain municipalities in Germany have taken and the lessons that they have learned in their sustainable energy transition. The information in this section forms the atlas of case studies that can be used in the methodological framework for finding needed actions for the case of Turku.

2.2.1 Covenant of Mayors (CoM)

CoM is an initiative launched by the European Union to increase the energy efficiency and usage of renewable energy in Europe (Schenone et al. 2015). European municipalities, who can voluntarily join this initiative, are committed to meet and exceed the European Union 20% CO_2 reduction objective by 2020 (The Covenant of Mayors 2015) and thus contribute to the goals of the Kyoto protocol (Schenone et al. 2015). Municipalities who join this initiative have to come up with a Sustainable Energy Action Plan (SEAP) in which the municipalities explain how they are going to reach the CO_2 reduction objective. The idea behind SEAP is that environmental policy, aimed at reducing CO_2, decided on high levels of governance (e.g. EU) needs to be tailored to actual situation in local conditions. Furthermore, SEAP emphasizes the importance of coordination between several actors on the municipality level. These actors can be for example public institutions, private stakeholders and ordinary citizens. (Schenone et al. 2015)

SEAP includes three phases, which are preparation, implementation and monitoring. The starting point of the SEAP is the execution of "*Baseline Emission Inventory*" (BEI), which quantifies the energy consumption and the emissions of a municipality in the current state or in a reference year. Furthermore, BEI shows actions to be taken in order to achieve the CO_2 reduction targets. The next stages of SEAP are the implementation of the presented actions, organizing monitoring activities and communicating and disseminating all related activities and experiences**.** (Schenone et al. 2015)

Table 5 below presents examples of the actions that some of the cities in the CoM initiative have taken towards CO_2 reduction. Furthermore, a short description of a SEAP study conducted in Genoa Italy is presented in order to highlight the steps taken in that process. The most important emphasis is put on the planned actions of the Genoa city. (Schenone et al. 2015) The actions presented in the tables below (Table 5 and 6) can be used as a benchmark for other cities sharing the same goals.

Table 5. Examples of city level action in CoM (Case Studies 2015)

City	Action	Description
Bristol (UK)	Green ICT for business and community	Making a website where local business can share expertise and best practices (e.g. replacing desktop computers with laptops and server virtualization, to the immediate, such as monitoring printer usage and requesting paperless billing.
Budabest	Green energy from the spa to the zoo	The heat in the spa is recycled to the zoo through heat exchangers
Gothenburg	From waste to wheels	Production of biogas from Gothenburg's sewage water-treatment system for use in cars and buses
Ivanić-Grad (Croatia)	Engaging citizens for energy-efficiency	Making citizens sign a personal energy-saving pledge and to have their energy consumption monitored
Vilnus	Urban renovation for energy efficiency	Creation of an innovative interactive energy classification map, displaying actual energy performance for every residential block

SEAP in Genoa

In the BEI the energy consumption and emissions were divided into two sectors: *"Buildings, equipment/facilities and industry"* and *"Transport."* The reference year was 2005 and the total emissions in that year where found to be 2.271,913 tons. Subsequently, the effectiveness of each actions presented in SEAP was compared to this value. (Schenone et al. 2015)

Overall, 77 actions were defined in the action plan. These actions were divided in the sectors of buildings and public lighting, local transport, local energy production and CHP, municipal planning and land-use and other actions. (Schenone et al. 2015) The following Table 6 will show examples of the actions for each sector.

Table 6. Examples of planned actions in SEAP Genoa (Schenone et al. 2015)

Sector	**Action**
Buildings and public lighting	- Increase of thermal insulation in new buildings - Energy audits for existing buildings in order to identify most appropriate and cost-effective technical solutions - Creation of general database including heat, electricity and hydro consumption - New rules for energy savings in buildings (e.g. home automation control systems for centralized heating) - Energy savings through air-conditioning system improvements and home automation - Performing an energy audit - Revamping of centralized heating systems, construction of RES plants - Replacement of low efficient light bulbs with modern high-efficiency lamps and LED lighting
Local Transport	- Implementation of alternative means of transport (e.g. transport, surface and underground local public transport, cycle paths, pedestrian isles, intermodal use of public elevators, funiculars, and introduction of increased water-based transport (Navebus)). - Rationalization of municipal fleet and more car sharing
Local energy production and CHP	- Use of offshore wind power platforms - Thermodynamic solar energy plant for educational and dissemination purposes - Increase in CHP and District Heating and Cooling (DHC) by expanding CHP/CCHP plants and related DHC networks
Municipal planning and land-use	- Conducting a Municipal Regulatory Master Plan
Other actions	- Promoting green procurement (e.g. furniture from recycled wood and non-toxic materials, low-consumption electronic devices, paper recycling in excess of 70%, and low-emission vehicles for the municipal fleet) - Involve citizens and stakeholders in a dialogue on energy sustainability to create a shared method for public decision-making and to respond appropriately to local community needs.

Finally, the SEAP monitoring actions consist of monitoring reports, which evaluate the progress of each action and calculate the actual CO_2 reductions. When the projects move on, a new BEI report will be done in order to update the emission inventory. According to this information adjustments can be made to the action plan by removing inefficient actions from the list and adding new actions based on the new conditions in the city. (Schenone et al. 2015)

2.2.2 City-zen

The objective of the EU project City-zen is to provide methodologies and tools to cities and their citizens to realize and boost energy efficiency towards 2020 and beyond in existing cities. In order to attain this objective a theoretical framework will be constructed so that suitable actions can be defined for different cities. Important in this framework is that it will be developed so that city planners and also other stakeholders (e.g. citizens) can use this framework. (Broersma & Fremouw 2015)

The theoretical framework consists of the six following steps. For some of the steps a further elaboration is given.

1. Map the present and near future
    - 1.1. Collect data on the geographical-physical environment (e.g. city's climate)
    - 1.2. Map and analyse the technical energetic potentials
    - 1.3. Analyse and map the economic system and financial barriers and opportunities
    - 1.4. Analyse the social environment
    - 1.5. Analyse the political and legal environment
    - 1.6. Map the near future (information from previous steps processed into an energy atlas, using the Energy Potential Mapping method)
2. Select potentially suitable measures
3. Determine scenarios
4. Create a vision
5. Define the roadmap (backcasting can be used)
6. Re-calibrate and adjust (process monitoring, compare milestones to targets) (Broersma & Fremouw 2015)

The Energy Potential Mapping (EPM) method mentioned in the step 1.6 *"aims to visualise the energy potentials and demands by making information of quantity, quality and location of demand and supply accessible."* (Broersma et al. 2013)

City-zen project is an ongoing project that won't be finished until 2019 (Broersma & Fremouw 2015). One activity during this project is to organise workshops in demonstration cities in order to reduce the gap between innovation and implementation and to share material knowledge (Objectives 2015). The theoretical framework will also be still expanded, tested and improved. The organised roadshows and co-authored follow-up papers in the coming years will further refine the City-zen process and elaborate its methodology (Broersma & Fremouw 2015).

2.2.3 Transform

Transform is a European funded program, which main goal is to develop a Transformation Agenda for European cities that have ambitious CO_2 reduction plans and that want to realize those ambitions. The cities involved in this program are Amsterdam, Copenhagen, Genoa, Hamburg, Vienna and the Grand Lyon metropolitan area. In the beginning these cities have already developed an energy strategy and the mission of Transform is to use this strategy to accelerate and optimize existing processes. The aim is to come up with the Transformation Agenda for the city. Transform supports the cities in their efforts by providing insights into how to come up with smart energy plans and executable projects. Important aspect in this process is a strong stakeholder involvement and that the plans and projects take into account all relevant energy flows, environmental aspects, urban mobility, water and waste. With the help of this program other similar projects can benefit from its learned lessons. (Transform 2015)

In the following a short description will be given of the Amsterdam's Transformation agenda. The description will concentrate only to the aspects described about renewable energy and energy efficiency in the city. Other aspects of the agenda are clean air, circular economy, climate-resilient city and sustainable municipality.

The targets of Amsterdam are:

- "*Renewable energy: between 2013 and 2020, renewable energy generation per capita will be increased by 20 per cent;*
- *Renewable energy: between 2013 and 2020, energy consumption per capita will be reduced by 20 per cent"* (Transformation agenda Amsterdam 2015)

The Transformation Agenda also presents interventions that Amsterdam is planning to make to achieve these targets. Some of these interventions are highlighted in the Table 7 below.

Table 7. Amsterdam's interventions related to renewable energy and energy efficiency (Transformation agenda Amsterdam 2015)

Intervention	Description
Increasing wind power	Establishing locations for wind turbines and enabling Amsterdam's residents to participate
Increasing solar power	Taking measures such as actively highlighting the potential of solar energy among target groups in the city, easing planning permission regulations, supporting projects and concluding agreements with housing associations and businesses about exploiting their roofs
Facilitating an increase in the number of connections to district heating	Drawing up a Heating Action Plan for the purpose, with an emphasis on the accessibility of the network, affordability of the solution and sustainability of resources
Committing to energy-neutral new construction	Weighing sustainability for at least 30 per cent (in significance) in the criteria used to select development plans and developers

Finally, the agenda determines the ways in which the municipality of Amsterdam can manage the energy transition efficiently. These activities include looking for flexibility in the municipalities' regulations, finding ways to finance the transition (setting up an energy fund), increasing understanding by developing a data programme, collaborate and make agreements within the city and monitor the transition process. (Transformation agenda Amsterdam 2015)

2.2.4 Municipalities in Germany

Germany is committed to produce 80% of its electricity from renewable energy by 2050 and its transition to renewable energy is widely recognized as the leading transition approach (Busch & McCormick 2014). Municipalities all over Germany are key players in contributing to this transition (Schönberger 2013) and that is why it is interesting to find out some of their stories in the transition towards renewable energy production and energy efficiency.

This part will discuss the barriers that the municipalities are facing and the measures that they have taken in their energy transition projects. Furthermore, the lessons learned from these projects are presented. These insights are drawn from the literature that discusses the German municipalities' involvement in enhancing renewable energy and energy efficiency in their area.

The measures are divided into five different modes: overarching measures, consumer behaviour of the municipal administration, regulation and planning, provision of energy, public transport and housing: municipality as business actor and support and information. This follows the structure that is used in Schönberger (2013) for the opportunity and instrument division of municipal renewable energy policy.

Municipalities' measures

Overarching measures: These measures are *"targets concerning the local share of renewable energy or the reduction of greenhouse gas emissions, local energy and climate action plans, cooperation with other municipalities, and the personnel institutionalisation of renewable energy and climate protection within the municipal administration."* (Schönberger 2013) They are seen useful in improving long-term orientation, creating a reliable environment for investors, justifying renewable energy regulations and to make sure agreed measures are implemented accordingly. Furthermore, budgetary crises are common in the municipalities nowadays and especially the cooperation with other municipalities can be a way of cutting down costs (e.g. co-establishment of energy consulting services. (Schönberger 2013)

One example of overarching measure comes from the German municipality of Saerbeck. In order to achieve their goal of being energy neutral and fully energy self-sufficient by 2030 the municipality developed a concept *Integriertes Klimaschutz- und Klimaanpassungskonzep,* that include seven spheres of activities and 150 individual measures to achieve the goal of 2030. Workshops and information evenings were held in order to build this concept. (Hoppe et al. 2015)

Consumer behaviour of the municipal administration: The municipal administration can take measures in their activities that can increase the usage of renewable energy and energy efficiency in the municipality area. These measures can be for example purchasing green power for the municipal buildings, installing photovoltaic systems on the roofs of municipal buildings, using biofuels in the municipal transport and practising green procurement. Taking these measures can legitimise the municipality's future regulations concerning renewable energy and energy efficiency and possible reduce costs in their own activities. (Schönberger 2013)

A suitable example to this mode comes again from the municipality of Saerbeck. There the municipality bought a former federal army munitions depot and started to build a bioenergy park to this location. Currently the park includes wind turbines, biogas plants and PV panels. This park produces 275% more renewable energy than the town needs. (Hoppe et al. 2015)

Regulation and planning: Through regulation and planning the municipalities can increase the usage of renewable energy and energy efficiency. Examples of these measures are building codes (obliges the owner to implement renewable energy and energy efficiency), urban development contracts (to determine the renewable energy and energy efficiency requirements) and designation of areas for renewable energy production. (Schönberger 2013)

Provision of energy, public transport and housing: the municipality as business actor: The way a municipality provisions energy, public transport and housing in their area affects the usage of renewable energy and energy efficiency. Municipality can for example produce renewable energy for the city by themselves or buy green energy and sell it to their citizens. Concerning the housing sector the municipality can found housing companies, which can build high energy efficient buildings that use renewable energy sources. (Schönberger 2013)

Support and information: These measures include energy consulting services, public relations and educational work, financial incentive programmes, and support/attraction of investment in renewable energy. (Schönberger 2013)

The municipality of Prenzlau in Germany gives financial support, through a special fund, to support the solar installations and citizen-owned solar systems in the town (Busch & McCormick 2014). Furthermore, the town of Saerbeck conducted a survey to have better information of the residents' needs and wishes concerning the renewable energy and energy efficiency (Hoppe et al. 2015).

Lessons learned

Increasing network activities is a trend that can be observed in the local renewable energy projects in Germany. These activities include cooperation within the municipality between administrations, citizens and non-governmental organizations and companies. Also different municipalities and cities cooperate with each other in order to share best practices towards renewable energy system and energy efficiency. (Schönberger 2013) Hoppe et al. (2015) emphasize the importance of this cooperation on the way to success in these projects. Especially how public officials interact with local actors and their professional networks at national and regional level and how much trust has been built in these relations are seen important. Furthermore managing expectations (i.e. how projects are presented to the public and whether they live up to the promises) and facilitation of learning are seen crucial. (Hoppe et al. 2015)

Finally, Busch & McCormick (2014) point out an interesting lesson learned in their article. They conclude that initiators of local energy transitions should not motive other actors by referring to abstract aspects like climate change or global energy transition. Instead, positive local impacts that profit several actors, are more important and effective when motivating local actors in the renewable energy transition. Moreover, it is seen important to focus on drivers and possibilities in the community instead of concentrating on the obstructions. (Busch & McCormick 2014)

2.3 Conclusion

The first part of the literature review presented the developments in BC, TM and SELD. These developments can be used to elaborate and strengthen the Ricken (2012) framework and to make the framework more suitable for urban environment. The second part presented the current state in local renewable energy and energy efficiency planning in Europe. This second part will also elaborate and strengthen the Ricken (2012) framework and form an atlas of case studies, which can be used in the methodological framework for finding needed actions for the case of Turku. All the suitable additions and modifications to the Ricken (2012) framework can be found from the Table 8 below.

3. Methodology development for the case of Turku

3.1 Research framework

The methodological framework of Ricken (2012) presented in the literature review part offers the methodological basis for exploring how to develop and implement locally a sustainable and self-sufficient energy system. However, this methodological framework was used for exploring the Wadden island Texel in the Netherlands, which cannot be considered as an urban area like the city of Turku in Finland. Therefore, the intention in this part is to use the information provided in the literature review part to make the methodological framework more suitable for exploring an urban area and to correct the discrepancies found in the Ricken methodology and BC framework. Furthermore, the developments of BC and SELD discussed in the literature review part will help in making the methodological framework more robust by answering to the shortcomings of these methods found from the literature. Figure 2 illustrates the research framework for this thesis.

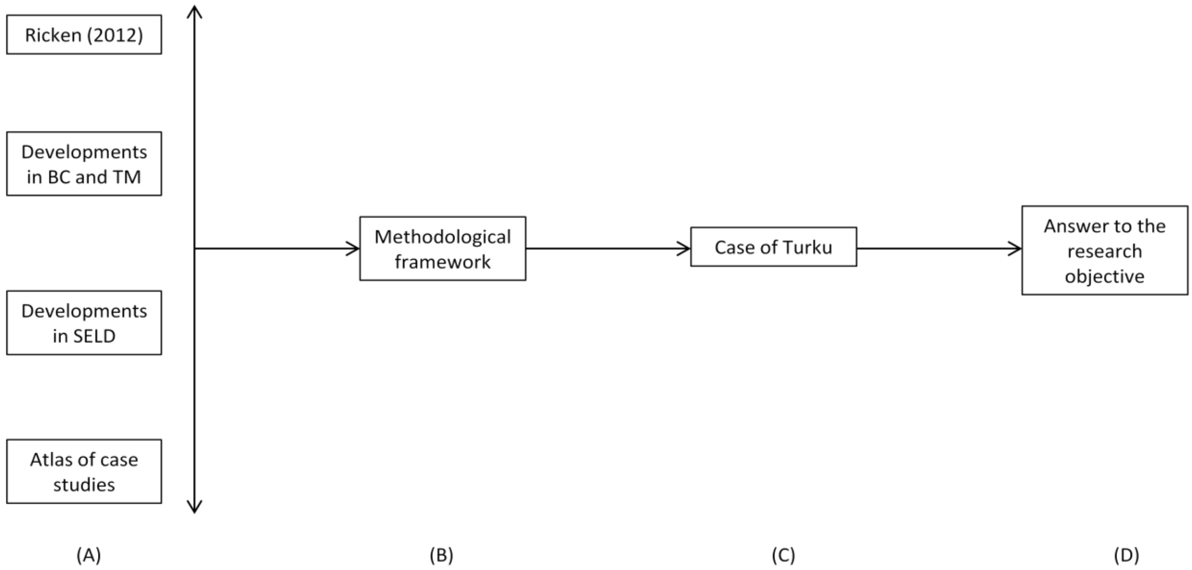


Figure 2. The research framework for the case of Turku

Figure 2 above reads as follows. After having studied Ricken (2012) and developments in BC, TM and SELD as well as after forming the atlas of case studies, the methodological framework of the thesis will be constructed (A). The basis of the methodological framework will come from the Ricken (2012) and it will be further strengthened and also guided towards exploring an urban area by using the information from part A of the research framework (B). This research framework will be used to explore the case of Turku in Finland (C) and this exploration will give an answer to the research objective described in the section 1.2 (D). The construction of the methodological framework will be explained in the following part 3.2.

3.2 Methodological framework of research

The Table 8 below shows which parts from the literature review will be added to the Ricken (2012) methodological framework. After these additions the methodological framework for the case of Turku can be constructed. Furthermore, the Table 9 below presents this methodological framework. In this framework the parts added from the literature review to the Ricken (2012) are included. The added parts were chosen because they are seen to make the methodological framework more robust and better suitable for exploring an urban area.

Table 8. Elaboration of the Ricken (2012) methodological framework

Ricken (2012): Steps	Developments in BC and TM	Developments in SELD	Atlas of case studies
1. Strategic problem orienation	Examination of agency dynamics Identification of disruptive technologies and social innovations through interviews and expert workshop.		Describing the climate conditions of Turku
2. Construction of scenarios	Estimates of the environmental improvement potential Expressing the key priorities (including values and norms) and guiding principles that are considered as the baseline conditions that the future urban system should comply with. Establishing clear and vivid images (mainly in the form of narratives) of the desirable sustainable future of the city; this vision and its scenario are meant to have a mobilising and guiding function and to contain 'living' material that can trigger a shift in mind-set.		
3. Backcasting analysis	Expert or stakeholder workshops to determine the needed changes Taking into consideration McCormick et al. (2013) themes for advancing sustainable urban transformation Adding drivers and barriers analysis to this step	Taking into consideration the key strategies of renewable energy science from de Waal et al. (2015) Evaluating the spatial interventions according to the sustainability criteria of Stremke (2015) when planning spatial interventions	
4. Elaboration (change to "pathways")			Adding suitable measures for Turku from the case-study examples
5. Implementation (change to "follow-up")	Describing ways to stimulate follow-up		

Table 9. Methodological framework for Turku

	Steps	Tasks	Description
Stakeholder involvement	1. Strategic problem orientation	• Specify goals, targets, boundaries and current status (theory, methodology and practice) of the research	Defining goals, targets, boundaries and current status (theory, methodology and practice) of the research
		• Present landscape characteristics	Presenting the characteristics of the landscape in the city
		• Present the climate conditions	Presenting the climate conditions of the city
		• Present employment, economic and education situation	Presenting employment, economic and education situation of the city
		• Determine the present energy system	Determining the current energy supply and energy demand in the city.
		• Identify renewable energy potentials	Identifying renewable energy potentials. This tasks includes also the identification of energy conservation potential in Turku.
		• Define current developments	Defining current political, economic, social, technological, environmental and spatial trends and projects related to RES which concern the city
		• Identify stakeholders	Identifying the stakeholders that are involved and their interest, power and influences regarding the vision.
	2. Construction of scenarios	• Estimate the energy demand	Estimations of the energy demand of Turku in 2030 will be presented
		• Define exogenous variables	Defining possible factors that can offer a certain constraint or an opportunity in the construction of the scenario.
		• Construct desirable scenarios	Constructing different scenarios, which take into account the desirable future vision. Estimates of the environmental improvement potential of future RES can be included. Furthermore, key priorities and guiding principles as well as clear and vivid images should be created.
	3. Backcasting analysis	• Identify suitable spatial interventions	Indicating which interventions should be implemented for achieving the constructed scenarios and evaluating the robustness of these possible interventions. The sustainability of the interventions can be also evaluated. Moreover, taking into account the key strategies of RE science when planning these interventions.
		• Define necessary changes	Defining political, economic, social, technological, environmental and spatial changes that are necessary for achieving the constructed desirable vision. Also taking into account the McCormick et al. (2013) themes for advancing sustainable urban transformation.
		• Identify drivers and barriers	Identifying the main drivers and barriers for achieving the constructed desirable vision.
		• Expert or stakeholder workshop	Organizing an expert or stakeholder workshop in order to define further necessary changes and identifying disruptive technologies and social innovations.
	4. Pathways	• Define possible pathways	Defining possible pathways that can lead to achieving the constructed desirable vision. Suitable measures for reaching the vision will be defined from the atlas of case studies and from McCormick et al. (2013).
	5. Follow-up	• Contruct follow-up agenda	Construction an action agenda in which is described what the stakeholders should do to work towards the desirable future.
		• Stimulate follow-up	Describing ways to stimulate follow-up.

3.3 Research questions

Based on the information provided in the previous sections the research questions can be formulated. The main research question of this thesis is:

What are the potentials, barriers and possibilities for developing and implementing a renewable energy system that can make the municipality of Turku energy independent by 2030 and what steps need to be taken to achieve this?

The sub-questions are:

- What is the status of the present energy system in Turku?
- What are the potentials of renewable energy in Turku?
- What are the developments concerning the RES and energy independence in Turku?
- What kind of vision and scenarios can be build which will lead to the RES and energy independence with renewable energies in Turku by 2030?
- What changes and interventions are needed for the vision?
- What changes were indentified in the stakeholder workshop?
- What kind of disruptive technologies and social innovations can be identified that can help in the transition towards the RES in Turku?
- What are the drivers and barriers of the vision?
- What are the pathways towards the RES and energy independence by renewable energies?
- What can different stakeholders do to achieve the future vision?
- In which ways these stakeholders could be stimulated in achieving the future vision?

The Figure 3 below links the methodological framework to these research questions above.

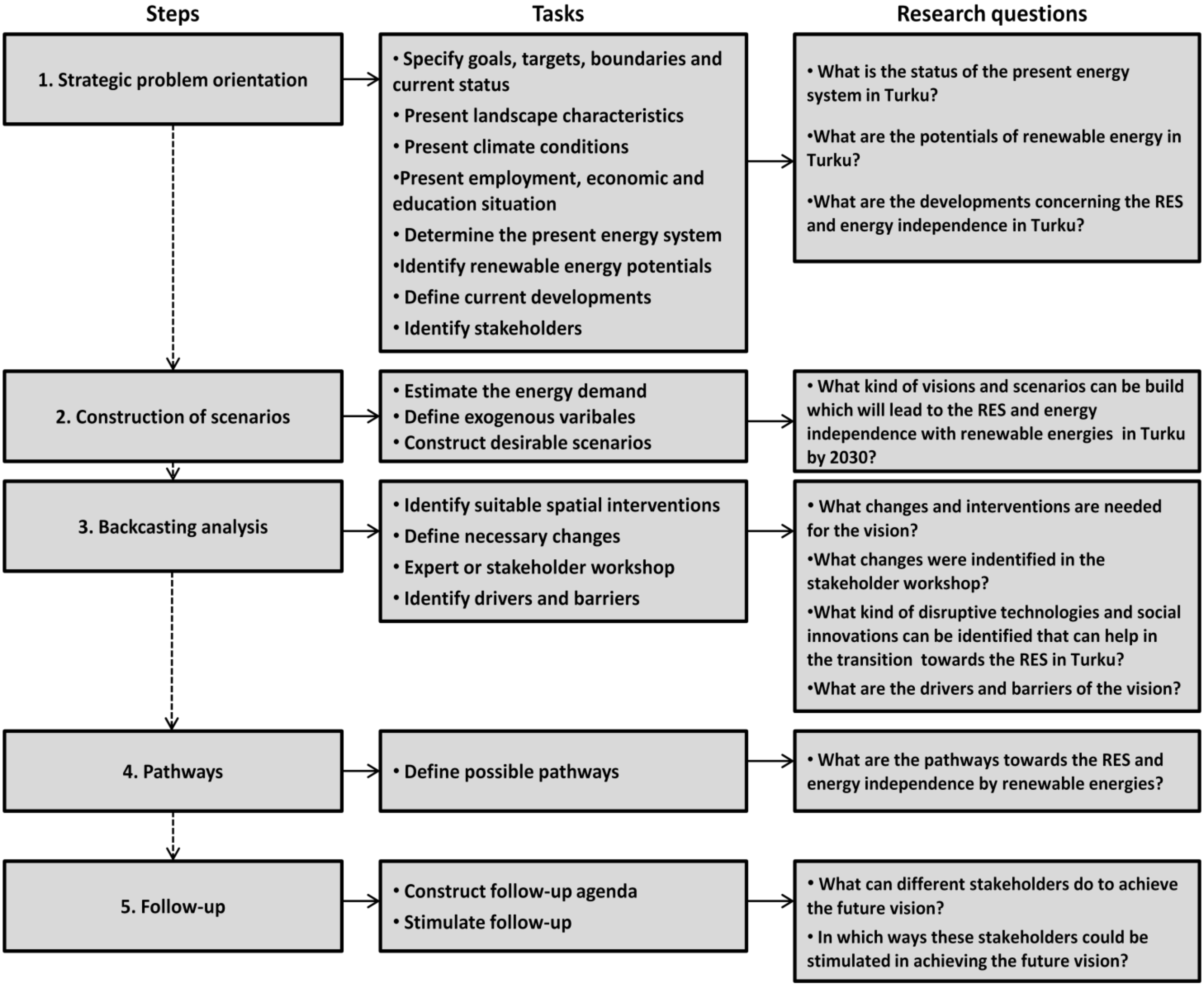


Figure 3. Methodological framework of Turku linked to research questions

4. Definitions

The following table 10 presents the definitions for the key concepts of this research.

Table 10. Definitions to key concepts of this research

Concept	Definition
Energy independency	Meeting the total direct energy need of a certain area (e.g. city) by using only the renewable energy sources of this area.
Renewable energy	Energy derived from resources that are regenerative or for all practical purposes cannot be depleted. The usage of these sources cannot cause harm to the environment.
Renewable energy system (RES)	The generation, supply, distribution and storage of renewable energy. Also the energy efficiency of this system is taken into account.
Renewable energy technology (RET)	Technologies related to renewable energy production, smart grids, energy storage and energy efficiency.
Exogenous variables	Factors that can offer a certain constraint or an opportunity in the construction of the scenarios. The value of these factors is determined by variables outside of the energy system in Turku and its stakeholders (mentioned in the section 8).
Spatial interventions	Interventions to which a suitable location or search area for renewable energy production or storage is indicated. These interventions make better use of local renewable energy qualities and sources.
Scenario	Scenario explains the different characteristics that a certain future state has. Example of this state can be a city which produces its energy fully with renewable energy.
Pathway and roadmap	Pathway and roadmap describe in a timely order the steps that need to be taken to achieve a vision.

5. Guidelines for the research of RES in Turku

The following text presents shortly the aspects that need to be included for each sections of the thesis research part. This text also acted as guidelines for constructing the research part of this thesis.

Strategic problem orientation step

<u>Landscape characteristics and climate conditions</u>

This part will describe the topography and land use in Turku as well as present its built environment and infrastructure. Furthermore, this part will describe the natural qualities and the soil qualities (geological monuments, archaeological values and groundwater protection areas) of Turku. Finally, the climate conditions of the city will be presented.

Data collection for this part will be done through a desk research (internet, reports and articles). Moreover, my contact in the municipality might have information concerning this part.

<u>Present employment, economic and education situation</u>

This part will shortly explain employment, economic and education situation in Turku. Data collection for this part will be done through a desk research (internet, reports and articles). Moreover, my contact in the municipality might have information concerning this part.

<u>Present energy system</u>

This part determines the current energy supply (renewable and non renewable) and energy demand for Turku. Data collection for this part will be done through a desk research (internet, reports and articles) and expert interviews. Moreover, my contact in the municipality might have information concerning this part.

<u>Renewable energy potential</u>

In this part the potential of several renewable energy sources will be examined separately. Initial potentials in Turku include solar, wind, biomass and geothermal. Other possibilities can be considered during the research. Maps of Turku will be created for the potentials in order to indicate where the potential is located in the municipality area. For each renewable potential an example is given and the potentials are compared to the total energy demand of Turku. The intention is to show clearly the match between energy demand and renewable energy potentials. Furthermore, the energy conservation potential of Turku will be determined.

Examples of possible information needs for this part are:

- Average amount of sun per year

- The yearly sum of global irradiation (for summer and winter)

- Capacity of solar panels, thermal collectors and wind turbines

- Efficiency of solar panels and wind turbines

- Total available roof and facade area (for different buildings)

- Average temperature increase when going deep into the ground

- Available biomass of individual farms (agricultural residues), forests, energy crops, food and green waste, industrial waste in Turku?

Data collection for this part will be done through a desk research (internet, reports and articles) and expert interviews. Moreover, my contact in the municipality might have information concerning this part.

Current developments related to RES

In this part the current political, economic, socio-cultural, technological, environmental and spatial trends and policies related to the RES in Turku will be defined. Data collection for this part will be done through a desk research (internet, reports and articles) and expert interviews.

Stakeholder analysis

This part will present the main stakeholders related to the future renewable energy system in Turku. Furthermore, the power and interest of these stakeholders will be presented. Also a power and interest grid will be presented in this part following the instructions in the Hoofdstuk's actor analysis framework. Data collection for this part will be done through a desk research (internet, reports and articles) and expert interviews.

Construction of scenarios

In this part first the energy demand of Turku in 2030 will be estimated. This will be done based on the present conditions and developments described in the previous part. Second, the exogenous variables are identified by performing a PESTEL analysis. Next, vision and scenarios will be constructed. The scenarios will be created based on the information drawn from the present conditions, current developments and exogenous varibales concerning the municipality of Turku. Furthermore, expert interviews and a Master's thesis: *Backcasting for ecologically sustainable urban development: Case study in the city of Turku* (Ahonen 2015) will help to elaborate further the scenarios. Ahonen (2015) describes in her Master's thesis the future city vision 2030 of Turku. Also Ricken (2012) can offer some guidelines in the scenario creation. These sources will give different indications of the possible future state for Turku and through these indications two different scenarios will be tried to be built concerning the RES in Turku.

Backcasting analysis

This part includes the following subjects:

- Identify suitable spatial interventions

- Define necessary changes

- Expert or stakeholder workshop

- Define drivers and barriers

Further information for these subjects can be found from the Table 9.

Pathway and follow up

This part includes the following subjects:

- Define possible pathways

- Construct follow-up agenda

- Pointing out ways to stimulate follow-up

Further information for these subjects can be found from the Table 9.

Conclusions and recommendations

References

Interviews

The target groups for the interviews are, for example, representatives of a local energy provider, sustainability foundations, municipal executive board members responsible for policy on sustainability, research institutes and professors of the Turku University. The initial plan is that the interview questions will mainly concentrate to the following tasks of the methodological framework:

- Analyze the present energy system
- Identify renewable energy potentials
- Define current developments
- Identify stakeholders
- Identify needed changes, drivers and barriers
- Identify needed actions to be taken

Here the stakeholders are seen to contribute the most to the projected outcomes. Moreover, the Ricken (2012) used also the outcomes of its interviews to these parts of the thesis and this was used as an example when deciding this initial interview plan. Furthermore, the interviewees will be asked to name disruptive technologies and social innovations in order to elaborate the possible scenarios and measures for Turku. According to the willingness of the interviewees, the interview will be recorded. Furthermore, notes will be taken during the interview. The Appendix B presents the interview guide that will be used during the interviews. The personal communications part in the end of the thesis will indicate the references for the interviews and for other forms of information acquisition.

6. Present conditions in the municipality of Turku

This section will discuss the present conditions in the municipality of Turku related to the RES. First, the landscape characteristics and climate conditions will be highlighted. Second the employment, economical and educational situation in Turku will be presented. Finally, the present energy system and renewable energy potentials in Turku will be presented and evaluated. These aspects are important in the strategic problem orientation step, because they give an image of the current state of Turku and give information of the renewable energy potential that the city possess and which it can utilize in the future.

6.1 Landscape characteristics

This part presents the landscape characteristics of Turku. Here, the term landscape characteristics comprise visible and non-visible features of the area. These features include the topography and land use, built environment and infrastructure as well as natural and soil qualities. These characteristics are important to take into account when planning for the suitable locations for renewable energy production and for defining necessary changes in the municipality of Turku.

6.1.1 Topography and land use

The city of Turku (in Swedish Åbo) is situated in the southwest coast of Finland as shown in the Image 2 below. Turku is the capital of the Western Province of Finland and used to be the capital of Finland until the year 1812. In 2029 Turku will celebrate its 800th birthday.

The total surface area of Turku is 306 km^2 (Tilastotietoja Turusta 2015) from which 246 km^2 is land area (Tilastokeskus 2015), 3.45 km^2 freshwater area and the rest is sea area (Turku 2015). Turku is situated on the coast of the Baltic Sea and the river Aura that runs to the sea divides the city in two parts. In the centrum of Turku there are seven hills that border the river Aura. The highest peak in Turku is the hill of Karhusauna (88.2 m) (Juomoja 2015) but in general the landform in the municipality is flat.

The population of the municipality is 185 893, which makes Turku the 6th biggest municipality in Finland (Väestötietojärjestelmä 2015). The population density of Turku is 748 habitants/km^2 (Tilastotietoja Turusta 2015) and in the city centre area the population is 42 000 (Turku 2015). The cityscape has stayed spacious thanks to the parks alongside the river of Aura and other parks in the city (Varsinais-Suomen käsikirja 2009). The Image 1 below presents the city centre area of Turku.

Image 1. The city centre of Turku. (Turku 2015)

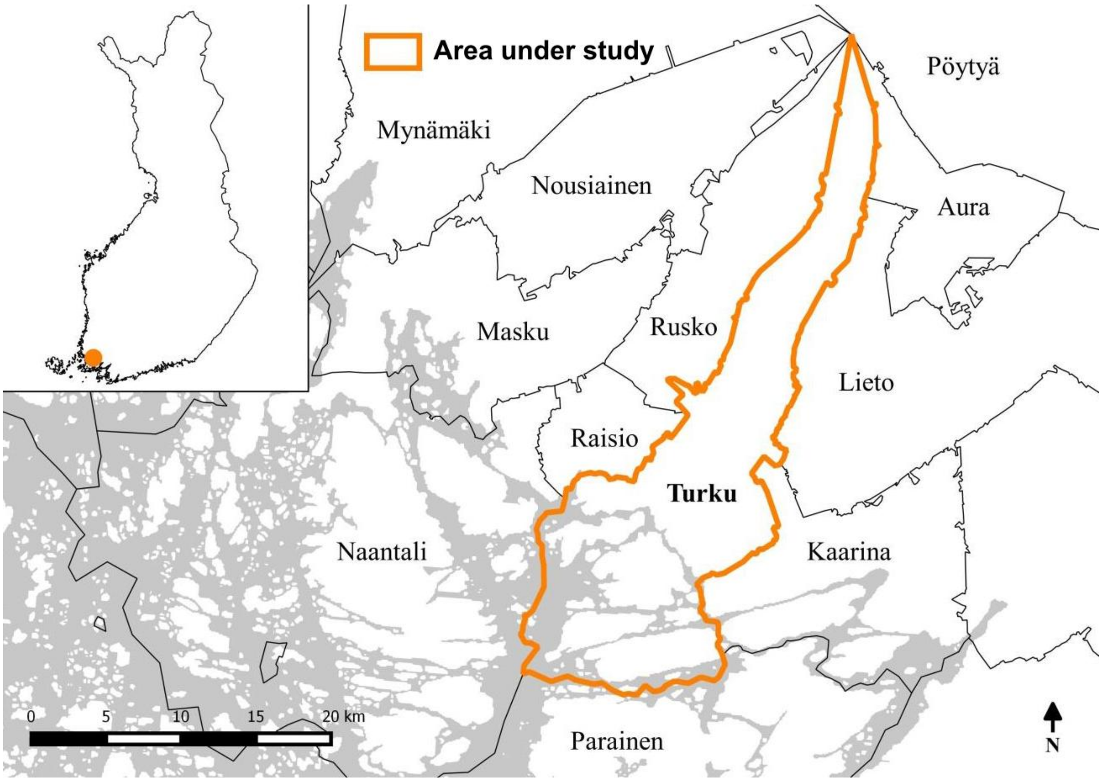


Image 2. The municipality of Turku under study and the surrounding municipalities (Ahonen 2015)
Note: Distance between the northernmost corner to the most southern corner is 45 km. The widest point is 15 km (Turku 2015)

The biggest islands situated in the southwest corner of Turku are Kakskerta, Satava, Hirvensalo ja Ruissalo (Varsinais-Suomen liitto 2010). The area of Turku used to be a part of the archipelago, but due to the natural post-glacial rebound it has partly become part of the continent of Finland. The most important water areas in Turku are the river of Aura, Maarian allas (water reservoir), couple of lakes and the sea area in Turku. Maarian allas is the municipalities reserve water reservoir, which works as a backup water reservoir for the city. (Juomoja 2015) Because of its location, Turku is a notable port city with cargo and passenger shipments going to Mariehamn and Stockholm.

Most of the area in Turku consists of arable land and coniferous and deciduous forests. The forests vegetation belongs to the hemiboreal zone. However, the centrum area consists of widely constructed residential, industrial and service areas. (Juomoja 2015) The landscape of the municipality can be classified into three types: archipelago area in the southwest with forests, arable land and water areas (lakes and sea), continental area in the northeast with forests, arable land and few villages and in the middle the city centre of Turku with residential, industrial and service areas (see Image 3). Other land covers in Turku are harbour and sand beach areas as well as water areas, meadows, parks and warehouse and transport areas. The soil constitutes of rock, peat, mud and clay. (Juomoja 2015)

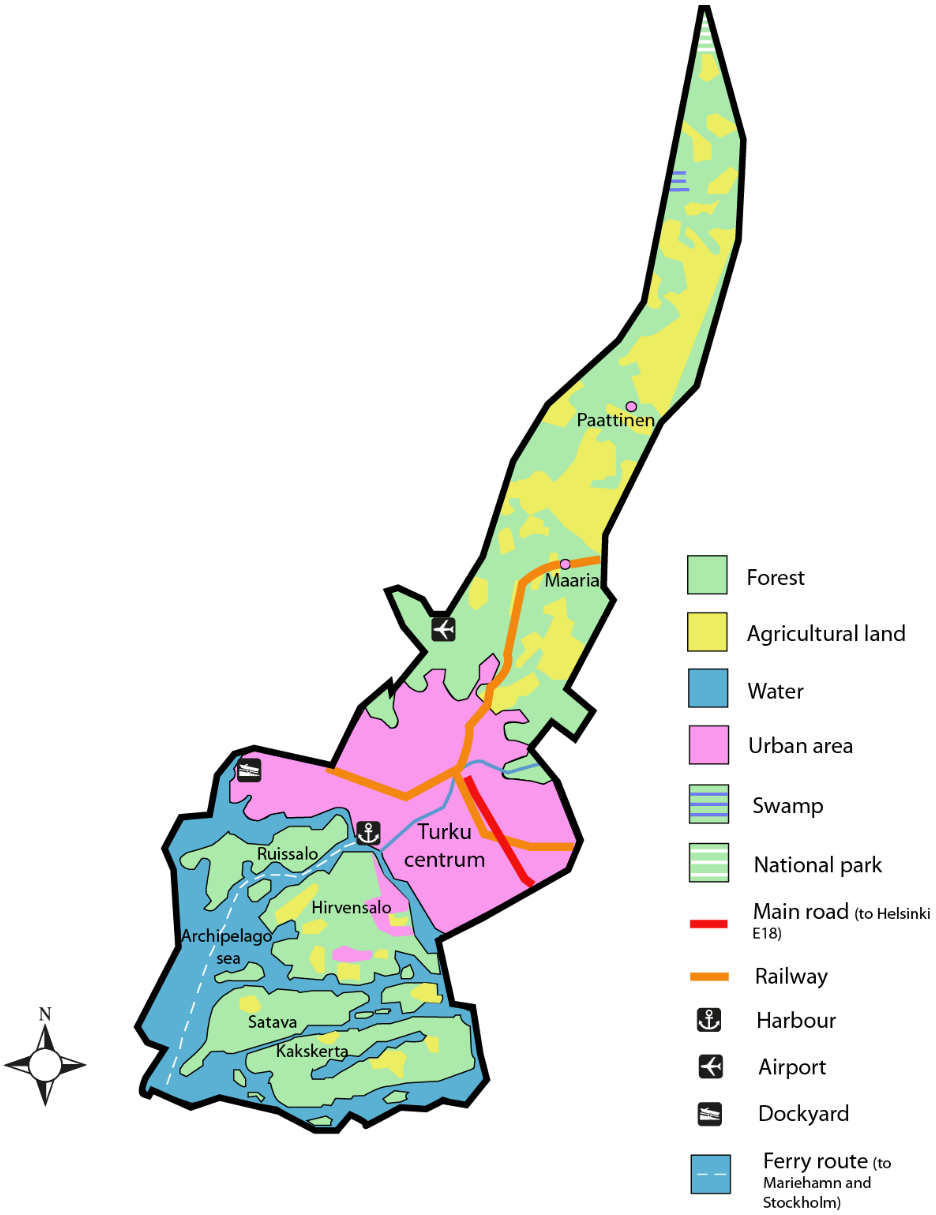


Image 3. Municipality of Turku (Paikkatietoikkuna 2015)

In the year 2010 there were 6635 farms in the municipality, which is 10.6% of the farms in Finland. The size of the agricultural land in Turku is 294 802 hectares, which is 12.3% of the agricultural land of Finland. The farms are producing pork meat (28%), beef (2%), other meat (9%) grain (23%), other plants (19%), eggs (10%) and milk (9%). (Juomoja 2015)

6.1.2 Built environment and infrastructure

Housing stock

In 2014 the total building stock of Turku was 21 806, from which the detached houses are the most common building type with 12 987 houses. The total floor area of the buildings is 15 151 159 m^2 (Tilastokeskuksen PX-Web-tietokannat 2014a) and the total building surface area/person is 38.2 m^2 (Tilastotietoja Turusta 2015). About half of the buildings are privately owned and the rest are rented or other forms of residency (Myytävät asunnot Turku 2015). The Figure 4 below presents the number of different types of buildings in Turku and the Figure 5 presents the age division of the building stock. Furthermore, the Figure 6 presents the heating mode of buildings in Turku in 2014. Electricity, oil and gas were the most common heating modes for the buildings in Turku in 2014.

