SCENARIOS FOR SUSTAINABLE ENERGY ON TEXEL

COMBINING BACKCASTING AND SUSTAINABLE ENERGY LANDSCAPE DESIGN FOR ACHIEVING ENERGY SELF-SUFFICIENCY IN 2020

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Master Thesis
26 March 2012

TU Delft Delft University of Technology

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Delft, 26 March 2012

PREFACE

This research is carried out in order to complete my Master's degree in Sustainable Energy Technology at the Delft University of Technology. The subject of this research is achieving energy self-sufficiency on Wadden Island Texel. The specific interest that I had for choosing this subject is that I am following the progression of Texel to achieve energy self-sufficiency for many years. Each year, I visit Texel for several weeks. Due to my interest in renewable energy and the island itself, this subject immediately caught my attention. Writing this thesis was therefore very interesting and challenging. By identifying the opportunities, potentials and barriers for making Texel energy self-sufficient in 2020, I hope that my thesis can help the Texel community in making decisions that have to be taken in the coming years.

Although this research was an individual project, several people have supported me very well during the process of writing my thesis. Therefore, I would like to express my grateful to several people. First of all, many thanks to my direct supervisors Jaco Quist and Siebe Broersma who have given me the opportunity to carry out this research. They helped me by giving new insights and feedback throughout the whole research. Furthermore, I would like to thank Andy van den Dobbelsteen. Although Andy was not much involved in the research, through his scientific articles, I became very interested in sustainable spatial development.

I would also like to thank Eric Hercules, Brendan de Graaf, Rikus Kieft, Peter Bakker, Corina Hordijk, Marjan Minnesma, Cees de Waal, Mark van Rijsselberghe, Roel Struick and Jurre de Vries for their time and information. They gave me valuable input for my research.

Last but not least, special thanks to my parents who have always supported me during my study. Without their support, I could not have achieved this.

SUMMARY

This research identifies the opportunities, potentials and barrier for developing and implementing a sustainable energy system that can make Wadden Island Texel energy self-sufficient in 2020. For many years, various parties on Texel are working on achieving energy self-sufficiency. With this ambition, Texel was at the forefront of achieving energy self-sufficiency in the Netherlands. It all started in 2000 when Stichting Duurzaam Texel expressed the ambition to make Wadden Island Texel energy self-sufficient in 2030. The municipality of Texel adopted this ambition and decided in 2007 to go for energy self-sufficiency in 2020. Although the most recent feasibility study by Weeda et al. (2007), which mainly took into account technical aspects, concluded that energy self-sufficiency could not be achieved in 2030, the municipality of Texel has indicated to maintain its ambition and that they are focusing on achieving energy self-sufficiency in 2020. As a result, a new study is needed that take into account previous studies but also missing aspects related to achieving energy self-sufficiency that can lead to planning for actions. For carrying out this research, a methodological framework was developed that has combined the methods backcasting and sustainable energy landscape design. This framework could take into account technological, economic, cultural, institutional, organizational and spatial aspects and emphasized the construction of different scenarios. Backcasting can be defined as first creating a desirable future vision, followed by looking back at how this desirable future could be achieved (Quist et al. 2006). In addition, sustainable energy landscape design can be defined as developing a physical environment where energy needs can be optimally fulfilled by locally available renewable energy sources (Stremke 2010).

The main research question was formulated as follows:

What are the opportunities, potentials and barriers for developing and implementing a sustainable energy system that can make Wadden Island Texel energy self-sufficient in 2020?

This research focuses on the municipal area. First, the present conditions concerning energy self-sufficiency were identified. The municipality of Texel consists largely of water and most land area consists of agricultural land and natural areas. The island includes seven villages of which Den Burg is by far the largest. From analyzing the landscape characteristics, it could be concluded that Texel has a very diverse landscape, which have resulted in many protected areas. Because of the diverse landscape also many tourists visit Texel. Due to the many tourists, the energy demand is relatively high compared to other municipalities in the Netherlands. Households and the service sector, of which many services are related to tourism, are largely responsible for the energy demand. In addition, the agricultural sector and industrial sector are responsible for a very small fraction of the energy demand. As a result, the total gas demand consists largely of the heat demand, which is the actual demand for space and water heating. From analyzing the current energy supply, it could be concluded that approximately 1.5% of the electricity demand and 1% of the heat demand is currently generated by renewable energy sources, which is very low.

From determining the renewable energy potentials in the municipal area, several conclusions could be drawn. Solar energy is very interesting for generating both electricity and heat due to the relatively high sum of global irradiation per year. In addition, wind energy is very interesting for generating electricity because of the very high average annual wind speed. The electricity and heat potential of geothermal energy in the municipal area is moderate. This is because the geothermal

potential from aquifers is small, while the potential from greater depths is relatively large. Furthermore, the heat potential of heat and cold storage is very large due to the good subsoil characteristics. This applies both for open and closed systems. Biomass is a very interesting source for generating electricity and heat and for producing liquid biofuels and biogas. Agricultural residues are by far the most interesting biomass source, because of the relatively large amount of manure and other residues that are available. Wave energy has a very small potential for generating electricity. Also, tidal energy has a small potential for generating electricity.