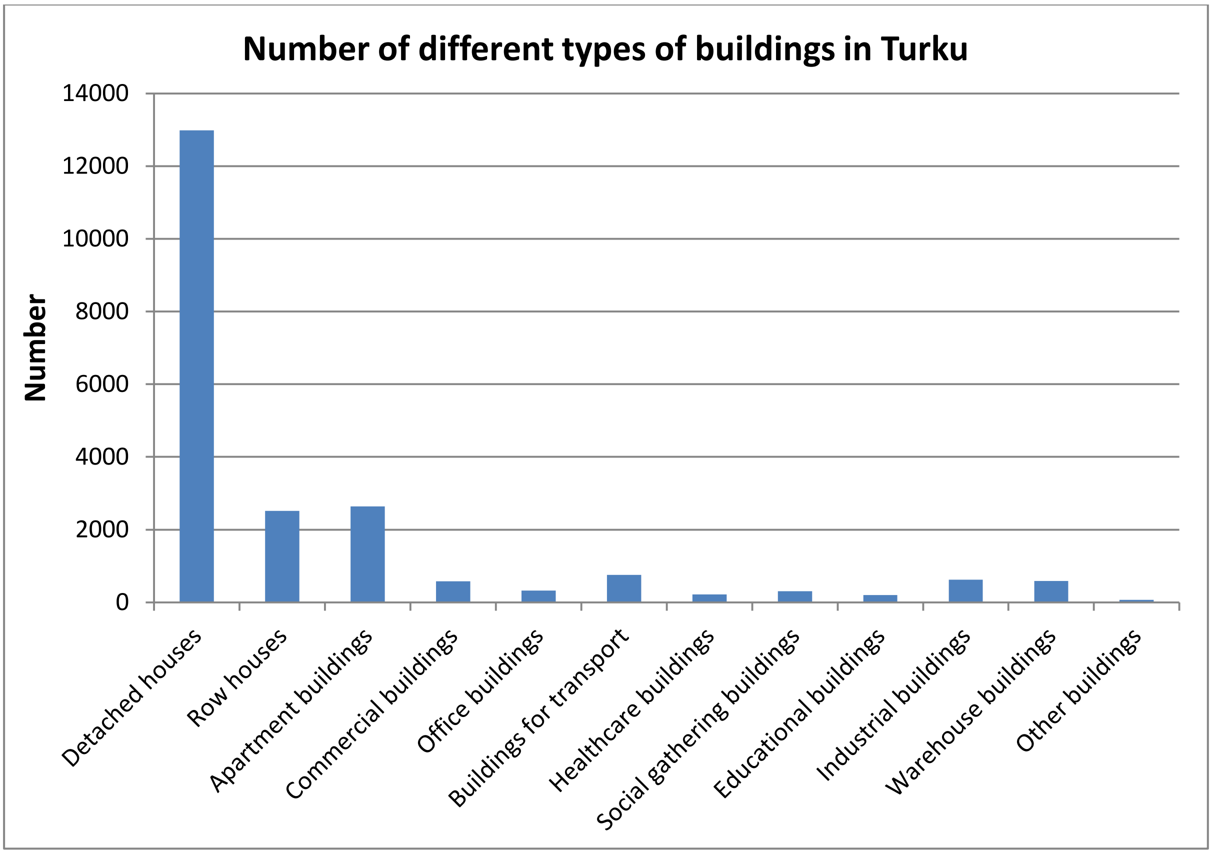


Figure 4. Number of buildings in Turku (Tilastokeskuksen PX-Web-tietokannat 2014a)

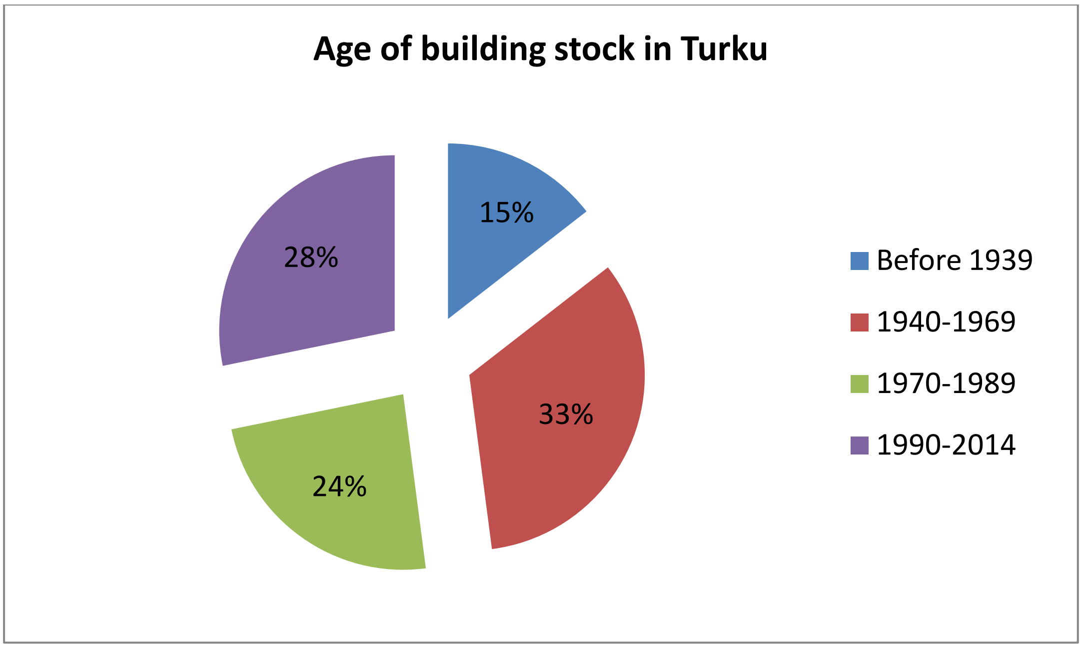


Figure 5. Age of building stock in Turku (Tilastokeskuksen PX-Web-tietokannat 2014a)

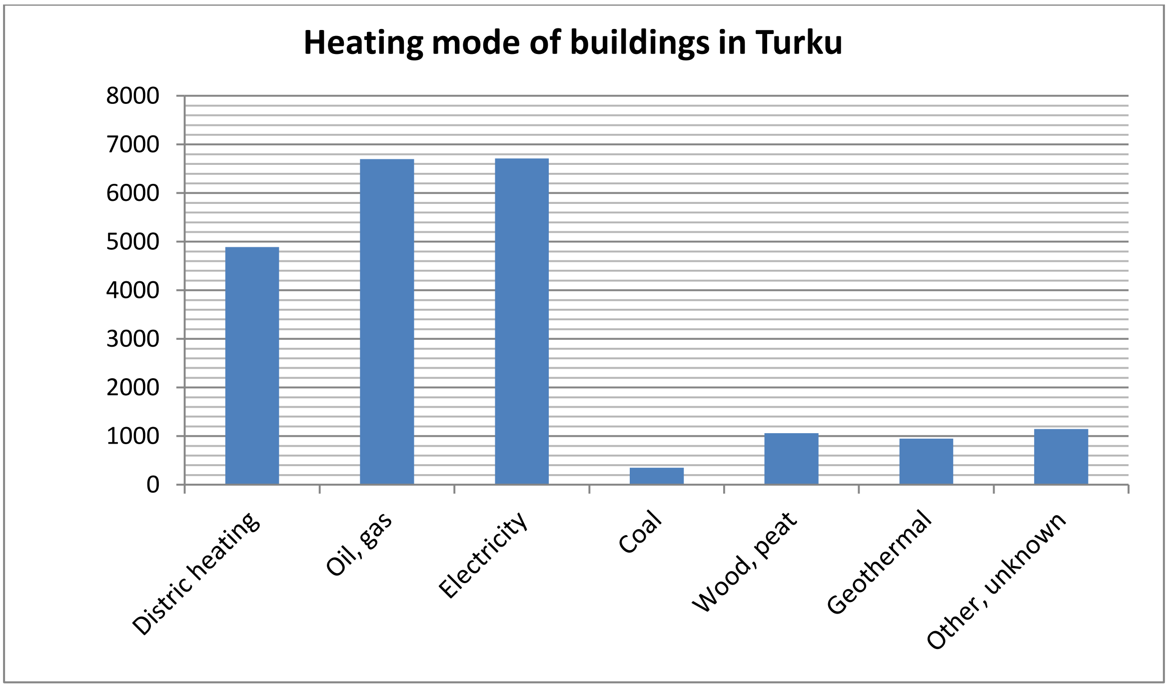


Figure 6. Heating mode of buildings in Turku (number of buildings) (Tilastokeskuksen PX-Web-tietokannat 2014b)

Turku Harbour

The harbour of Turku is the oldest harbour in Finland and currently Finland's second biggest harbour in passenger transport as well as in the top ten in cargo transport. Yearly, approximately 3 million passengers and 2-4 million tons of cargo goes through Turku harbour. (Turun satama 2015) In 2014 2185 vessels arrived to the harbour (Turun Sataman Liikennetilasto 2015). The main transport directions are Germany and Scandinavia (PortofTurku 2015).

Turku airport

The airport is located 8 km to the north from the city centrum of Turku. In the year 2012, 454 984 passengers and 8 012 tons of cargo travelled through the Turku airport, which makes the airport fourth biggest passenger airport and the second biggest cargo airport in Finland. (Turun lentoasema 2015)

Turku dockyard

The dockyard started its operation in the year 1737 and nowadays builds cruise ships, car-passenger ferries and special vessels. To this day the dockyard has built over 1300 ships for customers around the world. The current owner of the dockyard is a Meyer Werft company. The dockyard employs 1400 people and the whole cluster 40 000 people. Thus it can be considered a major employer in the area of Turku. (Meyer Turku at a Glance 2016) The surface area of the dockyard is 144 hectares (Pernon telakka 2015).

Turku Science park

This science park is situated in the city center of Turku and is one of the biggest and oldest science parks in Finland. The main activities in the park are from the fields of biotechnology and ICT. The Turku area is Finland's leading biotechnology area and about half of the pharmaceutical and diagnostics industries are in this area. The science park Turku includes businesses, university buildings and other organizations and employs 17 500 people. Just next to the science park is an industrial area called Itäharju, with small industrial and commercial activities. (Turun seudun yritysalueet 2015)

Logicity

This area close to the Turku Airport has a lot of businesses in the field of logistics. These companies offer transport and warehousing services as well as activities related to the logistics of the high-technology. TNT and DHL are one of the well known companies in the area. (Turun seudun yritysalueet 2015)

Protection of the built environment

The Image 6 below indicates the nationally valuable built cultural environment in Turku. These environments represent development and history of Finland and are important for preserving this heritage. It is important that these areas are built in a way that doesn't conflict with these values. Thus the aim of defining these areas is to preserve these environments and developing them in a way that it goes together with the special features of these areas. (Säteri & Vatilo 2009)

Furthermore, the protected buildings in the municipality of Turku are indicated in the Image 7 below. The aim of the protection is to preserve culturally important buildings, certain building types and the Finnish identity (Rakennussuojelu 2014).

Moreover, the Image 7 shows areas that are important for the cityscape as well as culturohistorically and naturally valuable.

6.1.3 Natural qualities

The municipality of Turku has a diverse natural landscape. In the southwest the sea area with a valuable archipelago, in the middle the city center with modern and ancient urban environment, and in the northeast farming land and forests. This is why there are several protected areas inside the municipality, which include Natura 2000 sites, other conservation areas, nationally and regionally valuable landscapes and bird conservation areas. These areas are not seen suitable for example for wind turbines. (Klap et al. 2011) Here, the characteristics and location of these areas will be described and indicated.

<u>Conservation areas</u>

In the municipality of Turku there are six Natura 2000 sites. These sites are the bay of Friskala, the islands of Kulho, Kurjenrahka national park, Pomponrahka, the Bay of Rauvola and the island of Ruissalo. Natura 2000 is a network of protected areas inside the borders of the European Union (EU). The aim of these areas is to protect its valuable species and habitats and to ensure their long-time survival (Natura 2000). Furthermore there are also some other protected areas in Turku. Some of these areas are described in the Table 11 below. Moreover, the Image 4 below indicates the location of the conservation areas on the map.

Table 11. Description of some conservation areas in Turku

Conservation area	**Description**
The bay of Friskala	The bay is part of the national bird protection program and also a Natura 2000 site. Fifty different bird species nest in this area.
The valley of Katarina	This valley in Turku is partly a hardwood forest and partly meadow with an area of 17 ha. There are also various mushroom species in the area.
The island of Kulho	This island belongs to the Natura 2000 program due to the existence of diverse bird species and rare plants.
Kurjenrahka	Kurjenrahka is a 29 km wide national park know for its primeval forest and swamps. It is commonly used as a hiking area. This national park belongs to the Natura 2000 program.
Metsäkylä-Kuninkoja	This area consists of meadows and forests. Here also different kinds of bird species are present.
Muhkurinmäki	This area has forests and different bird species.
Nunnavuori	On the top of this 63 m hill a protection area of 1 ha can be found, which consists of rocks that were formed during the different ancient stages of the Baltic sea.
Pomponrahka	This is an area with swamps that is part of the national swamp protection program. This area belongs to the Natura 2000 program
The bay of Rauvola	The bay is part of a national bird protection program and also a Natura 2000 site.
Ruissalo	The island of Ruissalo is culturally and naturewise a valuable area in Turku. From Ruissalo one can find old fields, gardens, old buildings and forests. Ruissalo is also a Natura 2000 site.
Toijainen	This protection area is on a hill covered with forest and boulder.

(Luonnonsuojelualueet 2015) (Suomen Natura 2000 – alueet) (Juomoja 2015)

Nationally and regionally valuable landscapes

These landscapes are important cultural sceneries of Finland, which are valuable due to their diverse nature, beautiful sceneries and traditional buildings. The land use and construction law require that these values are taken into account when planning the use of these areas. The aim of these areas is to protect these valuable landscapes and to raise the interest of conserving these areas. (Valtakunnallisesti arvokkaat maisema-alueet 2013)

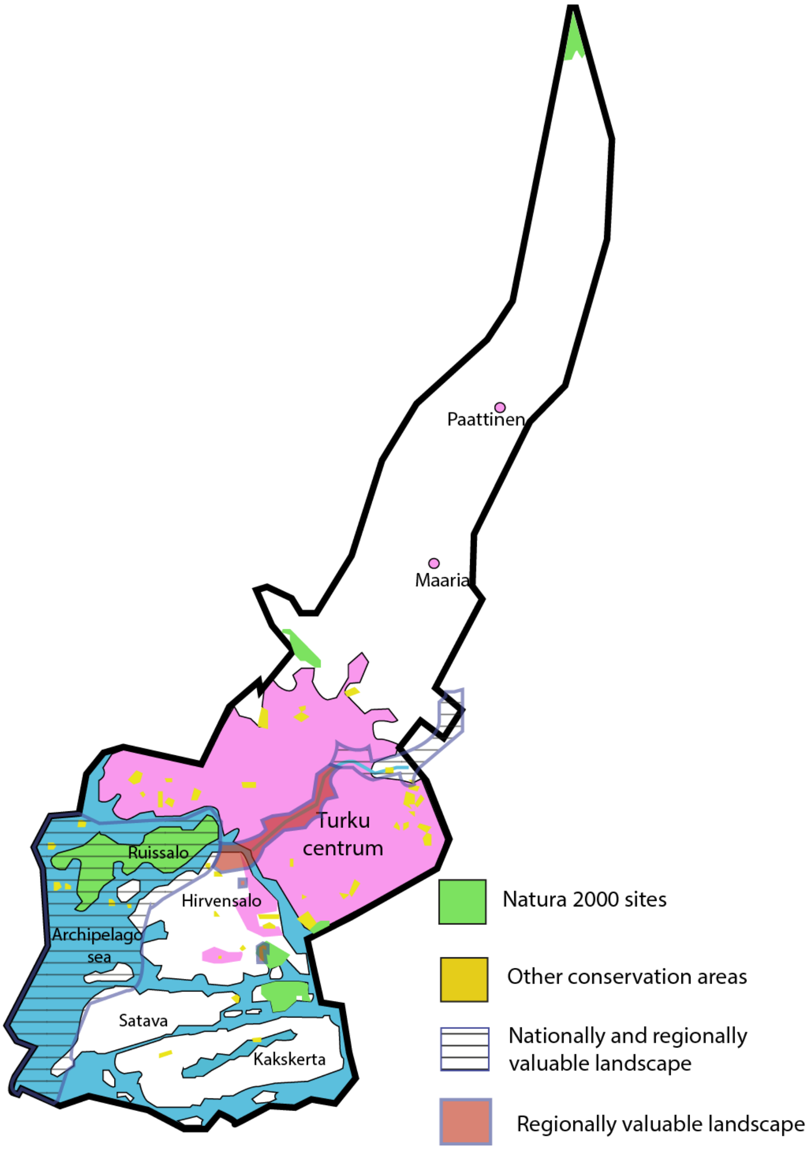


Image 4. Natura 2000 sites, other protected areas and nationally and regionally valuable landscapes in the municipality of Turku (Paikkatietoikkuna 2015) (Yleiskaava 2029) (Lounaispaikka 2015)

<u>Bird habitats (FINIBA)</u>

Finnish Important Bird Areas (FINIBA) program's aim is to preserve the important areas for birds in a way that they are suitable for birds. Another aim is to use these areas to monitor the changes in the bird population and environment. (Leivo et al. 2001) The Image 5 below shows the FINIBA areas in the municipality of Turku.

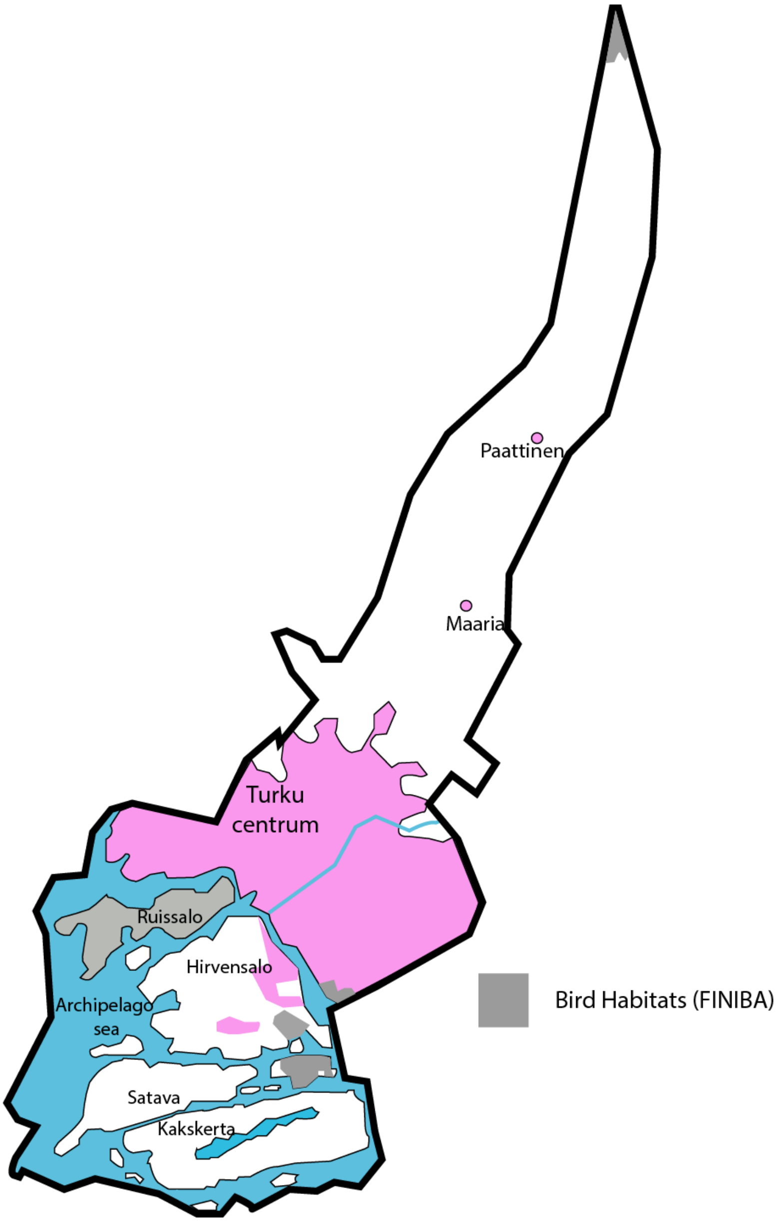


Image 5. FINIBA areas in the municipality of Turku (Lounaispaikka 2015)

The island of Ruissalo belongs also to the IBA area (Important Bird and Biodiversity Areas), which is an universal version of FINIBA. No other IBA areas are present in the municipality of Turku. (Suomen kansainvälisesti tärkeät lintualueet (IBA) 2015)

The protection of sea eagles' nests is also a serious matter in Finland and should be taken into account especially when placing wind turbines. However, this information is classified and thus can't be shown here on map. (Klap et al. 2011)

6.1.4 Soil qualities

The soil and subsoil of the municipality also contain protected areas. These are areas with archaeological values, groundwater protection areas and geological monuments. Here the characteristics and location of these areas will be described and indicated (see Image 6).

Archaeological values

Archaeological values are areas which are protected, because the area contains signs of history and previous habitats. These can be signs of build structures, layers in the landscape, soil, water, which are formed due to the actions of people who have lived in this area long time ago. Examples of these are ancient living areas, cemeteries and archaeological layers of ancient cities. (Muinaisjäännökset (2011) 2015) These areas are protected and only permission given by law can allow changing or removing these areas. (Muinaisjäännökset 2015)

Groundwater protection areas

These areas can have an effect to the quality and formation of the groundwater. Thus these areas are protected in order to prevent polluting the groundwater. In these areas the permeability of the soil is high or the area includes rock and moraine formations that essentially increase the amount of groundwater in the area. The municipality of Turku has three of these areas, which are shown below in the Image 6. (Paikkatietoikkuna 2015)

Geological monument

Geological monuments are geologically important sights that show the developments of soil and bedrock from the time of bedrock's formation until the end of the last ice age (Geologiset luontokohteet 2005). Based on the Maankamara (2015) web viewer the Municipality of Turku has one geological monument close to north-west cost of the island Ruissalo (see image 6). This geological monument is called Kukkarokivi and is Finland's biggest glacial erratic (Kukkarokivi 2015).

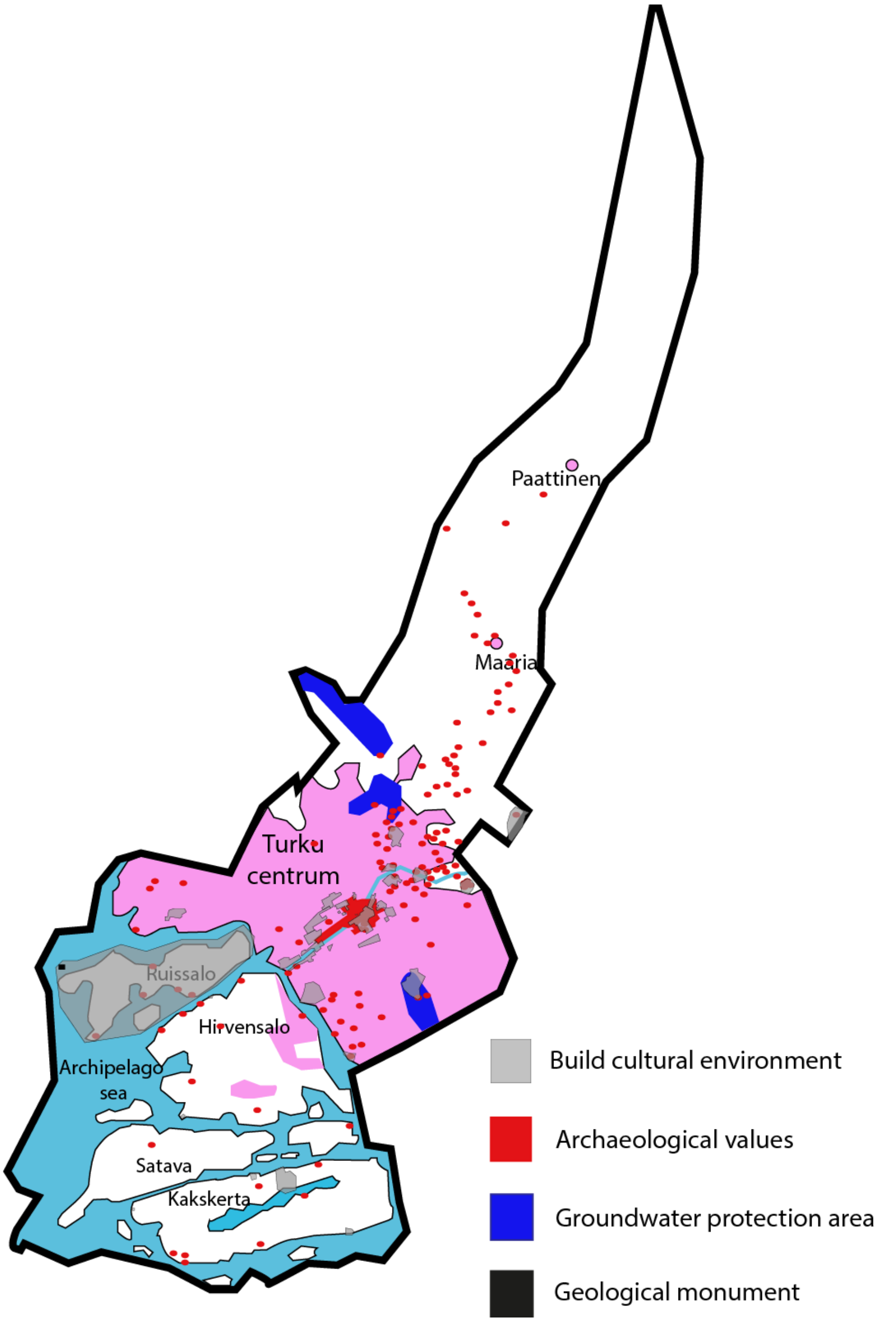


Image 6. Build cultural environment, archaeological values, groundwater protection areas and geological monuments of the municipality of Turku (Paikkatietoikkuna 2015) (Yleiskaava 2029) (Lounaispaikka 2015) (Maankamara 2015)

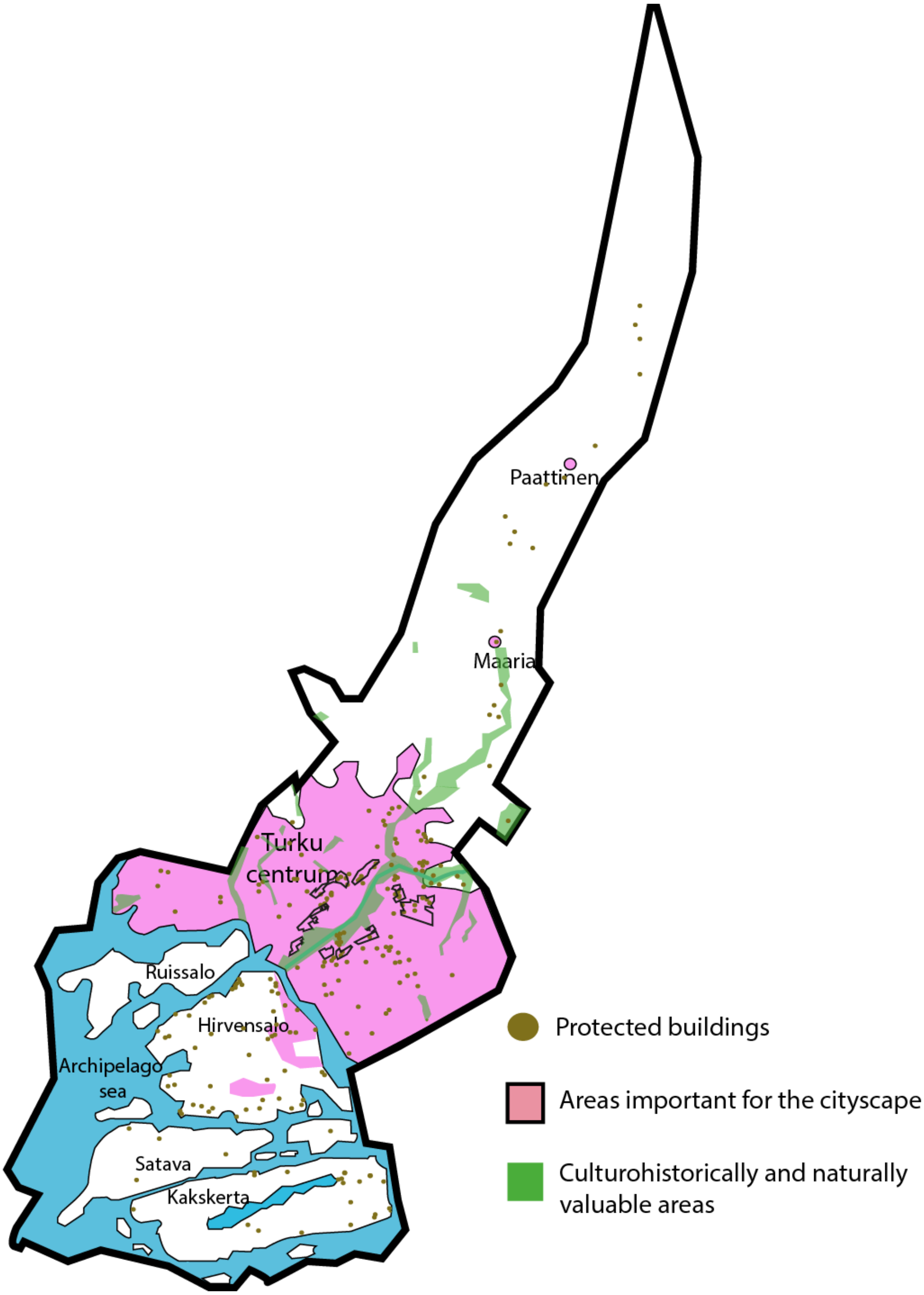


Image 7. Protected buildings and areas that are important for the cityscape and culturohistorically and naturally valuable. (Yleiskaava 2029)

6.2 Climate conditions

The south west part of Finland is one of the countries warmest areas due to its southern location (Kaate 2010) and closeness to the Baltic Sea. This means that the growing period is one of the longest in Finland, which is beneficial for growing biomass for example. The long coastline gives also advantages for wind energy, because there the wind speed is at its highest, due to the lack of obstacles for the wind. (Kaate 2010) However, the sea area in Turku and just outside of Turku has a dense archipelago, which sets an obstacle for the wind speed. The most common wind speeds in Turku vary from 1 m/s to 6 m/s, rarely exceeding 9 m/s. The wind blows 16% of the time from the south, 15% of the time from the south west, 13% of the time from the west, 12% of the time from the east and 11% of the time from the south east. (Average Weather for Turku, Finland 2015)

Table 12. Climate indications of Turku in 2014 (Tilastotietoja Turusta 2015)

The average temperature	7.4 ^{o}C
The highest temperature	32.4 ^{o}C
The lowest temperature	-19.1 ^{o}C
Amount of rain	605 mm
Days of rain (>0 mm)	168
Average hours of sun in a month (January-March) (h)	91
Average hours of sun in a month (June-August) (h)	272
Average temperature 1981-2010	5.5 ^{o}C
Average amount of rain 1981-2010	723 mm

Table 13. Monthly average temperature in 2015 in Turku (Heating degree days 2015)

January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
-0.9 °C	0.4 °C	2.0 °C	5.1 °C	9.3 °C	13.2 °C	16.0 °C	16.6 °C	12.2 °C	4.9 °C	4.5 °C	2.7 °C

6.3 Employment and economical situation

In the year 2013 there were 95 201 persons working in Turku. The change of workplaces compared to the year 2012 was -1611 workplaces. 83% of the jobs in Turku are in the service sector, 17% in the refinement and close to 0% in the primary production. (Työpaikat ja Työllisyys 2015) The biggest employer is the healthcare and social services domain, which employs 18 173 persons. (Tilastokeskus 2013) In the Figure 7 the composition of the working sector is shown in Turku.

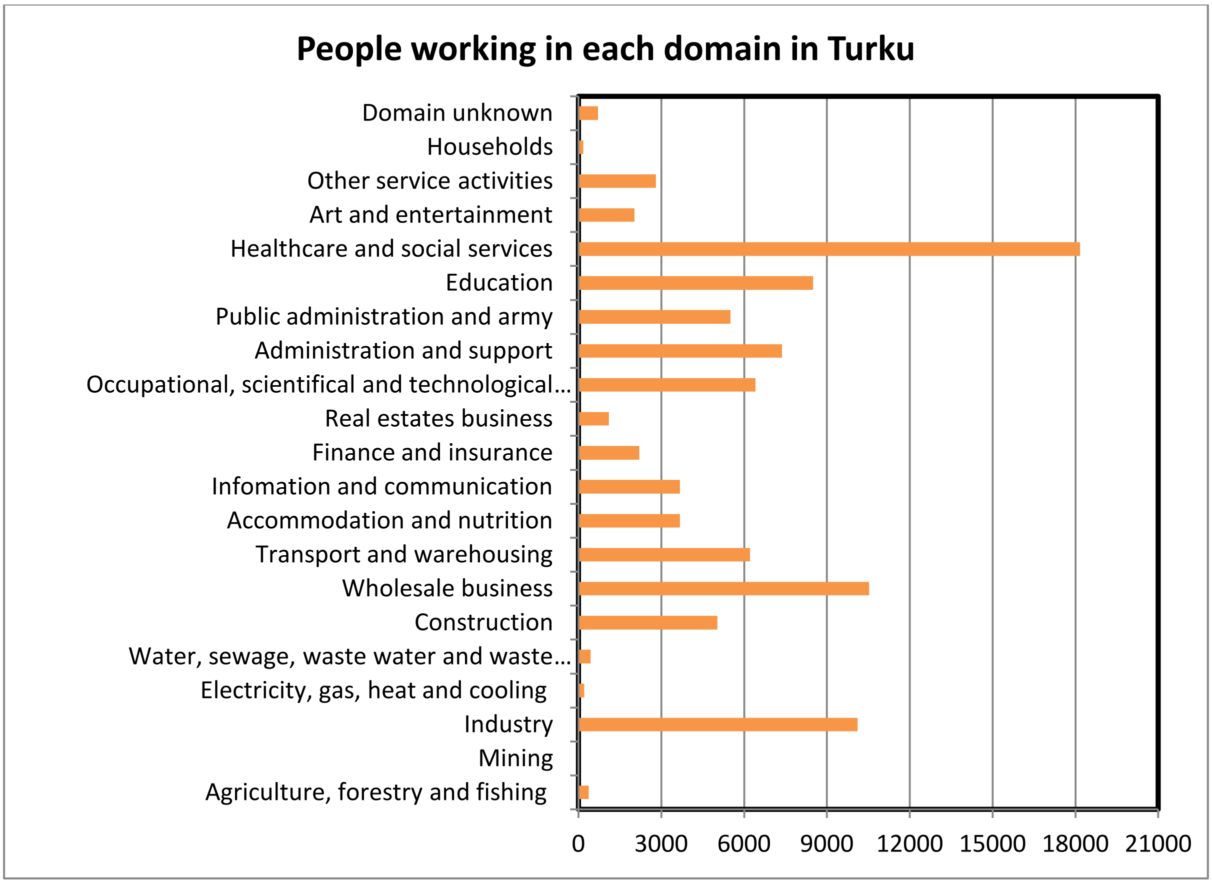


Figure 7. Employees in each domain in Turku (Tilastokeskus 2013)

In the year 2013 the gross domestic product of Turku was 37 484 €/habitant whereas in the whole Finland it was 37 276 €/habitant (Tilastokeskuksen PX-Web-tietokannat 2013). The unemployment rate was 13.4% (Turku-Åbo 2013)

6.4 Education

Turku is called a student city due to its many schools, universities and students. Turku has two universities (University of Turku and Åbo Akademi) and four universities of applied sciences. The total number of students in these universities is 31 500 students. In the year 2013, 31.9% of the people over 15 years of age in Turku had a university degree (Turku-Åbo 2013).

The University of Turku has 7 faculties, which are Faculty of humanities, Faculty of Mathematics and Natural Sciences, Faculty of Medicine, Faculty of Law, Faculty of Social Sciences, Faculty of Education and Turku School of Economics. (Tiedekunnat ja yksiköt 2015) The Åbo Akademi offers studies in Swedish and has 4 faculties, which are Faculty of Arts, Psychology and Theology, Faculty of Education and Welfare Studies, Faculty of Science and Engineering, Faculty of Social Sciences and Business and Economics. (Tiedekunnat 2015)The main focus areas of the universities of applied sciences are biotechnology, culture and information technology (Turku 2015).

6.5 Present energy system in Turku

This section explains the different power plants that produce energy for Turku and also the different ways energy is produced. Furthermore, the electricity, district heating and cooling supply for Turku are explained and also the current energy demand of Turku is determined. Finally, this section explains the challenges of the current energy system in Finland and in Turku.

6.5.1 Power plants in Turku

The power plant of Naantali

The power plant is situated in the city of Naantali few kilometres outside of Turku. This power plant uses coal to produce heat, process steam and electricity (CHP) for Turku and for the other municipalities and companies around Turku. The plant is owned by a company called Turun Seudun Energiatuotanto Corp (TSE). The plant can produce 350 MW of heat, 310 MW of electricity and 80 MW of process steam (TSE Oy Naantalin uusi voimalaitos 2014). Although this plant is situated just outside of Turku it is seen in this study as being part of the power plants inside Turku due to its close location and importance for Turku's energy supply. Next to this current power plant a new power plant will be built that uses biomass (mainly wood) and coal to produce heat and electricity. This new power plant will be operational in 2017 and the current plant will be then only used for high peak demands.

Oriketo bio power plant

This plant is situated in the municipality of Turku in the area of Oriketo. It is called a bio power plant, because it uses wood (logging waste and by-products of saw mill and forestry activities) to produce heat for the municipality of Turku. This wood is mostly gathered from the nearby forests. The plant is owned by a company called Turun Seudun Energiatuotanto Corp. The plant's peak producing power is 40 MW and yearly the amount of produced heat is around 300 GWh. The plant produces 17% of the heat used in Turku and it is seen to contribute to the CO_2 reduction goals of Turku, because it doesn't use fossil fuel based fuels in its production. (Orikedon biolämpökeskus 2015)

Kakola heat pump plant

This plant is situated in the city centre of Turku inside a hill and next to a waste water treatment plant. The plant uses electricity and heat from the waste water to produce heat and cooling for the premises of Turku. The plant produces 10% of the heat (Kakolan lämpöpumppulaitos 2015) and over 90% of cooling used in Turku (I Syrjälä & J Lahtinen 2016, pers. comm., 01 February) and it is seen to contribute to the CO_2 reduction goals of Turku, because it doesn't use fossil fuel based fuels in its production (Kakolan lämpöpumppulaitos 2015). The plant can produce 42 MW of heat and 29 MW of cooling (Kakolan lämpöpumppulaitos 2015). Annually the plant produces 220 GWh of heat and in 2015 the plant produced 30.6 GWh of cooling (I. Syrjälä & J. Lahtinen 2016, pers. comm., 01 February). The input power of the two heat pumps is 14 MW (electricity). This electricity for the heat pumps is purchased from certified renewable sources. (I. Syrjälä & J. Lahtinen 2016, pers. comm., 01 February) The plant is owned by a company called Turun Seudun Energiatuotanto Corp. (Kakolan lämpöpumppulaitos 2015) There are also two reserve air heat pumps for peak moments of consumptions. These pumps generated in 2015 1.4 GWh of cooling. (I. Syrjälä & J. Lahtinen 2016, pers. comm., 01 February)

Luolavuori pellet power plant

This plant is situated in the area called Luolavuori in Turku and it started its operations in the beginning of 2016. The plant was built to cover peak demands of heat in Turku. It uses pellets to produce heat for Turku. The plant can produce 40 MW of heat and the yearly amount of production is between 20 to 50 GWh depending on the winter temperatures in Turku. The plant is seen to contribute to the CO_2 reduction goals of Turku, because it doesn't use fossil fuel based fuels in its production. The plant is owned by a company called Turku Energia Corp. (Öljyä korvaavan pellettilaitoksen rakentaminen Luolavuoreen vuoden 2015 kuluessa 2015)

Power plants in reserve

In addition to these power plants mentioned above, Turku has reserve power plants that produce heat from oil for peak moments of consumption. These reserves are spread all around the municipality. Below you can find a list of these power plants according to the area they are in:

- Linnankatu 4 x 40 MW
- Härkämäki 2 x 40 MW
- Koroinen 2 x 40 MW
- Luolavuori 2 x 40 MW
- TYKS 2 x 40 MW
- Artukainen 1 x 37 MW

(Kiinteät öljylämpökeskukset 2016)

Saramäki

Saramäki is an area in Turku. Through this area come the water supply pipes for Turku. Because Saramäki is on a higher altitude than the rest of Turku the flow of the water needs to be slowed down and it is done with a water turbine, which creates annually 2 GWh of electricity for Turku. (J Hallivuori 2016, pers.comm., 23 February)

Biovakka

Biovakka is a company in Turku, which produces biogas from biowaste. It produces 0.3 GWh of electricity for Turku from biogas. (J Hallivuori 2016, pers.comm., 23 February) This biogas Biovakka produces from Turku's own waste water. Currently, Biovakka is not planning on investing to new plants in the municipal area of Turku, but instead are planning to build new plants outside of Turku (Laitoksemme 2016).