After the present conditions were identified, the current developments concerning energy self-sufficiency were defined. Three motives for achieving energy self-sufficiency were identified: reducing the use of fossil fuels, creating more economic activity and achieving independence from the mainland. Next to the municipality of Texel, many residents are committed to achieve energy self-sufficiency. However, the group of residents that want to take the lead and actively work on achieving energy self-sufficiency is significantly less. As indicated, the amount of renewable energy that is currently generated in the municipal area is very low. Social resistance against wind turbines, biomass power plants and solar fields, change in politics, laws and regulations, high investments, lack of funding, existing agreements and poor cooperation have resulted in a poor progression in the last few years. However, at this moment there are many initiatives and projects ongoing. An important observation is that in the next few years more renewable energy will be generated in the municipal area, particularly electricity.

Based on the current status and developments of sustainable energy technologies with regard to the renewable energy sources that are examined, it can be concluded that solar panels and onshore wind turbines are techno-economically the most interesting technologies for generating electricity in the municipal area. In addition, solar thermal collectors and heat and cold storage systems will be the most interesting for generating heat. Furthermore, anaerobic co-digestion plants will be the most interesting for producing biogas, which can be used for generating heat and electricity by using CHPs.

The current developments in the national and local policies indicate that the municipality of Texel is much more ambitious than the Dutch government. There are very large differences in the targets and focus areas that are set. In addition to the Dutch government, it is also expected that the policies of the province of North Holland will be less ambitious in the next years. Moreover, the laws and regulations, which are set by the Dutch government and province of North Holland regarding the many protected areas, affect the implementation of sustainable energy technologies. In particular, wind turbines, geothermal power plants, heat and cold storage systems and biomass power plants have relatively many restrictions in the municipal area.

By indicating the involved stakeholders and their related interests and influences regarding energy self-sufficiency, it could be examined which stakeholders are important in achieving energy self-sufficiency. Policy makers and users, particularly residents, are very important. These stakeholders have much influence on the continuity of the ambition. Research and knowledge institutes and technology and engineering companies have also much influence because of their importance with regard to technological developments. Moreover, TexelEnergie can also be very important. TexelEnergie focuses on realizing a renewable energy supply in the municipal area and represents currently 25% of the total energy market on Texel. Financers are also very much needed for providing the required investments. Organizations, including Stichting Duurzaam Texel and Stichting Urgenda, can be important in stimulating applying sustainable energy technologies and energy saving measures.

Next, based on current developments and exogenous variables, the development of the total energy demand in the period from 2010 to 2020 could be determined. It is expected that the electricity demand will increase with 8.7%, while the gas and fuel demand will decrease with 9.1% and 1.5%, respectively. In addition, it is expected that in the same period fossil fuel prices will increase and more international technological developments regarding renewable energy are taking place. Based on these far-future developments and the current status of sustainable energy technologies, it is expected that solar energy, wind energy, geothermal energy, heat and cold storage and biomass energy are able to compete economically with fossil fuels before 2020.

Based on the present conditions, current developments and exogenous variables, two very different scenarios were constructed. The first scenario, which was called scenario A, built itself on the assumption that energy self-sufficiency could be achieved, while the trend growth of the total energy demand in the period from 2010 to 2020 on Texel would be maintained. In this scenario, the main focus was on developing a decentralized energy system in which renewable energy sources were used on large scale for obtaining cost advantages. Moreover, there was no focus on energy conservation. In the second scenario, which was called scenario B, it was assumed that energy self-sufficiency could only be achieved when energy would be saved considerably. In addition, there was much focus on decentralized energy generation. In this scenario, solidarity played a very important role. From constructing the scenarios, it could be concluded that in both scenarios energy self-sufficiency could be achieved.

Furthermore, an important observation was that energy conservation can play a major role in achieving energy self-sufficiency. Because a large part of the housing stock is not well isolated, applying energy saving measures and introducing new regulations can affect the heat demand significantly. To significantly reduce the fuel demand, electric cars can be used and batteries can be used for propelling the ferries. Furthermore, energy saving measures can reduce the electricity demand. However, when the heat and fuel demand will be reduced significantly, a shift from gas and fuel applications to electric applications takes place, which will increase the electricity demand.

After the scenarios were constructed, the spatial interventions for achieving the constructed scenarios could be identified and the robustness of these possible interventions could be evaluated. For indicating the spatial interventions for each scenario, a map of the municipality of Texel was created in which suitable locations or search areas of energy-conscious interventions were shown. These spatial interventions were based on considerations, which were related to make better use of energy qualities and to gain energy from local energy potentials as much as possible. From assessing the possible spatial interventions, it could be concluded that constructing heat and cold storage systems, constructing anaerobic co-digestion plants, upgrading existing wastewater treatment plant, constructing CHPs based on biogas and constructing small district heating grids have the highest robustness. This means that these interventions are less depending on critical uncertainties and can be implemented in the short-term. Moreover, the backcasting analysis could be carried in which the necessary technical, structural institutional, organizational and cultural changes were defined. Many changes are necessary for achieving energy self-sufficiency in 2020.

When developing and implementing a sustainable energy system in the municipal area, several technological, economic, cultural, institutional, organizational and spatial aspects need to be taken into account:

- The existing power infrastructure has to be upgraded and district heating grids have to be constructed for dealing with the sustainable energy technologies.

- To create a diversified and resilient system, renewable energy sources that are not continuous available need to combined with sources that can be used when necessary. In this way, it is possible to minimize storage and to supply energy continuously.
- Due to laws and regulations related to the protected areas in the municipal area, heat and cold storage systems cannot be implemented in a large area. In addition, there are not many search areas for placing onshore wind turbines and constructing geothermal power plants.
- The scale of use of renewable energy sources has much influence on the implementation of sustainable energy technologies, including regulations, cost, required space and resistance.
- The organization of the energy system will influence whether users can benefit from the cost advantages that can be obtained by using renewable sources on large scale.

Subsequently, the main drivers and barriers for achieving both scenarios were identified. When taking into account the motives for achieving energy self-sufficiency while considering the main drivers, it could be concluded that when going for scenario A, more economic activity can be generated. However, when going for scenarios B, more independence from the mainland can be achieved. When analyzing the main barriers from scenario A and B, several conclusions could be drawn. In both scenarios, major barriers were related to meeting the fuel demand so that it is considerably difficult to meet the fuel demand using renewable energy sources in 2020. Furthermore because of the large social resistance against wind turbines, it is very difficult to make use of wind as a key resource for achieving energy self-sufficiency. Moreover, it is expected that in the next years the municipality of Texel will get limited support from the Dutch government and the province of North Holland, which will have consequences related to funding and laws and regulations. Also, the required investments for implementing sustainable energy technologies form are a major barrier.

Many considerations have to be taken before developing and implementing a sustainable energy system in the municipal area. Through interviews with key stakeholders, relevant input has been obtained that was used in the different steps of the methodological framework of this research. However, for getting a better understanding about the interests regarding achieving energy self-sufficiency so that good decisions can be made, broad stakeholder involvement is needed. To realize this, a follow-up agenda is constructed. First, residents and local companies have to gain more knowledge and be aware on the opportunities, potentials and barriers. Then it will be examined which aspects are of importance among residents, local companies and tourists regarding energy self-sufficiency. When these aspects are known, a strategic action plan can be developed. For doing this, it would be useful to set up a steering committee, which consists of residents and representatives of various local parties. Based on this plan, various stakeholders will actively work on developing and implementing a sustainable energy system that can make Texel self-sufficient in 2020. It should however be noted that the implementation of energy saving measures and sustainable energy technologies must be stimulated as long as no strategic action plan is developed.

Concluding this research, achieving energy self-sufficiency in 2020 is technically feasible and it is largely dependent on economical, institutional and cultural or social aspects. It is recommended not to focus too much on meeting the fuel demand using renewable energy sources. Furthermore, it is highly recommended to focus on energy conservation and to focus on solar energy, wind energy, heat and cold storage for generating renewable energy. Moreover, residents need to be more involved into the decision-making process and it would be very useful to set up a steering committee.

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1. INTRODUCTION

1.1 BACKGROUND AND CONTEXT OF REPORT

Until now, the world's population is highly dependent on fossil fuels to meet the worldwide energy demand. Fossil fuels, however, are finite resources, which mean that at one day the world will be running out of these conventional energy resources. As a result, fossil fuels are becoming more scarce and expensive and that renewable resources are needed. Furthermore, several greenhouse gases and pollutants are formed when fossil fuels are burned for generating energy. These greenhouse gases and pollutants affect the environment. Thus it is believed that the increasing emissions of greenhouse gases, which are formed from burning fossil fuels, are contributing to the global warming. Increasing concerns about the depletion of fossil fuels and climate impact by mankind's irresponsible behaviors have result in an increasing attention for renewable energy.

Besides these concerns there is also another important issue that has led to more attention towards renewable energy. Most countries are dependent on oil-producing countries for access to energy, which is essential for their economies. The uneven distribution of the worldwide energy resources among countries leads to threats to the energy security of non-producing countries. This important issue raises the question how the dependence on any source of imported energy could be reduced, which has led to strong interest in renewable energy. Renewable resources are not only unlimited and environmental friendly resources of energy; renewables are also more or less available in every country or region. By using renewable energy sources, a country or region can be more independent on any source of imported energy. It is even possible that countries or regions can generate enough renewable energy to meet their total energy demand, realizing self-sufficiency in terms of energy. Together with the uncertainty about the supply of fossil fuels and stricter regulation for reducing greenhouse gas emissions, growing attention to independency on any source of imported energy has led to greater interest towards energy self-sufficiency.

Also in the Netherlands there is attention towards energy self-sufficiency by using renewable energy and in particular on regional scale. In 2007, the municipalities of the five Dutch Wadden Islands, Texel, Vlieland, Terschelling, Ameland and Schiermonnikoog, have indicated that they want to become self-sufficient in terms of energy and water by 2020 (Gemeenteraden Waddeneilanden 2007). The Wadden Islands have indicated that they realize that fossil fuels are finite and that a transition is needed towards renewable energy sources. In addition, the Wadden Islands have indicated that they want to contribute to a solution to the global climate problem. However, currently energy is imported from the mainland that is generated from fossil fuels. To change this, the Wadden Islands have decided to deal with this issue and to go for energy self-sufficiency using renewable energy sources.