Varissuo power plant

This power plant produces and distributes heat to the area of Varissuo in Turku. The heat is produced by using wood and oil as fuel. The plant's maximum power is 64 MW. The plant is owned by a Varissuo lämpö Corp. (Lämmöntuotanto 2016)

Pansio power plant

This power plant produces 78 GWh/a of heat to the Turku Energia's district heating network by using wood as fuel. The plant is owned by a company called Pansion lämpö. (Pansion Lämpö Ky:n kattilalaitoksen ympäristölupapäätös 2009)

6.5.2 Energy supply for Turku

This part explains the electricity, district heating and cooling supply for Turku. Furthermore, the Table 14 below presents the different ways renewable energy is produced currently for Turku and the production amounts. Table 14 also presents the different ways renewable energy will be produced in 2017 for Turku and the production amounts. Unfortunately, information concerning the small scale energy production of households is not available. However, these production amounts are estimated to be very minimal. Moreover, the Figure 8 below presents the electricity, district heating and cooling supply for Turku.

Electricity supply

The electricity for Turku is produced inside Turku (Naantali power plant) and outside of Turku (several producers). Electricity comes from fossil fuel, peat and nuclear based power plants. Also electricity from wind, water power and biogas is used in Turku. (Energian alkuperä 2014) (TSE Oy Naantalin uusi voimalaitos 2014) (Sähkömarkkinoiden eri osapuolten roolit 2016)

Turku has two electricity distributors, which are Turku Energia Corp. and Caruna Corp. These companies buy the electricity from the market and sell and distribute it through their own electricity networks to the premises and technical infrastructure of Turku. Turku Energia is the biggest distributor in Turku and it distributes the southwest area of Turku whereas Caruna distributes the northeast area (area of Paattinen) (Tietoa Turku Energia sähköverkot Oy:stä 2016) (TLT-Group kaapeloi sähköverkkoa Rymättylässä 2015). The Figure 8 below shows how electricity is produced and supplied for Turku.

District heating supply

The heat for Turku is produced mainly inside Turku. Exception is a small heat amount that comes outside Turku and that is claimed CO_2 free (Energian alkuperä 2014). The exact amount of this CO_2 free heat is unknown in this study, but it is assumed to be minimal and thus not taken into account in this study.

The heat comes mainly from coal and wood based power plants but also from a heat pump power plant that uses heat from Turku's waste water (Kakola plant). The pipes of the district heating network transport the heat from the power plants to the premises of Turku. Each premises includes a heat exchanger, which transfers the heat to the premises' own heating system.

Turku Energia owns the district heating network and is the principal district heat supplier in Turku (Yleistä yhtiöstä 2016) (also Varissuo lämpö Corp. supply district heating). Turku Energia buys the heat from the heat producers and distributes it further to the premises of Turku. District heating is a very common way of heating premises in Turku, but also other heating modes exist. The Figure 6 presents the different heating modes in Turku.

District cooling supply

Almost the entire district cooling in Turku is produced in the Kakola plant. Some reserve plants are in place in case of very high temperatures or malfunctioning of the cooling network. (Kaukojäähdytys on ympäristöystävällinen ja taloudellinen tapa jäähdyttää kiinteistöjä 2016) The Kakola plant uses the water that is cooled in the end of its processes to cool down premises, which are connected to the district cooling network in Turku. (Kakolan lämpöpumppulaitos 2009) This solution is seen more environmentally friendly than individual cooling systems for buildings. This solution uses also renewable energy (end process water from waste water treatment). From the Kakola plant the cooled water is transported through pipes to the premises that are connected to the district cooling system. As mentioned in the earlier the Kakola plant produces 30.6 GWh of cooling and this is very close to the cooling demand of the district cooling network.

Turku Energia owns this district cooling network and is expanding it currently. (Kaukojäähdytys on ympäristöystävällinen ja taloudellinen tapa jäähdyttää kiinteistöjä 2016) As almost all of the current cooling for Turku is produced from renewable sources and because future cooling demands and cooling network expansion demands were not discussed during the research and information on the possible cooling demand increase was not found it has been concluded that it is not useful/possible to examine further cooling potentials in Turku. However, one indication of a future cooling potential in Turku is explained in part 6.6.4.

Table 14. Annual renewable energy supply for Turku. (Kivilä 2015) (Heikkinen & Satka 2013) (Orikedon biolämpökeskus 2015) (Kakolan lämpöpumppulaitos 2015) (I. Syrjälä & J. Lahtinen 2016, pers. comm., 01 February) (Öljyä korvaavan pellettilaitoksen rakentaminen Luolavuoreen vuoden 2015 kuluessa 2015) (Turku Energia panostaa uusiutuvaan energiaan 2015) (Turku Energian katolla tuotetaan aurinkosähköä 2015) (Turku Energian aurinkovoimalaan lisää paneeleita 2016) (TSE Oy Naantalin uusi voimalaitos 2014) (Skanssi alkaa hyödyntää aurinkoa 2013) (Heikkinen & Satka 2013) (Pelto-Timperi 2015) (Lämmöntuotanto 2016) (Kaukolämmitys 2014) (Pansion Lämpö Ky:n kattilalaitoksen ympäristölupapäätös 2009)

Energy Technology	**Current energy supply**			**Energy supply in 2017**		
	Electricity (GWh)	Heat (GWh)	Cooling (GWh)	Electricity (GWh)	Heat (GWh)	Cooling (GWh)
Oriketo bio boiler		300			300	
Kakola heat pump	- 67*	220	30.6	- 67*	220	30.6
Luolavuori pellet boiler		20-50**			20-50**	
Renewable electricity production for Turku (Sources outside of Turku)	323.1			323.1		
Linnankatu solar power plant	0.012			0,012		
Kupittaa solar power plant				0.063******		
Skanssi solar power plant	0.060			0.060		
Saramäki	2			2		
Biovakka	0.3			0.3		
New naantali power plant				144*******	363********	
Varissuo power plant		40***			40***	
Pansio power plant		78			78	
Geothermal heat of heat pumps for households		37****			37****	
Wood as source of heat for households		18*****			18*****	
Total energy supply	258,5	713-743	30.6	402,5	1076-1106	30.6

* 220 GWh / 3.3 COP. (Pelto-Timperi 2015). The electricity needed for the heat pumps comes from renewable sources. This amount is reduced from the total amount of renewable electricity that is produced for Turku, because it is also reduced from the total electricity demand of Turku in the Table 16 (included in the communal service). Therefore this amount is taken into account as electricity loss. **High peak power plant. ***50.6 GWh x 0.8. 80 % of the plants production (50.6 GWh) is renewable. (Lämmöntuotanto 2016) (Kaukolämmitys 2014) ****1831 GWh x 0.02. The amount 1831 GWh is the current total heat demand of Turku (calculated in the next part 6.5.3). The share in 2012 was less than 0.01 (Heikkinen & Satka 2013) but due to the popularity of geothermal heat for households the share in this study is assumed to be increased to 0.02. There is no information of how this figure will develop in the future so here it is assumed to stay as it is. The electricity consumed by these heat pumps is not reduced from the total amount of renewable electricity that is produced for Turku, because the electricity consumed by these heat pumps is taken into account in the total electricity demand (Table 16; included in the Housing). *****1831 GWh x 0.01. The amount 1831 GWh is the current total heat demand of Turku (calculated in the next part 6.5.3). 0.01 is the share in 2012 (Heikkinen & Satka 2013) and it is assumed to be the same currently and in the future, because there is no information of how this share will develop in the future. ******estimation. *******360 GWh x 0.4. Taken according to the current electricity production amount of TSE Naantali plant for Turku (360 GWh) (Kivilä 2015). 0.4 is the future share of renewable energy in the plant (TSE Oy Naantalin uusi voimalaitos 2014). ********1360 GWh x 0.66667 x 0.4, it is estimated that 2/3 of heat production will be used by Turku (Heikkinen & Satka 2013) and that 40 % will be renewable energy. 1360 GWh is the estimation of the heat production potential. (TSE Oy Naantalin uusi voimalaitos 2014) The planned share ownerships in future wind power parks are not taken into account due to the insecure nature of wind power project realization. The household's renewable energy production with

solar energy is not available, but it is assumed to be very minimal. Caruna's distribution of renewable electricity for Turku is not taken into account in the Table 14, because this information was not available. However, it is estimated in this study that this amount is minimal.

6.5.3 Energy demand of Turku

Heat demand

The Table 15 below presents the total heat demand of Turku. This heat demand includes the heat demand of the households, commercial buildings, public service buildings and industrial buildings (premises and processes). It was not possible to get separate information concerning the heat demand of industrial premises and processes. The district heating figures are from the year 2015 (Turku Energia, 2016, pers.comm., 03 March). Also the heat that the power plant of Varissuo produces to the premises of Varissuo needs to be added to these figures. This information is from the year 2014. The "Other" part is the heat demand for premises that are not connected to the district heating network in Turku. In 2012 this part was estimated to be 20 % (electrical heating not included) from the total heat demand for premises in Turku. (Heikkinen & Satka 2013). Here it is assumed that also currently 20 % of the heat demand comes from the premises outside of the district heating network of Turku.

Table 15. Total heat demand of Turku. (Turku Energia, 2016, pers.comm., 03 March) (Heikkinen & Satka 2013) (Lämmöntuotanto 2016) (Kaukolämmitys 2014)

Sector	Heat	%
	GWh	
Distric heating		80
- Households	787	
- Commercial buildings	188	
- Public service buildings	236	
- Industrial buildings	203	
- Varissuo	50.6	
Total	1464.6	
Other		20
Total	366	
Total heat demand	1831	

Electricity demand

The Table 16 below presents the total electricity demand of Turku in 2014. The electricity demand is based on the information given by the Energy Industry organisation of Finland from the year 2014 and information of the Turku Energia from the year 2015. The Energy Industry's information states the entire electricity use of Turku in 2014, whereas the Turku Energy information states only the electricity usage of the Turku Energia's customers. These customers are close or in the city center area of Turku. It was not possible to receive specific information of the electricity usage outside of the city center. Furthermore, it is assumed here that public lighting is included in the “service and construction” in the Table 16.

In the Table 16 the information from 2015 is only partly used in order to reduce from the entire electricity demand the sectors that are not included inside the boundaries of this research (agricultural production, communal service and construction). However it has to be noted that the amounts of 2015 include only the electricity distribution of Turku Energia and don’t include the amounts of electricity that Caruna distributed for these sectors. This information was not available.

So in this study it is assumed that the electricity consumption of these sectors has been the same in 2014 and 2015. Furthermore, it was not possible to get separate information concerning the electricity demand of industrial premises and their processes so both of these aspects are included in the electricity demand. Moreover, the electricity demand of public lighting is assumed in this study to be included to the total electricity demand of Turku in 2014.

Table 16. Total electricity demand of Turku (Kunnat sähkön käytön suuruuden mukaan 2014) (J Hallivuori 2016, pers.comm., 23 February)

Sector	Electricity
2014	GWh
Housing and agriculture	564
Industry	238
Service and construction	720
Total	1522
2015	
Agricultural production	-7.5
Communal service	-153
Construction	-5
Total electricity demand	1356.5

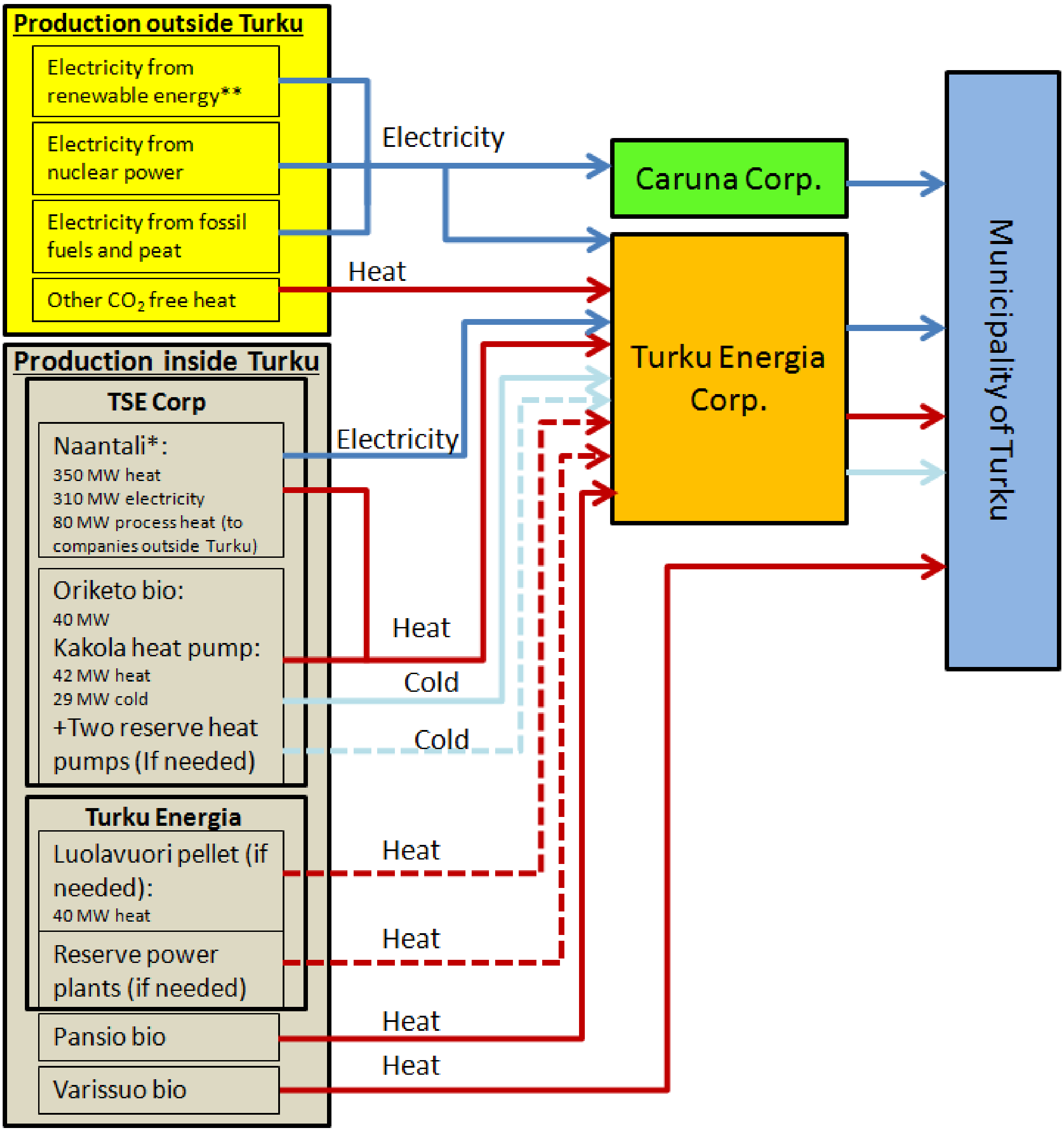


Figure 8. Electricity, district heating and cooling supply for Turku. (Saramäki, Biovakka and the small solar plants in Turku are not involved in this figure due to their small production capacity) * The plant of Naantali is just outside of Turku but here seen as production inside Turku. ** Water and wind power. (TSE Oy Naantalin uusi voimalaitos 2014) (Sähkömarkkinoiden eri osapuolten roolit 2016) (TLT-Group kaapeloi sähköverkkoa Rymättylässä 2015) (Energian alkuperä 2014)

6.5.4 Challenges of the current energy system in Finland and Turku

Fingrid (owner of the main grid in Finland) warns of the possibilities of electricity shortages in Finland during cold periods when the electricity demand is high. This is due to the shutdown of some oil and coal power plants in Finland due to their profitability issues. These profitability issues stem from the current low electricity prices in Europe and from the subsidies given to renewable energy producers. (Riski sähkönjakelun rajoituksista kovina pakkaspäivinä kasvanut 2015) Also Turku needs to take this warning into consideration and think ways of responding to this issue. One way of responding to this issue could be to find innovative ways of producing renewable electricity and enhancing energy efficiency in the area of Turku

In the district heating side the challenge is how to respond to the heat demand peaks without using fossil fuels. Currently, Turku has reserve power plants for peaks and these plants use fossil fuels. The challenge is how to change this reserve to power plants that use renewable energy for heat production. (A Ahtiainen 2016, pers.comm., 03 February) The construction of the Luolavuori pellet plant is positive advancement to this direction.

6.6 Renewable energy potentials

This section evaluates the renewable energy potentials in Turku for separate energy sources. These sources were chosen based on the stakeholder interviews in which interviewees were asked to name potential interesting renewable energy sources for Turku. These sources are solar energy, wind energy, biomass energy and energy conservation (not renewable but a very important aspect of RES). These sources are considered renewable in this study although the author of this thesis is aware of the sustainability problems related to burning biomass for energy production (further explained in part 7.2.3).

Also power plant level geothermal energy potential in Turku would have been interesting to evaluate but not enough information was found in order to conduct this evaluation. In the end of this section also disruptive technologies that can be used in Turku are described based on the information from the stakeholder interviews.

6.6.1 Solar energy

Solar irradiation can be converted to electricity and heat and in order to do this there are two kinds of solar technologies: solar panels or photovoltaic panels and solar thermal collectors. In the following parts the micro energy generation potential of these two technologies in Turku will be studied. In this study the micro generation means that these technologies are installed on the roofs of the different types of premises in Turku. The potential of installing solar panels on the facades is not evaluated in this study, because no surface area information of facades was found. Furthermore, it is not expected that solar energy generation will happen on the ground in Turku (Heikkinen & Satka 2013).

In this solar potential evaluation it is only assumed that solar technologies are not allowed to be installed on protected buildings in Turku. The description of the installation instructions for solar collectors can be found from the part 7.6.1.

Solar panels

In order to calculate the electricity production potential of solar panels in Turku the following information is needed:

- Yearly sum of solar irradiation in Turku (kWh/m^2)
- Technical information of the used solar panel (efficiency and performance ratio (PR))
- The suitable roof surface area for solar panels in Turku
- The optimal direction and the optimal angle of the solar panels in Finland

For Turku it was only possible to get information about the yearly sum of irradiation from Artukainen (district of Turku in the west). According to the Finnish Meteorological Institute the yearly sum of solar irradiation in Artukainen is 968 kWh/m^2 (Meteorologist, Finnish Meteorological Institute, 2016, pers.comm., 04 March). Because the irradiation information is available only from one location in Turku, it is not possible to evaluate the solar irradiation difference of different areas in Turku. Therefore, only this value from Artukainen will be used in the calculations.

In order to define the technical information, a SS-265W type poly-crystallinen silicon panel will be used as an example, because these types of panels will be used in the solar plant of Kupittaa (see Appendix A) (Areva Solar 2016, pers.comm, 07 March) (SaloSolar 2016a). These SS-265W type panels are produced by a Finnish company called Salo Solar (SaloSolar 2016b) and their efficiency at Standard Test Conditions (AM 1.5, 1000 W/m^2, 25^{o}C) is 16.33 %, (SaloSolar 2016a).

The PR is a coefficient for power losses that can occur during the lifetime of the panel. These losses are for example: inverter losses, temperature losses (high temperature decreases the panel's efficiency), cable losses, shadings and losses due to dust and snow. These factors depend on the site, technology, and sizing of the system. The PR of solar panels varies from 0.5 to 0.9, but here a default value of 0.75 will be used. (How to calculate the annual solar energy output of a photovoltaic system 2016)

Furthermore, according to the municipality of Turku the total surface area of all buildings' plinth in Turku is about 8.5 km^2. From this about 0.37 km^2 are protected buildings (see Image 7). In this study it is assumed that it is not possible to install solar technology on protected buildings in Turku. It has to be noted also that this surface area information is not 100 % accurate, but can still be used as an estimate. (J Helin 2016, pers. comm., 03 March)

In this study it is estimated that the total plinth area of detached and row houses corresponds to the suitable roof area for solar panel installation in Turku. This is due to the fact that the total roof area for detached and row houses in Turku has to be bigger than the plinth area (because of eaves and inclination of the majority of roofs), but at the same time it is estimated that not the whole roof area can be used for solar panels. In this study these two factors are seen to cancel each other. However, in this study the suitable roof area for solar panel installation is considered to be less than the plinth area of other types of buildings (not including detached and row houses) in Turku, because for example of ventilation units on the roofs. This is estimated to decrease the total suitable roof area with 10 %. Therefore, in this study the total suitable roof surface area for solar panels in Turku is the surface area of all buildings' plinth, minus the surface area of protected buildings' plinth, minus 10

%. This gives a value of 7.32 km^2. It has to be noted also that the roof area used for the solar panels in Kupittaa and Linnankatu as well as the roof area for private household solar panels should be reduced from this value. However, the surface area that these solar panels are very minimal and therefore they have a very minimal effect to the results of this evaluation.

Moreover, important technical information concerning the solar panels is the optimal direction and optimal angle of the solar panels in Finland. The optimal direction of the panels is towards the south and the optimal angle in Finland is 45 degrees (Aurinkopaneelien sijoitus ja asennus 2016). However, in this study it is estimated that not all the panels can be directed towards the south and installed in an angle of 45 degrees. This in turn lowers the electricity output of the solar panels. However, it has to be also noted that the maximum yearly irradiation in Artukainen (968 kWh/m^2) is taken from a horizontal square meter and not from a 45 degrees angle, which would increase the amount of yearly irradiation. So it is seen in this study that these two factors cancel each other. Therefore, it is assumed that the realistic yearly irradiation is the same as the maximum yearly irradiation in Artukainen (968 kWh/m^2).

Based on this information above the Table 17 below will present the electricity generation potential of the SS-265W type solar panel in Turku. The potential is calculated with the following equation: Electricity (kWh) = Total roof area in Turku (m^2) x solar irradiation (kWh/m^2) x solar panel efficiency (%) x PR (How to calculate the annual solar energy output of a photovoltaic system 2016).

Table 17. Electricity generation potential of the SS-265W type solar panel in Turku.

Basic information:	
Total roof area	7320000 m^2
Yearly sum of solar irradiation (Artukainen)	968 kWh/m^2
Characteristics:	
Efficiency	16.33%
Performance ratio	0.75
Total electricity generation	867.8 GWh

According to the Table 17 the electricity generation potential of the SS-265W type solar panel in Turku is 867.8 GWh, which is about 64 % of the total annual electricity demand of Turku. However, it has to be noted that this is only an indication of the potential and doesn't say a lot about the possibility of realization. Furthermore, it is important to realize that this potential amount cannot be produced in a steady flow of electricity, because of the differences in the solar irradiation according to the seasons. Therefore, the production rate in Finland is at its highest between May and August and lowest between November and January. (Aurinkopaneelien sijoitus ja asennus 2016) However, the energy consumption in Turku is at its highest between November and March (Heikkinen & Satka 2013).

Solar thermal collectors

The idea in this part is to evaluate whether there is potential in Turku to heat the oil, coal and peat heated premises outside the district heating network with solar thermal collectors. This is done because it is seen that in the area of the district heating network, solar thermal collectors don't bring that kind of economical or environmental benefits so that it would make sense to invest in them

(Heikkinen & Satka 2013) and also because changing the fossil fuel heated premises outside the district heating network to solar heated premises would enhance the usage of renewable energy in Turku. The solar collectors are not seen beneficial in the district heating network, because the usage of these collectors in the area of district heating would decrease the usage of district heating and thus the district heating water would return warmer back to the Naantali power plant. This would decrease the energy efficiency of the Naantali plant and would have a negative effect on the energy efficiency of the whole district heating network. However, it has to be noted that this negative effect would only occur when the energy demand doesn't surpass the Naantali power plant's heat production capacity.

The previous argument about the loss of energy efficiency is based on one of the stakeholder interviews performed during this research. According to Bastman (TSE, 2016, pers.comm., 21 January) the heat pumps in the premises that are connected to the district heating network have a negative effect to the energy efficiency of the district heating network. The heat pumps in the premises lower the amount of electricity produced in the Naantali plant and this electricity loss is more than the heat energy gained with the heat pumps. However, this negative effect would only occur when the energy demand doesn't surpass the Naantali power plant's heat production capacity. It is assumed in this study that it is the same case for solar collectors that are connected to premises that are in the district heating network. It is also assumed that these oil, coal and peat heated premises are not protected buildings and not situated in conservation areas or in the areas with archaeological values, because then it can be more difficult to install solar technology on these kinds of buildings and store this heat in the ground. The information whether some of the oil, coal and peat heated premises are protected buildings and where they are situated is missing.

In order to calculate the potential of solar collectors in Turku the following information is needed:

- The efficiency of a solar collector
- The energy needed to heat the oil, coal and peat heated premises in Turku
- The roof area that is needed to reach this energy need
- Estimation of the roof area of oil, coal and peat heated premises in Turku
- Realistic yearly sum of solar irradiation in Turku
- The optimal direction and the optimal angle of the solar collectors in Finland

Glazed collectors in domestic hot water systems will be used as an example in this calculation. The efficiency of these collectors is found to be 0.44 (Calculation Method 2016). Furthermore, as mentioned already in the Table 17 the realistic yearly sum of solar irradiation in Turku is 968 kWh/m^2. Moreover, it is assumed in this study that the optimal direction and the optimal angle of solar collectors is the same as for solar panels in Finland.

The energy needed to heat the oil, coal and peat heated premises outside the district heating in Turku can be determined based on the Table 15. In this table the "other" means the heat demand for premises that are not connected to the district heating network of Turku. This heat demand is 366 GWh. Furthermore, in 2012 the share of the oil, coal and peat heated premises' heat demand from the heat demand of other premises outside the district heating network was about 89.4 % (electrical heating not included) (Heikkinen & Satka 2013). However, because of the popularity of geothermal heating for households (heat taken from the shallow underground with a special liquid and a heat pump) it is assumed in this study that this share has nowadays decreased to 80 %. Therefore, it can be concluded that the heat demand for the oil, coal and peat heated premises in Turku is currently about 0.8 x 366 GWh = 293 GWh. This means that the solar collectors should provide this amount of heat in the future in Turku.

Next, the needed roof area for this 293 GWh needs to be determined. This can be found from the equation for calculating the energy output for glazed collectors. The equation is as follows: collector efficiency (%) x realistic yearly solar irradiation (kWh/m^2) x needed roof area (m^2) = total energy need (kWh) (modified from Ricken 2012). Applying the before mentioned amounts to this equation the needed roof area for producing the needed heat demand (293 GWh) is 0.69 km^2.

In 2014, the number of buildings heated with oil, coil, wood and peat in Turku was 8110 (Tilastokeskuksen PX-Web-tietokannat 2014b). It is estimated in this study that the number of buildings heated with oil, coil and peat is about 7500. According to the municipality of Turku the average surface area of the non protected buildings' plinth in Turku is 266.60 m^2 (J Helin 2016, pers. comm., 03 March). When this is multiplied with the number of buildings heated with oil, coal and peat (7500), the total plinth area for these buildings is about 2 km^2. As estimated in the "solar panels" part, concerning the detached houses and row houses the surface area of the plinth can be considered to be the same as the total suitable roof surface area for solar technologies. However, concerning other types of buildings the suitable roof surface area is considered to be less than the plinth surface area. Therefore, the total plinth area of 2 km^2 will be decreased with 10 % to 1.8 km^2, which indicates the total suitable roof area for solar collectors. Although this calculation method is a rough estimate, it indicates clearly that there is enough roof area for solar collectors to heat the oil, coal and peat heated premises outside of the district heating network in Turku. This is due to the fact that the needed roof area for producing the needed heat demand (0.69 km^2) is much smaller than the available roof area for solar collectors (1.8 km^2) concerning the oil, coal and peat heated premises outside of the district heating network in Turku.

The Table 18 below will present these calculations. The equation 1 is as follows: collector efficiency (%) x realistic yearly solar irradiation (kWh/m^2) x needed roof area (m^2) = total energy need (kWh). The equation 2 is as follows: (number of buildings heated with oil, coil and peat x average surface area of the buildings' plinth (m^2)) x 0.9 = total suitable roof area for solar collectors (m^2).

Table 18. Calculation of solar collector potential in Turku

Equation 1:	
Collector efficiency	44%
Realistic yearly sum of irradiation	968 kWh/m^2
Total energy need	293 GWh
Needed roof area for solar collectors	?
Answer to equation 1	0.69 km^2
Equation 2:	
Number of buildings heated with oil, coil and peat	7500
Average surface area of the buildings' plinth	266.60 m^2
Coefficient for suitable roof surface area	0.9
Total suitable roof area for solar collectors	?
Answer to equation 2	1.8 km^2

To conclude it can be said that the heat generation potential of the Glazed collectors in domestic hot water systems in Turku is 293 GWh, which is about 16 % of the total annual heat demand of Turku. However, it has to be noted that this is only an indication of the potential and doesn't say a lot about the possibility of realization. Furthermore, it is important to realize that this potential amount cannot be produced in a steady flow of heat, because of the differences in the solar irradiation according to the seasons. Therefore, the production rate in Finland is at its highest between May and August and lowest between November and January. (Aurinkopaneelien sijoitus ja asennus 2016) However, the energy consumption in Turku is at its highest between November and March (Heikkinen & Satka 2013). Therefore, in order to provide heat to the premises also during low solar irradiation period an adequate seasonal heating storage needs to be included to the solar collector systems. These storage possibilities are further discussed in the part 7.5.5.

6.6.2 Wind energy

Wind energy can be generated with two types of turbine technology: horizontal axis wind turbines and vertical axis wind turbines. The horizontal axis wind turbines are often for large scale production with big turbines and vertical axis turbines are often used for small scale production with smaller turbines. Below the potential of both of these production technologies and ways are evaluated in Turku.

Furthermore, below the regulations taken into account in this wind energy potential evaluation will be explained. Moreover, a general description of the regulations related to wind energy is given in the part 7.6.1.

Large scale production with horizontal axis wind turbines

The Regional Council of Southwest Finland has done a study in 2010-2011 where the most suitable areas for large scale wind power production (about 10 turbines or more) were determined in the region (incl. municipality of Turku). According to the study installing wind turbines to the sea is not realistic due to the level of feed-in tariff and construction prices. In this study it is assumed that this is still valid currently and thus potential in installing wind turbines in the sea won't be studied here.

This study of the Regional Council of Southwest Finland gives indications about suitable wind power production areas for the conduction of regional wind power production area plan (Tuulivoimavaihemaakuntakaava on vahvistettu 2016). In the study no areas for large scale wind power production were found in Turku. (Klap et al. 2011) Here, in the renewable energy potential evaluation part the idea is to see whether smaller scale horizontal axis wind power production (less than 10 turbines) has potential in the area of Turku municipality. This evaluation will be based on the findings of this Regional Council of Southwest Finland study and based on some further investigations and calculations of this thesis.

The study of the Regional Council of Southwest Finland started by excluding the unsuitable areas for wind power production. This was done by excluding the areas that are:

- Closer than 650 meters from the settlements or holiday settlements (from the middle of the grid square)
- Conservation and Natura 2000 areas (see Image 4)
- FINIBA areas (see Image 5)
- Sea eagle nesting areas
- Valuable landscape areas (see Image 4)

(Klap et al. 2011) (A Klap 2016, pers.comm., 29 February)

After this exclusion 1500 suitable areas remained from which eight were in Turku. These eight areas were evaluated to be too small (less than 1 km^2) for large scale wind power production (about 10 turbines or more). (Klap et al. 2011) (A Klap 2016, pers.comm., 29 February) However, for my study the suitability of these areas for less than 10 turbines scale wind power production will be studied as well as how much electricity can be produced in these areas. The Image 8 below shows these eight production areas found in the study of the Regional Council of Southwest Finland for Turku. It is important to notice also that 650 meters from the settlements or holiday settlements can be a too short distance between the wind turbines and the settlements (e.g. noise effects). However, this is case specific and in some cases a wind turbine, which is 650 meters away from the settlements doesn't cause disturbance to the settlements. Therefore, in this study it is assumed that these 650 meters is enough to not cause disturbance. However, before installing turbines in Turku a careful evaluation of the effects of each turbine needs to be performed.

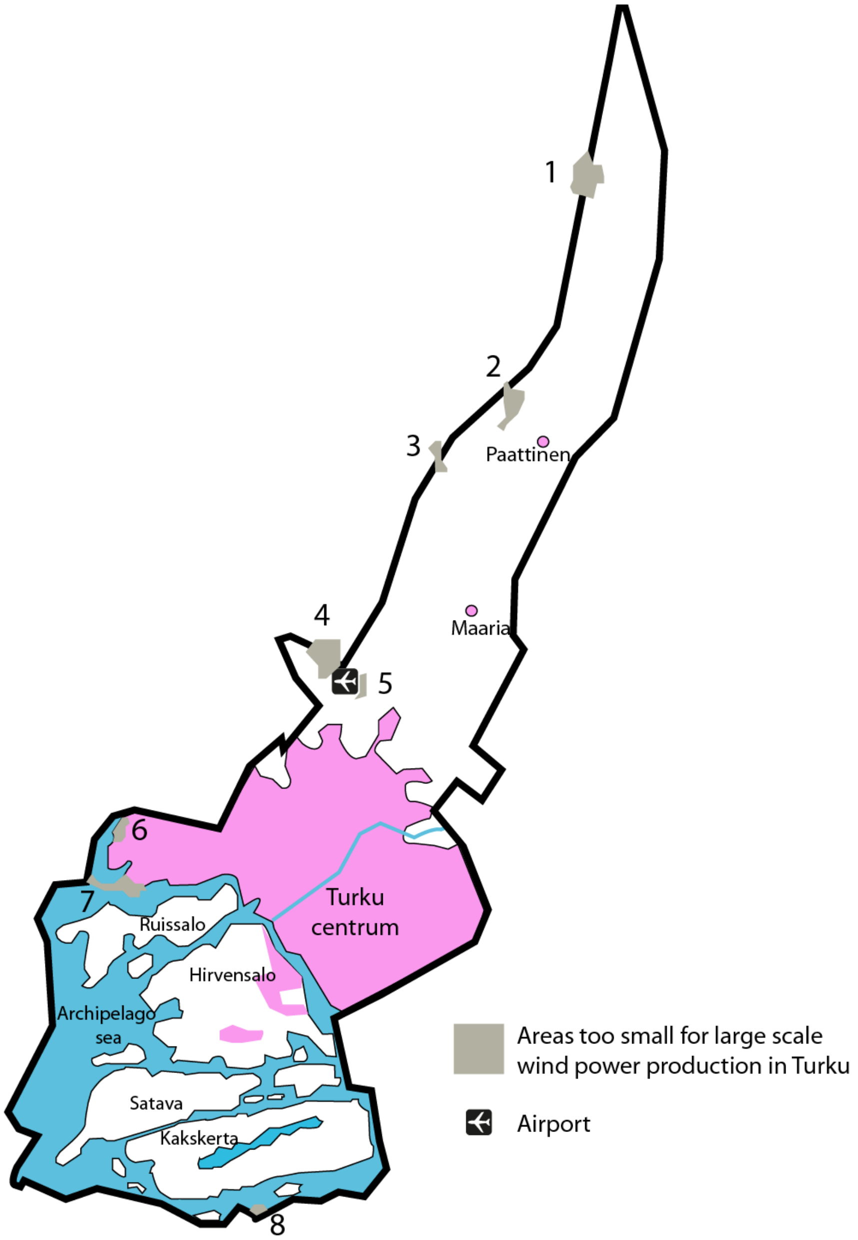


Image 8. Production areas too small for large scale wind power production (about 10 turbines or more) in Turku (Klap et al. 2011) (areas are marked with numbers for identification)

In order to study the suitability of these production areas (indicated in the Image 8) to less than 10 turbines scale wind power production, the following additional criterion will be used:

- International aviation regulation concerning the construction of wind turbines. This regulation states that no wind turbines can be built within 15 km distance from the ends of the runway and 6 km from the sides. (A Klap 2016, pers.comm., 29 February) Therefore, it has to be analysed whether these production areas are within these distances from the Turku airport?
- Production area inside a built cultural environment? (see Image 6 and part 6.1.2)
- Production area inside an area including archaeological values? (see Image 6 and part 6.1.4)
- Production area inside areas important for the cityscape? (see Image 7)
- Production area inside culturohistorically and naturally valuable areas? (see Image 7)
- Closeness to the valuable landscapes? (see Image 4 and part 6.1.3)
- Definition of these production areas in the local master plan 2020 of Turku (Yleiskaava 2020)

In this study it is seen that wind turbines shouldn't be placed in these areas/environments and so these criterions are also seen to determine whether wind turbines can be implemented to these production areas (Image 8) or not. The Table 19 below gives answers to these criterions/questions above. These answers are given only concerning the production area inside the municipality of Turku. The area that passes the municipality borders in the Image 8 is not analyzed. "Yes" in the Table 19 below means that the production area is inside the areas/environments in question or close to valuable landscapes. Thus, these production areas with "Yes" cannot be used for wind power production.

Table 19. Answers to the criterions/questions concerning wind power production suitability

Production area	Airport	Built cultural environment	Archaelogical values	Cityscape	Culturohistorically and naturally valuable areas	Closeness to valuable landscapes	Master plan 2020
1	No	No	No	No	No	No	Agriculture and forestry area
2	No	No	No	No	No	No	Agriculture and forestry area
3	No	No	No	No	No	No	Agriculture and forestry area
4	**Yes**	No	No	No	No	No	Airport and production and warehousing area
5	**Yes**	No	No	No	No	No	Airport area
6	No	No	No	No	No	No	Production and warehousing area
7	No	No	**Yes**	No	No	**Yes**	Special area and sea area
8	No	No	No	No	No	No	An island; more precise definition not indicated

From the Table 19 it can be concluded that unsuitable areas for less than 10 turbines scale wind power production in Turku are production areas 4, 5 and 7 whereas suitable production areas are 1, 2, 3, 6 and 8. However, it should be noted that this analyses doesn't take into account the entire criterions important in implementing wind turbines to a certain area. For example, criterions like impact to the water system, constructability, profitability or connectability to the grid are not evaluated. Concerning constructability an important remark is that according to the Image 3 the production area 1 includes a swamp area. This can have a negative effect on the constructability of wind turbines in that area.

Furthermore, it is difficult to determine the optimum amount of turbines for these production areas, because of the lack of information concerning the surface area. The study of the Regional Council of Southwest Finland indicates only that the surface area of these production areas is less than 1 km^2. Consequently, this study will make safe estimations of the number of turbines that can be implemented to these production areas depending of the size difference of these areas (see Image 8). Thus, it is estimated that the areas 1, 2 and 6 will all have two turbines and areas 3 and 8 will have one turbine. So in total there will be 8 turbines of 3 MW implemented in the municipal area of Turku.

Next, it is time to define how much electricity can be produced in these areas for the electricity need of Turku. These amounts can be derived from a webpage called Tuuliatlas. This webpage indicates the wind speeds in Finland from 50, 100 and 200 meters altitude and gives production amounts, in MWh, for a 3 MW turbine from every location in Finland (Tuuliatlas 2016). The purpose in this study is to find out the annual production amounts for the production areas 1, 2, 3, 6 and 8 indicated in Image 8. This annual production amount will be given from the 100 meter altitude, because as indicated in the part 7.5.3, the height of a 3 MW turbine is 100 meters. Table 20 below shows the production amounts found from Tuuliatlas for the production areas 1, 2, 3, 6 and 8 for one 3 MW wind turbine and for the production area from a 100 meters altitude.

Table 20. Annual production amounts of the chosen production areas (Tuuliatlas 2016)

Production area	**Production amount for one turbine** (MWh)	**Production amount for the production area** (MWh)
1	5300	10600
2	5800	11600
3	5940	5940
6	8500	17000
8	8900	8900
Total	34 440	54 040

It is not possible to get a completely accurate production amount for specific locations from Tuuliatlas. Therefore, these amounts in the Table 20 are approximations. Furthermore, it needs to be pointed out that placing one or two wind turbines in small areas is against the national area usage goals, which state that wind power production should be centralized to big entities (A Klap 2016, pers.comm., 29 February). However, municipalities can reserve space for smaller wind power production areas during the composition of their local master plan (Klap et al. 2011). The municipality of Turku is currently drafting their local master plan 2029 (Yleiskaava 2029 2015).

Moreover, one thing that this study doesn't take into consideration is the possibility that after the Regional Council study 2010-2011 some new settlements might have been built closer than 650 meters from these areas. If this is the case for some areas then their suitability for wind turbines needs to be re-evaluated.

Based on the Table 18, 54.04 GWh of electricity can be produced with 3 MW wind turbines in these defined and suitable production areas. This represents 4 % of the total electricity demand of Turku.

Small scale production with vertical axis wind turbines

Vertical axis wind turbines can be used for distributed wind power production. There is a Finnish company called Windside, which is producing these vertical wind turbines with different types and sizes. According to Windside the benefits of vertical wind turbines are: its good durability and usability in the storms, production maximum reached in the storms, production of energy already in low wind speeds, unneeded to direct the turbine against the wind, silent functioning, withstands snow, ice, heat, humidity and corrosion, allowed to be used on buildings, very long lifetime and almost maintenance free (Windside® WS-4—Kauneutta ja tehokkuutta 2016). Image 9 below presents one of the Windside turbines.

Image 9. Windside vertical axis wind turbine (Cleantech 2009)

The aim of this study is to examine the electricity production potential of Windside vertical axis wind turbine in Turku. This study will be done for Windside WS-2 and WS-4 type turbines, because they are suited for multiple installation scenarios (Strong and Durable 2016). The idea is to evaluate the potential by calculating how much electricity can be produced when one Windside turbine (either WS-2 or WS-4) is installed on the buildings in Turku. First, a very rough suitability evaluation of these turbine types for different kind of buildings will be performed. Here, the idea is that for bigger constructions (e.g. industrial buildings) the WS-4 will be installed, because WS-4 is bigger and heavier than WS-2 and thus seen more suitable for larger constructions. Consequently, the WS-2 is seen in this study to be more suitable for smaller construction. Table 21 below will indicate the division of the turbine types to different building types and the amount of the different types of buildings. Turku has also 67 buildings, which are categorized as “other buildings”, but these won’t be taken into consideration (Tilastokeskuksen PX-Web-tietokannat 2014a).

Table 21. Installation of the Windside turbines to different building types (Tilastokeskuksen PX-Web-tietokannat 2014a)

Types of buildings	WS-4	WS-2
Detached houses		12987
Row houses		2519
Apartment buildings	2642	
Commercial buildings	579	
Office buildings	324	
Buildings for transport	758	
Healthcare buildings	218	
Social gathering buildings		303
Educational buildings	201	
Industrial buildings	622	
Warehouse buildings	586	
Total	**5930**	**15809**

However, in this study it is not seen realistic that every building in Turku would have a vertical axis turbine (e.g. protected buildings). Therefore, in this study the wind power potential will be determined for 50 % of the buildings suitable for WS-4 and 50 % for WS-2. Furthermore, the wind speed used for this calculation will be taken from 10 meters altitude, because it is seen to approximately correspond with the height of the buildings. The average wind speed of Turku in the 10 meters altitude is 3.4 m/s. This was measured in the airport of Turku. (Meteorologist, Finnish Meteorological Institute, 2016, pers.comm., 29 February) However, the wind speed for these calculations will be 4 m/s, because the webpage of the company Windside presents annual power production amounts for this speed (Strong and Durable 2016) and because the airport is not on the coast and the wind speed is estimated to be higher closer to the coast in this study. The Table 22 below presents the annual wind power production amount with Windside vertical axis turbines.

Table 22. Annual wind power production amount with Windside vertical axis turbines.

Description	WS-2	WS-4
Number of suitable buildings	15809	5930
Realistic number of suitable installations	7905	2965
Estimated wind speed (m/s) in 10 meters alt.	4	4
Annual power production (MWh) at 4 m/s	0.12	0.4
Total annual production (MWh)	949	1186
Total combined annual production (MWh)	**2135**	

Based on the Table 22, 2.135 GWh of electricity can be produced with the combination of WS-2 and WS-4 wind turbines. This represents 0.16 % of the total electricity demand of Turku. However, it has to be noted that this is only an indication of the potential and doesn't say a lot about the possibility of realization. Furthermore, no precise regulation was found concerning the installation of small scale vertical axis wind power production. This is maybe due to the lack of experience in deploying this technology in Turku. It has to be noted that there can be some construction regulations that can place further restrictions on the installation of this technology.

6.6.3 Biomass energy

As indicated in the Appendix A the new power plant of Naantali will use biomass (mainly wood) for heat and electricity production in the future. This power plant will be situated in the municipality of Naantali (see Image2) but due to the plant's location close to Turku it is seen in this study as part of the municipality of Turku. First, the share of biomass will be 40 %. This mass is planned to be purchased from about 150 km radius from the plant (excluding the sea area). The need of biomass in the beginning will be about 1000 GWh/year. In the long run the share of biomass is planned to be increased to 60-70% and then the annual need of biomass will be about 2000 GWh. This new share will probably mean that biomass will have to be imported by sea cargo. (TSE Oy Naantalin uusi voimalaitos 2014) The forest biomass potential of Turku has been determined to be 41 GWh and the field biomass (e.g. straw) 7 GWh. (Hallvar 2014) Thus, it can be concluded that the municipality of Turku doesn't have even nearly this kind of biomass potential and therefore the biomass for the plant needs to be transported from a wider area. Thus, the future energy production of Naantali cannot be fully considered as renewable energy production inside Turku, because the biomass will come mainly outside of Turku.

The new power plant of Naantali is planned to produce annually on average 830 GWh of electricity and 1360 GWh of heat. (TSE Oy Naantalin uusi voimalaitos 2014) The Table 14 shows the amounts of renewable energy that this Naantali plant will produce for Turku with the 40 % share.

No other biomass energy sources will be studied here, because it is estimated in this study that due to the new huge investment to the Naantali plant's energy production with biomass other interests and investments towards biomass energy production will be minimal in the near future in Turku. Furthermore, extensive studies concerning biomass availability have been done already in the area of Turku by for example Hallvar (2014) and Alijoki & Paloposki (2014) and thus it is not seen useful to study this area. Moreover, the timetable of this study sets restrictions on the extensive study of several biomass energy production potential. One future potential source of energy for Turku could be blue-green alga by creating hydrogen from the blue-green alga. The University of Turku is currently studying this possibility. (K Koskinen 2016, pers.comm., 05 February) (Ermakova 2015)

6.6.4 Cooling

Over 90 % of the district cooling needed in Turku is produced by renewable energy. Due to this high share of renewable production it is not seen as a key issue to study the renewable cooling potential in Turku and include it in the following sections of this study. Furthermore, prediction amounts of possible future cooling demand increase in Turku were not found in this study. However, if the district cooling demands increase rapidly in the future in Turku, one possibility to produce more cooling for the city is to get it from the seawater. This kind of a system is already operational in Stockholm (Lind et al. 2016).

6.6.5 Energy conservation

The energy efficiency in Turku's premises is seen as a big potential (S Lyytinen 2016, pers.comm., 08 February) (A Ahtiainen 2016, pers.comm., 03 February). In this part a rough evaluation of the energy saving potential of Turku's premises will be performed. First, the energy saving potential of non accommodation premises will be evaluated and then the energy saving potential of the accommodation buildings will be evaluated. The energy saving potential of the public lighting in Turku is not evaluated here, because a major transition to street LED-lights has already been done in Turku and it is seen that not a lot of energy savings can be achieved in this field.

Non accommodation premises

This part includes the evaluation of the following premises: commercial buildings, office buildings, buildings for transport, social gathering buildings, educational buildings, industrial buildings and warehouse buildings. In order to evaluate the energy saving potential of these buildings an expert interview was performed with a person who has a long experience in improving the energy efficiency of these types of buildings in the Finland's biggest cities. This interviewee is Jukka Paloniemi who is a Development manager in the Caverion Corporation and his current responsibility is to develop technologies related to improving premises' energy efficiency. He has worked in the field of premises' energy efficiency since 1994. (J Paloniemi 2016, Pers.comm., 18 March)

The interviewee has drawn a chart of the energy saving potential of the non accommodation premises in the Finnish cities based on his own experiences of performing energy reviews in these types of premises. The Figure 9 below presents this chart. This chart presents the sum of the heat and electricity saving potential. The saving potential decreases towards the present time. This is because of the development in the energy efficiency regulations and energy efficiency technology as well as due to the decrease in the price of these technologies (J Paloniemi 2016, Pers.comm., 18 March).

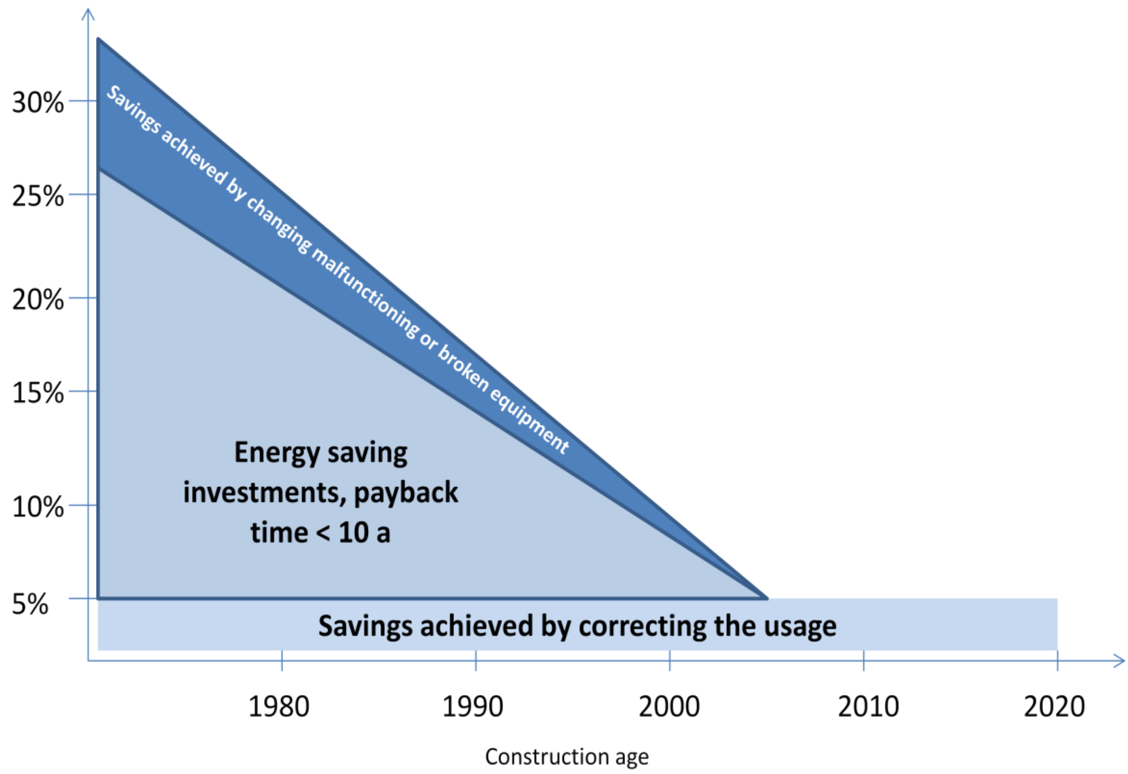


Figure 9. Energy saving potential of non accommodation premises. (Modified from J Paloniemi 2016, Pers.comm., 18 March).

The savings achieved by correcting the usage means that these savings can be achieved if the premises' heating and electricity system would be used according to the need of the users and that energy wouldn't be used in vain. This means for example that the temperature in the premises can be raised during the summer and decreased during the winter. The energy investments in the chart mean for example investments to sensors, frequency changers, heat recovery ventilation and lighting. This chart evaluates the saving potential only for investments, which payback time is less than 10 years. Moreover, the upper part of the chart means changing equipment that is malfunctioning or broken. Often these changes improve the energy efficiency of premises. (J Paloniemi 2016, Pers.comm., 18 March)

It is assumed in this study that although the information presented in Figure 9 represents an estimate of the energy saving potential of several different cities in Finland, it can be applied in this case only for Turku. Noteworthy is also that this chart represents the potential of built premises starting from the year 1970. This is because the interviewee has estimated that the premises built before 1970 have already been renovated and thus the technology used in these premises is newer than their construction age (J Paloniemi 2016, Pers.comm., 18 March). Thus in this study it is estimated that:

- Premises built before 1920 correspond to the premises built in the 1970's
- Premises built between 1921 and 1939 correspond to the premises built in the 1980's
- Premises built between 1940 and 1959 correspond to the premises built in the 1990's
- Premises built between 1960 and 1969 correspond to the premises built in the 2000's

Furthermore, it is estimated in this study that the premises built in 1970's and the premises that's "age" corresponds to 1970 have been renovated again and they now correspond to the premises built in the 1990's.

In order to calculate the energy saving potential the following information is needed:

- The amount of premises built and renovated in each decade
- Average construction/renovation year of the premises in Turku
- The average energy saving potential (%) based on the chart and on the average construction/renovation year
- The total amount of energy demand in Turku for non accommodation premises
- The share of heat saving potential and electricity saving potential in the chart

In 2014 there were 3117 non accommodation premises in Turku. When these premises are divided based on their construction age (Tilastokeskuksen PX-Web-tietokannat 2014a) and assumed renovation age (explained above), this study estimates that the average year of construction of the premises in Turku is about 1996. Thus from the Figure 9 it can be seen that the average saving potential is about 13 % (according to the year 1996).

Furthermore, from the Tables 15 and 16 it can be roughly estimated that the total energy demand for non accommodation buildings is 1427 GWh (Industry + commercial + service). Moreover, the shares of heat and electricity potential in the chart are estimated to be 1/3 for electricity and 2/3 for heat (J Paloniemi 2016, Pers.comm., 18 March).

Now the energy saving potential of the non accommodation premises in Turku can be calculated. The calculation can be found below.

Total energy saving potential: 1427 GWh x 0.13 = 186 GWh

Heat saving potential: 186 GWh x (2/3) = 124 GWh (7 % of the total heat demand of Turku)

Electricity saving potential: 186 GWh x (1/3) = 62 GWh (5 % of the total electricity demand of Turku)

Accommodation premises

In this part the heat saving potential of the accommodation buildings in Turku will be evaluated. Unfortunately not usable information was found on the electricity saving potential of these buildings.

The accommodation heat saving potential evaluation is based on the report of Heljo & Vihola (2012). This study evaluated the accommodation and service buildings' heat saving potential of the premises in Finland based on the building stock in 2010. This study concluded that the realizable heat saving potential is 0.2-0.7 % of the premises' heat demand per one year. This was based on the information concerning the rate of renovations conducted in the premises in Finland. It is stated in this report that it is only economically feasible to perform energy renovations alongside general renovations for the premises. The energy saving actions included in this report are heat recovery ventilation, improving the insulation of the walls, installation of water meters and correcting the usage of the heating system. (Heljo & Vihola 2012)

The report stated that the theoretical heat saving potential in the Finnish accommodation and service buildings' is around 40 %. However, only about 20 % of this potential will be realized until the year 2050 as heat savings due to technical, economic, functional and political reasons.

For the evaluation of Turku's accommodation premises it is assumed in this study (based on Heljo & Vihola (2012)) that the realizable heat saving potential is 0.45 % per year from the premises' heat demand. This means that until the year 2030 the heat saving potential is 6.75 %. The Table 15 indicates that the heat demand of the accommodation buildings in Turku is 787 + 50.6 = 837.6 GWh (Households + Varissuo). Thus, it can be concluded that the heat saving potential for the accommodation premises in Turku is 837.6 GWh x 0.0675 = 56.5 GWh.

6.6.6 Disruptive technologies

In the literature review part of this thesis it was explained that a possible additional dimensions that can be used with a backcasting study is to identify disruptive technologies and social innovations from a case study. This was also the idea in this study and therefore in the interviews the interviewees were asked to name possible disruptive technologies and social innovations that could help Turku in the change towards renewable energy systems. In the Table 23 below the disruptive technologies that were mentioned during these stakeholder interviews will be described. No social innovations were mentioned during the stakeholder interviews. These disruptive technologies can be used as recommendation if more RETs are needed for the RES in Turku. The part 10.1.1 will explain these recommendations.

Table 23. Disruptive technologies mentioned during the stakeholder interviews.

Technology	Description
Low temperature district heating	See Appendix A. Suitable for new buildings and new living districts. (T Bastman, TSE, 2016, pers.comm., 21 January)
An electricity producing carpet	This summer in Ruisrock (music festival in Turku) an electricity producing carpet will be installed in the festival area. This carpet will produce electricity when people will step on the carpet. (A Ahtiainen 2016, pers.comm., 03 February)
Energy poles connected to the district heating network	The over heat from the district heating network can be stored to the ground through energy poles. When the heat is needed the heat could be extracted back to the district heating network. (Energiapaalut tulossa korjausrakentamiseen 2014) (A Ahtiainen 2016, pers.comm., 03 February)
Electricity producing construction materials from solar energy	These materials can be for example balcony windows. (A Ahtiainen 2016, pers.comm., 03 February)
Deep geothermal heat	Turku Energia is interested to start exploring the possibilities of deep geothermal heat in Turku. (I Syrjälä & J Lahtinen 2016, pers. comm., 01 February) So far no explorations in Turku have been conducted. In the town called Espoo these kinds of explorations have just been started and it is the first deep geothermal plant project in Finland. (Lämpöä syvältä maan uumenista 2016) Maybe in the future deep geothermal heat will be a suitable solution for adding new renewable energy sources to Turku's energy production.

6.7 Comparison of RE supply and potentials to the total energy demand

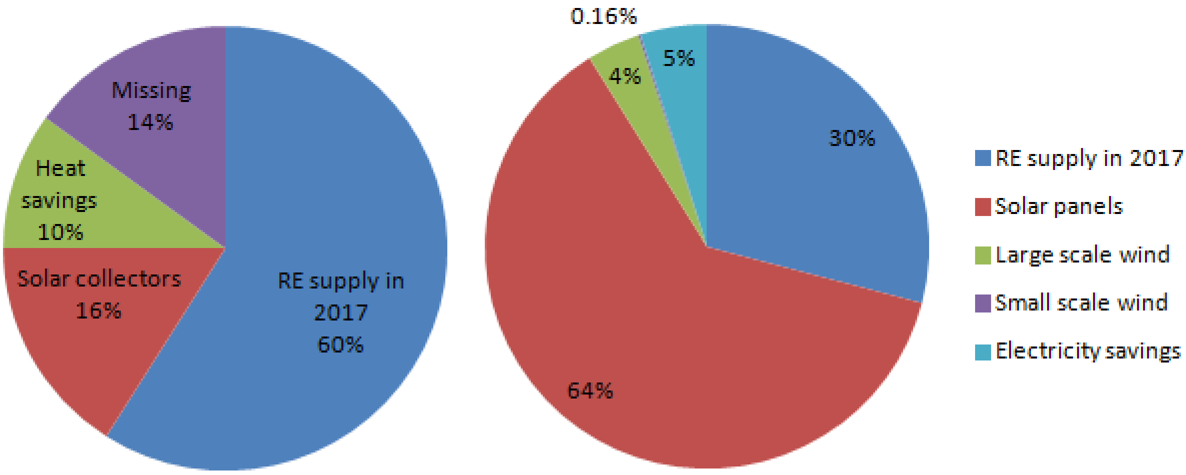
The Table 24 below compares the RE supply in 2017 and potentials studied in the sections 6.5 and 6.6 as well as in the Table 14 to the total energy demands presented in the Tables 15 and 16. The energy saving potential describes the saving potential of non accommodation and accommodation buildings in Turku, excluding the electricity saving potential of accommodation buildings. The Figure 10 below describes the shares of renewable heat and electricity potential.

Table 24. Comparison of RE supply in 2017 and current RE potentials to the current total energy demand

	Heat (GWh)	% of total heat demand	Electricity (GWh)	% of total electricity demand
Total energy demand	1831		1356.5	
RE supply in 2017	1106*	60%	402.5*	30%
Solar panel potential			867.8	64%
Solar collector potential	293	16%		
Large scale wind potential			54.04	4%
Small scale wind potential			2.135	0.16%
Deep geothermal potential	Unknown		Unknown	
Energy saving potential	180.5	10%	62	5%
Total demand - (RE supply in 2017 + RE potentials)	251.5		-31.975	
Total %		86%		103.16%

*These amounts are taken from the Table 14

Figure 10. The shares of renewable heat and electricity potential



From the Table 24 it can be concluded that the RE supply in 2017 for heat and potentials found for heat production are not enough to cover the total heat demand of Turku. Furthermore, it can be concluded that the RE supply in 2017 for electricity and potentials for electricity are enough to cover for the total electricity demand of Turku and there will even be some over production. However, RE supply in 2017 includes RE sources from outside of Turku. Again it has to be noted that these results are only indications of the potential and they don't say a lot about the possibility of realization.

7. Current developments related to RES in Turku

Currently many developments are taking place inside and outside of Turku, which have an effect to the RES in Turku. Here these developments are divided to political, economic, social, technological, policy and spatial developments. Furthermore, motives for developing a RES in Turku are described as well as local initiatives and projects. Defining the current developments is part of the strategic problem orientation step indicated in the Table 9.

7.1 Motives for developing a renewable energy system

First motive that the municipality of Turku has is to strengthen the economy of the area by increasing the share of renewable energy production and by developing a renewable energy system. This change is needed in order to create more jobs in the area and to attract businesses. The municipality of Turku has already done studies, which show that favouring coal in the area's energy production won't increase the employment rate of the area but instead favouring wood in the area's energy production would increase it. (R Veivo 2016, pers.comm., 11 February)

Second motive is to create possibilities for local and national green technologies and solutions and to enhance their development and implementation (R Veivo 2016, pers.comm., 11 February). This on the other hand will indirectly increase the export of these technologies and solutions, which has a valuable effect to the area's economy.

As a third motive, can be seen the boost that developing a renewable energy system would give to the image of Turku. Nowadays the cities all over the world are competing about who is the most sustainable city. This competition demands for ambitious goals and ability to make the change. (J Pelkonen 2016, pers.comm., 13 February) A positive image is linked also to the positive effects mentioned above, because it can attract habitants and businesses to the area and increase the export activities of the area.

Fourth motive is improving the competitivity of heat production in the area. Due to the high share of taxes (taxes: 14€/MWh; Price of heat: 56€/MWh) on fossil fuels, emission trading scheme and the ongoing rising trend of fossil fuel taxes, Turku Energia (the heat provider in Turku) is seeking improvements in their competitivity by increasing the share of renewable sources in the energy production. (I Syrjälä & J Lahtinen 2016, pers. comm., 01 February)

Fifth motive is the positive effects that changing to a renewable energy system would bring to the habitants of Turku. Using renewable energy in the energy production would decrease the area's emissions and pollution of the soil. This would in turn affect positively and indirectly to the economy of the area (e.g. reductions in the healthcare costs). (K Koskinen 2016, pers.comm., 05 February)

The sixth motive is a very general one, but it comes from the change that is coming and present in the society. Several parts of the society (e.g. habitants, businesses, political system and education) are demanding sustainable solutions and interested in enabling them. Turku wants to be involved in this development, and better yet, has the possibility of being one of the forefront cities in this process.

7.2 Political development

In general it can be said that there are clear signs of a strong political will (locally in Turku, nationally in Finland and also internationally) towards developing sustainable energy systems. The following paragraphs will give examples of this. Furthermore, the agency dynamics in the case of Turku will be explained.

7.2.1 The goals of Turku municipality

Turku has set ambitious goals for the future concerning coal neutrality and renewable energies. In 2009 the municipality of Turku set in its environment and climate program a goal that in 2020 at least 50 % of district heat used in Turku is produced using renewable sources. Furthermore, it was set in this program that by 2013 all the electricity used by the municipality of Turku group should come from renewable sources. This goal of 2013 was achieved and the goal of 2020 is becoming true. (R Veivo 2016, pers.comm., 11 February)

Turku Energia (the energy provider for Turku), which is owned by the municipality of Turku, has set a similar goal concerning district heating. Furthermore, their goal is that at least 50 % of the electricity that they distribute will come from renewable sources by 2020. Also this goal is becoming true. (R Veivo 2016, pers.comm., 11 February)

A long term goal is set to the year 2040. This goal was set by the city council in 2014 as part of accepting the city's strategy. The goal is that by 2040 the city of Turku will be completely coal neutral (consumption based calculated). This goal includes also the emissions coming from the transport. (R Veivo 2016, pers.comm., 11 February) According to the city's strategy the energy production system is a key to reaching the coal neutrality goal. Thus in order to reach this goal the municipality of Turku will advance the development of a regional renewable energy system. (Ahonen 2015)

7.2.2 Energy and climate strategy of the Finnish government

The current Finnish government has made an alignment in their program, which states that the usage of coal in the energy production must be stopped by the year 2030. One tool that will help in achieving this is to increase the share of renewable energy to 50 % by 2030. In addition to this nuclear power and energy efficient measures will be used to stop the usage of coal. Furthermore, the second alignment is cutting the oil imports to half from the current state. (Hallitusohjelma: Irti hiilestä, ravinteet meren sijaan talteen 2015)

Currently, the Finnish government is preparing their energy and climate strategy to where these alignments will be included. The strategy is planned to be given to the Finnish parliament by the end of 2016. This strategy is aligned with the EUs climate and energy package 2030. (Sipilän hallituksen energia- ja ilmastostrategia 2016) The current Finnish government is putting mainly their focus to the solutions that biomass and bioeconomy can bring to the country (K Koskinen 2016, pers.comm., 05 February).

7.2.3 Sustainability of the wood in energy production

Currently, wood is considered as a renewable energy source on the EU level. However, if this political decision changes in the future it will be a major setback for the climate and energy goals of the Finnish government and municipality of Turku (T Bastman, TSE, 2016, pers.comm., 21 January) (J Hallivuori 2016, pers.comm., 23 February) as well as a major setback for the Finnish economy (Pakko päästä puusta pitkälle 2016).

Currently, there is an ongoing discussion concerning the sustainability of using wood as an energy source. This discussion is going on in the EU level and in United Kingdom, Germany, Holland and Italy there has been severe criticism towards using wood in the energy production. This is due to its possible negative impacts to the environment and because the wood's utility to cut down greenhouse gas emissions is questionable. (Pakko päästä puusta pitkälle 2016)

Currently, EU is preparing a proposal for sustainability criterions that will be used for all biomass types. This proposal will be ready in the summer 2016. Finland has to find a way to convince EU that a sustainable forest economy is not a threat to the environment (Pakko päästä puusta pitkälle 2016) if Finland wants to pursue its current climate and energy goals.

7.2.4 Paris Climate agreement

In December 2015, 195 countries made an agreement of the first legally binding global climate deal. The agreement helps to fight against the climate change, because in the agreement an action plan is presented that will help to limit the global warming below 2^{o}C and even an aim of limiting it to 1.5^{o}C. In the following the key elements of the agreement are presented. (Paris Agreement 2016)

The countries agreed to:

- *"Come together every 5 years to set more ambitious targets as required by science;*
- *Report to each other and the public on how well they are doing to implement their targets;*
- *Track progress towards the long-term goal through a robust transparency and accountability system.*
- *Strengthen societies' ability to deal with the impacts of climate change;* (Paris Agreement 2016)

The agreement also:

- *"Recognises the importance of averting, minimising and addressing loss and damage associated with the adverse effects of climate change;*
- *Acknowledges the need to cooperate and enhance the understanding, action and support in different areas such as early warning systems, emergency preparedness and risk insurance."* (Paris Agreement 2016)

Another important aspect of the agreement is that the developed countries are willing to support the developing countries in the fight against climate change. Developed countries will for example raise 100 billion $ every year until 2025 to help developing countries to tackle climate change. (Paris Agreement 2016)

7.2.5 New nuclear power plant to Pyhäjoki in Finland

A Finnish nuclear power company Fennovoima together with the company Rosatom is building a new nuclear power plant to Finland. Turku Energia (owned by the municipality of Turku) owns shares of this project. This can be seen as a hindering aspect to the development of renewable energy system for Turku. It can be argued that Turku's investments to nuclear power are decreasing the investments made to renewable energy system in the future. (S Lyytinen 2016, pers.comm., 08 February).

7.2.6 Agency dynamics

Nevens et al. (2013) indicate in their article that agency dynamics is an important further research direction for transition management in an urban context. They state that it is important to examine how agency dynamics affect the urban sustainability transition. Agency dynamics take into consideration the dynamics of politics and power and how these dynamics negatively or positively affect the urban transition process. The following paragraphs will explain the agency dynamics that were mentioned during the stakeholder interviews for the case of Turku.

The political power comes from the voters who make their voting decision according to the information they receive and the interpretation that they make based on that information. (R Veivo 2016, pers.comm., 11 February) Thus, it can be said that the dynamics of politics and power are significantly decided by the voters.

When it comes to Turku's goal of coal neutral city by 2040 (incl. Renewable energy system), so far the political system and the voters haven't significantly protested against it. The decision of coal neutral city by 2040 went through easily in the local political system and there were no major debates concerning this goal. (A Ahtiainen 2016, pers.comm., 03 February) This shows that the political system has a strong will to develop a renewable energy system for the city. Furthermore, the current political activities are seen to be heading to the right direction and contributing to the development of the renewable energy system in the city (R Veivo 2016, pers.comm., 11 February).

On a national level the Finnish government's goals are strongly based on the EUs climate and energy goals. According to Pelkonen (2016, pers.comm., 21 January) Finland is currently in process of fulfilling the minimum requirements that the EU has demanded when instead it should actively search for new innovations and analyse thoroughly all the improvements that can be made in the energy system in order to define the maximum emission reductions possible. So the problem is that the Finland is doing what is demanded from the EU, but nothing more. Sitra (see section 8.1.2) has tried to bring this view to the discussion about the future renewable energy system, because actively changing the current energy system would bring new possibilities for renewable energy technologies and to exporting Finnish solutions. (J Pelkonen 2016, pers.comm., 21 January)

Another aspect that is hindering the development of the renewable energy system is the ideological differences that the political parties have in Finland when it comes to energy production. Due to these differences the political support (e.g. subsidies and taxes) towards the renewable energy production changes according to which political parties are in power. Consequently, the investors of renewable energy are hesitant in investing to renewable energy technologies, because they don't know whether they will have long-term support from the political system. (K Koskinen 2016, pers.comm., 05 February)

7.3 Economic development

Internationally it can be seen that investments to the renewable energy systems are increasing and the price of its technologies are decreasing. This in turn changes the functioning of the energy market in a way that alongside of the conventional market, with only few big actors, there are coming many smaller actors (e.g. energy producers and innovators). (R Veivo 2016, pers.comm., 11 February)

In the case of Turku it can be said that the economic development towards renewable energy systems has taken place mostly through investments in the energy productions (e.g. construction of the new power plant of Naantali; Appendix A). One reason for this can be that the price of energy in Finland and in Turku is fairly low and consequently the investments have gone more to the production side and less to the improvement of energy efficiency (S Lyytinen 2016, pers.comm., 08 February).

However, there are also some national and international taxes and subsidies that affect the situation in Turku. The part 7.3.1 below presents these taxes and subsidies. Furthermore, the part 7.3.2 presents an example of sustainable budgeting in Turku and the part 7.3.3 gives an example of economical incentives in Turku.

The problem in Europe with the energy subsidies and taxes concerning the energy production is that in different areas in Europe the subsidies and taxes are different from each other. This doesn't offer an equal competition (T Bastman, TSE, 2016, pers.comm., 21 January) (J Hallivuori 2016, pers.comm., 23 February) between the different energy producers and technologies.

7.3.1 Taxes and subsidies

Feed-in tariff

Finland has a feed-in tariff system, which purpose is to give financial support to wind power, biogas plants and wood power plants. This system was started in 2011. The feed in tariff in Finland is 83.5 €/MWh except for the woodchip power plants the tariff is determined according to the prices in the cap and trade system. The government pays the producer the difference between the feed-in tariff and the market price of the electricity. A power plant can get this support for 12 years. (Syöttötariffi 2015) This feed-in tariff has been criticized to be too generous for wind energy and giving too much support for only one renewable technology.

Sweden and Norway have EL- certificate system concerning the feed-in tariff. In this system the electricity producer is given certificates according to the amount of electricity that the producer produces. Then the electricity producer can sell its electricity to the electricity market and sell certificates to the certificate market. The price of the certificate is determined by the demand and availability of the certificates. The electricity user (not the small scale user) or retailer is obliged to buy certificates in relation with its electricity consumptions or sales. The final electricity users pay the expenses in the end. The electricity users and retailers have to inform the systems authority the number of certificates they have bought and thus according to this the authority can annul these certificates. (Patronen 2015) There are also investigations in Finland, which analyze how beneficial this system in Sweden and Norway could be if it were implemented in Finland (J Hallivuori 2016, pers.comm., 23 February).

Energy tax

Finland has an energy tax, which is an excise tax of liquid fuels, and some other fuels (e.g. coal and gas) that are used for energy production. However, there is no tax for fossil fuels that are used in the production of electricity (T Bastman, TSE, 2016, pers.comm., 21 January).The amount of the tax is determined by what the fuel's heat value is and how much CO_2 it contains. In addition to this, fossil fuels and bio based fuels have a so called maintenance security fee. In recent years the taxation of biofuels has been changed so that it is more favorable than the taxation of fossil fuels, because this contributes to the fight against climate change. (Energiaverotus 2016) The energy taxation has varied a lot during the years for natural gas, peat and biofuels whereas the tax for coal has only been raised consistently. This is partly due to the changes of parties in the Finnish government. However, it would be very important that the tax and prices of raw materials would stay the same so that the predictability of the energy production would be better. (T Bastman, TSE, 2016, pers.comm., 21 January)

Energy subsidy

The energy subsidy can be given to municipalities, companies, organizations or individual house owners by the Finnish government.

The energy subsidy for house owners is given to them who invest in equipment and material that will improve the energy efficiency of the house, decrease the emissions of the energy usage and/or increases the usage of renewable energies (Pientalojen harkinnanvarainen energia-avustus 2013). In the year 2015 the Finnish government granted 2 million Euros for this subsidy (Korjaus- ja energia-avustukset 2015 2014). This subsidy encourages house owners to invest in environmentally friendly energy systems. Also the municipality of Turku gives this kind of energy subsidy to its habitants with low incomes (Pientalojen energia-avustus 2016).

On the other hand the energy subsidy for municipalities, companies and organizations is given to them who invest to or perform studies that advance:

- Renewable energy based production or usage
- Energy savings or efficiency of energy production or usage
- Reduction of environmental problems coming from energy production and usage

This subsidy, given by the Finnish government, helps in enabling the investment, because it improves the profitability of the investment and decreases the risks involved in deploying new technologies. This in turn helps bringing new sustainable technology in the market. (Energiatuki 2016)

Cap and trade system in Finland

Finland is part of the EUs Cap and Trade system. Actors who have to buy the emission licenses of this system are power plants (bigger than 20 MW) and some industrial companies. The license permits the actor to emit a certain amount of emissions in the environment. Energy authority is the organization that administrates the cap and trade system in Finland. (Yleistä päästökaupasta 2016) The feed-in tariff is said to act against the cap and trade system in Finland, because the tariff lowers the price of emissions and thus enhanced the profitability of greenhouse gas emitting energy production. (J Hallivuori 2016, pers.comm., 23 February)

New system for subsidising the RE production

A working group of the Finnish Ministry of Employment and Economy has conducted a research concerning the future suitable subsidy possibilities for renewable energy production. According to this group the most cost efficient subsidy possibility is a technology neutral RE production subsidy that is based on competitive bidding. In this system the Finnish government would set a yearly target amount for renewable energy production and the energy producers will offer a price with which they are able to produce this energy. The lowest bidders will receive the RE production subsidy. This will guaranty that the most cost efficient projects will be successful. This could be the future possibility for subsidising the renewable energy production and this system could replace the current feed-in- tariff system in the future. (Jokela 2016)

7.3.2 Sustainable budgeting by the municipality of Turku

The aim of this budgeting is to encourage the users of the municipality's real estates to energy savings in the premises. The idea is that if a real estate achieves energy savings, through correct budgeting, the financial benefit of those savings will be directed to the development of those premises. The old system directed the benefits to the overall budget of the municipality and thus it didn't benefit the energy saver directly. This new budgeting encourages more the users to find energy efficient solutions in the premises. (R Veivo 2016, pers.comm., 11 February)

7.3.3 Solar power plant of Kupittaa and ESCO- projects

The idea behind these projects can be seen as an economical development, because these projects have found how to involve actors to these projects by giving new kind of economical incentives. More information from these projects can be found from the Appendix A.

7.4 Social development

In general it can be said that the public discourse concerning renewable energy systems has increased internationally. This in turn means that people are more aware of the possibilities and potentials of renewable energy systems. This ongoing discourse has also helped the people to better accept the changes occurring in the energy system. This acceptance is related also to the urbanization trend that is ongoing in the world. People are more willing to live in denser neighborhoods and understand also the energy saving potential of this style of living. (K Koskinen 2016, pers.comm., 05 February)

The following parts will present several social actions and developments that have taken place in Turku. However, according to Veivo (2016, pers.comm., 11 February) more social inducement should and could be done on a local level.

7.4.1 Social acceptance

The attitudes of Turku's habitants are described to be positive towards the developments of renewable energy. A proof of this is that often the house owners in Turku are investing in renewable and energy efficient systems (e.g. geothermal heating and air-source heat pumps) instead of conventional fossil fuel based systems. (R Veivo 2016, pers.comm., 11 February)

Another example is the success of the solar plant soon to be built in Kupittaa. At first the plant was planned for 170 panels, which were rented by the habitants in less than two weeks. After this success it was decided that even 80 solar panels will be added to the plant. This also confirms the observation that solar energy draws a lot of interest among the citizen's of Turku (A Ahtiainen 2016, pers.comm., 03 February).

One aspect that can facilitate the success of renewable energy and its social acceptance is that Turku Energia has managed to create an easy electricity purchasing process for the habitants of Turku, when it comes to buying certified renewable energy (A Ahtiainen 2016, pers.comm., 03 February).

Despite of these positive attitudes, it must be said that the investments to the renewable energy hasn't affected significantly the price of energy in Turku. If this kind of development will occur in the future it can also affect negatively the habitants attitudes towards renewable energy (T Bastman, TSE, 2016, pers.comm., 21 January).

7.4.2 Energy guidance

Valonia (see section 8.1.2) gives energy guidance to the habitants of Turku. This guidance happens through organizing energy guidance evenings for the citizens, through eneuvonta.fi portal and by offering an energy guidance hotline, where the citizen's of Turku can call and ask advices concerning their energy matters. The subjects of the guidance are for example energy consumption, acquisition of energy equipments and ways of heating the premises. (Valonia on alueellinen energianeuvoja Varsinais-Suomessa 2015).

7.4.3 Turku Energy's social activities

Turku Energia has a customer magazine called Valopilkku, which is published four times a year. Through this magazine Turku Energia tries to make the customers aware of renewable energy and its possibilities. Furthermore, Turku Energia uses its website to same kind of purposes. Moreover, Turku Energia informs about its separate projects also through the local newspapers. (I Syrjälä & J Lahtinen 2016, pers. comm., 01 February).

However, according to Koskinen (2016, pers.comm., 05 February) Turku Energia and the municipality of Turku could do a lot more communication in the social media. Through this communication these two actors could affect the energy usage of the habitants and could acquire more customers that would purchase renewable energy. Important would be to maintain the conversation with the customers in the social media. (K Koskinen 2016, pers.comm., 05 February)

Another Turku Energy's social activity is that it gives smart electricity meters to its customers so that it can monitor the customer's electricity usage and give feedback to the customer. Furthermore, the customer can have a mobile device from where the customer can monitor his/her electricity usage. (R Veivo 2016, pers.comm., 11 February)

7.4.4 Turku municipality group's ecological assistance

The municipality group has established an ecological assistance function in their activities. The purpose is to name a responsible person to every domain of the municipality group and this person will advice and support its co-workers to sustainable actions in their workplace. The idea is that if a domain achieves for example energy savings the profits will be directed to the use of that domain. (Esimerkkinä Turun kaupunki 2016)

7.4.5 Finnish renewable energy discussion

According to Lyytinen (2016, pers.comm., 08 February) in the current energy discussion in Finland often people relate to renewable energy negatively by stating its problems and challenges. Finland has a small population compared to its surface area and has a big potential in renewable energy, but still people see many challenges and problems and close their eyes from the development that is going on in Germany and Denmark for example. How could this negative attitude be changed to positive and how this positive attitude could be used as a driver for enhancing renewable energy system in Finland? (S Lyytinen 2016, pers.comm., 08 February)

7.5 Technological development

7.5.1 Biomass energy

Biomass is and will be a big energy source for Finland and Turku. In Finland wood is the biggest energy source. In 2013, from the total energy use of Finland, 25 % came from wood sources. The second biggest was oil with 23 %. (Torvelainen et al. 2014) In Turku wood is also used to produce heat in the Oriketo plant and in the Luolavuori plant (just became operational) (see Table 14 and Figure 8). In the future the biomass is seen as a big potential for energy production for the area of Turku (K Koskinen 2016, pers.comm., 05 February). According to the study done in the Turku University of Applied Sciences, the maximum potential of biomass (forest and agriculture) in Turku is 97 GWh (Hallvar 2014). Also blue-green alga can have energy production potential in Turku in the future by creating hydrogen from the blue-green alga. The University of Turku is currently studying this possibility. (K Koskinen 2016, pers.comm., 05 February) (Ermakova 2015)

In the new power plant of Naantali (see Appendix A) wood will be the most important biofuel used in order to produce heat and electricity. Other fuels will be straw, industry's by-products, peat, coal, oil and possibly recovered fuel. (TSE Oy Naantalin uusi voimalaitos 2014) This new power plant is called a multi-fuel CHP plant in which the latest technology will be used. A circulating fluidized bed boiler will be used in the plant, which enables the usage of several different kinds of fuels and also enables a 100 % usage of biofuels in the heat and electricity production of the new plant. Furthermore, this boiler is very environmentally friendly, because it reduces efficiently its emissions to the environment. The operating efficiency of the plant is 92 %. (NA4 CHP-projekti 2015)

The future question mark concerning the power plant of Naantali is the availability of the wood due to the area's location and land use. According to Bastman (TSE, 2016, pers.comm., 21 January) it is possible that in the future the wood has to be brought from abroad. Bastman states that in this kind of situation the question mark is how sustainably the wood is grown and cut in these forests and how expensive this wood will be. Furthermore, it can be questioned also how sustainable the logistical chain is, if the wood is transported from far away. This also reduces the value of energy independence of Turku.

Consequently, the logistical chain of the biomass is very crucial for the efficient operation of the Naantali plant. For example for wood the logistical chain starts from the forest. First it is transported by trucks to the conveyor line, which transports the wood to the plants warehouse. From the warehouse the wood is transported via another conveyor line to the boiler. This process includes also the cutting the wood to suitable pieces and purification of the wood from unwanted materials for the production. (NA4 CHP-projekti 2015) According to Bastman (TSE, 2016, pers.comm., 21 January) the current technological development concerning the biofuels is concentrated especially to the improvements in the logistical chain (e.g. harvest and crushing). (NA4 CHP-projekti 2015)

7.5.2 Solar Energy

There has been major technological development in the field of solar photovoltaics (PV) and concentrated solar power (collectors).

Below some indications of the global developments of PV panels:

- From 2009 to 2014 the prices of PV panels have decreased with around 75 %. For example in Italy a price of a 1000 kW panel in 2009 was 3.5 USD/W when in 2013 it was only 0.8 USD/W.
- From 2010 to 2014 the installation costs of a utility-scale PV system has decreased by 29 % to 65 %, depending on the region. For example in Germany these costs have decreased from 7200 USD/kW in 2008 to 2200 USD/kW in 2014.
- From 2003 to 2012 the average efficiency of PV panels has increased with about 4.8 %. For example the crystalline silicon PV panel's (the most efficient panel) efficiency increased from 15.5 % to 21%.
- The global average LCOE (levelized cost of electricity) of utility-scale solar PV has fallen by half in four years. For example from 2010 to 2014 the LCOE of an average utility-scale PV panel has decreased from 0.32 USD/kWh to 0.16 USD/kWh and the most competitive PV projects are achieving 0.08 USD/kWh without financial support.
- From 2010 to 2014 the global cumulative installed capacity has increased by about 360 % (from 39 GW to 179 GW)

(Renewable power generation costs in 2014 2015)

Furthermore, below some cost and production indications of solar collectors:

- The global LCOE range for collectors was in 2010 0.33-0.44 USD/kWh and in 2014 0.20-0.35 USD/kWh (in Europe 0.25 USD/kWh).
- From 2010 to 2014 the global cumulative installed capacity of solar collectors has increased by 286 % from 1.3 GW to 4.8 GW.
- The capacity factors of these collector power plants range from 43 % to 79 % (Renewable power generation costs in 2014 2015)

Currently only 1 % of the electricity used in the world comes from solar panels. However, the International Energy Agency has estimated that in 2050 solar energy can be the biggest single electricity producers from all the energy producing methods. (Mielonen 2015) Currently the amount of electricity produced with solar panels or collectors is very low in Finland (about 0.001 %), but the amount is seen to rapidly increase in the future. (Aurinkoenergia ja aurinkosähkö Suomessa 2014)

7.5.3 Wind energy

In the recent years there haven't been a lot of improvements in the efficiency of wind turbines, because they are currently close to the maximum achievable efficiency. However, current technological developments have occurred that have made the turbines bigger (rotor diameter and hub height). (Ricken 2012) This in turn has increased the environmental issues related to wind turbines (e.g. visibility and audibility) (T Bastman, TSE, 2016, pers.comm., 21 January).