1.2 PROBLEM DEFINITION

The focus of this study will be on achieving energy self-sufficiency on Wadden Island Texel. Where energy self-sufficiency refers to meeting the total energy needs by using renewable energy sources. For many years, various parties on Texel are actively working on achieving energy self-sufficiency. With this ambition, Texel was at the forefront of achieving energy self-sufficiency in the Netherlands. It all started in 2000 when Stichting Duurzaam Texel, a local foundation that was supported by the municipality of Texel, expressed the ambition to make Wadden Island Texel energy self-sufficient in 2030 as a way to stimulate tourism (Interview Hordijk 2011). This led to several initiatives and projects at Texel and also to some studies that were carried out by Dutch consulting company Ecofys and research institute ECN (De Beer et al. 2001; Weeda et al. 2007). Eventually, the municipality of Texel, also known as Gemeente Texel, decided in 2007 to go for energy self-sufficiency in 2020. This ambitious plan was received well and new projects and initiatives were carried out. However, up to now the amount of renewable energy that is generated on the island is very little. From this, it is becoming clear that rapidity is needed.

Although some reports have been written about whether energy self-sufficiency can be achieved, none of these reports have used a research methodology in which technical, economic, cultural, institutional, organizational and spatial aspects were taking into account. Some studies were mainly taking into account the technical aspects and considered 2030 as end-point (De Beer et al. 2001; Weeda et al. 2007). The most recent study by Weeda et al. (2007) concluded that a sustainable energy supply for meeting the total energy demand could be possible, but that energy self-sufficiency could not be achieved. Although this study indicated that energy self-sufficiency in 2030 could not be achieved, the municipality of Texel has indicated to maintain its ambition and even is focusing on achieving energy self-sufficiency in 2020. As a result, it is becoming clear that new strategies are needed, which could provide a major step towards achieving this ambition. A new study is needed that take into account previous studies but also missing aspects related to achieving energy self-sufficiency that can lead to planning for actions. For taking into account these missing aspects, the methods backcasting and sustainable energy landscape design can be very useful. Backcasting can be defined as first creating a desirable future vision, followed by looking back at how this desirable future could be achieved (Quist et al. 2006). In addition, sustainable energy landscape design can be defined as developing a physical environment where energy needs can be optimally fulfilled by locally available renewable energy sources (Stremke 2010). A combination of these methods can lead to a research methodology, which provides tools and methods that can take into account technological, economic, cultural, institutional, organizational and spatial aspects. However, until now these methods are not combined in any research. As a result, it must first be examined how these methods can be integrated into a methodological framework that can be used for determining whether the ambition of the municipality of Texel can be achieved.

Achieving energy self-sufficiency can be a great opportunity for not only Texel, but also for The Netherlands as a whole. Texel can play an exemplary role in the Netherlands to develop knowledge on technical, economic, social and institutional level. This is also recognized by the Rathenau Instituut, which is a Dutch organization that deals with scientific, technological and social issues to inform the Dutch government. The Rathenau Instituut considers the ambition of Texel as a good example of a regional initiative that can help developing knowledge about the dynamics of transition towards renewable energy in the Netherlands (Leguijt et al. 2008). Furthermore, Stichting Urgenda, a

Dutch organization that actively deals with stimulating sustainability initiatives, has declared Texel as icon project for putting sustainability on the map of the Netherlands (Interview Minnesma 2011). What is so special about Texel, besides the clear boundaries, is that many local stakeholders want to cooperate for making this ambition a success. There are only a few municipalities in The Netherlands that are so ambitious as the municipality of Texel. In addition, most residents are committed to achieve energy self-sufficiency in 2020 (Interview Hercules 2011).

1.3 Goal and research questions

The goal of this research 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. By doing this, technological, economic, cultural, institutional and spatial aspects are taken into account. Moreover, this research emphasizes the development of a sustainable energy system on regional scale that is fully using the potential of locally available renewable energy sources and its consequences for the organization of spatial functions and the built environment.

The main research question is formulated as follows:

What are the opportunities, potentials and barriers for developing and implementing a sustainable energy system that can make Wadden Island Texel energy self-sufficient in 2020?

For answering the main research question the following sub questions are derived:

- How can backcasting and sustainable energy landscape design be integrated into one methodological framework?
- Which present conditions can be identified concerning energy self-sufficiency?
- What are the current developments concerning energy self-sufficiency?
- Which desirable scenarios can be developed for achieving energy self-sufficiency in 2020?
- Which spatial interventions can be identified for optimal developing and implementing a sustainable energy system?
- Which technological, structural, institutional, organizational and cultural changes are needed for achieving energy self-sufficiency in 2020?
- What are the main drivers and barriers for achieving energy self-sufficiency in 2020?
- What could different stakeholders do and what should be on their action agenda?

As can be noted, the first sub question is important for answering the other sub questions. In this research, two very different scenarios will be developed. The first scenario builds itself on the assumption that energy self-sufficiency can be achieved, while the trend growth of the total energy demand in the period from 2010 to 2020 on Texel will be maintained. In this scenario, the main focus will be on developing an energy system that is economically efficient. To do this, economies of scale are important, which means that renewable energy sources will be used on large scale. Moreover, there will be no focus on energy conservation. In the second scenario, it is assumed that energy self-sufficiency can only be achieved when energy will be saved considerably. There will be also much focus on decentralized energy generation. In this scenario, solidarity plays a very important role.

1.4 RESEARCH BOUNDARIES

Before doing research, it is important to define the boundaries of this research. These boundaries can be set by defining the starting points of this research. For defining these starting points it is important to take into account the conditions that are set by the municipality of Texel and other relevant actors for achieving energy self-sufficiency. This limits the freedom in doing research, but is relevant in order to determine the focus of this research and to decide to what extent this research is successful. Also because of the limited timespan that is reserved for this research, starting points are needed in achieving a good research.

The following starting points for this research are defined:

- The focus in this research will be on achieving energy self-sufficiency. Although the municipality of Texel has indicated that they have also the ambition to make Wadden Island Texel self-sufficient in terms of water, this will not be discussed in this study.
- The focus in this research will be on the municipal area. This means that the municipal boundaries will be taking into account and not the boundaries of the island. This means that also sea area and the uninhabited sandbank Noorderhaaks will be taking into account.
- Self-sufficiency in terms of energy can only be achieved when renewable energy sources are used. This indicates that in no way fossil fuels can be used for generating energy. Even if it appears that in the next years conventional energy resources are detected on Texel. This constraint is also in line with the conditions that are set by the municipality of Texel (Leguijt et al. 2008).
- Energy generation must take place within the municipal boundaries. This means that renewable energy cannot be imported for achieving energy self-sufficiency. This constraint is not in line with the conditions that are set by the municipality of Texel, where is stated that energy generation can take place outside the municipal boundaries if necessary (Leguijt et al. 2008). Texel is then willing to invest in the necessary installation.
- Although energy cannot be imported from outside the municipal boundaries for achieving the ambition, the island remains connected to the grid with the mainland. This grid connection can serve as back-up to provide energy security or it can be used for exporting excess energy.
- To determine the total energy demand, only the energy demand within the municipal boundaries will be taking into account. Also a distinction will be made between direct and indirect energy consumption. Direct energy consumption, which consists of the primary fuel consumption, energy for heating and electricity, will be taking into account. However, indirect energy consumption for producing goods that are used on Texel will not be taking into account. These constraints are also in line with the conditions that are set by the municipality of Texel (Leguijt et al. 2008).
- To achieve self-sufficiency regarding fuels, only the fuel demand of motor vehicles and the ferries will be taking into account. The fuel demand of the fishing fleet on Texel will be excluded. This also applies to the fuel demand on Texel International Airport and fuel demand for sand replenishment that is meant for Texel. The argument for excluding these data is that these activities take place outside the municipal boundaries. These constraints are also in line with the conditions that are set by the municipality of Texel (Leguijt et al.

2008). It should however be noted that the total fuel demand of these activities is substantial. Based on Leguijt et al. (2008), the fuel demand of these activities will account for more than 50% of the total fuel demand when this demand will be taking into account.

- To determine the fuel demand of motor vehicles, the amount of fuel that is tanked on the island will be taking into account. When doing this, the amount of fuel will be determined that is tanked by both residents and tourists, while the amount of fuel that is tanked by residents outside the municipal boundaries will be excluded. However, based on De Beer et al. (2001), it will be assumed that this is approximately equal to the total fuel demand of motor vehicles of the residents.

1.5 Outline of report

In the next chapter, the methods backcasting and sustainable landscape design will be discussed after which both methods will be combined to develop the methodological framework of this research. In this chapter, the research questions will also be linked to the framework. Chapter 3 will identify the present conditions in the municipal area. In this chapter, the landscape and present energy system will be analyzed and renewable energy potentials will be identified. Chapter 4 will describe the current developments concerning energy self-sufficiency in the municipality of Texel. These developments will be distinguished in technical, economic, cultural, spatial trends and policies. In Chapter 5, first the total energy demand on Texel in 2020 will be defined based on exogenous variables after which two scenarios will be constructed. Chapter 6 will identify the spatial interventions for achieving the constructed desired scenarios. Also, the backcasting analysis will be carried out in which technical, cultural, structural and institutional changes that are necessary for achieving the constructed desirable scenarios will be defined. In Chapter 7, the two scenarios will elaborated in which the main drivers and barriers are identified and pathways are defined. Furthermore, an action agenda will be constructed in which is described what the involved actors should do for following the possible pathways. In the final chapter, conclusions and recommendations are presented.

2. Theory and methodology

Backcasting and sustainable energy landscape design are very useful methods for finding out how Texel can be energy self-sufficient in 2020. This chapter will discuss both concepts and will also explain why these are interesting for dealing with the ambition of Wadden Island Texel. Furthermore, several methodological frameworks of these concepts will be illustrated. Eventually, two approaches of backcasting and one approach for designing sustainable energy landscapes will be compared, after which a new methodological framework will be developed. This methodological framework will be used for carrying out this research and answering the research questions.