The wind turbines can be divided to big size onshore and offshore turbines and to small size onshore turbines (mainly onshore). Furthermore, the onshore turbines can be divided into vertical and horizontal axis turbines. The following will describe the technological development of the big size horizontal axis turbines and describe where the smaller turbines (vertical and horizontal) can be used.

During the last 25 years the size of the big size horizontal axis wind turbines has manifold (see Image 10 below). In 1981, the rotor diameter was 15 meters and the hub height 22 meters, but nowadays the diameter can be 130 meters and the height over 140 meters. The capacity has increased from 55 kW to 3000 kW or even to 7000 kW. Currently, the hub heights for the wind turbines built in Europe and in Finland are between 120 and 140 meters and the yearly electricity production amount has become 100 times bigger compared to the first wind turbines. This has been achieved thanks to the higher hub heights and better aerodynamics. (Tuulivoimatekniikka 2016) This development has increased the competitiveness of the wind energy production by decreasing its costs and increasing its efficiency. In 2011, the LCOE of one wind turbine (2 MW) in the western Finland was 38.9 €/MWh. (Hakkarainen 2014) Developments in the competitiveness and size are seen to continue also in the future (Tulevaisuus tuo kasvua 2016) (Hakkarainen 2014). The technical lifetime of current wind turbines is around 20-30 years (Taloudellisuus 2016).

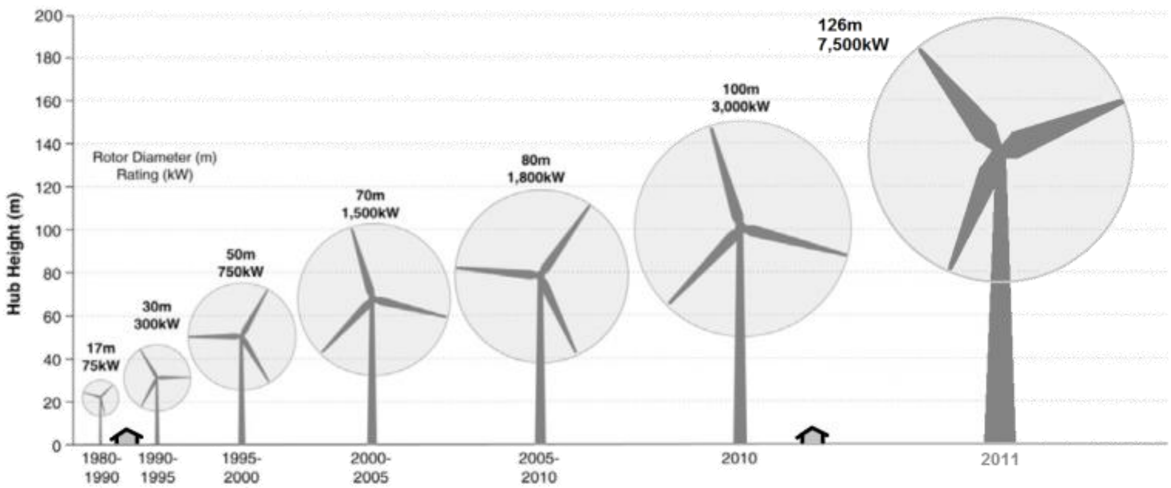


Image 10. The size increase of horizontal axis wind turbines during the years. (Tuulivoimatekniikka 2016)

In 2014, Finland had 459 MW of installed wind power capacity, and these turbines produced only 0.9 % of the year's electricity consumption in Finland. However, Finland's goal is to achieve a wind power production of 6 TWh by the year 2020 and 9 TWh by 2025. (Joensuu 2014)

The small size turbines (vertical or horizontal) are suitable for decentralised electricity production. They can be used either in agriculture, facilities, households or sailing boats in order to increase the self-sufficiency and decrease the electricity bill. The turbines where the surface area of the rotor is under 200 m^2 and the capacity is under 50 kW are called small size horizontal turbines. (Pientuulivoima 2016)

There is one producer of the vertical axis turbines in Finland. This is a company called Windside. (Luettelo tuuliturbiinien valmistajista 2014) The typical size of their vertical turbines vary from 0.15 m^2 to 12 m^2 (wind sweep area) (Esitteet 2016). The annual production amount of a 0.15 m^2, with 7.5 m/s average wind, is 96 kWh. The annual production amount of a 12 m^2, with 7.5 m/s average wind, is 22 MWh. (Tekniset tiedot 2016) The advantage of the vertical axis turbine is that it can produce electricity during very high winds when the horizontal axis turbine needs to be stopped.

7.5.4 Geothermal energy

Developments in Finland

In Espoo Otaniemi the first project in Finland concerning building a geothermal district heating plant has just started this year. (I Syrjälä & J Lahtinen 2016, pers. comm., 01 February) (Lämpöä syvältä maan uumenista 2016) Turku Energia is also interested in starting a similar project in Turku, but so far no actions have been taken towards it (I Syrjälä & J Lahtinen 2016, pers. comm., 01 February).

The Espoo project is run by an energy company St1 and as their first action they have started to drill a hole of 2 km deep in order to examine the properties of the soil. Based on this drilling, St1 is going to build a pilot power plant, which is planned to be operational in 2017. St1 estimates that an industrial scale power plant's maximum capacity in Otaniemi will be 40 MW. (Lämpöä syvältä maan uumenista 2016) The future plant will have two holes of 7 km deep in the ground. From one hole water will be fed down and this heated water will come up from the other hole. The heat of this water will be fed through a heat exchanger to Espoo's district heating network. (Lämpöä syvältä maan uumenista 2016)

Current technologies

The current technologies in use for geothermal electricity production are flash steam plants, dry steam plants and binary steam plants. The flash steam plants and dry steam plants are used in temperatures above 180 ^{o}C and they use steam from the underground reservoirs to produce electricity. Binary plants are used in temperature between 73 ^{o}C and 180 ^{o}C. These plants use an organic fluid, which is heated by the geothermal fluid to produce electricity. In addition to these plants that produce electricity, there are plants that use only the heat from the underground reservoirs to heat up the area's district heating network (e.g. the future plant of Otaniemi). (Technology Roadmap 2011) The history has shown that the average lifetime for an underground geothermal reservoir is around 30 years. (Matek & Gawell 2014)

LCOE of some technologies

The LCOE of geothermal energy production vary widely. The average costs for flash steam plants are estimated to be between 50 USD/MWh to 80 USD/MWh, whereas the average costs for binary steam plants are estimated to be between 60 USD/MWh to 110 USD/MWh. (Technology Roadmap 2011) However, it has been estimated that these costs will decrease in the future. (Technology Roadmap 2011)

7.5.5 Energy storage

When the amount of renewable energy production is increased in the energy system more flexibility from the system is required. The energy storage technology offers one solution by which this flexibility can be increased. For example electricity can be stored in batteries and heat can be stored in different kind of materials or reservoirs. (J Pelkonen 2016, pers.comm., 13 February) However, these technologies are still in their development phase, not economically competitive (J Pelkonen 2016, pers.comm., 13 February) and currently offer a very minimal energy storage capacity compared to the energy volumes (T Bastman, TSE, 2016, pers.comm., 21 January) (S Lyytinen 2016, pers.comm., 08 February). However, it is seen that these technologies will develop in the future (T Bastman, TSE, 2016, pers.comm., 21 January) and become an important part of the future energy system. (J Pelkonen 2016, pers.comm., 13 February)

Electricity storage

"The integration of high shares of renewable energy sources in future energy systems will require a variety of complementary storage solutions. It has been previously determined that electricity storage devices will be needed once 50% of power demand is met with variable RE, and that seasonal storage devices will be needed once more than 80% of electricity demand is met by RE." (Child & Breyer 2016)

Child & Breyer (2016) state in their article that solar and wind power technologies can be the main annual electricity producers in Finland, despite of their intermittent nature, if a variety of complementary electricity storage solutions are provided. These possible storage solutions can be for example stationary batteries, vehicle-to-grid (V2G) connections and grid gas storage for Power-to-Gas (PtG) technologies (PtG explained in Appendix A; Neo carbon energy project). According to Child & Breyer (2016) V2G and stationary batteries facilitate the usage of large amounts of renewable electricity in a short term whereas PtG is a solution for seasonal intermittence issues. Furthermore, the Child & Breyer (2016) explain that PtG facilitates also the efficient usage of CHP, because the gas could be possibly used as a fuel in a CHP plant.

As mentioned in Stenberg (2014) especially lithium ion batteries are considered as the future of electricity storage for renewable energy systems because of their high energy density. In the beginning of their commercial use lithium ion batteries were very successful in the utility products like mobile phones but now lithium ion batteries start to be an attractive technology also for large scale energy storage. However, there are three major development goals for the future concerning lithium ion batteries. These goals are reducing the capital costs of the batteries, electrode development and making the battery even more suitable for large scale applications. One way of cutting the capital costs is to optimize the packaging and overcharge protection circuitry components. Development in the electrodes can be achieved by fundamental research in materials science. Moreover, lithium battery can be made more suitable for large scale applications by improving packaging, state-of-charge estimation, interconnectors, thermal management, protection, cell equalization and control. It is likely that there will be also improvements in the materials processing, fabrication and manufacturing techniques concerning lithium batteries. (Stenberg 2014)

One good example of applying this technology for large scale power systems comes from Germany where a company called Wegman AG opened Europe’s largest commercial battery plant in 2014, which uses 25,600 lithium-ion batteries. The plant receives 80% of its energy from renewable sources and the installation costs of this plant are 6 million Euros. (Stenberg 2014) This plant is able to store 5 MW of electricity. (Germany opens first renewable energy storage facility 2014)

Another possibility for large scale energy storage in the future could be superconducting magnetic energy storage (SMES). According to Bastman (TSE, 2016, pers.comm., 21 January) this will be the future’s energy storage technology. Billions of Euros are spend on this technology so it is highly likely that this technology will come to the market (T Bastman, TSE, 2016, pers.comm., 21 January). In the SMES technology the electricity is stored to a superconducting coil’s magnetic field. Due to the coil’s superconducting ability electricity can be stored there for long durations without major energy losses. The advantages of this technology are its quick response time, charging time and long lifetime. The disadvantages of this technology are its small energy density, high price and its surrounding magnetic field. (Seppänen 2014)

Heat storage

Concerning the heat storage of for example solar collectors, long term and short term solutions are available. Long term heat storage possibilities include for example ground storage using drilling holes or pipes in the ground to store heat whereas steal tank reservoirs are suitable for short term storage (Esterinen et al. 2014). For district heating network storage some water reservoirs could be added to the network in order to assure the supply of district heating during high demand peaks.

Energy storage in Turku

Currently there are two heat reservoirs (5000 m^3 and 15000 m^3) in Turku's district heating network. These reservoirs are water reservoirs, which are filled with hot water when the demand for heat is low and during high demands the heat is released from these reservoirs to the district heating network. The heat reservoirs reduce the usage of peak time reserve plants, which often use oil to produce energy. The number of these heat reservoirs in Turku will increase in the future. (I Syrjälä & J Lahtinen 2016, pers. comm., 01 February)

Also the district heating network itself could be used for storing heat. This could happen by increasing the network's temperature during low demand and releasing the temperature during high demand. Both of these solutions (heat reservoir and district heating network) are suitable for short term heat storage. (T Bastman, TSE, 2016, pers.comm., 21 January)

Future possibility for Turku in the field of energy storage could be to store the overproduction electricity to gas (PtG). The University of Turku is involved in a development project where this possibility is studied. Further information on this project and the technology can be found from the Appendix A (Neo carbon energy project).

7.5.6 Smart grid and heating network

In order to have a fully renewable energy system the energy grids need to become smarter and more flexible. Digitalisation and energy storage technologies are key solutions in this development. For example smart meters are already used to provide real time energy consumption data to the energy providers and users, which can adjust their activities according to this data in order to save energy. It is possible that the future energy system won't longer be a linear system, where the energy provider distributes the energy to the households, but a two way system where the energy user can also produce energy to the system. Also the smart meters are suitable for this, because they enable the metering of the usage and production (Etäluenta 2016) and they enable to run the grid better, identify outages more efficiently and reduce losses in the grid (Hashmi 2011).

Smart grid development in Turku

Modelling of the district heating network with a computer program is in its development stage in Turku. Data (e.g. heat production rate, pumping stations, and customers) can be fed into this program and it gives you a result, which indicates how the power plants and the network should be "driven". The program indicates, for example, what is the optimal temperature and pressure difference in the network. (I Syrjälä & J Lahtinen 2016, pers. comm., 01 February)

Turku is also studying the possibilities of creating a two way low temperature heating network for the area of Skanssi in Turku. This network would better enable the exploitation of waste energy and the usage of renewable energy technologies (e.g. solar collectors). This kind of network is better suited for new buildings, because the energy efficiency requirements are stricter and thus the amount of heat demand is smaller. (T Bastman, TSE, 2016, pers.comm., 21 January) More information on this Skanssi project can be found from the Appendix A.

7.5.7 Energy efficiency

Starting from the year 2021 an EU directive comes into power, which states that all new buildings need to be almost zero energy buildings. The low amount of energy that is needed for these buildings will mostly come from renewable sources (Nearly zero energy buildings 2016). The directive is even stricter for public buildings, because it states that these buildings need to be almost zero energy buildings starting from the year 2019. (Lähes nollaenergiarakennus 2016) This directive will cause a lot of changes in the construction industry (Lähes nollaenergiarakennus 2016) and increase the costs of new buildings (Talojen energiamääräyksiä kiristetään 2016). On the other hand it is seen that these measures will pay off in a long run due to the energy savings of the new buildings (Talojen energiamääräyksiä kiristetään 2016). The following will describe technologies that can help in making the buildings more energy efficient.

Sensors are one example of a technology that can be used to achieve more energy efficient premises. With the help of the sensors the energy users' behaviour in the premises can be monitored and according to this information the energy consumption of the premises can be adjusted. One example of this is that sensors can give information about when the different rooms of a building are used. According to this information the heating of the building can be adjusted in a way that the rooms are heated only when they are used. (S Lyytinen 2016, pers.comm., 08 February) Also lighting can be switched off when some areas of a building are not used. Here Passive Infra Red technology can be used to detect human behavior in a building. (World Energy Perspective 2013)

Another example of a sensor technology is the usage of daylight sensors which can be connected with the lighting of a building. These sensors track the daylight coming to the building and lights can be switched on/off or dimmed accordingly. (World Energy Perspective 2013) The part 6.6.5 also indicated already some energy efficiency measures.

Energy efficiency in Turku

Turku has a lot of potential in reducing the energy demand of its premises, which is significantly directed by the citizens' behaviour and attitudes. A lot is to be done and can be done in making the premises energy efficient. (S Lyytinen 2016, pers.comm., 08 February) (A Ahtiainen 2016, pers.comm., 03 February) Below some examples of technological measures towards energy efficiency that have been taken in Turku.

Turku's University of Applied Sciences is planning to build a visual energy tracking system into one of its premises. This way, students could use this system and realise where the energy is used in the building, what actions should be taken and what kind of energy savings can be achieved from these actions. (S Lyytinen 2016, pers.comm., 08 February)

Another example of energy efficiency measures in Turku are collecting the waste heat of a local newspaper's printing machine for district heating and changing the streetlight bulbs to LED-lights. More information on changing the LED-lights can be found from the Appendix A.

According to Pelkonen (2016, pers.comm., 13 February) Turku is putting a lot of focus to renewable energy production, but should put also more focus to the whole energy system (e.g. energy efficiency and energy storage).

7.6 Local policy for renewable energy technologies

7.6.1 Installation regulations

Solar energy

The local construction regulation instructs how to construct in Turku in a way that it fits to the circumstances of the area (e.g. cultural and natural values). The current construction regulation in Turku came into effect in 2007 (Turun rakennusjärjestys uudistetaan 2015) and the new one will come to effect in 1st of March 2016 (Uutiskirje 2016). The 2007 regulation doesn't include instructions on installing solar energy technologies in the municipality. However, this regulation includes instructions on what is allowed for the facades of the building and what needs to be taken into consideration when some construction/renovation activities are performed for these facades. Based on these instructions some interpretations concerning solar energy technology installations can be made. Based on this it can be said that for solar systems smaller than 5 m^2 an action permit needs to be applied from the municipality of Turku. If the system is bigger than 5 m^2 a construction permit needs to be applied. (Tarvainen 2016)

The regulation concerning the solar energy technologies are vague in the 2007 contract and no clear rules have been set in it. When a person or a company is planning to install solar energy technology, it is advised to contact the construction supervision authority of Turku and they will make a decision case by case. Especially in the city centrum area and in the city plan areas it is more difficult to get an installation permit. (Tarvainen 2016)

The 2016 construction regulation instructs the installation of solar collectors. In this regulation it is indicated that a solar collector system under 22 m^2 can be installed to buildings' roof or façade (not street side façade) without a permit if they are outside of a protected area or not on a protected building. These collectors have to also fit the composition of the building and the city. (Turun kaupungin rakennusjärjestys 2016)

In the zoning regulations solar energy technologies have not been taken into account in Turku. One exception is the area of Skanssi in Turku (see Appendix A). In its zoning regulations it has been instructed that in the construction planning and implementation solar energy technologies should be anticipated. (Tarvainen 2016)

Wind energy

The regional land use plan in Finland should provide general indications of areas suitable for wind power projects. *"Any wind power project of regional importance should, as a ground rule, be based on regional land use planning. Detailed land use planning may not conflict with the regional plan. The land use planning will require extensive studies on e.g. noise and flicker, nature values, endangered species such as flying squirrels, nesting and migrating birds, bats, impact of relics, reindeer herding (where applicable) as well as the impact on the landscape."* (Holmström et al. 2014, p. 3-4) In the land use plan of southwest Finland (including Turku) there is indicated suitable areas for wind power production for 3 to 9 turbines and for over 10 turbines. None of these areas for over 10 turbines are inside the municipality of Turku. (Tuulivoimavaihemaakuntakaava 2014)

However, the municipality of Turku is allowed to deviate from the regional land use plan and grant construction permits when only few turbines are installed in their area. These grants may be given for example for industrial areas or harbours. (Holmström et al. 2014)

Other regulations that concern the wind power construction are for example:

- Conduction of environmental impact assessment (for projects with minimum 10 turbines)
- Natura 2000 assessment when turbines are close to Natura sites.
- The conditions of The Nature Conservation Act need to be fulfilled. These include for example the protection of nature conservation areas, nationally and regionally valuable landscapes and endangered species. (Luonnonsuojelulaki 1996) One important protected bird in Finland is the sea eagle (Holmström et al. 2014).
- The conditions of the Land Use and Building Act need to be fulfilled
- Environmental and water permits need to be accepted and given by the municipality if there is a risk of burden to people or impact on the water system
- Approval from the air traffic service provider for turbines higher than 60 meters need to be received.
- Approving statement from the Finnish Defence force need to be received
- Approval from Finnish Energy Authority for the grid connection (if the grid is 110 kV or higher)

(Holmström et al. 2014)

The problem with the advancement of new wind energy projects in Finland is the broad possibility of filing complaints against the construction of new wind turbines. This can cause difficulties for example to Turku Energia who's goal is to buy more electricity from a Finnish wind power company Hyötytuuli. Hyötytuuli's goal is to increase their production from 40 MW to 180 MW by the year 2020. (J Hallivuori 2016, pers.comm., 23 February)

Concerning the small scale vertical axis wind power production, no precise regulation was found. This is maybe due to the lack of experience in deploying this technology in Turku.

7.7 Development of the built environment

Turku municipality's goal is to increase the number of habitants and jobs in the city center of Turku (Yleiskaava 2035 2013). It has been estimated that the population in Turku will increase with 30 000 by the year 2029 (Ahonen 2015). Furthermore it has been estimated that the need for new dwelling construction will be 3 314 000 m^2 in floor surface area (surface area of all the floors) by the year 2035. (Turun kaupunkiseudun rakennemalli 2035 2012) The making of the local master plan for the year 2029 is currently going on in Turku.

The problem of the planned new dwelling zones is that often it is unknown when the construction in the area will start and how many dwellings will be built in that area. This hinders the possibility to use renewable energy production in the area, because one doesn't know when to invest to this production and how much production is needed. (A Ahtiainen 2016, pers.comm., 03 February)

7.8 Local initiatives and projects

In the Table 25 below current relevant initiatives and projects concerning renewable energy systems in Turku are shortly presented. Table 25 also presents the actors involved in this project and the time period of this project. A more thorough presentation of these initiatives and projects is given in the Appendix A.

Table 25. Relevant local initiatives and projects in the municipality of Turku

Initiative/project	Actors	Period
Two way low temperature district heating network for the area of Skanssi	Technical Research Centre of Finland VTT, Municipality of Turku, Shopping center of Skanssi, YH Kodit , Hartela, Turku University of Applied Sciences	2014-?
Solar power plant of Kupittaa	Turku Energia, citizens of Turku and Areva Solar	Spring 2016
New power plant of Naantali	Turun Seudun Energiantuotanto, Valmet power, Siemens, Pöyry, Raumaster, YIT and A-insinöörit	2015–2017
Turku university of applied sciences campus in Kupittaa	Turku University of applied sciences, the municipality of Turku	2015-2018
Renovation of a living area for students	Turun Ylioppilassäätiö (TYS), Consti, Turku Energia, Aalto University	2014–2016
ESCO service in Turku	Municipality of Turku, Caverion, Are, Customers (several)	2000-?
Waste gasification project	Turun Seudun Energiantuotanto (TSE) (maybe other actors; information not available)	2015-?
Development cooperation between the municipality of Turku and Sitra	Municipality of Turku, Sitra, Turku Energia, Lounais-Suomen Jätehuolto, Turku University of applied sciences, University of Turku and Climate Pledge.	2015-2018
Planning of Energy efficient cities (PLEEC)	Eskilstuna Energy Miljö (SE), Eskilstuna City (SE), Mälardalen University (SE), Turku City (FI), Turku University of Applied Sciences (FI), Tartu City (EE), Stoke-on-Trent City (UK), Hamburg University of Applied Sciences (DE), Vienna University of Technology (AT), University of Copenhagen (DK), Delft University of Technology (NL), University of Rousse (BG), LMS IMAGINE (FR), Smart Technologies Association SMARTTA (LT), Santiago de Compostela City (ES), Santiago de Compostela University (ES), Jyväskylä City (FI), University of Ljubljana (SI)	2013-2016
Neo carbon energy project	Technical Research Centre of Finland VTT Ltd, Lappeenranta University of Technology LUT, and University of Turku, Finland Futures Research Centre FFRC + 15 industrial partners, 3 NGOs and 5 international partners.	2014-2019
Municipalities' energy efficiency agreement	The Finnish government and several Finnish municipalities.	2008-2016; 2017-2025

8. Stakeholder analysis

Here, a stakeholder analysis will be performed that will present the main stakeholders related to the subject of this research. These stakeholders were found based on the stakeholder interviews and other research. First, these stakeholders will be presented and then their power and interest will be evaluated. Defining the stakeholders is part of the strategic problem orientation step indicated in the Table 9.

8.1. Overview of the stakeholders

8.1.1 Policy makers

The municipality of Turku has set ambitious goals concerning the RES and towards coal neutrality and is a very important stakeholder in the pursuit of achieving these goals. These goals can be read from the part 7.2.2. Furthermore, the motives of the municipality can be found from the part 7.1.

In order to achieve these goals several development and innovation projects in Turku have been initiated (part 7.8). When it comes to district heating for example it is important for the municipality to invest in the basic and peak heat production as well as to renewing the district heating system. The municipality's role is to be involved in the biggest projects in guiding and creating them. The biggest efforts the municipality puts in the beginning of these projects, but the projects are also followed and results are put to use by the municipality. (R Veivo 2016, pers.comm., 11 February)

For the municipality of Turku it is also important to create partnerships with other organizations in order to receive expertise from them and support in developing and implementing solutions. The partnership with Sitra is one example of this (see Appendix A). (R Veivo 2016, pers.comm., 11 February) Another important role that the municipality has is to show example to other actors. One good example of this is the municipality's decision to buy all the electricity that it uses from renewable sources (A Ahtiainen 2016, pers.comm., 03 February).

In order to pull through these projects and developments the municipality has to use its power given to it by the democratic political system and by the ownership power that it has over Turku Energia (local energy distributor), which is completely owned by the municipality of Turku (R Veivo 2016, pers.comm., 11 February). The democratic political system gives the municipality the possibility to strongly contribute to the developments of the city by granting financial support and changing regulations that enhance the developments. However, the municipality's decisions need to follow the laws and regulations of the Regional Council and that of Finnish Government.

The Finnish Government can set targets related to renewable energy system implementation and drive for those targets by creating laws, regulations and policy instruments (e.g. financial incentives and subsidies). However, the Finnish Government needs to align the international laws and regulations set by the European Union and also with international agreements (e.g. Paris agreement on climate change). One strong signal of the Finnish Government for developing the RES in Finland is their goal of stopping the coal usage in Finland by the year 2030.

8.1.2 Research and knowledge institutes

Valonia

Valonia is a service center for sustainable development and energy in the Southwest Finland. It is part of the Regional Council of Southwest Finland and gets its funding from the different municipalities of the Southwest Finland and also from the EU. (Valonia 2016)

"Valonia's role is to act as an unbiased regional advisory organization for municipalities and companies in matters concerning sustainable development. Another important task is to offer municipalities and companies a wide range of services that help them to promote sustainable development." These services include promotion of sustainable energy use, waste water treatment, sustainable consumption, material efficiency, sustainable mobility, sustainable logistics, water protection and environmental education. (Valonia – Service Centre for Sustainable Development and Energy of Southwest Finland 2016)

Sitra

Sitra is a public innovation fund aimed at building a successful Finland for tomorrow. Sitra is an important stakeholder, because it has created a partnership with the municipality of Turku in order to guide and support Turku in its aim of becoming a coal neutral city. One way of supporting Turku in its project is to provide information for Turku about other similar projects in Finland and abroad. The execution of Turku's project will be left on the hands of the different organizations in Turku. (J Pelkonen 2016, pers.comm., 13 February)

The general goal of Sitra's activities is a sustainable and resource wise society. Sitra tries to find practices that benefit the society as a whole and these practises are tried to be promoted to decision makers. One way of doing this is to support the businesses towards coal neutrality in a way that also improves the businesses' profitability. (J Pelkonen 2016, pers.comm., 13 February)

Turku University

The University of Turku is a notable player in providing knowledge in order to enhance the RES in Turku. The university is currently involved in an international Neo-Carbon Energy project, which can offer interesting solutions for RES. More information about this project can be found from Appendix A.

Furthermore Turku University has a Finland Futures Research Center, which aim is to create ecologically durable models and try to advance matters related to sustainability (K Koskinen 2016, pers.comm., 05 February). This research center can also create sustainable future visions for the energy system in Turku.

Turku University of Applied Sciences

Alongside the University of Turku, the University of Applied Sciences in Turku is also a notable player in providing knowledge in order to enhance the RES in Turku. This university has a program called energy and environment technology, which is an interesting program concerning RES. The aim of this program is to be involved in the changes of the energy system towards renewable energy production and varied micro generation of energy. Their intention is to provide knowledgeable employees to the area's businesses and public actors. One important aspect of the program is to provide its students an understanding of what matters work as drivers in this society. (S Lyytinen 2016, pers.comm., 08 February).

Other

These other stakeholders below can also affect the development of RES in Finland and in Turku by conducting research and giving funding to the public and private actors.

- VTT (Technical Research Center of Finland)
- Tekes (Finnish Funding Agency for Technology and Innovation) (Tekes 2016)
- Motiva (Expert company in energy and material efficiency) (Motiva 2016)

8.1.3 Technology and engineering companies

To this group fits well the solar panel suppliers, fuel suppliers for energy production and the actors involved in the ESCO-projects. One important solar panel supplier in the case of Turku is Areva Solar, which supplied the 250 solar panels to Kupittaa's solar power plant.

Furthermore, the idea of the ESCO-project and its actors are presented in the Appendix A. Moreover, the information concerning the fuel suppliers is classified information and thus these actors won't be further described in this analysis.

8.1.4 Energy companies

Turku Energia

Turku Energia is the biggest local energy distributor of electricity, heat and cooling and a very important stakeholder in implementing a renewable energy system in Turku. Turku Energia also produces some heat for the district heating network of Turku (see Figure 8). The goal of Turku Energia is that by 2020 half of the heat production for district heating in Turku will come from renewable energy sources and this will be achieved as soon as the new power plant of Naantali will be operational in 2017 (I Syrjälä & J Lahtinen 2016, pers. comm., 01 February). Furthermore, another goal is that 50 % of the electricity that Turku Energia sells should come from renewable energy sources by 2020 (J Hallivuori 2016, pers.comm., 23 February).

The only owner of Turku Energia is the municipality of Turku so together they are very powerful actors in Turku when it comes to changes in the energy system. Turku Energia has a lot of preparer, executor and owner investment power (Turku Energia owns 39.5 % of the biggest local energy producer TSE), but the company is guided by the municipality of Turku (R Veivo 2016, pers.comm., 11 February). Through communication Turku Energia can also influence the changes in Turku's energy system. By communicating the advantages of renewable energy technologies and increasing their knowledge among the citizens, Turku Energia can influence the mindset of people. This in turn can affect the targets and decisions of the municipality of Turku, which in turn affects Turku Energia's actions.

Turku Energia has also started projects (Skanssi and Kupittaa) in Turku related to renewable energy. Through these projects Turku Energia has an important possibility to influence the future's RES in Turku. Noteworthy is also that Turku Energia owns the whole district heating network in Turku and part of the electricity network. Through this ownership Turku Energia has the power to carry out experiments related to renewable energy (A Ahtiainen 2016, pers.comm., 03 February).

Turun Seudun Energiantuotanto (TSE)

TSE is the biggest energy producer in the area of Turku. It provides heat and electricity to Turku and to other municipalities around Turku as well as process heat to some industrial companies in the area (not to Turku). The ownership of TSE is as follows: Fortum Power and Heat 49.5 %, Turku Energia 39.5 %, the municipality of Raisio 5 %, the municipality of Kaarina 3 %, the municipality of Naantali 3 %. (Yhtiön omistus 2016). TSE is an important stakeholder that can have a big influence in changing the energy system towards renewable energy production, but the company is managed by their biggest owners Fortum and Turku Energia.

TSE's goal is that in their future power plant in Naantali (see Appendix A) the share of biomass, as energy source, will be 40 % and in the long run 60-70 % (T Bastman, TSE, 2016, pers.comm., 21 January).

Fortum

Fortum is a big Finnish energy company that produces and sells electricity, heat and process heat. Its biggest owner is the Finnish Government. In the area of Turku, Fortum is an important player, because they are the biggest owner of TSE and thus have a major influence on TSE's decisions and activities. Fortum is also a listed company, whose interest is to generate profits to its owners and this aspect can have a major influence on the fuel base of the TSE's new power plant in Naantali. This is because biofuels are currently more expensive than coal so it is not in Fortum's interest to raise the biofuel share up to the level when producing energy is no longer profitable. This wouldn't be profitable for the owners of TSE. This is why the share of biofuels in the new Naantali plant will be 40 % in the beginning and not 60-70 %, because 40 % share is still seen profitable. If the share of biofuels is increased to 60-70 % it becomes more expensive (due to longer biofuel supply chains and biofuel price) and then the energy production in the new Naantali plant won't longer be economically profitable. (T Bastman, TSE, 2016, pers.comm., 21 January).

Caruna

Caruna company is the electricity distributor in the northeast part of Turku (area of Paattinen). Recently Caruna raised a lot of headlines due to the intention of significantly increase their electricity prices, which are justified by upcoming investments in their electricity grid. This can be seen as positively affecting the development of RES, because due to higher electricity prices, the electricity users are more interested in investing to renewable energy technologies. Caruna is not seen as a key stakeholder in this analysis, but the company can have small influence to the development by these kinds of decisions.

Renewable electricity producers outside of Turku

As shown in Table 14 almost all of the current renewable electricity used in Turku comes from these producers (e.g. Hyötytuuli). These stakeholders use wind and water power to produce their electricity and sell it to Turku Energia and other energy distributors. They are seen as important stakeholders, because as mentioned they supply a very considerable amount of renewable electricity to Turku and thus their decisions seriously affect the amount of renewable electricity used in Turku.

8.1.5 Financers

The possible financers of the RES in Turku can be seen as large corporations, private investors, banks and subsidy providers. This group is a small but an important group since the investments in the renewable energy technologies and RES requires large amounts of capital. So far the biggest investors in renewable energy in the area of Turku have been the municipality of Turku, Turku Energia, Fortum and the TSE. One potential corporation that could invest in renewable energy in the future is Meyer Turku Corp. which owns the dockyard in Turku. The dockyard is also seen as a potential area for installing wind turbines (see part 6.6.2).

8.1.6 Users

The habitants of Turku are also a powerful stakeholder that can especially affect the actions of Turku's political system via elections and by expressing their opinions about RES to the city's decision makers. The habitants are also the future investors and users of renewable energy technology so their choices in what kind of energy they want to receive or possibly how they want to produce their own energy is important for the development of the RES in Turku. Thus it can be said that when it comes to the power of the citizens it is important how this power is channelled and how it is used.

Professional users belong also to this group. These stakeholders are for example companies and public organisations like educational organizations and hospitals. The same powers apply to these stakeholders as to the habitants of Turku (except the voting power).

8.2 Power-interest grid

The Figure 11 presents the level of interest and power of the above mentioned stakeholders in a power-interest grid. This grid is made out of four quadrants: key players, subjects, crowd and context setters. In this analysis it is seen that:

- Key players have a lot in stake in developing the RES in Turku and will and ability to make the change towards it.
- Subjects are seen to have a lot in stake in developing the RES in Turku, but have a minor ability to make the change.
- Crowd is seen to not have a lot in stake in developing the RES in Turku and have a minor ability to make the change.

- Context setters are seen to not have a lot in stake in developing a RES in Turku, but still have the ability to make the change towards the RES in Turku.

This analysis helps to identify the stakeholders who have ability and will to make the change and who don't. Furthermore, the analysis determines which stakeholders are the most important ones when addressing the subject of this research and fulfilling the research's target. Moreover, this analysis gives some advices on how to deal with the different stakeholders.

Below, an explanation is given to why the different stakeholders are placed to a certain position in the Figure 11. The interest and power of each stakeholder is set by evaluating their interest and power of developing a RES in Turku. This energy can also come from outside of the city boundaries since it was noticed during the stakeholder interviews that none of the stakeholders' interest is to develop an independent RES inside Turku. After these explanations the Figure 11 will present this power-interest grid.

8.2.1 Policy makers

The municipality of Turku has a very high interest and a lot of power in developing the RES for Turku. The city has set a goal of becoming a coal neutral city by 2040 and developing the RES is an important part of this goal. Furthermore, they have a lot of power in changing regulations towards enhancing the RES and through their ownership of Turku Energia.

The Finnish Government is also seen as a powerful actor with a lot of interest. Their power comes from setting regulations that the city of Turku needs to conform. However, they are not a local actor with a big influence to the local energy providers that are interested in changing the energy system so this is why their power is seen less than that of the municipality of Turku. Their interest is also lower than that of the municipality, because their interest lies on developing the whole of Finland and not just the city of Turku. The Regional Council of Southwest Finland is seen to have a slightly more interest than the Finnish Government due to their higher locality, but the power is seen to be the same, because they don't have company ownership to local important actors.

8.2.2 Research and knowledge institutes

Valonia's interest is seen quite high, because enhancing the usage of renewable energy is one of their tasks in the region of Southwest Finland, but still it is not their only task. Their power is seen low since they are very dependent on the decisions and funding of the Regional Council and of the different municipalities.

Sitra's power is seen fairly high due to their partnership project with the municipality of Turku where renewable energy is one of the key topics. Their interest is seen also fairly high since their mission is developing the future sustainable Finland where renewable energy plays a key role. However, their interest lies in the entire country and not solely in Turku.

Furthermore, Turku's Universities' interest is seen high, because the development of the RES requires research that these universities are able to perform and are already performing. However, their power is seen fairly low since they are dependent of the decisions and funding of the political system.

VTT's and Tekes's interest is seen fairly high since their goal is to do research and give funding to these kinds of development goals concerning sustainability and renewable energy technologies. However, they are national or even international actors and their interest doesn't lie solely in Turku. Their power is seen to be fairly low, because according to this study they are only involved in the development projects of Skanssi (see Appendix A) and not in every aspect of developing the RES in Turku.

Also the interest of Motiva is seen to be fairly high since this company's goal is to enhance the energy and material efficiency in Finland (Motiva 2016), but at the same time they are national actors. However, their power is seen to be low since based on the findings of this study they are related to the case of Turku only by offering the ESCO services (see Appendix A) in Turku as well as in the other parts of Finland.

8.2.3 Technology and engineering companies

These actors are seen to be key players because their interest and power are seen to be high. Their interest is high, because through the enhancement of RES the level of demand for their technology and services will increase. They are seen to have also fairly high power, because they have a lot to say in the prices of their products and services, which in turn has an important effect on the usage of products related to renewable energy.

8.2.4 Energy companies

Turku Energia is seen to have a lot of power as the municipality and Turku Energia can be seen as almost the same actor. However, the interest of Turku Energia is seen to be less than that of the municipality, because Turku Energia's primary mission is to provide energy to the area of Turku and make financial profits to the municipality of Turku. Here, it is seen that in order to fulfil this mission RES is not necessarily needed. This same applies to TSE, which primary mission is the same as mentioned here for Turku Energia, but here the main owners are Turku Energia and Fortum. TSE's power is high, because they have the biggest energy production facilities in the area, but still they are seen to have less power than their owners Turku Energia and Fortum.

Fortum has a lot of power over the TSE and thus also over the development of RES in Turku. However, their interest in the development of the RES in Turku is not seen to be the highest since they are an international company and for Fortum it is important to make profit to its owners and enhancing the development of the RES is not always the best way of achieving this. Notable is however that the biggest owner of Fortum is the Finnish Government so matters that are sustainable have to be also seen important in Fortum.

Caruna is seen to have fairly high power, because it is one of the two energy providers in the area and owns part of the electricity grid in Turku. However, it owns a smaller piece of the energy provision in Turku and thus Caruna is seen to have less power than Turku Energia. Furthermore, Caruna operates nationally in Finland and its owners are not seen to have particular interest in Turku, and this in turn lowers Caruna's interest in developing RES in Turku.

Finally, the power of renewable electricity producers outside of Turku is fairly high due to the considerable amount of renewable electricity that they currently supply to Turku. However, it is seen that their power is not the highest since they don't have a decision power in Turku, and because also other sources of renewable electricity are available outside of Turku. These stakeholders are also seen not to have a particular interest towards the development of the RES in Turku, since they can produce energy also to other areas and are not dependent of the supply to Turku.

8.2.5 Financers

The financers have a lot of power in developing the RES in Turku, because the development of RES requires a lot of investments. So far the public actors like the municipality of Turku and companies owned by public actors (e.g. Turku Energia, TSE and Fortum) have made big investments (e.g. new power plant of Naantali) in the RES in Turku. However, the investments of fully private actors are missing in Turku. The investment interest of financers is greatly based on the return of profit that they evaluate for their investment and how reliable this evaluation is. It can be that currently RES is not still seen as a reliable and profitable investment, but this can change in the future. This is why financers' interest is placed on the middle of the x-axis in the Figure 11. One possible private investor in Turku could be the owner of the Turku dockyard Meyer. This company has a good opportunity to start wind power production in the area of the dockyard.

8.2.6 Users

The interest and power of this group is explained in the part 8.1.6.

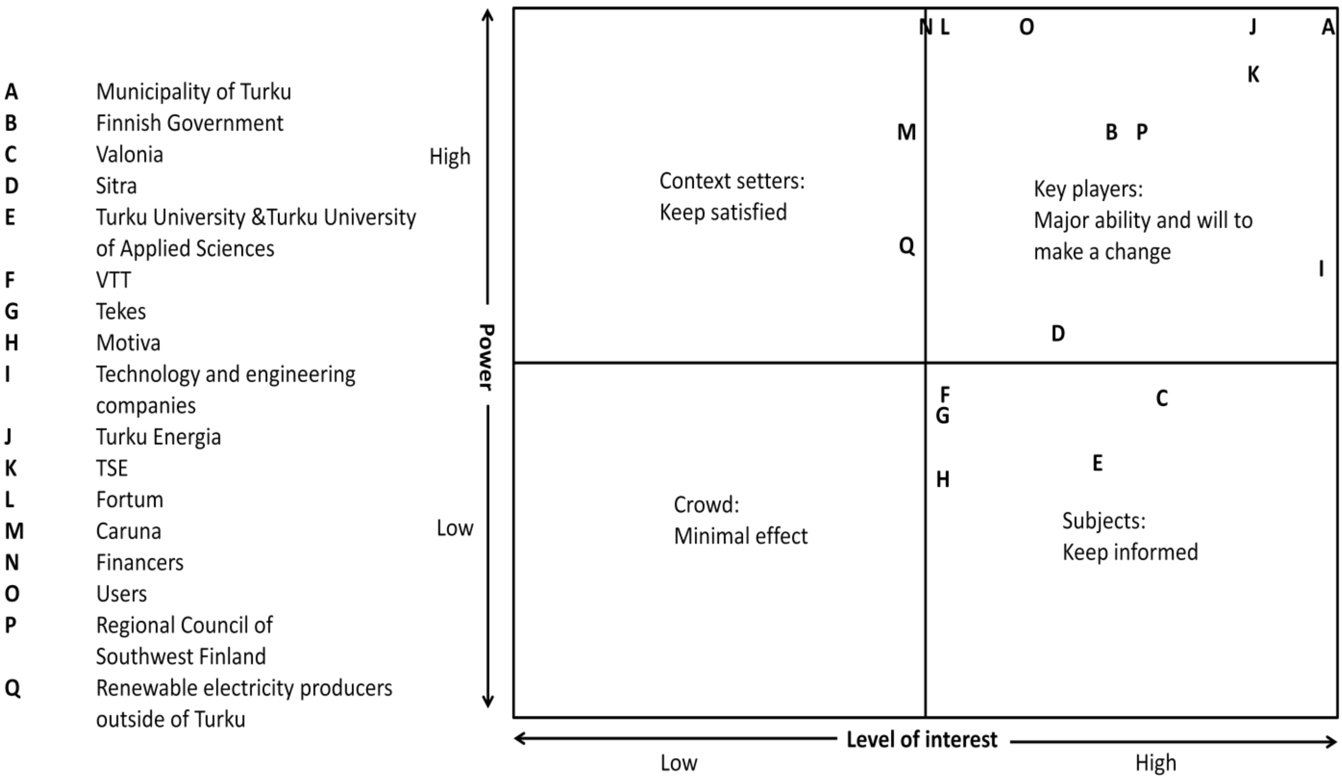


Figure 11. Power-interest grid of the stakeholders related to RES in Turku. (Modified from Hoofdstuk 2016)

9. Construction of scenarios

In this section first the energy demand in Turku in 2030 will be determined. Second, the exogenous variables will be determined. Finally the vision and scenario of the RES in Turku in 2030 will be presented. This vision and scenario will give a clear and vivid image of the RES in Turku in 2030.