2.1 Backcasting

Backcasting can be defined as first creating a desirable (sustainable) future vision, followed by looking back at how this desirable future could be achieved (Quist et al. 2006). By using backcasting, the feasibility of a desirable future and the necessary changes for achieving that future can be determined. It also stresses the importance of designing an operational plan for the present for moving towards the desirable stage in the future. This is in line with Robinson (1990), who indicated that backcasting is not intended to reveal or indicate what futures are likely to happen but how desirable futures can be achieved. This distinguishes backcasting from forecasting: backcasting is not based on the extrapolation of the present into the future, but extrapolates a desirable future back to the present. Backcasting is a normative approach to foresight using desirable and alternative futures (Quist et al. 2011).

The term backcasting was for the first time used by Robinson (Dreborg 1996), describing backcasting as a method for determining necessary policy measures for reaching a particular desirable future end-point (Robinson 1990). Robinson (1990) also emphasized that backcasting is intended to determine to what extent undesirable futures can be avoided or responded to. However, the origin of backcasting is in the 1970s, when Lovins proposed backcasting as an alternative planning technique for electricity supply and demand (Quist and Vergragt 2006). At that time, Lovins suggested that it would be useful to define desirable futures for determining policy measures to guide the energy industry. The early focus in backcasting was on exploring and assessing energy futures and on its potential for policy analysis in the traditional sense of supporting policy and policymakers using mainly governmental perspective (Quist and Vergragt 2006). However, in the late 1980s backcasting has been broadened towards sustainability issues. This was first mentioned by Robinson (1990), who described that in the late 1980s backcasting started to be used for sustainability issues, such as the two-year project called 'Designing a Sustainable Society for Canada'. Other examples in which backcasting was applied for sustainability issues, are the Sustainable Technology Development (STD) programme in the Netherlands and the Nutrition case study of the Sustainable Households (SusHouse) project (Quist and Vergragt 2006).

Backcasting has become a useful approach for dealing with complex sustainability issues. This is also in line with the argument of Dreborg (1996). According to Dreborg, complex problems need an approach that focuses on the problem to be solved rather than on present conditions and current trends. Which makes backcasting better suited for long-term and complex sustainability issues than a regular forecasting approach. Forecasting is based on dominant trends and therefore it is unlikely to generate solutions that would include breaking trends (Dreborg 1996). Although backcasting is better suited for complex sustainability issues than forecasting, forecasting can be useful in backcasting studies. Höjer and Mattsson (2000) indicate that forecasting can be complementary in backcasting studies, it may give a reference point that can be compared with the desirable future end-point. Dreborg (1996) have also indicated which characteristics of a problem may favour the use of backcasting as approach, which makes it possible to see how the issue of Wadden Island Texel fits into this pattern. According to Dreborg, backcasting is very useful when a problem is complex, when there is need for a major change, when dominant trends are part of the problem, when the problem is a matter of externalities and when the time horizon is long. The issue on how Wadden Island Texel can be energy self-sufficient in 2020 fits into this pattern. However, Robinson (1990) denoted that end-points are usually chosen for a time between 25 to 50 years into the future. In the case of Texel the end-point is 2020, which is 9 years into the future and therefore relatively short in backcasting studies.

Another important characteristic of backcasting is its possibility to involve actors, such as companies, governmental authorities, research and knowledge institutes and the public. Backcasting can be broadened with these actors to provide relevant input to a policy-forming process. There is not one single, well-defined decision maker. As a result, it is good to address many actors in backcasting studies (Dreborg 1996). This is also supported by Quist and Vergragt (2006), who argued that stakeholders are important in backcasting because of their context specific knowledge. They also emphasized that stakeholders are important for achieving approval for results and realizing the proposed agenda and specific follow-up. Also in the case of Texel, many actors are involved which makes backcasting a useful approach.

Now backcasting is discussed, two different approaches of backcasting will be illustrated, which will be used for developing the methodological framework of this research. First, a five-step methodological framework for participatory backcasting by Quist and Vergragt (2006) will be discussed, after which a six-step methodological framework for backcasting by Robinson (1990) will be treated. Although both approaches have many similarities, the specific differences will be used for developing the methodological framework of this research.

Quist and Vergragt (2006) created a methodological framework for participatory backcasting based on several backcasting studies, including the papers of Robinson (1990) and Dreborg (1996). They concluded that in the early 1990s a shift had been made to broad stakeholder participation and towards a focus on realizing follow-up and implementation. Based on this observation they proposed a framework that consists of five main steps, see Figure 1.

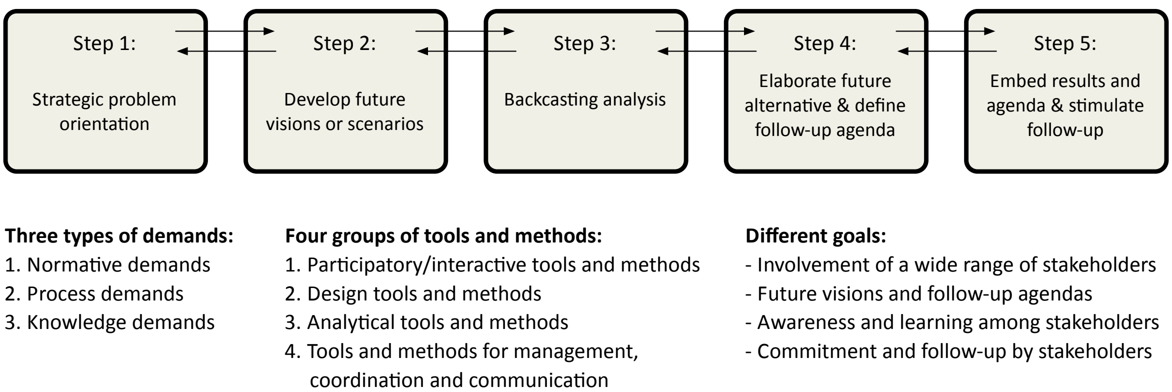


FIGURE 1 – METHODOLOGICAL FRAMEWORK FOR PARTICIPATORY BACKCASTING (QUIST AND VERGRAGT 2006)

In the first step, the normative assumptions and goals will be set. In this step it is also important that agreement is reached among the normative assumptions between the various stakeholders. Sometimes these assumptions and goals are already set before strategic problem orientation starts. Also, in this step the present system will be described and current developments and involved stakeholders will be defined. In the second step, future visions or scenarios will be constructed. Next, the backcasting analysis will be carried out, in which changes will be defined that are necessary for achieving the constructed future scenarios. Then in the fourth step the results of the backcasting analysis will be elaborated and embedded. In this step, drivers and barriers for achieving the future scenarios can be determined after which possible pathways can be defined. In the last step, a follow-up agenda will be constructed in which is described what the involved actors should do. This step contains implementation of the actions that are needed. Although these steps are illustrated as stepwise and linear, iteration cycles and influences on one another are possible. Quist and Vergragt (2006) also emphasized that for using the participatory backcasting approach, broad stakeholder involvement is needed. This can be done in different ways, including workshops and interviews.
In Figure 1, also four groups of tools and methods can be seen. These tools and methods are a useful toolkit when applying this framework in a backcasting study and can be used in every step. First, there are participatory and interactive tools and methods. These are tools that involve stakeholders and increase the interactivity between these stakeholders. Next, there are design tools and methods that are useful in constructing scenarios and elaborating and detailing systems. Third, also analytical tools and methods are important. These tools can be used for scenario assessment, process analysis and evaluation, stakeholder identification and stakeholder analysis. Fourth, there are tools and methods for management, coordination and communication. This includes methods for communication, for shaping and maintaining stakeholder networks and methods from constructive technology assessment.

The methodological framework for backcasting proposed by Robinson (1990) consists of six main steps as can be seen in Figure 2. In contrast to the framework proposed by Quist and Vergragt, this framework was not intended for broad stakeholder involvement. However, it should be mentioned that Robinson has also developed backcasting further and has included participation in a later study (Robinson 2003), which will not be discussed further. Compared to the framework proposed by Quist and Vergragt, the steps for problem orientation are more extensive which also explains the extra steps. The first four steps in the methodological framework by Robinson are part of the problem orientation. These steps differ from the problem orientation step by Quist and Vergragt on a few points. Robinson indicates that where possible qualitative goals or constraints should be expressed in quantitative targets. These quantitative targets can then provide a good reference point for the development and scenario analysis. Furthermore, Robinson also specifically refers to exogenous variables, which are important to specify. Exogenous variables describe that part of the world that is not included within the backcast itself. These values are however very important because they can offer a certain constraint to the scenarios. For example, it would be important to specify the overall economic growth, which can provide some of the inputs to the scenarios. Although these predictions seem more connected to forecasting, they are part of the backcasting approach.
In the fifth step of the framework by Robinson scenarios will be constructed, based on the inputs that are developed. This step can be seen as the second step in the framework of Quist and Vergragt. The sixth step includes the backcasting analysis and comparison of the results to the specific targets. In order to make this analysis useful in practice, it must be connected to the policy process.

Therefore Robinson added a policy implication box with an iteration loop back to the goals. Whereas Quist and Vergragt see this as a step in their framework, Robinson indicates this is not as a single step in his framework because it is moving outside the analytical context and into the policy arena. As can be seen in Figure 2, iteration cycles and influences on one another are possible.