9.1 Energy demand in Turku in 2030

Based on estimations of energy demand and supply (Table 24), assumptions and developments (presented in section 7) concerning the RES in Turku, the development of the energy demand in the municipality of Turku will be determined from the current state until the year 2030. In order to define the future estimations and assumptions the Climate and Energy Strategy of the Southwest Finland will be used.

In 2011 the Climate and Energy Strategy of the Southwest Finland (including Turku) was conducted until the year 2020. In this report it was determined that the total energy consumption of the region will stay the same during the years 2007-2020. (Luotsi 2011) The report stated that this will be achieved for example by the following measures related to energy conservation:

- All the actors in the region will participate in the energy efficiency programs of their field
- Energy saving guidance will be offered to the households and companies
- The potential waste heat sources in the region will be exploited
- The industries' by-products will be exploited as a source of energy
- The main criteria of the public procurement will be material and energy efficiency (Luotsi 2011)

Based on this strategy it is assumed in this study that the energy demand of Turku between 2016 and 2020 will stay the same as indicated in the Tables 15 and 16.

Next, the energy demand between 2021 and 2030 will be determined in Turku. In 2021 a European Union directive will come in place, which states that all the new premises need to be almost zero energy premises. The definition of an almost zero energy premises is a building which energy demand is almost fully produced in the building or on the spot. (Sepponen et al. 2013) Also district heating is seen as energy produced on the spot if it comes from renewable sources (Sepponen et al. 2013), but in this study district heating is not seen as energy produced on the spot due to the geographical location of the main district heat provider Naantali power plant (location outside of Turku and far from the premises of Turku).

Due to this directive it is assumed in this study that the energy demand from 2021 to 2030 in Turku will stay the same. This is because it is seen in this study that the current building stock will consume the same amount of energy as before the year 2021, minus the energy renovation/saving actions performed for the current building stock during 2021 and 2030 and minus the energy demand of old dismantled buildings. It is estimated that the fairly moderate energy savings indicated in the part 6.6.5 will be achieved by the 2030.

However, the new almost zero energy buildings starting from 2021 will still consume small amounts of energy, because they will be almost zero energy buildings. Moreover, it has to be noted also that the population in Turku will increase with 30 000 by the year 2029 (Ahonen 2015) and this will increase the energy usage. Thus, in this study it is seen that together the current building stock, energy renovation/saving actions, more compact residency, dismantled buildings, the consumption of new almost zero energy buildings and the increase in population will cancel the effects to the energy demand and that is why the energy demand will also stay the same from 2021 to 2030. This is only an assumption and no precise estimations can be made because there are no estimations available concerning the amount of future dismantled buildings, the rise of energy use due to population increase and amount and energy consumption of new buildings in Turku. However, according to Ahonen (2015) all the main future construction projects will include major energy efficiency actions. Drafting of Turku's future master plan 2029 is on its way where the places and amounts of new buildings will be determined.

The public lighting (included in the boundaries of this study) is seen as a minor effecting factor to the total energy demand of Turku and developments in that sector are not taken into account in defining the total energy demand of Turku. Thus, it can be concluded that the total energy demand of Turku in 2030 will stay as it is indicated in the Tables 15 and 16.

It is also assumed in this study that the determined energy saving potential in the part 6.6.5 is included in the measures indicated in the climate and energy strategy of the Southwest Finland and in the energy renovation actions performed during 2021 to 2030.

9.2 Exogenous variables concerning the sustainable energy system in Turku

In this part the exogenous variables will be presented. The meaning of the exogenous variables is explained in the chapter 4 of this study. These variables will be presented by dividing them to political, economic, socio-cultural, technological, environmental and regulatory variables.

9.2.1 Political variables

The ideological difference of the political parties concerning the energy production (explained in the part 7.2.6) can be considered as an exogenous variable. This variable can hinder the willingness of investors to invest in the renewable energy system and thus can also set constraints to the development of the RES in Turku.

Also the EU's almost zero energy directive is an exogenous variable (see part 7.5.7). When this directive will come in place it will offer an opportunity of increasing the usage of RETs and energy savings in the premises.

Another political variable is the current global political crises. This is due to the current global political situation where no single country has the power or will to genuinely pursue the common good. After the last financial crises the G-20 countries have focused more on pursuing their own good rather than the common good. (Wilenius 2015)

Furthermore, the cooperation of the biggest economies USA and China is not functioning, because China has not yet accepted its responsibility of the global politics. Moreover, the economical power structure has changed and given more power to the countries in Asia, which has led to increasing competition between the western countries and Asia. This global political crisis will probably manifest itself by increasing the amount of conflicts in the future for example in the field of climate politics. A possible solution for this crisis would be the creation of a supranational decision maker organization, which would have enough power to make decisions baring in mind the global scale and also the ability to monitor the implementation of these decisions. (Wilenius 2015)

This global political crisis mentioned above can have influences to the development of the renewable energy system in Turku. As long as this crisis is present it will be challenging to make and execute global decisions concerning the climate change, which can in turn hinder the possibilities of developing a renewable energy system on a local level. The Paris Climate Agreement is one example of a supranational agreement concerning the climate change, but its effectiveness will remain to be seen.

Also inside the US politics there are variables that affect the development of the RETs globally. One example of this is the Supream Court's decision to temporarily block Barrack Obama's legislation pursuit to limit power plants' greenhouse gas emissions in USA due to the many lawsuits against this legislation from several states and from the energy industry. (de Vogue et al. 2016)

9.2.2 Economic variables

Economical growth

The economical growth is one economical variable, which has influence to the development of Turku's renewable energy system. If the economical growth is booming the investors are willing to take risks and invest in the RES of Turku for example, whereas when there is no economical growth the investors are usually very careful in taking risks. Although there is currently growth in the world's economy, Finland's economy is in a long stagnation. This has major effects concerning the investments made in Finland for example to local renewable energy systems.

Globalisation

The globalisation is increasing and as it progresses it will increase the world's economy, which in turn decreases the availability of the important raw materials (e.g. oil). This will increase the prices of the raw materials and when for example the price of oil increases it puts pressures on decreasing the oil usage and increases the search for other possibilities. (Wilenius 2015) In the field of energy production these other possibilities are renewable energy and nuclear power. Thus, it can be said that globalisation can have a positive effect to the development of RES.

According to Wilenius (2015) the scarcity of oil is clearly foreseeable and thus the world will start using more and more renewable energy technologies. In order to enhance this development it would be favourable if also the renewable energy production costs would come down. According to Wilenius (2015) sun and wind power technologies will become competitive in the 2020's.

Currently, the oil price is low partly due to the decisions related to the production amounts in the Arabic countries. However, the increase in the oil price is a very valid scenario in the long run. (Wilenius 2015)

9.2.3 Socio-cultural variables

Demographic changes

In many countries, especially in Europe, the population is aging and more and more people will be retired. This can hinder the economical growth and will cause difficulties for countries to offer basic services (e.g. healthcare) to people. In order to minimise the negative effects of this change it is important that the resource productivity is increased. In the field of energy production it can be done by changing to renewable energy production. (Wilenius 2015) Thus, it can be said that demographic change in Europe can have a positive effect to the development of RES.

Mindset of the energy consumers

The energy consumers have a lot of power to develop the RES worldwide through their energy and energy production technology purchases. If their mindset towards renewable energy is positive and they understand the importance of green energy, they can more easily purchase renewable energy and renewable energy technologies. Through their “green” purchases the field of renewable energy receives more income, which in turn can be used in the field’s research and development. Furthermore, the increasing usage of green energy and technology among energy consumers increase the knowledge of the technology and offers showcases to the renewable energy industry and energy users. Thus, if the mindset is negative it can have a negative effect to the development of the RES and vice versa.

According to the present conditions in Turku the general mindset of the energy consumers of Turku towards RES has been positive. However, the investments in the RES in Turku haven’t still caused major increases in the energy prices. It remains to be seen how the energy consumers will react if and when the building of the RES will affect the energy prices.

9.2.4 Technological variables

Development of the renewable energy technologies

Investments to the renewable energy technology’s research and development are important for building the RES in Turku. Through these investments this technology will become more efficient and their levelized costs of production will decrease, which in turn will increase the competitivity of the renewable energy technologies. As mentioned already it is been predicted that at least sun and wind power technologies will become competitive in the 2020’s (Wilenius 2015).

Furthermore, digitalisation will offer solutions for building the future renewable energy systems. Especially in the field of energy efficiency and smart grids, digitalisation will have a major contribution in the future. Examples of these technologies are smart meters and sensor technology.

Development of the nuclear power technology

The R&D of the nuclear fusion power is currently ongoing in the world. If this technology is managed to be used in a larger scale and in a secure way and if its production costs in the future are competitive it can become a very important source of energy. Thus nuclear fusion and fission power and renewable energy technologies can be seen as competing technologies where one is possibly taking market share from the other in the future.

Geothermal heat project in Espoo Finland

The part 7.5.4 in this study describes this project. If this Espoo project will be successful it can inspire also the actors in Turku to conduct a similar project. This in turn can mean that in the future Turku can produce part of its needed heat (maybe electricity also) from deep geothermal sources.

9.2.5 Environmental variables

Climate change

As the effects of the climate change become more apparent, the mankind starts to better understand that actions need to be taken in order to fight against the climate change. Transferring to RES is one of the key changes in reducing the effects of climate change.

Furthermore, climate change can affect the world by increasing the amount of dry seasons, heat waves, floods and by raising the sea levels. This in turn threatens people's livelihood and the availability of the basic resources (e.g. agricultural products). This development can cause serious conflicts around the world, which in turn can hinder the development of climate politics and renewable energy technologies around the world. This is because the societies around the world would have their hands full of work solving the different imminent conflicts and no time would be left for solving long term issues like the climate change.

9.2.6 Regulatory variables

One crucial exogenous variable concerning the RES in Turku is the EU's decision concerning the sustainability of burning wood in order to produce energy. If this decision is not favourable for Finland it can be a major setback for developing a RES in Turku or in other areas of Finland. This exogenous variable is further explained in the part 7.2.3 of this study.

Another important variable is the effectiveness of the Paris Climate Agreement. This depends of the joining countries motivation and willingness to cooperate towards a common good. If the terms of this agreement are fulfilled it can have major positive effects in the climate change and also in the development of renewable energy systems.

9.3 Vision for achieving the RES in Turku

It became clear during the stakeholder interviews that an independent RES is not seen possible or even desirable in Turku and this is why already a considerable amount of the renewable energy currently used in Turku is bought outside of the municipal boundaries. Furthermore, also the renewable energy potentials determined, indicated that it will be challenging to build renewable energy independence in Turku and that all the current RE sources and RE potentials are needed if the energy independence will be even nearly achieved. Therefore, the following vision is set for Turku:

By 2030 the energy system in Turku will use only the needed energy from renewable sources and this energy is being produced inside of the Turku municipality boundaries as much as possible. The energy system in this vision includes the energy production, distributions, storage and the system's energy efficiency for the premises and public lighting of Turku. Solar, wind and biomass energy play a major role in producing the needed energy for Turku in 2030. Therefore, the future distribution and storage infrastructure need to play a vital role in this RES due to the seasonal differences of energy availability.

Next, the scenario will be described that gives a more elaborated image of the vision. Below the important characteristics of the scenario are described in the Table 26.

Table 26. Important characteristics of the scenario (further explained in the part 9.4)

RES in Turku in 2030
Centralized and decentralized energy production
Large and small scale energy production
Moderate energy savings
Energy storage, smart grid and heating network important
Close cooperation with the stakeholders
RETs competitive with fossil fuel technologies
Biomass from certified sources
Residents positive towards RETs
Energy users willing to pay higher energy price

9.4 Scenario for achieving the RES in Turku

One scenario for achieving the RES in Turku will be created. This scenario is based on the present conditions, developments and exogenous variables concerning the RES of Turku, which are described in the previous sections. This means that all of the aspects of the current renewable energy system and future potentials in Turku are put under one scenario. This is because during the strategic problem orientation step it was noticed that it will be challenging to build energy independence in Turku with the gathered information. This is due to the constraints that a fairly highly populated municipality gives to building renewable energy production (e.g. wind turbines) and because of the high energy demand in the municipality and also because information concerning the potentials on some of the renewable energy sources was missing (e.g. deep geothermal heat). Consequently, as shown in the Table 24 all the current RE sources and RE potentials are needed if the energy independence will be even nearly achieved. Moreover, the stakeholder interviews revealed that in the stakeholders' own RES visions several different kinds of actions are described in order to produce the needed energy for Turku from renewable sources (e.g. centralized and decentralized renewable energy production).

Furthermore, the energy system and developments described show that the municipality has started its progress towards the RES and that several different kind of actions are taken in order to build this system. Examples of these are centralized and decentralized RE production, large and small scale RE production (e.g. Naantali power plant and Kupittaa solar plant) and executed energy saving measures (e.g. municipality's energy efficiency agreement) as well as energy guidance of consumers (e.g. Valonia's energy guidance). Next, the different characteristics of the scenario are described in detail.

9.4.1 Energy demand

The energy demand in 2030 in Turku will stay on the current level. The current energy demand is described in the Tables 15 and 16 and the reasons why the energy demand is assumed to stay the same are explained in the part 9.1.

9.4.2 Energy supply

The Tables 27 and 28 will present the technologies and supply amounts of renewable energy for Turku in 2030 and also a comparison is made to Turku's energy demand in 2030. Concerning the renewable energy technologies it is assumed in this scenario that thanks to positive mindset of the energy users towards RETs and the investments to R&D, the costs of these technologies are lower than the costs of fossil fuel technologies, which have increased due to the increased fossil fuel taxes and its availability problems. Furthermore, it is estimated that the nuclear power technologies are not able to compete with RETs. This is due to the radiation and security problems of the fission technology and up scaling and safety problems of the fusion technology.

Moreover, this scenario assumes that the geothermal heat project in Espoo Finland was a success and deep geothermal heat production for district heating has been started in Espoo. This means that Turku has also gone through a similar project and deep geothermal heat is also used for heating Turku's district heating network. The part 10.1.1 will further explain the factors related to this technology in Turku.

Electricity supply

The Table 27 below presents the technologies and supply amounts of renewable electricity for Turku in 2030. In the same table a comparison is made to Turku's electricity demand in 2030. The information for this table is gathered from parts 9.1, 6.6.1 and 6.6.2 as well as from the Tables 14 and 16 (plus the sources indicated below the Table 27).

Table 27. Renewable electricity supply in 2030 in Turku compared to Turku's electricity demand in 2030

Technology	**Characteristics and information**	**Electricity (GWh)**	**% from total demand**
Solar panels in 2030 (roof)	Total roof area: 5.702 km^2 Average efficiency: 20% Yearly solar irradiation: 968 $kWh/y/m^2$	827.97	61%
Large scale wind turbines in 2030	Amount: 8 turbines of 3 MW	54.04	4%
Planned renewable electricity supply in 2030		*474.5	35%
Total electricity supply in 2030		1356.5	100%
Total electricity demand in 2030		1356.5	100%
Total electricity demand in 2030 - Total electricity supply in 2030		0	0%

*This is the amount of renewable electricity production that has been already targeted for the city of Turku for 2030. This amount is taken from the Table 14 except for the production amount for the plant of Naantali. In this study the production amount of Naantali is assumed to be higher in 2030. The production amount of Naantali is calculated by the following equation: 360 GWh x 0.6. 360 GWh is taken according to the current electricity production amount of TSE Naantali plant for Turku (360 GWh) (Kivilä 2015). 0.6 is the target share of the renewable energy in the far future of the Naantali plant (TSE Oy Naantalin uusi voimalaitos 2014)

The total roof area for solar panels is calculated from the following equation: Total roof area for solar technology in Turku (7.32 km^2) – roof area needed for solar collectors in Turku (0.69 km^2) – assumed roof surface are not used for solar panels (0.928 km^2). It is recognised in this study that it will be highly challenging to cover all the non protected buildings' roof surface area with solar technology. Therefore, it is assumed in this study that for 0.928 km^2 of roof area no solar panels are installed in the year 2030. This surface area can stay uncovered from solar panels and still the electricity demand of Turku will be managed to be supplied by renewable electricity. However, it also has to be noted that the potential of implementing solar technology on the buildings' facades is not evaluated in this study. Therefore, it can be stated that if it is not possible to cover the total roof area for solar panels with solar technology, some of the facades can be used in order to produce the remaining amount of needed solar energy for Turku.

In the scenario of 2030 the share of produced renewable energy of the Naantali power plant in 2030 will be 60 %. The target of the plant for this share is 60-70% in the far future. However, it is seen in this study that only the minimum target will be achieved by the year 2030, due to the availability problems of wood and profitability issues of using wood in the energy production (explained in the part 7.5.1 and Appendix A). Furthermore, in this scenario, due to technological development, the solar panels have an average efficiency of 20% in 2030.

The Table 27 clearly shows that all the electricity demand of Turku in 2030 can be supplied with the potentials determined in part 6.6 plus with the "Planned renewable electricity supply in 2030" indicated in the Table 27. The "Planned renewable electricity supply in 2030" is the amount of renewable electricity that is already been supplied and also the amount that is targeted in the future for the city (i.e. the 60 % share of renewable energy of the Naantali power plant). However, this means that the electricity independence in Turku cannot be achieved, because the "Planned renewable electricity supply in 2030" (in the Table 27) includes already sources of renewable electricity that are situated outside of Turku. These sources are assumed in this scenario to be used also in 2030. Furthermore, the biomass for the Naantali plant will come mainly outside of Turku and thus it decreases the value of Turku's energy independence. In order to achieve the renewable electricity independence some additional renewable electricity sources need to be implemented in Turku. One potential source could be solar panel fields.

Furthermore, it has to be noted that potential of small scale wind turbines (determined in part 6.6.2) is left out from this scenario. This is due to the low potential that this technology has in Turku, and because in this study it is not seen economically rational to implement this technology in Turku in a large scale. Also the energy saving potential (determined in part 6.6.5) is not included in the Table 27. This is because as assumed in the part 9.1, the energy saving amount achieved in Turku in the future and the energy use reduction due to dismantled buildings will be approximately equal to the energy demand of new built premises during the years 2021-2030 plus the increase of energy use due to population increase in Turku.

Heat supply

The Table 28 below presents the technologies and supply amounts of renewable heat for Turku in 2030. In the same table a comparison is made to Turku's heat demand in 2030. The information for this table is gathered from parts 9.1 and 6.6.1 as well as from the Tables 14 and 15 (plus the sources indicated below the Table 28).

Table 28. Renewable heat supply in 2030 in Turku compared to Turku's heat demand in 2030

Technology	Characteristics and information	Electricity (GWh)	% from total demand
Solar collectors in 2030 (roof)	Total roof area: 0.69 km^2 Average efficiency: 44%	293	16%
Planned renewable heat supply in 2030		*1287	70%
Total heat supply in 2030		1580	86%
Total heat demand in 2030		1831	100%
Total heat demand in 2030 - Total heat supply in 2030		256	14%

*This amount is taken from the Table 14 except for the production amount for the plant of Naantali. The production amount of Naantali power plant is seen to be higher in 2030. The production amount of Naantali power plant is calculated by the following equation: 1360 GWh x 0.66667 x 0.6. It is estimated that 2/3 of heat production of the plant will be used by Turku (Heikkinen & Satka 2013) and that 60 % will be renewable energy. 1360 GWh is the estimation of the total heat production potential of the Naantali plant in the future. (TSE Oy Naantalin uusi voimalaitos 2014). The total amount 1287 GWh is the Naantali production amount in 2030 + the other heat sources in Table 14.

The solar collectors are installed on the roof of the oil, coal and peat heated premises currently in Turku as explained in the part 6.6.1. Moreover, the average efficiency of the solar collectors used in Turku in 2030 is estimated to be 44 %.

Also for this Table 28 the share of produced renewable energy of the Naantali power plant in 2030 will be 60 % and the same explanation is valid for this Table 28 as given for the Table 27 concerning the share of renewable energy in the Naantali power plant. The "Planned renewable heat supply in 2030" (in Table 28) is the amount of renewable heat that is already been supplied and also the amount that is targeted in the future for the city (i.e. the 60 % share of renewable energy of the

Naantali power plant). It is assumed in this scenario that renewable heat that is already been supplied will be the same also in 2030.

The energy saving potential (determined in part 6.6.5) is not included in the Table 28. This is because as assumed in the part 9.1, the energy saving amount achieved in Turku in the future and the energy use reduction due to dismantled buildings will be approximately equal to the energy demand of new built premises during the years 2021-2030 plus the increase of energy use due to population increase in Turku.

The Table 28 clearly indicates that the heat independence with renewable energy sources is not able to be achieved by 2030. 256 GWh of renewable heat is needed to be supplied from some other sources. The part 10.1.1 will explain how deep geothermal heat could increase the energy independence in Turku. Other possible RETs for producing heat are extracting heat from the sea, blue-green alga, solar collector fields and waste heat from the industry or commercial buildings.

Turku Energia and Fortum (biggest owners of TSE) are powerful stakeholders in effecting how much heat is produced from renewable sources in Turku. This is because they have the power to decide whether to increase or decrease the amount of renewable fuel used in the new Naantali plant.

9.4.3 Energy storage

The Table 29 below will shortly present the different energy storage possibilities in Turku. More elaborate explanation of usage of these technologies in Turku is given below in this part and also in the part 10.1.1. These technologies were chosen based on the part 7.5.5 and based on the articles of Child & Breyer (2016) and Esterinen et al. (2014), which discuss about suitable energy storage technologies in Finland.

Table 29. Different possibilities for energy storage in Turku

Type	Technology
Electricity storage	Vehicle-to-grid connections
	Stationary batteries
	Power-to-gas
Heat storage	Drilling holes in the ground
	Pipes in the ground
	Steal tank reservoirs

As can be seen from the previous part 9.4.2 the energy system in Turku won't be a very diversified when it comes to renewable energy production technologies. Thus energy storage will be an important part of this energy system and it is assumed in this study that energy storage technology will be economically and technologically viable in 2030.

When creating a 100% RES in Turku the energy storage system needs to be carefully designed in order to provide steady renewable energy for the municipality. Unfortunately, the careful consideration of this storage system in this study is not possible due to the limited time resources and limited amount of information gathered in this study concerning the energy storage in Turku.

However, below some examples of energy storage technologies are given as well as how these technologies could be used in Turku.

Electricity storage

Battery storage

In Turku every premises or a group of premises with solar panels could have an electricity storage facility inside a premises or nearby. The electricity there could be stored in lithium ion batteries and the size and amount of batteries should be adjusted according to the size of the electricity need of the premises. The possible extra electricity could be directed to the grid.

Other possibility is that the overproduction of the solar panels and wind turbines in Turku could be directed through a smart grid to one big storage plant with lithium ion batteries. This plant would be situated inside of Turku. This storage plant would offer electricity to Turku when the level of sun irradiation and wind speed are low. Also using several storage plants is possible. Another way of supplying electricity to Turku during the low wind speeds and absence of sun is to supply it from outside of Turku from the renewable sources already currently used for Turku (see Table 14 and Figure 8). This means that these sources would be used less when the level of sun irradiation and wind speed are high in Turku and vice versa. Finally, also the Naantali power plant could offer a balancing effect. For example, during the summer the plant could run with a low production capacity when usually sun and wind are more available and vice versa during the winter.

Power-to-gas storage

Then again also the PtG can be used in Turku for storing electricity. This means that the overproduction of wind and solar power together with the CO_2 from the air is turned into gas, which could be used for electricity production when the sun and wind is not providing enough electricity. This storage system requires a facility which produces the gas and another facility for producing the electricity from the gas. These facilities should be inside the municipal area if the energy independence is wanted to be achieved as much as possible. The Neo carbon energy project (explained in Appendix A) is currently studying the possibilities of building this kind of energy storage system. However, it is important to note that this process will include some losses, which means that the same amount of electricity won't be produced from the gas than what was initially produced by solar and wind power.

Heat storage

Child & Breyer (2016) also state that thermal energy storage will also be needed in Finland in order to store and distribute the renewable heat energy according to its demand. In Turku, the premises using solar collectors in this scenario should include a heating storage system in order to provide heat also during a low solar irradiation period. These heat storage systems are either long term heat storage or short term heat storage systems. In Finland a long term seasonal heat storage system is needed but a short term system could be used alongside the seasonal one. Seasonal heat storage possibilities include for example ground storage using drilling holes or pipes in the ground to store heat whereas steal tank reservoirs are suitable for short term storage (Esterinen et al. 2014). If these solutions are not enough to warm the premises during the winter time in Turku, air source heat pumps, fire places, heat recovery ventilation and geothermal heat pumps can be used. This of course would increase the investment costs and electricity or wood usage. In this scenario it is assumed that in 2030 the heat storage technology has advanced enough so that an adequate and reliable heat storage system is in place for these solar collector heated premises to provide the needed annual heat for them.

When it comes to the heat storage of the district heating system some additional district heating water reservoirs can be added to the district heating network. This is done to secure an efficient way of providing the needed heat to the district heating network during the heat demand peaks.

9.4.4 Smart grid and heating network

The general idea of this scenario's power infrastructure is that alongside distributing the energy where it is needed it can also monitor, control and optimize the performance of the renewable energy system in Turku. Previously presented energy storage and energy conservation are important factors for enabling an efficient power infrastructure. This is because energy storage can balance the differences of energy supply and demand and energy conservation can lower the amount of energy supplied through the power infrastructure and thus enable its better and more secure control and optimization. Furthermore, it is also important that this power infrastructure produces lot of information concerning the energy usage in Turku and that this information is easily accessible to everybody (Ahonen 2015).

In the following chapters the technologies for creating future power infrastructures are presented and also descriptions are given on how the future power infrastructure would work in a 100% RES. This is done based on the part 7.5.6 and Hashmi (2011). First, a smart grid for electricity supply will be described and then a description of the possible future heating network in Turku will be given.

Electricity grid

In this scenario it is estimated that a smart electricity grid has been built in Turku by 2030 and that it is a smart grid inside of Turku with few connections to the national grid. This means that this smart grid won't longer be a linear system, where the electricity provider distributes the electricity to the households, but a two way system where the energy user can also provide/sell electricity to the grid (e.g. with solar panels). Smart meters are an important part of this system, because they enable the metering of the usage and production. Furthermore, they enable to run the grid better, identify outages more efficiently and reduce losses in the grid (Hashmi 2011). In general digitalisation is further advanced by 2030 and it will offer solutions for enabling the management of the smart grid.

However, although the energy supply and demand are usually matched through efficiently working energy storage and smart grid, the connection to the national grid is maintained in this scenario. This is done for securing the electricity supply to Turku during the moments when electricity is urgently needed and for enabling the selling of overproduction electricity to the national grid. This urgently needed electricity will be supplied from the renewable electricity sources that currently come from outside of Turku.

Heating network

The current district heating network is still in use in 2030 in Turku. This network would provide heat to what is left of the current building stock and also offer a back-up heating source for the different smaller two way low temperature heating networks in the city. Indeed, in this scenario the current project of Skanssi (see Appendix A) has been successful and this developed concept is used to build a two way low temperature heating network for Turku’s new residential areas starting from the year 2021 when the almost zero energy building directive comes in place. The premises included in the two way low temperature heating network can provide/sell their overheat production to their own low temperature heating network or to the current high temperature network. The reason why this current district heating network is still in use is that the changes to the RES have required a lot of effort and investments by 2030 and thus there hasn’t still been time and finance to replace the current district heating network with the two way low temperature network.

Another development in the heating network is that the computer modelling of the current district heating network has developed to a phase where it has become a basic tool for “driving” the network. With the help of this modelling program the district heating network in Turku can be “driven” optimally.

9.4.5 Energy savings

In this scenario the moderate energy saving potential determined in the part 6.6.5 will be achieved. This part also describes the ways to achieve these savings.

9.4.6 Organization

First, it is important to note that all of the renewable energy sources indicated in Table 14 will be in use in 2030 for Turku. Turku Energia will be the only energy distributor (except for Varissuon lämpö) in Turku and Caruna won’t longer distribute electricity to Turku due to its current unpopular energy price increase decisions, which makes residents of Turku want to choose Turku Energia, because they see that Turku Energia will offer them a fair price of energy. This is because the municipality of Turku owns Turku Energia and the residents are confident that the municipality will look after its residents. It is also seen that one local actor can more efficiently handle and assure the functioning and future of a 100 % RES and Turku Energia is more motivated to stick with the RES since it is owned by the municipality of Turku. Moreover, Caruna is not seen motivated in this scenario to build, monitor and maintain a RES inside of Turku, because Caruna is a national electricity provider whereas Turku Energia is providing electricity only for the municipality of Turku.

The smart grid is owned completely by Turku Energia, including the electricity storage (except the batteries of some of the premises). This way the smart grid in Turku can be better implemented, monitored, controlled and maintained when only one actor owns the grid and this way there are no competing demands. Furthermore, it is easier for the municipality of Turku to achieve its coal neutrality goal of 2040 when Turku Energia owns the whole electricity grid. However, it has to be noted that in the implementation phase of the smart grid, a cross-functional governance group needs to be set up, due to the cross-functional nature of the smart grid functions. The functions included to this group are for example customer care, energy distribution operations, engineering, IT, energy production operations (Asthana et al. 2010). In general it can be said that a steering group will be established that will manage all the major projects related to the RES in Turku. These projects will be related for example to increasing renewable energy production and building the other needed power infrastructure for renewable energy. Also an energy board of the municipality will be established that will nominate this steering group and cooperate with the steering group concerning the needed policy changes.

Turku Energia buys the electricity from the market (i.e. from the renewable electricity producers outside of Turku and from TSE) and distributes the electricity through their own electricity grid to the premises and technical infrastructure of Turku. On the other hand, Turku Energia also buys electricity from the premises and makes sure that they buy the electricity from the premises with the same price that they sell it to them.

District heating and cooling are also managed by Turku Energia and it owns the current district heating and cooling network as well as the two way low temperature heating networks for new residential areas. Turku Energia buys part of the heat from the heat producers, produces part of the heat itself and distributes all of the heat further to the premises of Turku. Also the energy users of the new residential areas are able to provide/sell heat to the low temperature heat network or to the district heating network. In this case, Turku Energia makes sure that they buy the heat from the premises with the same price that they sell it to them.

The current production plants' ownerships are the same in 2030 as indicated in the part 6.5.1. Some of the new wind turbines installed in the area of Turku (indicated in part 6.6.2) are owned by Turku Energia and some of them are owned by other companies or private investors. Turku Energia leases part of the solar technology (panels, collectors, wiring and batteries) to the premises, but also part of the solar technology is owned by the premises. Furthermore, the possible deep geothermal operations are owned by Turku Energia and also the facilities used for these operations. Turku Energia uses the deep geothermal heat for heating their district heating network.

Finally, also the PtG technology will be used in Turku. In this case the gas and electricity production facilities are needed in order to produce the gas and turn it into electricity. It is seen in this scenario that TSE will be the correct owners of these facilities, because this gas could be used in their new Naantali plant to produce heat and electricity. On the other hand, also some other company could own the gas production facility (e.g. Biovakka) and sell the gas to TSE.

In order to develop all of this technology, innovations and knowledge mentioned in the previous parts, the municipality of Turku is cooperating with different research and knowledge institutes. These institutes are mentioned in the part 8.1.2. For example efficient and close cooperation with the universities in Turku is active in 2030. Also cooperation with the local companies is creating added value to the RES and the companies understand the importance of the RES for Turku. For example cooperation with the technology and engineering companies (e.g. Areva Solar) is conducted in order to develop the renewable energy technologies and find the most suitable technologies for Turku. Finally, the energy users are also involved in this cooperation to express their opinions and needs related to the RES as well as in order to inform them about how their behavior affects the RES.

9.4.7 Policies

In this scenario the only policy set in Finland between the current time and the year 2030 concerning the energy efficiency of the premises will be the almost zero energy building directive, which will become effective in 2021. It is seen that this directive requires major developments and adjustments in the building sector and thus all activities need to be directed in carrying out this directive.

However, concerning the renewable energy production a new policy will be set in order to enhance diversified RE production. This policy sets a new system for subsidising the RE production in a technology neutral way. This subsidy system is explained in the part 7.3.1.

Concerning the renewable energy technologies it can be said that they are competitive with fossil fuel technology in 2030 without the need for subsidies and regulations (e.g. feed-in tariff or fossil fuel taxes). One facilitating factor of increasing the price of fossil fuel is globalization, which will decrease fossil fuel's availability.

Furthermore, renewable energy technologies (large or small scale) are not allowed to be installed in protected areas or on protected buildings (see part 6.1) due to the importance of these areas and buildings to the city and its citizen and due to the importance that is given to preserving the nature in Turku. Furthermore, also the restrictions explained in the part 6.6.2 are taken into account when installing wind turbines in the municipal area.

When it comes to the decision concerning the sustainability of burning wood for producing energy this scenario states that burning wood for energy production is considered sustainable as long as the wood is purchased from certified sources. Therefore, the wood purchased for the power plants in Turku will come from certified sources in the year 2030.

Finally, in this scenario the Paris Climate Agreement is fully followed and carried out efficiently by the joining countries. This in turn increases the actions taken towards RES worldwide, which in turn adds know-how of this system and develops the efficiency of its technologies. These benefits can also be exploited in Finland and in Turku. This also means that the global political crisis mentioned in the part 9.2.1 is no longer existent and the global cooperation is working among the joining countries of this agreement. Partly due to these political changes mentioned above, the citizens of Turku have a positive attitude towards the RES.

9.4.8 Finance

By the year 2030 the municipality of Turku and Turku Energia have managed to attract some private investors or companies (e.g. Meyer Turku) to invest in wind turbines in the municipal area. This means that some of the wind turbines are owned by the investors and some of the turbines are owned by Turku Energia. Furthermore, Turku Energia invests in building the smart grid and energy storage for Turku as well as to solar technology, which they lease to some of the premises in Turku. Naturally, financing for these investments comes from the energy users, which buy Turku Energia's energy and pay rent for the solar technologies. Moreover, Finnish Government and the EU are financing part of these RES investments of Turku Energia. One good example of the EU's funding is the EFSI (European Fund for Strategic investments), from where Turku will also receive funding for building its RES. The technology needed for the RES is bought from the technology and engineering companies (e.g. Areva Solar). These developments indicate that in 2030 the Finnish economy is in a better shape and investors are more willing to invest in the RES.

Concerning the energy efficiency the residents are aware of the energy savings that can be achieved with the different energy saving measures and invest in these technologies in order to improve the energy efficiency of their premises. Residents are also willing to invest in renewable energy technologies (e.g. solar panels) and they have the money for it, because they see it as a profitable investment in the long run. Also the owners of industrial, commercial and public premises are investing in energy saving technology and ESCO-projects (see Appendix A) are widely used in Turku in order to finance these projects.

In general it can be said that the developments towards RES (e.g. area of Skanssi) brings about new businesses and innovation to Turku and these innovations are also exported abroad, which in turn increases the prosperity of the municipality. (Ahonen 2015). These kinds of development projects are supported financially by the municipality of Turku or Finnish Government and local companies.

9.4.9 Built environment

The coal neutrality of Turku and building the RES are very important goals for the city and this is why they will significantly affect the land usage in the municipality. This means more compact residency, considering the energy saving needs of the premises and designing of the local master plan in a way that it supports these goals are done by 2030. (Ahonen 2015)

Furthermore, in 2030 the population of Turku will be 30 000 higher than currently. In order to not increase the energy usage, the built environment is more compact and it uses and develops the existing city structure as much as possible. Also the renovations for the current building stock are done in a way that it improves their energy efficiency. (Ahonen 2015) Partly, the increase in the energy prices has also led to this development.

The municipality of Turku, construction companies and the citizens of Turku are important actors in this development. These actors can affect the local master plan, construction and energy savings in the city.

9.4.10 Culture

Energy users in Turku are willing to pay a more expensive price of energy due to the investments made to the RES. This is because the energy users understand the importance of the RES for the environment, which is partly due to the changes they have seen through the development of the climate change. Furthermore, the energy users understand the importance of the RES for the economical development of Turku. However, the citizens are not willing to harm the nature, landscape and protected buildings of Turku by building the RES. This is why the natural environment and built environment are taken carefully into consideration when designing and building the RES. Furthermore, the citizens appreciate highly the reliability of the energy supply.

Moreover, the citizens of Turku are open-minded and interested in RES and also in reducing their energy usage. Therefore, energy savings are being achieved and the almost zero energy building directive is followed carefully. The energy savings are achieved by installing energy saving technology to the premises and by the changes of citizens' energy usage.

Important actors in creating this culture are the municipality of Turku, Turku Energia, Valonia and the universities of Turku. Important activities that these actors are performing are marketing and educating the solutions, benefits and importance of the RES as well as guiding in the usage of renewable energy technologies and achieving energy savings. Also the example from these stakeholders of acting in a sustainable way is important. Public procurement of renewable energy technology is a very important part of this example as well as building green university campuses.

Due to the successful build up of the RES in Turku and the benefits that the RES has for the city's environment and economy, Turku is seen worldwide as an important showcase of a booming and environmentally friendly town. Furthermore, in 2030 the 800 year old Turku is creative, communal and culturally rich and this is why in 2030 Turku is called the most interesting town of the Baltic Sea (Ahonen 2015).

10. Backcasting analysis

This section will indicate the spatial interventions needed for building the RES in Turku. These spatial interventions were determined by the present conditions and the scenario developed in the previous part. Furthermore, in the parts 10.2-10.4 the backcasting analysis will be conducted where the needed changes for reaching the vision and the drivers and barriers of this vision will be presented. These factors were determined based on the literature review, present conditions, and developments and by the created vision and scenario.

10.1 Spatial interventions

This part will give indications of the possible interventions in the municipality of Turku for renewable energy technologies. Especially the suitable areas for production and storage technologies are indicated. These areas are chosen in order to make better use of the energy qualities in the municipality and to produce renewable energy as much as possible from local energy potentials. Also the key strategies of renewable energy science from de Waal et al. (2015) explained in the part 2.1.3 are taken into account.

The areas for deep geothermal heat are not indicated due to the lack of information for determining these areas, but still it could be a vital energy source for Turku in the future. Furthermore, the robustness of these interventions won't be evaluated since there is only one scenario created for the RES in Turku in 2030. In the case of several scenarios the robustness of interventions could be determined.

10.1.1 Interventions for the scenario

Renewable energy production technologies

As indicated in the part 9.4, solar technology, wind turbines, biomass, deep geothermal heat and the exisiting RE sources will be used to produce the needed energy for Turku (only part of the heat demand). Furthermore, energy savings will be performed in order to keep the energy demand of Turku on the same level as currently. The found energy saving potentials and measures are explained in part 6.6.5.

As indicated in the part 7.6 the installation regulations concerning the solar technology are vague in Turku and it cannot be directly determined when this technology can be installed on the roof and when not. This is why it is assumed in this study that solar technology cannot be installed on the protected buildings, but it can be installed on other buildings. Thus the area where solar technology can be installed comprises the whole area except the protected buildings. These protected buildings are indicated in the Image 7. Furthermore, it is assumed in this study that the oil, coal and peat heated premises are not protected buildings and that they are not situated in conservation areas or in areas with archaeological values.

The suitable areas for wind turbines are indicated in the Image 11 below (areas 1-3 and 6-7) and reasons for these selections are explained in the part 6.6.2. Moreover, the new Naantali power plant will burn biomass to produce heat and electricity. As indicated also before, this plant is situated in the municipality of Naantali just outside of Turku (see Image 11 below).

Renewable energy storage

If the renewable electricity storage will be on the responsibility of the premises using solar panels, the electricity will be stored in each of these premises and this would mean a decentralized electricity storage infrastructure in Turku. On the other hand, if the renewable electricity from wind and solar will be stored in a battery storage plant, this would mean a centralized electricity storage in Turku. This would mean that an area or few areas for the plants/facilities would be needed.

One possibility for the battery plant would be the areas 4 and 5 from the Image 11 below. These are the areas, which are not suitable for wind power production (see Image 8) due to the closeness of the airport. However, in this study it is assumed that a battery storage plant won't harm the airports activities and thus these areas could be suitable for storing electricity. Furthermore, these areas are close to the city center (a lot of solar electricity production) and almost in the middle of municipality (south-north wise) and also in the middle of the suitable wind power production areas. This indicates that the distance that the electricity from the different parts of the municipality needs to travel for this battery storage plant would be close to optimal. Moreover, these areas are close to the Logicity (see part 6.1.2), which offers transport and warehousing services related to high-technology. Therefore, it can be stated that building a modern battery storage plant for renewable electricity in this area could be suitable for the future development plans of this area. It has to be noted however that the information presented in this study is not enough to thoroughly estimate the suitable area for a battery storage plant(s) in Turku and thus a more thorough and elaborate evaluation needs to be performed for identifying the most ideal areas. For example, as the Image 6 indicates these areas are situated inside a groundwater protection area and thus it may cause difficulties in building a battery plant to this area.

Concerning the PtG storage technology the most suitable area for these facilities is seen in this study to be the area of the new Naantali plant (see Image 11), because the gas produced trough this PtG technology can be burned in the new Naantali plant to produce heat and electricity and thus the gas wouldn't have to be transported to the power plant from far distances.

When it comes to storing the heat of the solar collectors it can be said that this heat is best to store near the solar collector premises in the ground. If steal tank reservoirs are used, they can be installed inside the premises. Moreover, some additional district heating water reservoirs will be added as well, but the evaluation of a suitable location for these reservoirs is not feasible based on the information presented in this study.

Child & Breyer (2016) estimate in their article the energy storage capacities needed in the future RES in Finland. They state that an electrical storage capacity of 21 % is needed from the energy demand. Furthermore, a heat storage capacity of 4 % is needed from the energy demand (storage capacity for solar collectors not included). If this is reflected to Turku, this represents 285 GWh of electricity storage and 73 GWh of heat storage capacity.

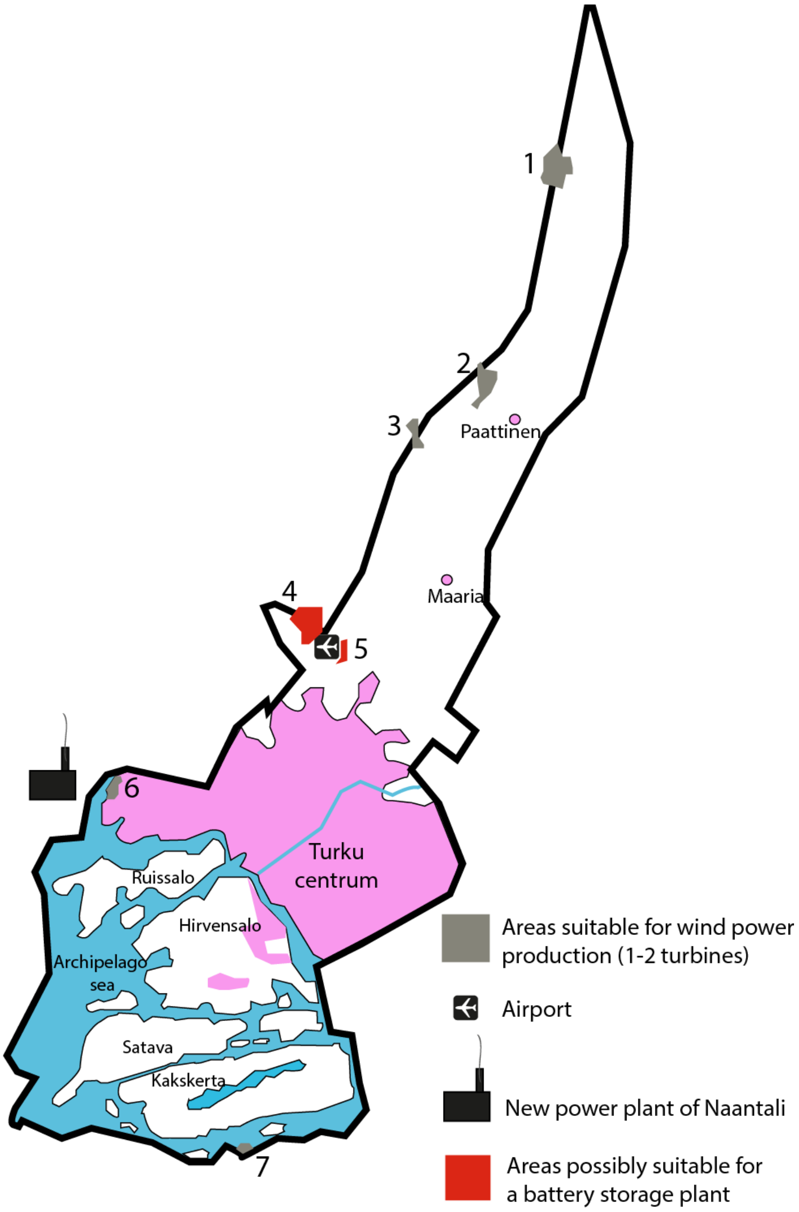


Image 11. Indications of suitable areas of RETs in Turku (Solar technology can be installed everywhere in the municipality but only on the non protected buildings' roofs).

Smart grid and heating network

Based on the information presented in this study it is hard to estimate the shape of the smart grid of Turku in the scenario. However, the part 9.4.4 gives some general indications of the possibilities for the smart grid in Turku. The current heating network will be used in 2030. Plus the new residential areas will have a two way low temperature heating network.

Disruptive renewable energy technologies

As can be seen from the Table 28 the renewable heat independence cannot be achieved with the scenario described. 256 GWh of heat needs to be produced from some other sources of renewable energy and with some other RETs. Here, the disruptive technologies (described in part 6.6.6) can offer a solution that will bring Turku closer to renewable heat independence. For example the deep geothermal heat could offer one solution. Unfortunately, not enough information is available for the evaluation of this potential in the area of Turku and no suitable locations for this heat production in Turku can be identified. However, some rough estimates of this potential can be made based on the deep geothermal heat project in Espoo explained in part 7.5.4.

It has been estimated that the holes drilled in Espoo could provide 10% of the district heat demand in Espoo (Lämpöä syvältä maan uumenista 2016). The district heating demand of Espoo in 2014 was 1888.8 GWh (Kaukolämmitys 2014). So the provision of these drilled holes could be 0.1 x 1888.8 GWh = 189 GWh. If assumed that Turku has this same potential and a similar technology would be used in Turku the amount required to achieve the renewable heat independence would decrease to 67 GWh (256 GWh – 189 GWh). However, it has to be also noted that the biomass for the Naantali plant will come mainly outside of Turku and thus it decreases the value of Turku's energy independence.

10.2 Needed changes for the vision

In this part the needed changes for achieving the vision will be determined. These changes are divided into political, economic, socio-cultural, organizational, technological, regulatory and spatial changes. Also examples of needed actions related to the changes are described. A more elaborate description of the needed actions will be given in the next chapter 11. The Table 30 will summarize the changes and important stakeholders for these changes.

10.2.1 Political changes

- Almost zero energy building directive

The EU's almost zero energy building directive has to come into effect in 2021 so that the energy demand of Turku will develop as indicated in part 9.1. This directive will require major developments and adjustments in the building sector. The Finnish Government, municipality of Turku, construction companies and building owners are important stakeholders in making this change. These stakeholders need to make sure that this directive is followed and that actions are taken to fulfill the aim of this directive. Furthermore, Valonia is also seen as a key actor in giving guidance for the building owners in order to fulfill the requirements of this directive. Finally, the research and knowledge institutes and technology and engineering companies presented in part 8.1 are seen important stakeholders in providing solutions for fulfilling this directive.

- Oriented policy on energy conservation and centralized and decentralized energy generation

To facilitate the implementation of energy conservation and centralized and decentralized energy generation the policies on local and national level need to be oriented towards this change. These policies include for example creating a policy that follows the zero energy building directive, policy that facilitates the installation of wind turbines in Turku and policy that facilitates the installation of solar panels on the roofs. The Finnish Government and the municipality of Turku are seen as important actors in this change.

- Subsidies for solar technology

Currently there are no subsidies for the implementation and usage of solar technology in Finland. This change is needed in order to increase the investments to the solar technology in Turku. One possible way of giving subsidy to the solar technology could be an installation subsidy in case a premises wants to install solar technology. Finnish Government and the municipality of Turku are seen as actors which are able to set these policies.

- Paris climate agreement

Following this agreement is seen also an important change needed in order to develop the RES in Turku. The exogenous variable (current global political crises) mentioned in the part 9.2.1 is a key variable in realizing this agreement, because it will facilitate global decision making in the matters of climate change and this in turn enhances the possibilities of fulfilling the terms of the Paris agreement. The important stakeholders in making this change are the most powerful political leaders and countries in the world.

- Purchasing wood from certified sources for energy production power plants

A decision is needed from the EU level that considers burning wood for energy production as sustainable and renewable when this wood is purchased from certified sources. The certification would require forestry actions that assure the healthy and sustainable growth of these wood sources. The energy companies need to also start purchasing their energy wood from these certified sources. EU, Finnish Government, energy companies and the forest owners are seen important in facilitating this change.

- Partnership of Turku Energia with Fennovoima

Turku Energia is part of the Fennovoima's project of building a new nuclear power plant to Finland. This means that Turku Energia will purchase part of its electricity from this power plant in the future. This goes well together with Turku's aims of coal neutrality in 2040, but doesn't fit the aim of this study, because in this study nuclear energy is not considered to be renewable. Therefore, no electricity from nuclear power can be used in Turku in 2030 if the aim of this study is wanted to be achieved.

10.2.2 Economic changes

- Changes in the subsidy system of renewable energies

The feed-in tariff has been criticized to be too generous for wind energy and giving too much support for only one renewable technology, whereas the cap and trade system's emission license price is too low partly due to the effects that the feed-in tariff has to it. A change to this system is needed in order to effectively pursue to the increasing usage of RETs. One action can be to change to a technology neutral RE production subsidy that is based on competitive bidding (see part 7.3.1). The EU, Finnish Government and Finnish political parties are important stakeholders in making this change happen.

- Investments needed for the RES in Turku

In order to build the RES in Turku investments are needed in its technology. These investments can come for example from companies or citizens of Turku. One example of a big investment already made in Turku is the new Naantali power plant. However, a lot more investments are needed if the RES is wanted to be achieved. These investments are for example investments in solar panels, energy saving technologies, energy storage and smart grids. Important is that the environment is made suitable for investors to invest, and that investors are induced to invest in Turku RES. For example, increasing the interest of local companies (e.g. Meyer) is important. Also the continuity of political decisions and economical growth worldwide and in Finland are seen important facilitating factors. Furthermore, applying funding from the EU can be an important source of finance for the investments. The European Union, Finnish Government, municipality of Turku and Turku Energia are seen important stakeholders that have the ability to carry out these actions. Finally, of course the financers and citizens of Turku are an important stakeholder as well, because they will make the investment decision in the end.

- Economical growth in Finland

Current economical situation in Finland and Turku is difficult, which hinders the possibilities of investing to the RES. A major change towards the positive is needed and then it is more likely that important investments to the RES in Turku will be made. These investments in turn would enhance the economical situation of Turku and would give room for innovations in the energy system. These innovations could be exported abroad, which in turn would enhance Turku's economy. This change is very much in the hands of the Finnish Government and that of the Finnish citizens. The research and knowledge institutes and technology and engineering companies presented in part 8.1 are seen important stakeholders in making this change happen.

- Increase of fossil fuel prices

This increase is needed in order to make the RETs cost competitive with technology that uses fossil fuels. When RETs become competitive, the investments to this technology increase. This development can be seen to happen in some year's time due to the taxes on fossil fuels and due to the future availability problems of oil. Finnish Government is an important actor in this change, because it can decide what kind of taxes it sets for fossil fuels. Also the OPEC countries have a major effect to the price of oil. In 2030 the RETs need to be competitive with fossil fuel technology without the need for taxes and subsidies.

- Increase in the price of electricity produced with current technologies

Currently the price of electricity is low in Finland. The increase in this price would possibly make the electricity users to look for alternatives ways of producing electricity (e.g. RETs). Furthermore, the increase in electricity prices would give more income to the electricity producers, which could use this income to the development of the RETs and RES. The energy producers are a decisive actor in this change and also the fuel suppliers.

- Economic viability of the energy storage, two way low temperature heating network and smart grid

The distribution and storage are very important parts of the future RES in Turku. Currently, the economic viability of these technologies is not on the level that it would be profitable to install these technologies in large scale. Increasing research and development activities in this field is an important action to be taken here. This change is needed for the RES in Turku. The research and knowledge institutes and technology and engineering companies presented in part 8.1 are seen important stakeholders in developing this technology and its economical viability.

10.2.3 Socio-cultural changes

- Acceptance of the fact that change will require financial investments

The stakeholders building the RES need to come in terms with the fact that these investments will make them loose money in the beginning and that a change doesn't come for free. This change in the mindset is needed. (J Pelkonen 2016, pers.comm., 13 February). All the stakeholders involved in building the RES are concerned here.

- Citizens' willingness to change their living habits and the cityscape

Transferring to an RES will bring several changes to the city and to its cityscape. These changes are for example the presence of wind turbines and other RETs and more compact residency. Citizens need to be aware of the benefits of these changes and accept them and embrace the new way of life, which can be healthier, more social and prosperous than the former one. This can be done for example through education (universities and energy guidance), newspapers and social media. The municipality of Turku, Valonia and the citizens of Turku are seen as important stakeholders in making this change.

- Energy users in Turku are willing to pay a more expensive price of energy

Due to the investments made to the RES the energy price in Turku is seen to increase. Currently, the energy users in Turku are very strict with the level of the energy price and demand low prices. This was proven by the Caruna case explained in the part 8.1.4. This mentality needs to change when moving towards the RES in Turku and energy users need to accept the increase in the energy prices due to the investments in the RES. In this change it is important that the environmental awareness of the energy users increase and that the short term financial factors become subordinate to the environmental, cultural and long term financial factors. The effects of climate change is seen as a facilitating factor in making the energy users realize the importance of the RES. Correct communication of the benefits of RES is seen also important here. The municipality of Turku, Turku Energia, Valonia and the energy users are seen as important stakeholders in making this change.

- The population increase of Turku

The population increase is estimated to increase in Turku with 30 000 habitants by the year 2029. This increase is needed for the scenario of this study to realize itself. Municipality of Turku and the citizens' of Turku are seen as important stakeholders in this change.

- Improving and increasing cooperation between the stakeholders

The cooperation between the different stakeholders needs to be increased if the RES is wanted to be achieved in Turku by 2030. Building a RES is a very complex transition and it requires cooperation of several actors from different fields. Solidarity is an important aspect of this change and more solidarity is needed in order to facilitate cooperation. Also learning from this collaboration is seen important in the transition to the RES in Turku (McCormick et al. 2013). Urban labs and creating dialogue between the stakeholders are examples of actions needed for this change. All the stakeholders of the RES in Turku are seen important in this change.

- The Finnish energy discussion

This energy discussion has quite negative tone and it doesn't take enough into consideration the global developments in RES (e.g. developments in Germany). In Finland the population compared to the surface area is low and Finland has a big renewable energy potential, but still the Finnish energy discussion is concentrated to the problems related to the RES. If this tone of discussion changes, it would facilitate the transfer to the RES in Finland and also in Turku. (S Lyytinen 2016, pers.comm., 08 February) All the stakeholders of the RES in Turku are seen important in this change.

10.2.4 Organizational changes

- Clearer governance of energy matters in the municipality

This change is needed in order to have a clear responsible organizational entity concerning the developments and decisions related to the RES in Turku. This can be done by creating an energy board of Turku's municipality and a steering group for the build up of the RES. The municipality of Turku and its city council are seen important actors in this development. Also the organizations participating to this steering group are important stakeholders.

- Clear rules and steps in building the RES in Turku for 2030

A pathway or a roadmap for building the RES in Turku for 2030 should be created. This pathway would clearly show the steps that need to be taken in order to build a RES for 2030. The municipality, technology and engineering companies, energy companies, energy users and the research and knowledge institutes are important stakeholders in this change.

- From short term project management to long term project management

The problem with short term sustainability projects is that companies are not very keen on participating in these projects, because their intention is to continue their business in a long term. Therefore, in the field of sustainability (e.g. transition to RES) long term projects should be preferred. (K Koskinen 2016, pers.comm., 05 February) All the stakeholders of the RES in Turku are seen important in this change.

- Focus on the whole energy system in Turku and not only to renewable energy production

In Turku quite a lot has been done already for renewable energy production, but the attention should be focused also more on the whole energy system in Turku. These other focus points are for example energy efficiency and energy storage. (J Pelkonen 2016, pers.comm., 13 February). Important actors in this change are seen to be the municipality of Turku and Turku Energia.

- Turku Energia only energy provider in Turku

Caruna won't longer distribute electricity to Turku and thus Turku Energia will be the only energy provider in Turku. This means that each premises need to buy their energy from Turku Energia. Also the needed action from Turku Energia is to buy Caruna's power infrastructure. Important stakeholders in this change are the energy users, Caruna, the municipality of Turku and Turku Energia.

- Concept of two way low temperature heating network and the smart grid

The change needed here is to find out how these two aspects of the power infrastructure will function in Turku for delivering energy to the premises and receiving energy back from the premises. Also how the energy trading works in this power infrastructure needs to be determined. The Skanssi project (described in Appendix A) is currently studying these matters. The stakeholders involved in the project are seen important in facilitating this change.

- The energy wood purchased from certified sources

The wood burned in Turku's power plants need to be purchased in the future from certified sources in order to guaranty the coal neutrality of these activities (T Bastman, TSE, 2016, pers.comm., 21 January). This should be managed by the energy producers (e.g TSE) and the forest owners.

10.2.5 Technological changes

- Improving the efficiency of RETs

In order for the RETs to be competitive with the fossil fuel technology the efficiency of the RETs need to be improved. This means that the operating efficiency and the levelized costs (see part 7.5.2) of the RETs need to be improved. The facilitating factors of this change are the positive global mindset of the energy users towards RETs and the investments to R&D. Especially important for this scenario is that energy storage technologies, smart grids and two way low temperature heating networks achieve considerable improvements in technical and economical efficiency. Important stakeholders in realizing this change are technology and engineering companies, research and knowledge institutes and energy users.

- RETs more competitive than the nuclear power

In order to build a 100% RES in Turku no nuclear power should be used. Important here is that the nuclear power will lose its competitivity against RETs. This will facilitate the popularity of the RETs.

Important stakeholders in realizing this change are technology and engineering companies, research and knowledge institutes and energy users.

- Upgrading the power infrastructure in Turku

The power infrastructure needs to be upgraded and new installations are needed in order for it to produce the needed renewable energy (small and large scale production) and manage the distribution of intermittent renewable energy in Turku (energy storage, smart grid and two way low temperature heating network). One important factor of this change is to choose correct energy storage technologies and their location. Important stakeholders in realizing this change are technology and engineering companies, research and knowledge institutes, municipality of Turku and the owners of the premises.

- Energy savings in the premises of Turku

Energy savings in the premises are needed in order to keep the energy demand of Turku on the current level. The suitable actions for making these savings are explained in the part 6.6.5. Technology and engineering companies, research and knowledge institutes, the municipality of Turku and the energy users are seen vital actors for facilitating this change.

- Production of deep geothermal heat in Turku

The production of deep geothermal heat in Turku needs to be started so that Turku can come as close as possible of achieving the renewable heat independence. In order for this to happen the current geothermal heat project in Espoo (explained in the part 7.5.4) should be a succes and it would give a positive sign of the geothermal potential for other cities in Finland. The key actors here are the municipality of Turku, Turku Energia, technology and engineering companies and research and knowledge institutes.

- Share of renewable energy in the new Naantali power plant to 60%

This change is needed in order for the scenario of this study to realize. Furthermore, the renewable energy (e.g. wood) for the plant needs to be considered sustainable. Thus, the wood for the plant needs to be purchased from certified sources. Important actors in this change are TSE, Fortum, Turku Energia, municipality of Turku and forest owners.

- No more premises outside the district heating network without heating from renewable sources in Turku

This change is needed in order to achieve the RES in Turku. A change in regulation in the municipality is needed in this period that will prohibit the usage of oil, coal and peat as a heating mode for the premises. Turku municipality is the relevant actor for making this change.

10.2.6 Regulatory changes

- Clearer regulation for solar technology

Regulations for installing solar technologies in the premises' roofs are needed in order to clearly communicate the rules and boundaries related to solar technology installation in Turku. The municipality of Turku is the key actor in this change.

- Finnish regulation concerning the almost zero energy building directive

When this EU's directive will come in place the Finnish regulation needs to be aligned with this directive. The new regulation needs to facilitate the goals of this EU directive. Furthermore, Turku's policy concerning the Finnish regulation needs to be aligned as well. The Finnish government, Finnish Parliament and the municipality of Turku are seen as important stakeholders in this change.

10.2.7 Spatial changes

- Spatial planning for the year 2030

Spatial planning is needed for the year 2030 in order to indicate and facilitate new residential areas, zero energy buildings or residential areas and areas for RES in Turku. It is important to take the RES into account in spatial planning in order to construct energy efficient residential areas (J Pelkonen 2016, pers.comm., 13 February). In general it can be said that taking ecology into account in spatial planning is important for the development of RES in Turku (K Koskinen 2016, pers.comm., 05 February). Important action here is to create a local master plan in Turku for the year 2030. The municipality of Turku is seen as the stakeholder who takes responsibility of the spatial planning of Turku.

Table 30. Needed changes and important stakeholders for these changes.

Change	Stakeholders
Almost zero energy building directive	Finnish Government, municipality of Turku, construction companies and building owners, Valonia, research and knowledge institutes and technology and engineering companies
Oriented policy on energy conservation and centralized and decentralized energy generation	The Finnish Government and the municipality of Turku
Subsidies for solar technology	Finnish Government and the municipality of Turku
Executing the Paris climate agreement	Most powerful political leaders and countries in the world
Purchasing wood from certified sources for energy production power plants	EU, Finnish Government, energy companies and the forest owners
Cancelling the partnership of Turku Energia with Fennovoima	The municipality of Turku, Turku Energia and Fennovoima
Changes in the subsidy system of renewable energies	EU, Finnish Government and Finnish political parties
Investments needed for the RES in Turku	EU, Finnish Government, municipality of Turku, Turku Energia, financers and citizens of Turku
Economical growth in Finland	Finnish Government, Finnish citizens, research and knowledge institutes and technology and engineering companies
Increase of fossil fuel prices	Finnish Government and Opec countries
Increase in the price of electricity produced with current technologies	Energy producers, fuel suppliers
Economic viability of the energy storage, two way low temperature heating network and smart grid	Research and knowledge institutes and technology and engineering companies
Acceptance of the fact that change will require financial investments	All stakeholders
Energy users in Turku are willing to pay a more expensive price of energy	Municipality of Turku, Turku Energia, Valonia and energy users
The population increase of Turku	Municipality of Turku and the citizens' of Turku
Improving and increasing cooperation between the stakeholders	All the stakeholders
Changing the Finnish energy discussion	All the stakeholders
Clearer governance of energy matters in the municipality	Municipality of Turku and its city council
Clear rules and steps in building the RES in Turku for 2030	Municipality, technology and engineering companies, energy companies, energy users and the research and knowledge institutes
From short term project management to long term project management	All stakeholders
Focus on the whole energy system in Turku and not only to renewable energy production	Municipality of Turku and Turku Energia.
Turku Energia only energy provider in Turku	Energy users, Caruna, the municipality of Turku and Turku Energia.
Concept of two way low temperature heating network and the smart grid	Stakeholders involved in the Skanssi project

The energy wood purchased from certified sources	Energy producers and forest owners
Improving the efficiency of RETs	Technology and engineering companies, research and knowledge institutes and energy users.
RETs more competitive than the nuclear power	Technology and engineering companies, research and knowledge institutes and energy users.
Upgrading the power infrastructure in Turku	Technology and engineering companies, research and knowledge institutes, municipality of Turku and owners of the premises.
Energy savings in the premises of Turku	Technology and engineering companies, research and knowledge institutes, the municipality of Turku and the energy users
Production of deep geothermal heat in Turku	Municipality of Turku, Turku Energia, technology and engineering companies and research and knowledge institutes.
Share of renewable energy in the new Naantali power plant increased to 60%	TSE, Fortum, Turku Energia, municipality of Turku and forest owners.
No more premises outside the district heating network without heating from renewable sources in Turku	Turku municipality
Clearer regulation for solar technology	Municipality of Turku
Finnish regulation concerning the almost zero energy building directive	The Finnish government, Finnish Parliament and the municipality of Turku
Spatial planning for the year 2030	Municipality of Turku

10.3 Drivers for the vision

In this part the drivers for the vision will be presented. These drivers are divided into political, economic, socio-cultural, technological and environmental drivers.

10.3.1 Political drivers

- Almost zero energy building directive

This directive will affect positively the energy efficiency of the premises in Turku and increase the usage of RETs in the premises. This is why it is seen as a driver towards building a RES in Turku.

- The goal of coal neutrality in Turku in the year 2040

This goal set by the municipality of Turku is a major driver towards the vision set in this study. This goal also indicates the high political will related to the sustainable development of the city. This will has a major effect to the decisions made concerning sustainability in Turku. This goal can also be seen as factor of success for Turku, which increases the value of this goal as a driver. This will has already created new renewable energy production to Turku, which also can be seen as a driving force for the scenario.

- Voting power of the citizen

Very important decisions concerning the RES are done in the political system nationally and locally in Finland. This political system is directed by the voters. Thus it can be said that the voters are a major driving force in deciding whether the development of the RES will be enhanced nationally and locally.

- National and international climate policy

In addition, to the goals set in Turku also the national and international climate policy are important drivers for the RES in Turku. Examples of these policies are the Paris Climate agreement and the Energy and climate strategy of the Finnish government. In order for these policies to come to power and be effective, the national and international political leaders must be as united as possible and political crises should be avoided.

- Political continuity

The political continuity is important for securing a steady investment environment for investors who want to invest in RETs. Today's political system doesn't have this continuity due to the changes in power and ideological differences that the political parties have. Therefore, political continuity is an important driver when thinking of a secure and steady investment environment for building a RES. Furthermore, building an RES in Turku is a long term project with the year 2030 as an end point and therefore also political continuity is an important driver at the local and national level.

10.3.2 Economic drivers

- Investments to the RES in Turku

The past and future investments to the RES are very vital driver for building system. The economical growth worldwide and in Finland is a very important enabler of investments. Currently, the Finnish economy is in stagnation, but if there will be economical growth in the future it will have an important positive effect to the RES investments in Finland.

Furthermore, funding is important facilitator of investments. One very potential way of receiving funding to the build up of the RES in Turku is the European Fund for Strategic Investments (EFSI). EFSI (European Fund for Strategic Investments) its purpose is to give 315 billion euros for investments in Europe. The vice president of the European Commission Jyrki Katainen says that for example the decision makers in the cities who are planning smart energy systems for their cities often feel that investing to this energy system is difficult because investments from the market are missing due to the risks related to the investments to these technologies. EFSI is a good option outside of the market for getting funding for these plans. (Rautio 2016)

- Subsidies for solar technology

Currently there are no subsidies for the implementation and usage of solar technology in Finland. If these subsidies would be realized it will be an important driver for installing solar technology in the

RES of Turku. One possible way of giving subsidy to the solar technology could be an installation subsidy in case premises want to install solar technology.

- Increase in the price of energy

Increase in the price of energy produced with non-renewable technologies and decrease of energy produced with RETs will make energy users start to search for alternative energy production ways and this in turn will enhance the usage of RETs. Taxes for fossil fuels and subsidies for RETs are ways of affecting the energy price as well as making the RETs more cost effective.

- Strengthen the economy of the area by the RES

Increasing the share of renewable energy production and by developing a renewable energy system can enhance the economy of Turku. This project can create innovation, which can be exported and thus the economy will be more prosperous. Furthermore, building and maintenance of the RES will create jobs, which in turn will affect positively the economy.

10.3.3 Socio-cultural drivers

- Discussion on renewable energy

Increasing discussion concerning the sustainability and renewable energy will enhance the awareness and knowledge concerning these aspects. This in turn will have a positive effect to the usage of these technologies. Important here is also that this discussion would highlight the possibilities that renewable energy can bring for the society.

- Renewable energy education

Another thing that will enhance the awareness and knowledge of RES is the education of this field. Turku is known as a university city and offers education on matters related to renewable energy, which can be considered a major driver towards the RES in Turku.

- Interest towards RES among citizen in Turku

It is clearly perceptible that the interest towards RETs is high in Turku. Especially the solar technology is gaining interest in the city. For example the starting up of the Kupittaa solar plant didn't cause any resistance and many citizens joined this project quickly. One enabler for the interest towards RETs in Turku is the energy guidance of Valonia explained in the part 7.4.2.

- Image factor of the RES

Turku's image in the eyes of the rest of the world will be valued more if this RES will be built for the city. This will give more publicity to Turku and more tourists and companies will come to Turku. There are also a lot of competitions between cities around the world and building a RES would increase the place of Turku in this competition.

- Energy security

In the scenario of this study the energy independence of Turku will increase, which means that the energy security in Turku will increase. This means that if the national grid has problems of delivering electricity to Turku, the city can still provide a considerable amount of electricity by its own production. This is an important factor especially when considering the challenges of the current energy system in Finland (explained in part 6.5.4).

- Cooperation among stakeholders

Cooperation is a very important driver for building the RES, because it is required that expertise from several different fields is put together for a common goal. Cooperation enhances also the knowledge exchange among the stakeholders.

- Demographic changes

This factor can also be considered as a driver for the scenario. The effects of this factor are explained in the part 9.2.3.

- Mindset of the energy consumers

The driving effects of this factor are explained in the part 9.2.3.

10.3.4 Technological drivers

- Technological development of RETs

The ongoing technological development of the RETs is a strong driver for building the RES in Turku. Especially the solar power technology's efficiency is developing rapidly and they are estimated to be competitive (efficiency and costs) in 2020's. Also there is no resistance against the solar technology in Turku. The technological development will facilitate the RETs of becoming more competitive than fossil fuel and nuclear power technologies, which can be seen as a major driver as well.

- Digitalisation

Especially in the field of energy efficiency and smart grids, digitalisation will have a major contribution in the future. Examples of these technologies are smart meters and sensor technology. These technologies are important for the RES.

- Geothermal heat project in Espoo Finland

The driving effects of this factor are explained in the part 9.2.4.

- Skanssi project

This project is explained in the Appendix A. If this project is successful it can be seen as a major driver for building residential areas in Turku that have an RES in their area.

10.3.5 Environmental drivers

- Resource scarcity

The resource scarcity in the future will be a major driver for the development of the RES (K Koskinen 2016, pers.comm., 05 February). This will make societies look for efficient and renewable sources. The predicted future scarcity of oil is one good example. When oil becomes scarce on the planet the energy normally generated from oil needs to be replaced by other sources on energy. One possibility is renewable energy.

- Positive effects to the climate of Turku and to citizen

The positive health effects that the energy production from renewable sources will bring with it are very important for the wellbeing of the Turku's citizens. Fossil fuel technology has affect negatively the air that the citizens breath, but using only renewable energy will improve the air quality in Turku.

10.4 Barriers for the vision

In this part the barriers for the vision will be presented. These barriers are divided into political, economic, socio-cultural, technological, environmental, regulatory and spatial drivers.

10.4.1 Political barriers

- Sustainability of the wood in energy production

Wood in energy production is politically currently considered as renewable energy, but this opinion may change in the future (T Bastman, TSE, 2016, pers.comm., 21 January). If the energy wood in the future is considered as non-renewable almost all of the biomass used for energy production in the scenario will be considered as non-renewable and thus the energy system cannot be called anymore a RES. This would mean also that the climate and energy goals of the Finnish Government and municipality of Turku won't be achieved.

- Difficulties in the wind power construction projects

There are difficulties in Finland concerning the realization of the wind power construction projects. This is due to the broad appeal rights that the Finnish citizens have concerning these projects. The citizens can for example appeal concerning the noise effect that the wind turbines can have. These appeals slow down these wind power projects and their acceptance for receiving the feed-in-tariff. (J Hallivuori 2016, pers.comm., 23 February) There is also quite common negative attitude against wind power in Finland due to its noise effects and landscape disturbances.

- National and international climate policy

This factor is also mentioned as a driver for the scenario, but it can be considered as a barrier as well. For example if the Paris climate agreement won't be effective, it can seriously influence the societies' motivation in using renewable energies. Furthermore, if this agreement is not effective it will be difficult to tackle the climate change due to the global nature of this problem. This development would also seriously hinder the development of RES internationally, nationally and locally. One example of this hindering policy is the Supreme Court's decision to temporarily block Barrack Obama's legislation pursuit to limit power plants' greenhouse gas emissions in USA.

- New nuclear power plant to Pyhäjoki in Finland

The municipality of Turku is engaged in the construction of the new nuclear power plant in Finland with Fennovoima and this can set a major barrier to the scenario developed in this study. Municipality being part of this project means that electricity from this nuclear power plant will be purchased to Turku and nuclear electricity is not considered as renewable energy in this study.

- Voting power of the citizen

This factor is mentioned also as driver, but it can be also considered as a barrier. If the voters in Finland decide to vote political parties that don't strongly enhance the possibilities of developing the RES, it will form a major barrier for this development.

- Changes to the social and health system and to municipalities' autonomy

The Finnish Government is currently planning major changes in the social and health system and to the municipalities' autonomy. The question remains how these changes will affect the possibilities of building the RES in Turku. Once these reforms need to be performed on the municipality level, it can require major efforts from the municipalities and it is possible that less time and money will be left for the developments of the RES. (A Ahtiainen 2016, pers.comm., 03 February)

- Political continuity

The political continuity is important for securing a steady investment environment for investors who want to invest in RETs. Today's political system doesn't have this continuity due to the changes in power and ideological differences that the political parties have. Therefore, the lack of political continuity is an important barrier when thinking of a secure and steady investment environment for building a RES. Furthermore, building a RES in Turku is a long term project with the year 2030 as an end point and therefore also the lack of political continuity is a barrier at the local and national level.

10.4.2 Economic barriers

- Economical growth

This factor has been mentioned as a driver also, but it can be considered as a barrier as well. The Finnish economy is in a long stagnation and if this continues it will be a major barrier for the RES investments. The amount of investments needed for building the RES are considerable so an attractive investment environment is needed.

- Fortum the biggest owner of the new Naantali power plant

The new Naantali power plant is owned by TSE, which biggest owner is Fortum. Fortum is a listed company whose interest is to generate profits to its owners and this aspect can have a major influence on the fuel base of the TSE's new power plant in Naantali. This is because biofuels are currently more expensive than coal so it is not in Fortum's interest to raise the biofuel share up to the level when producing energy is no longer profitable. This wouldn't be profitable for the owners of TSE. This is why the share of biofuels in the new Naantali plant will be 40 % in the beginning and not 60-70 %, because 40 % share is still seen profitable. If the share of biofuels is increased to 60-70 % it becomes more expensive (due to longer biofuel supply chains and biofuel price) and then the energy production in the new Naantali plant won't longer be economically profitable. (T Bastman, TSE, 2016, pers.comm., 21 January).

10.4.3 Socio-cultural barriers

- Energy users willing to pay a higher price of energy

This factor has been mentioned as a driver also, but it can be considered as a barrier as well. If the energy users are not ready to pay a higher price of energy it will be difficult to do investments to the RES. This mentality can also cause the premises to detach from the district heating network and start building their own heating systems (e.g. oil or air-source heat pumps). This will have a negative effect on the overall efficiency of the heating system in Turku. (T Bastman, TSE, 2016, pers.comm., 21 January)

- Changes that the RES brings to the citizens' lives

The RES will affect also citizens' everyday life and changes are possible. One barrier can be that how willing the citizens are to make these changes. For example the scenario requires that a lot of solar panels will be installed on the premises' roofs. How willing the citizens are to install this technology in large scale and how realistic it is to install all the needed solar panels on the roofs?

- Discussion on renewable energy

This factor has been mentioned as a driver also, but it can be considered as a barrier as well. If the renewable energy discussion stays negative in Finland it can affect negatively the development of the RES in Turku.

10.4.4 Technological barriers

- Availability of wood

The availability of wood can be a major barrier for increasing the share of renewable to 60 % in the new Naantali power plant. For example the area around Turku is not the best area for findng wood due to the agriculture and the sea area. This means that the energy wood has to be brought to Naantali from longer distances. Especially difficult to find wood for the plant is to find it from certified sources as described in the scenario. A facilitating factor in this availability problem can be the decrease in energy use and increase in decentralized energy production and energy storage (R Veivo 2016, pers.comm., 11 February).

- Usage of air source heat pumps in the premises connected to the district heating network

These heat pumps have a negative effect to the electricity production of the new Naantali power plant. The heat that an air source heat pump brings to the premises is less than what the plant looses in electricity production. Therefore, it can be considered as a minor barrier for building an efficient RES in Turku. This is true as long as the new Naantali plant is a CHP plant and the energy demand doesn't exceed the plant's capacity. (T Bastman, TSE, 2016, pers.comm., 21 January)

- Focus only in the renewable energy production

Currently Turku is focusing a lot in building renewable energy production and not a lot of attention is put on the other parts of the RES. One of these parts is for example energy storage. If this continues it will cause major difficulties for building and RES.

- The level of diversity of RETs

The scenario presented in the part 9.4 shows that the imagined future RES in Turku won't be very diversified in terms of RETs. Only wind, sun, biomass and deep geothermal heat power will be used. This is why energy storage is very important in this system. However, currently the energy storage technologies' capacity to store energy is minimal compared to the needed energy volumes so major developments are needed in this field in order to build a RES in Turku. However, making the RES in Turku more diversified in terms of RETs could decrease the need for energy storage.

10.4.5 Environmental barriers

- Climate conditions for RETs

The climate conditions in Turku can set constraints to the usability of the RETs, especially for the solar technology. One example is the snow that can prevent the solar technology from producing energy. Another difficulty can be the low temperatures during winter that can affect the efficiency of the solar technology. Then again very warm temperatures are not suitable for solar power either.

10.4.6 Regulatory barriers

- Regulation in the energy industry

Currently there is too much regulation in the energy industry when instead the business market should more solve its matters. The regulation often hinders the development of this field and of its technology. One example is the energy efficiency requirements by regulation. It could be more beneficial to let the energy price decide what the best solutions for energy efficiency are. (T Bastman, TSE, 2016, pers.comm., 21 January)

- Missing regulation on solar technology installations

This regulation is missing in Turku and forms a barrier for solar technology installations. Clear regulation would give the premises owner clear idea of what is needed for the installation and this would speed and make easier the installation process. Sometimes also the policy of the condominiums prohibit these installations (S Lyytinen 2016, pers.comm., 08 February).

10.4.7 Spatial barriers

- The landscape characteristics of Turku

Turku is at least on a Finnish level a highly populated municipality and partly densely constructed. Furthermore, Turku has a lot of valuable landscape and protected buildings and areas. This all sets barriers for the implementation of RETs.

- City planning

When the city decides that a certain area will be reserved as a residential area, it is often the case that it is not known when the constructions will start in that area and how many premises will be built. This is why it sets barriers on deciding when to invest and how much to the area's district heating network and RETs. (A Ahtiainen 2016, pers.comm., 03 February) Furthermore, another barrier for the RES is that the ecology criteria that should direct the city planning is missing (Ahonen 2015)

- The soil of Turku

The clay soil of Turku is a challenge if geothermal heat is wanted to be extracted for Turku. Furthermore, the city center area is protected from underground operations, which also sets restrictions on the usage of geothermal heat in the city center of Turku. (A Ahtiainen 2016, pers.comm., 03 February)

11. Pathway

Based on the needed changes, drivers and barriers and atlas of case studies the pathway towards energy independence and RES is created and presented here. This pathway will describe the important milestones and actions for reaching the vision and the related drivers and barriers. The description of the pathway is divided into short, - mid and long term periods. Furthermore, the Figure 12 in the end of this chapter will present the important milestones for reaching the vision. Moreover, the tables 31, 32 and 33 will describe the important milestones of the pathway and describe the needed actions.

11.1. Period 2016-2020

It is important that the pathway towards the RES in Turku in 2030 will be started by creating clearer governance of energy matters in the municipality. This change is needed in order to have a clear responsible organizational entity concerning the developments and decisions related to the RES in Turku. Thus, in this period an energy board of Turku's municipality will be created, which will be the primary responsible organization for building the RES in Turku. This energy board will nominate a steering group that includes actors from the different fields of the society related to the RES and this group will conduct a roadmap plan for the RES in Turku in this period. This roadmap will clearly show the steps that need to be taken in order to build a RES for 2030. One possible framework for this roadmap is the Sustainable Energy Action Plan (SEAP) described in the part 2.2.1 of this thesis, and also this thesis will be used as a guideline for conducting this roadmap. Furthermore, this steering group will manage or supervise the major projects related to RES in Turku and report to the energy board of the results and needs for policy changes in Turku. It is important that this governance is created as a first step in order to create the roadmap that will be followed in the future and that the steering group starts managing the RES related projects from the beginning.

In this period Turku will also orient its policies towards energy conservation and centralized and decentralized energy production. It is important to set these policies in this period due to the demands coming from EU (i.e Almost zero energy directive) and because it is important to set clear policies from the very beginning in order to speed up the implementation of RETs. These policies will be guided by the roadmap plan, almost zero energy building directive and the goal of coal neutrality in Turku in the year 2040. Furthermore, the policy makers want to make this change, because they understand the positive effects that this will bring for Turku. These policies include for example creating a policy that follows the almost zero energy building directive, policy that facilitates the installation of RETs and energy savings (creation of local master plan, which indicates the areas for RETs, new residential areas and supports compact residency) in Turku and a policy that facilitates the installation of solar panels on the roofs (clear regulation that explains clearly the rules and makes faster the permission process). These policies will be aligned with the policies of the Finnish Government. In order to pull through these policies, support from the citizens of Turku is needed. This will be achieved by increasing the knowledge of the citizens concerning the RES and explaining the benefits of this system for Turku (e.g. economical development of the city and environmental friendliness). This will be done for example through education (universities and energy guidance), newspapers and social media. These policies and RES knowledge increase among citizen will increase the implementation of RETs also from bottom-up (i.e. RET implementation done by the citizens of

Turku). Also the price increase of electricity produced with current technologies will increase this implementation.

In this period it is also important to improve and increase the cooperation among the stakeholders related to the RES in Turku. To facilitate this change the project management related to the RES will be handled in a long term instead of short term. This means that the major projects related to the RES will be long term projects, where different suitable stakeholders will be invited in a suitable moment to give their input to the project and then they would step out from the project when their input is no longer needed and when the stakeholders have received their wanted added value from the project. After this, when their input is needed again they could come back to the project. On the other hand, the stakeholders could also join the project by themselves whenever they see it beneficial for them. This could facilitate the stakeholders to give their optimal input to the project and facilitate the learning from the project. According to Koskinen (2016, pers.comm., 05 February) this kind of project management would be suitable for long term projects related to sustainability.

The new steering group will manage these projects and this way of working will continue all the way to the year 2030. These projects will be related for example to increasing renewable energy production and building the needed distribution and storage infrastructure for renewable energy. One way of performing these projects is creating urban transition labs (e.g. Skanssi) in the city. These labs, situated in a well manageable area like a certain precinct (e.g. abandoned areas like army base), will increase the cooperation among stakeholders and increase the knowhow related to the RES. Here, the documentation of processes, key decisions, mistakes and unexpected results is important for the success of further sustainable urban transformation. The lessons learned from the projects on precinct level are valuable when scaling up towards sustainable transformation on a whole city level. (McCormick et al. 2013) One of the important projects started in this period will be the exploration of the deep geothermal potential in Turku. This will be done by performing some test drillings to explore the potential. The Table 31 below will describe other possible ways of improving and increasing cooperation in this period among the stakeholders related to the RES in Turku.

In the last phase of this period, investments to the RES will be conducted. These investments will be directed to the solar and wind power production, to the smart grid, to the two way low temperature heating network of Skanssi and to energy savings. These investments will be facilitated and driven by the coal neutrality goal of Turku, the Paris Climate Agreement, changes in the RE subsidy system, economical growth in Finland, efficiency improvements of the RETs and the positive renewable energy discussion in Finland. There are several actions to be taken that will facilitate the realization of these investments. One of them is public procurement that will give an example for the private sector and to the energy users and legitimise the municipality’s future regulations and actions concerning renewable energy and energy efficiency. Funding is also important for investments. One very potential way of receiving funding to the build up of the RES in Turku is the European Fund for Strategic Investments (EFSI). The first important action in getting money from EFSI in Finland is to contact the European investment banks Finnish office in Helsinki. (Rautio 2016)

Furthermore, also policy changes are important actions in facilitating investments. These actions are for example creating the local master plan, where suitable and reserved areas for RES will be indicated and setting clear rules for the solar technology installations. Also one important action taken here on a national level is to create a subsidy system of technology neutral bidding.

Finally, increasing the utilization of solutions as ESCO and the Kupittaa solar plant will increase investments and implementation of the RES. Also the leasing of solar panels by Turku Energia will increase the willingness of the citizens to invest in solar technology. These solutions are explained in the Appendix A. The Table 31 will describe the important milestones of this period and describe the needed actions.

Table 31. Important milestones and actions for period 2016-2020

Milestone	Action	Description
Clearer governance	Creation of energy board	Primary responsible organization for building the RES. This energy board will nominate a steering group
	Creation of steering group	This group will conduct a roadmap plan and manage major projects related to RES.
Orientation of policies	Creation of policies	These policies include a policy that follows the almost zero energy building directive, policy that facilitates the installation of RETs and energy savings and a policy that facilitates the installation of solar panels as well as a subsidy of technology neutral bidding.
Increasing knowledge	Communication	Communication through education, newspapers and social media.
Increasing cooperation	Change in project management	Project management related to the RES will be handled in a long term instead of short term.
	Urban labs	Urban transition labs that will explore the possibilities of the RETs and develop the RES
	Creating a website	Making a website where local stakeholders can share expertise and best practices.
	Creating dialogue	Involve citizens and stakeholders in a dialogue on energy sustainability to create a shared method for public decision-making and to respond appropriately to local community needs. This dialogue could take place in the social media for example.
	Conducting a survey	Conducting a survey to have better information of the residents' needs and wishes concerning the renewable energy and energy efficiency.
	Cooperation among municipalities	Different municipalities and cities cooperate with each other in order to share best practices towards renewable energy system and energy efficiency.
Deep geothermal heat	Exploration of the potential	Test drillings started
Investments to the RES	Public procurement	Public procurement of technology related to the RES
	Applying for funding	Applying funding from EFSI
	Policy changes	Creating the local master plan and subsidy system of technology neutral bidding.
	Utilization of solutions ESCO and the Kupittaa solar plant	Increasing the usage of these solutions in other projects related to RES.
	Investment	Making needed investments

11.2 Period 2021-2025

In this period, the investments to the RES will continue and they will be again directed to the solar and wind power production, to the smart grid and to the energy savings. Energy savings will be achieved for example by investments to home automation, heat recovery ventilation and lighting. Also correcting the energy usage of the premises will result in energy savings. Furthermore, all the new residential areas will have a two way low temperature heating network, driven by the almost zero energy directive. This network will be connected to the main district heating network. Also improvements to the main district heating network (high temperature) will be made. This will be done by implementing computer modelling of the network and adding district heating water reservoirs for peak demand periods. Moreover, at this moment the amount of renewable energy in Turku's RES will already be significant and thus further investments to the energy storage are also executed. The same drivers and actions can be considered as facilitating factors for these investments as in the previous period. Plus the increase in fossil fuel prices in this period will be a significant driver for these investments, because this will increase the price of energy and cause a search for alternatives ways of producing energy. The suitable actions to enhance this development and the investments are further taxing of fossil fuels and subsidising the usage of solar technology.

These changes will require financial investments and at this phase there will be increases in the energy prices, and changes to the cityscape and citizens' living environment and living habits. Consequently, it is important in this phase to find ways to counteract the negative attitudes that these changes will bring about. The important drivers in this development will be the interest and the positive mindset of the energy users towards RES in Turku as well as the environmental friendliness of the citizens and effects of the climate change. Important here is the correct communication towards the citizen and organizations of Turku and involvement of the citizens and organizations to the dialogue. Special attention needs to be paid on how the RES projects are presented and whether they live up to the promises. Furthermore, the motivation of other actors shouldn't be based on referring to abstract aspects like climate change or global energy transition. Instead, positive local impacts that profit several actors, are more important and effective when motivating local actors in the renewable energy transition. These positive effects are for example economic growth of the area and positive health effects. Moreover, it is seen important to focus on drivers and possibilities in the community instead of concentrating on the obstructions. This positive communication can be handled for example through Valonia's energy guidance and social media. Table 32 below will further describe actions to enhance the acceptance of change and to counteract the negative attitudes that the need for financial investments, increases in the energy prices, and changes to the cityscape and citizens' living habits will bring about.

Another major change in this period will be that Turku Energia will become the only energy provider in Turku. This means that Turku Energia will buy the Caruna's electricity grid inside of Turku and that the electricity users of this grid will become customers of Turku Energia. It is important to make this change here in order to develop Caruna's electricity grid to a smart grid that will be suitable and adequate with the power infrastructure in Turku.

Finally, it is important to start the drilling for the geothermal power plant in this period. This power plant will be built in the next period and then its heat production will be also started. The Table 32 will describe the important milestones of this period and describe the needed actions.

Table 32. Important milestones and actions for period 2021-2025

Milestone	Action	Description
Investments to the RES	Taxing	Taxing of fossil fuels
	Subsidies	Subsidies for solar technology
	Investment	Making needed investments
Accepting the change	Communication and dialogue	Correct presentation of RES projects and avoid references to abstract factors like climate change. Focus on local positive effects and drivers
	Using the ESCO-solution	In this solution the risk of the investor is smaller and thus it can facilitate the investment decision.
	Indicating the potential of solar energy	It is important to clearly indicate to the target groups of the city the potential of solar technology. One way of doing this is to create a sun atlas of Turku's roof to internet
	Installation of RETs	Installing the RETs in a way that it doesn't harm the nature and the landscape.
	Presenting the amounts of energy usage	Creation of an innovative interactive energy classification map, displaying actual energy performance for every residential block and their level of CO2 emissions.
	Founding of housing companies	The municipality can found housing companies, which can build high energy efficient buildings that use renewable energy sources.
One energy provider	Acquisition	Acquisition of the electricity distribution infrastructure from Caruna by Turku Energia
Deep geothermal heat	Drilling	Drilling starts for the geothermal power plant

11.3 Period 2026-2030

An important change in this period will be the increase of renewable energy share (wood or straw) of the Naantali plant to 60 %. Important here is that the energy wood will be purchased from certified sources, which are forests that are grown and maintained in a way that it can be considered sustainable. Only this way the energy wood used in the plant can be called CO_2 neutral. This decision was made by the European Union in the period from 2016 to 2020, but only in this last period it is possible to purchase the required amount of wood from certified sources. This delay is due to the changes that forest owners needed to perform in how they manage their forests, due to changes to the wood supply chain and due to finding correctly certified wood sources by the energy producers. This increase of renewable energy share was possible due to the increase of economical competitivity of wood and straw compared to fossil fuels and due to the discoveries of new certified wood sources. This way also Fortum the biggest owner of the plant is willing to increase this share.

Another important development in this period is that Turku Energia will break out from its partnership to the Fennovoima nuclear power plant. This is because it has been noticed in Turku that the RETs will provide enough electricity for the municipality and because the RETs are more competitive than the nuclear technology. It is important to make this decision in order to ensure that the electricity used in Turku in 2030 will be 100 % renewable.

Also the final investments to the RES in Turku are needed in this period. All the investments mentioned in the previous period will continue also in this period. In addition to this, the deep geothermal heat production will start in this period and investments for its equipment and facilities are needed. Only one deep geothermal heat plant will be constructed until the year 2030. Furthermore, the PtG storage technology will be started to be used in order to produce gas from the wind and solar overproduction. This gas will be used in the Naantali power plant for heat and electricity production. The PtG storage technology will be started in this period, because the development of this technology has taken time and only in this period this technology can be considered economically and technologically viable.

In this period also the oil, coal and peat heated premises outside of the district heating network will be changed to premises heated with solar collectors. This means that also the adequate heat storage technology needs to be installed for these premises. Indeed, this storage technology will be technologically and economically competitive in this period and the solar collectors and its storage technology are able to provide heat to the premises all around the year. In order to realize this, a change in regulation in the municipality is needed in this period that will prohibit the usage of oil, coal and peat as a heating mode for the premises. Also research and development activities in the previous periods are needed in order to make this storage technology technologically and economically competitive.

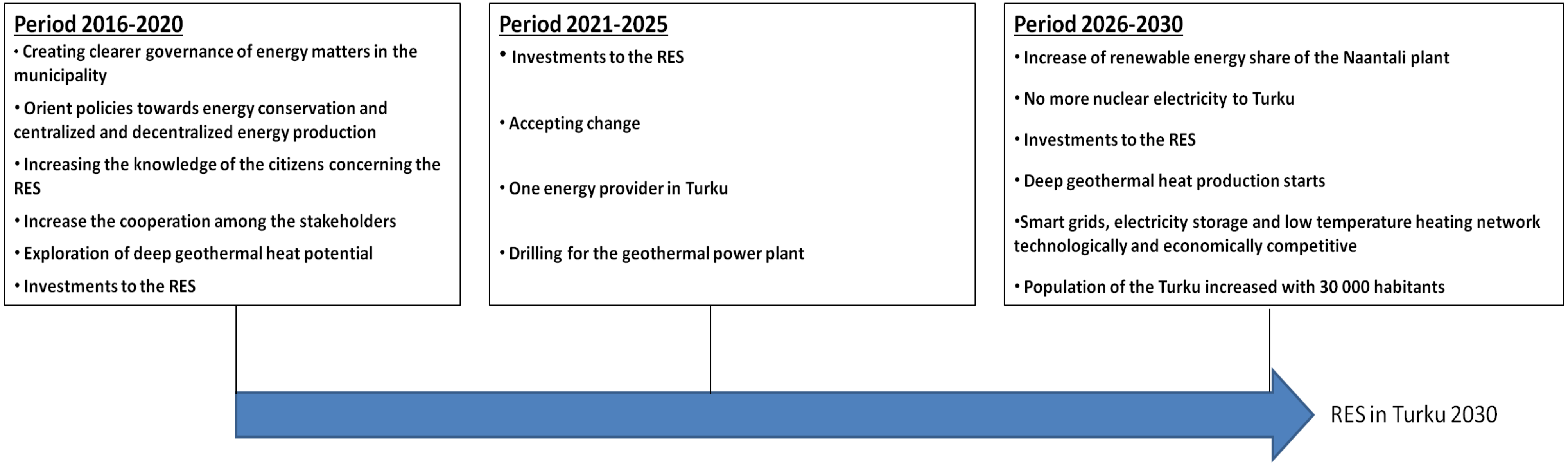
Furthermore, the technology related to smart grids, electricity storage and two way low temperature heating network will also be technologically and economically competitive in this period. The technological development of this technology, digitalization, fossil fuel prices and the lessons learned from the urban transition labs (e.g. Skanssi), have affected this development. Thus, it is important to notice that in this period the availability of fossil fuels has decreased dramatically and this has further increased its price. This means that the RETs become competitive with the fossil fuel technology in this period without the need for taxes and subsidies. Also the technological development of RETs has affected to this development.

Finally it can be said that arriving to the end of this period the population of the municipality has increased with 30 000 habitants and also new residential areas have been built. This in turn has affected the energy demand of Turku. However, the energy savings achieved in the premises by the year 2030 and more compact residency have enabled to cancel the effects to the energy demand. The compact residency has been achieved by designing the local master plan in a way that it doesn't expand a lot the residency area, but instead uses as much as possible the existing building stock and residency area for accommodating the citizens. Furthermore, citizens' mindset of wanting to live more compactly and energy efficiently is important here. Thus, it can be said that in 2030 the RES is functioning, thanks to the changes and actions described in this pathway and the RES is able to meet fully the electricity demand of Turku's premises and public lighting in 2030. However, in this pathway the heat demand of Turku's premises cannot be totally supplied with renewable sources and thus some additional renewable heat sources are needed. The Table 33 below will describe the important milestones of this period and describe the needed actions.

Table 33. Important milestones and actions for period 2026-2030

Milestone	Action	Description
Naantali plant's renewable share to 60%	Search for certified sources	Wood is needed to be found from forests that are grown and maintained in a way that it can be considered sustainable.
No more nuclear electricity to Turku	Decision making	Turku Energia breaks out from its partnership to Fennovoima
Investments to the RES	Investment	Making needed investments (e.g. PtG and solar collectors)
	Change of policy	Prohibit the usage of oil, coal and peat as a heating mode for the premises.
Deep geothermal heat	Construction and production	Deep geothermal heat production will start and construction of facilities is needed.

Figure 12. Important milestones towards vision of 2030



12. Follow-up agenda

In this section the follow-up agenda will be created. The follow-up agenda describes what different stakeholders related to the RES in Turku should do and which action agenda they should follow in order to reach the vision set in the part 9.3 of this thesis. Furthermore, some indications on how the stakeholders can be stimulated to perform these actions are given. This follow-up agenda has been built based on the previous chapter 11. Moreover, the Table 34 below will give a summary of this follow-up agenda.

1. Creating clearer governance of energy matters in the municipality

In this part of the follow-up agenda the municipality's energy board needs to be created. This board will in turn nominate a steering group that will construct a roadmap plan and manage the major projects related to the RES in Turku. This group will also report to the energy board the results and needs for policy changes in Turku. Thus, it can be said that the municipality of Turku, its city council and the participating organizations to the steering group are seen important actors in this change. It is important that the steering group will include representative persons from several fields of the society. It is seen in this study that at least representatives from the municipality, research and knowledge institutes, technology and engineering companies and energy companies are needed in this steering group. Furthermore, it is very important that the wishes and needs of the energy users are listened and taken into account when designing the roadmap and managing the projects. One stimulating factor for the technology and engineering companies to join this steering group is the possibility that they will be chosen as suppliers for these RES projects that the steering group will manage. Joining the steering group raises these possibilities considerably. All the other stakeholders are seen to participate this steering group by their duty, interest and position in the power structure.

2. Orient policies towards energy conservation and centralized and decentralized energy production

These policies include for example creating a policy that follows the almost zero energy building directive, policy that facilitates the installation of RETs and energy savings (creation of local master plan, which indicates the areas for RETs, new residential areas and supports compact residency) in Turku and a policy that facilitates the installation of solar panels on the roofs (clear regulation that explains clearly the rules and makes faster the permission process). Furthermore, the national subsidy system of renewable energy production needs to be changed towards a competitive technology neutral bidding system. The municipality of Turku and the Finnish government need to set these policies for Turku.

3. Increasing the knowledge of the citizens concerning the RES and explaining the benefits of this system for Turku

Here communication is important, which can be done through education (universities and energy guidance), newspapers and social media. Turku's universities, the municipality of Turku, Valonia and Turku Energia are the main communicators.

4. Improve and increase the cooperation among the stakeholders

Here the needed actions are changing from short term projects to long term projects, creating urban transition labs, creating a dialogue among the stakeholders and conducting surveys. All the stakeholders are needed for this development. Especially the cooperation between the energy board and the steering group is vital. Furthermore, cooperation between the municipality of Turku, different research and knowledge institutes, technology and engineering companies and other municipalities is important. This cooperation is conducted in order to develop the renewable energy technologies and find the most suitable technologies for Turku. Finally, also involving energy users to the cooperation is important. The cooperation can be stimulated by urban transition labs, conducting surveys, through social media and taking examples from other cities and other similar projects.

5. Investments and implementation of RETs to the RES

First, it is important to notice that these investments need to be directed on the whole energy system (e.g. energy storage, smart grids and energy savings). As a starting point for these investments public procurement and applying for funding are important actions to be taken. Furthermore, adequate policies (e.g. new subsidy system for RETs, taxing fossil fuels and forbidding the usage of oil, coal and peat as heating mode) and solutions like ESCO and Kupittaa solar power plant as well as leasing the solar panels will increase the investments and implementation of RES. Finnish Government, municipality of Turku, energy companies, technology and engineering companies, financers and the energy users are needed for creating a suitable environment for investments, for making these investments and for implementing this technology.

6. Accepting the change

The financial investments and implementation of RETs is needed in order to build the RES. The need for financial investments, energy price increase, and changes to the cityscape and citizens' living habits will raise negativity in the city towards the RES. It is important to counteract these negative attitudes so that the citizens will accept this change. Here also correct communication is important and involvement of the citizens and organizations to the dialogue. Important is to emphasize the positive local effects that the RES will bring about and indicate the potentials of the RETs in Turku. Furthermore, ESCO solution, founding of municipality's housing agencies, indicating the potential of solar energy, installation of RETs and presenting the amounts of energy usage in Turku are actions that can facilitate the acceptance of change. The municipality of Turku, Turku Energia and Valonia are important actors in tackling these negative attitudes and the citizens of Turku are the ones who need to accept this change.

7. Turku Energia the only energy provider in Turku.

Turku Energia will buy the electricity distribution infrastructure from Caruna and the former Caruna customers need to join Turku Energia. This change is required because one local actor can more efficiently handle and assure the functioning and future of RES in Turku. The municipality of Turku, Turku Energia and Caruna need to come in terms with this deal. In order to stimulate Caruna to this change, Turku Energia could promise to share their knowhow on building the RES if Caruna has similar goals elsewhere in Finland.

8. Increase of the renewable energy share (wood or straw) of the Naantali power plant to 60 %

Important here is that the wood will be supplied from certified sources. Forest owners need to come in terms with the requirements that the certification has, and the energy producers need to find enough certified wood sources so that the share can be increased. Important actors here are the Fortum, Turku Energia and TSE as well as the forest owners. Environmental organizations could stimulate this change by searching for certified sources and presenting them to these stakeholders.

9. Turku Energia will break out from its partnership to Fennovoima nuclear power plant

This needs to be done in order to reach the RES in Turku. The municipality of Turku and Turku Energia need to make this decision.

10. Producing deep geothermal heat in Turku

Here, first the deep geothermal potential needs to be evaluated in Turku. Based on this evaluation the drillings need to be performed, the facilities need to be built and the production of deep geothermal heat needs to be started in Turku. The key actors here are the municipality of Turku, Turku Energia, technology and engineering companies and research and knowledge institutes.

Table 34. Summary of the follow-up agenda

Milestone	Actions	Stakeholders	Stimulating factors
Creating clearer governance of energy matters in the municipality	Creations of energy board and steering group	Municipality of Turku and its city council and participating organizations	Business opportunities
Orient policies towards energy conservation and centralized and decentralized energy production	Creation of policies (e.g. policy for solar panels)	Municipality of Turku and the Finnish government	
Increasing the knowledge of RES	Communication through education, newspapers and social media	Turku's universities, municipality of Turku, Valonia and Turku Energia	
Improve and increase the cooperation among the stakeholders	Change in project management, urban labs, creating dialogue, conducting surveys, cooperation with cities	All stakeholders	Urban transition labs, surveys, and taking examples from other cities and similar projects.
Investments and implementation of RETs to the RES	Public procurement, funding, creation of adequate policies, ESCO and Kupittaa solar plant solutions, and making the needed investments	Finnish Government, municipality of Turku, energy companies, technology and engineering companies, financers and the energy users	
Accepting the change	Communication and dialogue, ESCO solution, indicating the potential of solar energy, installation of RETs, presenting the amounts of energy usage, founding of housing companies	Municipality of Turku, Turku Energia, Valonia and the citizens of Turku	
One energy provider	Acquisition of the electricity distribution infrastructure from Caruna by Turku Energia	Municipality of Turku, Turku Energia and Caruna	Share of knowledge of RES
Increase of the renewable energy share of Naantali plant	Search for certified sources	Fortum, Turku Energia, TSE and forest owners	Search of certified sources by the environmental groups
Turku Energia breaks out from its partnership to Fennovoima	Decision making	Municipality of Turku and Turku Energia	
Producing deep geothermal heat	Deep geothermal potential evaluation, drilling, construction of facilities and starting the production	Municipality of Turku, Turku Energia, technology and engineering companies and research and knowledge institutes.	

13. Discussion

In general it can be said that the developed methodology for this study worked well, because through this methodology the objective of this study was reached and the research questions were able to be answered. Also the adjustments to the Ricken (2012) methodology that were used in this research proved to be valuable for this thesis and made the methodology more suitable for exploring an urban area. For example the formed atlas of case study proved to be valuable by offering important recommendations for needed actions in Turku. Also the search for disruptive technologies proved to be valuable and indicated that the deep geothermal heat could be an important source of heat in the future for Turku.

However, this thesis includes also some shortcomings and weaknesses and in this chapter those shortcomings and weaknesses will be discussed. The division in the coming parts is made into shortcomings and weaknesses related to the methodology and RET potentials.

13.1. Methodology

The Master's thesis "*Scenarios for Sustainable Energy on Texel*" by Ricken (2012) offered a methodological starting point for this thesis and changes and addition where done to the Ricken (2012) methodology by this thesis. However, not all of the additions described in the methodology of this thesis were able to be used during this thesis. The unused additions mentioned in the methodology of this thesis were the conduction of the workshop, estimates of the scenarios environmental improvement potential and evaluating the spatial interventions according to the sustainability criteria (see Table 8). This was due to the fact that Ricken (2012) offered already a very broad methodology for analysing the thesis' subject and due to this broadness not all of the additions were able to be used. This enabled also the conduction of the thesis process in reasonable time limits. However, these additions can be considered as part of the methodology for future similar studies. Also transportation in Turku was not taken into account in this study although it was part of the Ricken (2012). This was also due to the time constraints and because the municipality of Turku estimated that the data provision for the energy demand of transportation will be difficult.

In this thesis it was chosen also to construct only one scenario for the RES in Turku. This was done based on the present conditions and current developments, which showed that the objective of this thesis is only able to be nearly reached with putting all the aspects under one scenario. However, normally at least two scenarios are developed in similar studies in order to give a more elaborated view of the possibilities in achieving the vision. For example Ricken (2012) created two scenarios and this way the robustness of these scenarios was able to be assessed as well, which was not the case in this thesis for Turku.

Finally, it can be noted the author of this thesis had difficulties in the backcasting analysis step to make a difference between needed changes, drivers, barriers and needed actions. Based on the authors view one factor can be considered to be for example a needed change but at the same time also a driver. According to the author, the backcasting theory should discuss more about how to handle this dilemma.

13.2 RET potentials

The RES built in this study is not very diversified when it comes to the amount of different renewable energy production technologies. Thus, in order to create energy security in the RES and reach the energy independence in Turku, it could be beneficial to add more renewable energy production technologies into the system. However, in this study no time was left to evaluate the potentials of several renewable energy production technologies. Also the lack of information hindered the evaluation possibility

Furthermore, due to the lack of diversity in the RES, the energy storage and the smart grid have a key role in this system and that is why the possible shape and technologies of these solutions are explained to some extent in the parts 9.4.3 and 9.4.4. However, the author of this thesis believes that the development of the energy storage technologies is still primitive and it is currently difficult to clearly determine the future shape, reliability and cost-benefit ratio of these kinds of system. Especially, the ability of the solar collector’s storage technology to provide year around heating for the premises in Turku can be questioned. Also it is important to notice that the PtG storage solution mentioned in this study will include energy losses in its processes. This means that the PtG solution will provide less energy than the amount of electricity provided for its processes. Thus, if this solution will be used for the new Naantali plant some additional renewable electricity sources are needed in order to produce the amount of energy lost in the PtG process and in the Naantali power plant. Some examples of the possible renewable energy sources are given in the part 14.2 below.

Moreover, it has to be noted that, as for the energy storage, also the smart grid development is a new idea across Europe (Hashmi 2011) and thus it is currently also difficult to clearly determine the future shape, reliability and cost-benefit ratio of this kind of system. Thus, it can be said here that a thorough determination of the future shape of the energy storage and smart grid in Turku is not possible in this thesis due to the limited time resources, limited amount of information gathered and due to the limited amount of practical experiences concerning the current and possible future power infrastructures. However, more information and technological development is needed in order to design and build an adequate storage system and a smart grid for Turku.

14. Conclusion and recommendations

14.1 Conclusion

The methodology for this thesis was based on the Ricken (2012) methodology. This methodology was further elaborated in this thesis based on the literature review related to this subject. This developed methodology proved to be valuable and correct for the aim of this thesis although not all of the made additions were able to be used due to time constraints.

The aim of this study was to find out the potentials, barriers and possibilities for developing and implementing a RES that can make the city of Turku energy independent by 2030 and to give recommendations concerning the steps that need to be taken in order to develop and implement this renewable energy system. This study was set to be conducted for the energy demand of the premises and public lighting of Turku and this boundary was followed throughout the study. The vision and the scenario for achieving the objective of the study were developed based on the present conditions, developments and exogenous variables concerning the RES of Turku.

The results of this study indicate that solar energy has a big potential in Turku. Problematic factor with this solar technology is the need for energy storage. So far the energy storage technologies don't offer an adequate solution for storing large amount of renewable energy. Despite of the big solar energy and other determined potential, the energy independence with renewable energy sources in Turku was not able to be achieved in this study. The electricity demand of the city can be supplied fully from renewable sources, but this includes also external sources. This means that if the renewable electricity independence in Turku is wanted to be achieved additional renewable electricity production technologies need to be implemented inside of the municipal boundaries. Furthermore, the heat demand cannot be fully supplied with renewable sources. This means that if the renewable heat independence is wanted to be achieved, additional renewable heat production technologies need to be implemented inside of the municipal boundaries. Indications for renewable energy sources and additional renewable energy production technologies were given in this thesis. One potential source in the future could be the deep geothermal heat. Furthermore, also adapting more energy savings in the premises of Turku can lead closer to achieving the energy independence. For example the theoretical heat saving potential of the premises in Finland was claimed in this study to be 40 % of the heat demand, but only 6.75 % savings was considered achieveable from Turku's heat demand.

Furthermore, spatial interventions were determined, which indicates the most suitable areas for the renewable energy production and storage. Also the needed changes, drivers and barriers were determined and after this the pathway for reaching the set vision was presented. Moreover, the follow-up agenda for important stakeholders related to the RES in Turku was built. The pathways and the follow-up agenda describe important short, mid and long term steps or actions to be taken in order to reach the vision. One very important step is to set up a steering group that will manage the transition to RES in Turku.

This study also revealed that motivation for building the RES in Turku is high and the reasons for the motivation were explained. It is highly recommended that the defined potentials, barriers, possibilities and steps towards the RES in Turku are taken into account when building this RES. This study is seen as a highly useful source of information for the build up of the future renewable energy system in Turku. For example this study could be used as a source of information in the cooperation project between the municipality of Turku and Sitra, where these two parties together are working together in order to develop a renewable and smart energy system in Turku.

14.2 Recommendations

This part will highlight the subjects for future study that are seen important based on this thesis for the development of the RES in Turku. These recommendations are directed to the stakeholders related to the RES in Turku. Especially the municipality of Turku is seen as an important stakeholder in taking action based on these recommendations.

1. Energy storage and smart grid

An important future subject for study related to the RES in Turku is the study of the possibilities of energy storage and smart grid in Turku and the evaluation of the energy storage potential. In this thesis these subjects have been touched upon, but a more thorough and elaborate study is needed in order to analyze these subjects. These studies are very crucial for the future of the RES in Turku.

2. Energy need of the industry and transportation

In this thesis only the energy demands of Turku's premises and technical infrastructure was taken into account when building the RES for Turku. However, the energy demands of the industry and transportation were not taken into account. A future study is needed that will evaluate the energy demand for the industry and transportation and define RE potentials for supplying them the needed amount of energy.

3. Study on the region level

This thesis studied only the renewable energy potentials inside the municipality of Turku. However, as concluded in this study the energy independence inside Turku is very difficult to achieve. Thus, it would be important to change the boundaries to the region level and evaluate what kind of RE potentials there could be for the energy demand of Turku.

4. Diversification of the RES in Turku

As mentioned several times in this thesis, the built RES in Turku is not very diversified in terms of renewable energy production technologies. Thus, an important study subject could be to evaluate the potential of other RE sources inside of Turku. These RE sources could be for example heat or cooling from the sea, solar panels on facades, solar panel/collector fields (e.g. inside the wind power production areas defined in this thesis), blue-green alga, deep geothermal heat plants, higher share of energy savings and waste heat from the industry or commercial buildings. Also electricity producing construction materials from solar energy can be used. Furthermore, integrating water, waste and energy infrastructures is a desired action to be taken when transferring to sustainable energy production (McCormick et al. 2013) and this potential for RE production should be further studied as well. By evaluating these potentials Turku can find ways for becoming closer to the energy independence.

5. Electricity conservation of accommodation buildings

Not enough information was able to be gathered for the electricity conservation potential of accommodation buildings. Evaluation of this potential is an important subject for future study. By evaluating this potential Turku can find ways for becoming closer to the energy independence.

6. Construction of more scenarios for the RES in Turku in 2030

Based on the information found in this study, only one scenario was able to be created. Conducting a study which would construct more possible scenarios for achieving the objective of this study is recommended. This could lead to discovery of new drivers, barriers, needed changes and actions for reaching the vision. This study could also include the unused methodological additions of this thesis (e.g. stakeholder workshop)

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Appendix A - Local initiatives and projects

Appendix A will give a short description of the initiatives and projects that are going on in the municipality of Turku. Furthermore, the actors involved and the time period of the projects and initiatives will be given.

Skanssi project

Actors: VTT (technical research center), municipality of Turku, shopping center of Skanssi, YH Kodit and Hartela (construction companies), Turku University of Applied Sciences, Tekes.

Period: From 2014 to ?

Summary: Turku Energia is developing a two way low temperature district heating network for the area of Skanssi in Turku. Currently, this initiative is being conducted with the actors mentioned above.

The current cooperation with VTT aims to find out the possibilities that a two way low temperature district heating network could give to the area's habitants in selling the heat that they produce to the district heating network. The two way low temperature district heating network would enable the use of renewable energy technologies and require the use of smart technologies. These solutions would enable the decrease of energy use in the area. If this area could be built according to the aims of the initiative it could offer new business opportunities and create valuable reference cases and export possibilities for the Finnish technology industry. (Uusiutuvaa lähienergiaa Skanssin alueelle 2016) Turku Energia receives funding for this project from Tekes (Keskeisimmät hankkeet 2014).

Solar power plant of Kupittaa

Actors: Turku Energia, Areva Solar, and people renting the solar panels.

Period: Spring 2016

Summary: At first Turku Energia decided that it will build a solar power plant of 170 panels on the building roof in Kupittaa Turku. The idea of the plant is that individual persons can rent panels (4.30 Euros/month) from this plant to contribute to the increase of the renewable energy production. The production amount will be deducted from the person's electricity bill. It is been estimated that the production of the 170 panels will be 0.035 GWh annually. (Turku Energia panostaa uusiutuvaan energiaan 2015) However, according to the latest information 80 more panels will be added to this power plant, which can be seen as an indication of interest towards solar energy in Turku. This can be seen also as social and economical development from Turku Energia's side, because it is offering the citizen's of Turku a low risk possibility to contribute to Turku's goals in increasing the share of renewable energy production in the city.

New power plant of Naantali

Actors: Turun Seudun Energiantuotanto, Valmet power, Siemens, Pöyry, Raumaster, YIT and A-insinöörit

Period: From 2015 to 2017

Summary: TSE is building a CHP plant to the city of Naantali, which can use several fuels (biofuels, coal, peat, oil and possible recycled fuels) to produce energy. The plant is built just outside of Turku but in this study it is seen as part of Turku due to its closeness and its big share in the energy supply for Turku. The new plant is being built next to the old coal plant of Naantali. The new plant (like the old plant) will produce electricity and heat to Turku and to the surrounding municipalities as well as process heat for the surrounding industries. The goal is that in the beginning the share of biofuels (wood, straw and industry byproducts) will be about 40 % and finally 60-70 % depending on the availability and price of biofuels. However, the plant can operate with 100 % renewable energy. The initiative to enable this in the plant came from the municipality of Turku, which shows the high political will that Turku has in turning towards renewable energy production. (A Ahtiainen 2016, pers.comm., 03 February) The estimated cost of the new plant is 260 M€. (TSE Oy Naantalin uusi voimalaitos 2014) As mentioned above the first share of biofuels will be 40 % so the short term investment to biofuels is 260 M€ x 0.4 = 104 M€. The 40 % share of biofuels won't cause major additional costs to the production process thanks to the Finnish Government's energy subsidy that is given for this new plant. However, if the share of biofuels will be increased to 60-70 % the biofuels need to be transported from longer distances, which increase the price of the biofuels. In this case, with current prices and current production levels, the energy production with biofuels is no longer economically justified. This can significantly hinder the TSE's main owners (Fortum and Turku Energia) willingness to use biofuels in the plant's energy production. (T Bastman, TSE, 2016, pers.comm., 21 January) The future developments in energy efficiency, decentralized energy production and energy storage can help in this problem (R Veivo 2016, pers.comm., 11 February). This new power plant will secure the availability of district heating in the area of Turku for decades to come. (NA4 CHP-projekti 2015)

Turku university of applied sciences campus in Kupittaa

Actors: Turku University of applied sciences, the municipality of Turku

Period: From 2015 to 2018

Summary: Turku University of applied sciences is planning its new campus area in the area of Kupittaa in Turku. The municipality of Turku has announced that the area needs to be built in a sustainable way. This means that the water consumption, waste creation and energy use need to be minimized and that the campus area produces and uses as much as possible energy from renewable sources. (Kupittaan kampus 2013) Currently, the project is waiting for its final acceptance in the city council of Turku (Uudessa kampuksessa innovoidaan syksyllä 2018).

Renovation of a living area for students

Actors: Turun Ylioppilassäätiö (TYS), Consti, Turku Energia, Aalto University

Period: 2014-2016

Summary: In this project 14 building blocks for students are being renovated with a goal of reducing their energy use. Also geothermal heat will be started to be used in heating the buildings and studies will be made on how renewable energy technologies can be exploited in the buildings. Furthermore, TYS, Turku Energia and Aalto University are studying the possibility to warm the future geothermal wells in the area with the return water of the district heating network. (Turun ylioppilaskyläsäätiön Haliskylän rakennusurakka Constille 2016)

ESCO service in Turku

Actors: Motiva, Municipality of Turku, Caverion, Are, Turku Energia, Customer (several)

Period: From 2000 to ?

Summary: In the ESCO service an energy expert company (e.g. Caverion and Are) performs renovations and changes in a customer's premises in order to achieve energy savings. The energy expert company can be a construction company, energy company or a producer of energy efficient equipments. The customers are industrial companies and public and private service sector. The general idea of the ESCO service is that the expert company performs the renovation to its own expense and through the achieved energy savings the customer pays the expert company the expenses accumulated during the renovation. (ESCO-palvelu 2015) One example of this service in Turku is the renovation of one football hall and one ice hockey hall. The actors of this project were the Caverion Corp. and the municipality of Turku. The result of this project was that the heat generated in the ice creation in the ice hockey hall was used to warm the interior air of the football hall (A Ahtiainen 2016, pers.comm., 03 February).

Another example of an ESCO-project is the changing of street lights in Turku to LED-lights. This decision was done by the municipality of Turku and the supplier of these LED-lights is Turku Energia. The new led lights consume 70 % less electricity (Keskeisimmät hankkeet 2014).

Waste gasification project

Actors: Turun Seudun Energiantuotanto (TSE) (maybe other actors; information not available)

Period: From 2015 to ?

Summary: TSE has a project going on where they are studying the possibilities of waste gasification. This gas they could use in their new Naantali power plant, which will be operational in 2017. (Jätteistä lämpöä Turkuun 2015) Tapani Bastman (CEO of TSE) sees a big potential in using this gas to produce energy in the new power plant (T Bastman, TSE, 2016, pers.comm., 21 January).

Development cooperation between the municipality of Turku and Sitra

Actors: Municipality of Turku, Sitra, Turku Energia, Lounais-Suomen Jätehuolto, Turku University of applied sciences, University of Turku and Climate Pledge.

Period: 2015-2018

Summary: Turku has started a cooperation with Sitra (a public innovation fund aimed at building a successful Finland for tomorrow) in order to enhance circular economy in the area and become a coal neutral city by 2040 (Sitra 2015). The cooperation with Sitra includes projects that concern the circular economy, renewable energies, water conservation and enhancement of green entrepreneurship. (Sitra 2015) One of the projects that these two parties will start together in 2015 is to find out how the municipality's energy production could be realised fully with renewable energies. Furthermore, this project will study how the change to renewable energy production will influence (circular) economy, employment, innovation activities and greenhouse gas emissions. (Turku 2015)

Planning of Energy efficient cities (PLEEC)

Actors: Eskilstuna Energy Miljö (SE), Eskilstuna City (SE), Mälardalen University (SE), Turku City (FI), Turku University of Applied Sciences (FI), Tartu City (EE), Stoke-on-Trent City (UK), Hamburg University of Applied Sciences (DE), Vienna University of Technology (AT), University of Copenhagen (DK), Delft University of Technology (NL), University of Rousse (BG), LMS IMAGINE (FR), Smart Technologies Association SMARTTA (LT), Santiago de Compostela City (ES), Santiago de Compostela University (ES), Jyväskylä City (FI), University of Ljubljana (SI)

Period: 2013-2016

Summary: The goal of PLEEC is to create an action plan in order to increase energy efficiency and sustainable development in cities. This will be done by creating a model of city planning, which will include energy efficiency potentials in a city. One model will also be created to the city of Turku. (PLEEC – Planning for Energy Efficient Cities 2016)

Neo carbon energy project

Actors: Technical Research Centre of Finland VTT Ltd, Lappeenranta University of Technology LUT, and University of Turku, Finland Futures Research Centre FFRC + 15 industrial partners, 3 NGOs and 5 international partners.

Period: 2014-2019

Summary: This project studies the possibilities of creating an entirely new energy system from three solutions: overproduction of electricity from sun and wind, neocarbonization and energy storage. The new system would produce emission free fuel by combining electricity from sun and wind as well as water and CO_2. Energy storage would provide a balancing factor to the electricity production from sun and wind. (About Neocarbon energy 2016)

Municipalities' energy efficiency agreement

Actors: The Finnish government and several Finnish municipalities.

Period: Ending contract 2008-2016; new contract 2017-2025

Summary: This agreement is a contract between the Finnish government and the municipalities. This contract is ending in the year 2016 and a new contract will start in 2017. In the ending contract the municipalities agreed on 9 % energy saving goal in their activities. The new contract is soon ready and it sets a 7.5 % energy saving goal for the joining municipalities. Through this voluntary contract Finland can show to the EU its ambition to achieve energy savings. (A Ahtiainen 2016, pers.comm., 03 February) The contract includes also goals for the use of renewable energy that the municipalities have to fulfil. This means that the municipalities have to study the renewable energy usage possibilities and implement renewable energy as much as possible. (Kunta-alan energiatehokkuussopimus 2014)

Turku has achieved the 9 % goal of the ending contract and has already agreed to join to the new contract. (R Veivo 2016, pers.comm., 11 February) (A Ahtiainen 2016, pers.comm., 03 February) One way of achieving these goals are the ESCO-projects mentioned above. (R Veivo 2016, pers.comm., 11 February)

Appendix B - Interview guide

Interviewer	: ??
Interviewee	: ??
Location	: ??
Date	**:** ??
Duration	: ??
Objectives	: ?? to find out the potentials, barriers and possibilities for developing and implementing a fully renewable energy system for Turku and to find out recommendations concerning the steps that need to be taken in order to develop and implement this renewable energy system.

The interviewers and the interviewee will introduce themselves
- State the objectives and main questions of the interview
- State the duration of the interview
- State what will happen with the interview results (what's in it for them)
- Ask if the interview can be recorded

Part 1: Introductory questions

- How long have you been involved with REs?

- Could you describe what is the nature of your involvement in REs in the Turku area?

- What are the goals of your organization concerning REs in the area of Turku?

Part 2: Present situation of RES (Step 1. Strategic problem orientation)

- What are the motives for increasing RE in Turku?

- What RETs have the biggest potential in the area of Turku? (production, storage, saving energy)?

- Name disruptive technologies and social innovations that can enhance the implementation of REs

- What are the developments concerning RES? (production, storage, saving energy)

    - Political developments?

        - Level of political will (local and national) and public engagement and examples of these?

        - What are the targets set by the national government and municipality of Turku concerning RES?

        - What are the focus areas of national government and municipality of Turku when it comes to RES? (technologies, storage, saving energy)

        - What policy incentives have been done for RES?

    - Economical developments?

        - What economical incentives have been done for RES?

    - Social developments?

- What cultural incentives have been done for RES?

- Technological developments?

- Environmental developments?

- Legal developments?

    - What laws and regulations are related to the implementation of sustainable energy technologies?

- What are the current projects and initiatives related to renewable energies in Turku?

- How your organization is involved in these projects and what are the experiences from these projects?

- How is the progress of the project and what are the difficulties?

- What are the main stakeholders for RES in Turku (govt, NGOs, knowledge/research, business, users- society)?

- What are the interests, power and influences of the stakeholders?

- How agency dynamics affect the transition to renewables?

Part 3. Visions, needed changes and actions for reaching the vision

- What is your vision for RES in Turku and how does this future look like?

- What changes are needed to realise this vision?

- What are the drivers and barriers for this vision?

- What actions need to be done or extended in order to reach this vision?

- Which stakeholders should do these actions?

Part 4: Finalizing questions

- Do you feel that something important has not been addressed?

- What would be your willingness to participate to a stakeholder workshop concerning this subject?

- If the workshop won't be held what is your willingness to participate to a second round of interviews face to face or by email?

- Do you want to receive by mail the minutes of this interview?