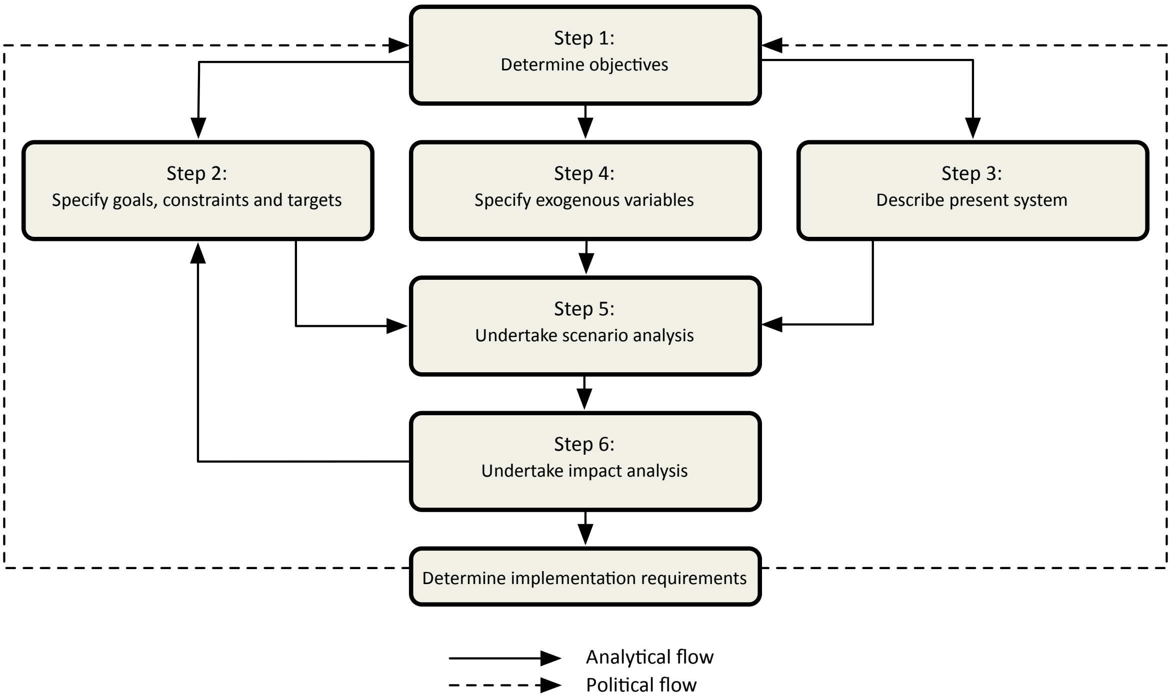


FIGURE 2 – METHODOLOGICAL FRAMEWORK FOR BACKCASTING BY ROBINSON (1990)

Partially based on the methodological framework proposed by Robinson, an interesting project was carried out, called the Tyndall decarbonisation project (Mander et al. 2008; Anderson et al. 2008). In this project alternative scenarios were developed and different pathways were defined for achieving a 60% reduction in CO_2 emissions from 1990 levels by 2050 in the UK. This ambition was set out by the UK government for reducing CO_2 emissions in order to combat climate change. In this project different stakeholders were invited to participate in workshops in which they gave input for developing the scenarios. The scenarios that were developed were ranging from halving the energy consumption from current levels to a near doubling. The impacts and consequences of the scenarios were assessed by means of a multi-criteria framework. This analysis indicated that in high-energy demand scenarios the society is locked into an energy system that is less flexible, responsive and more resource intensive than in scenarios where the energy demand is reduced. Eventually, the studies that were carried out by Mander et al. (2008) and Anderson et al. (2008) concluded that a 60% reduction in the UK could be achieved but that strong governmental leadership is needed.

2.2 SUSTAINABLE ENERGY LANDSCAPE DESIGN

Sustainable energy landscape design can be defined 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 (Stremke 2010). This means that the energy requirements of such landscapes may not exceed locally available energy resources (Stremke and Koh 2010a). The underlying idea is that in order to develop and implement a sustainable energy system, it needs to be well integrated in the landscape design. In which a sustainable energy system refers to a cost-efficient, reliable and environmental friendly energy system that effectively utilizes local resources and networks (Hepbasli 2008). Transition from fossil fuels to renewable energy requires much more than only installing sustainable energy technologies. It requires also energy-conscious organization of the physical environment, which not only determines where renewable energy is assimilated and consumed, but also influences how much energy at which quality and at what time is assimilated (Stremke and Koh 2010a).

Over the past years, there has been an increasing attention towards designing sustainable energy landscapes. Although many researchers emphasize the importance of energy in spatial planning and landscape design, there were no clear principles and strategies found in the literature by which sustainable energy landscapes could be designed (Stremke 2010). However, in the last five years several studies on sustainable energy landscape design were carried out in which the knowledge gaps were identified. These studies were part of the research project called 'Synergies between Regional Planning and Exergy' (Exergieplanning 2011). This research project, also called SREX, was funded by Agentschap NL, which is an agency of the Ministry of Economic Affairs, Agriculture and Innovation, and consisted of researchers of the Delft University of Technology, Wageningen University and the University of Groningen. The goal of these studies was to develop sustainable design principles, design strategies and spatial concepts. An important finding from these studies was that for developing sustainable design principles two key sources of insight were found: nature and thermodynamics (Stremke and Koh 2010). Regional case studies in Southeast Drenthe and South Limburg (Van den Dobbelsteen and Broersma 2009a, 2009b, 2010a, 2010b) have also showed that from these sources, principles can be defined that not only inform the design of sustainable energy landscapes, but also help implementing sustainable energy technologies.

First, natural ecosystems can provide relevant information that can be used in designing sustainable energy landscapes. Ecological concepts, such as system size, source and sinks, and ecological strategies, such as energy cascading and symbiosis, can inspire many energy-conscious interventions in the physical environment (Stremke and Koh 2010a). However, it should be noted that these design principles should inform and not determine decision making (Stremke and Koh 2010b).

Furthermore, thermodynamics is an important key source of insight in developing design principles because it can increase efficiencies. The Second Law of Thermodynamics is a well recognized by engineers and industrial ecologists for reducing primary energy reduction and is now being embraced by architects and urban planners (Stremke et al. 2011). According to Van den Dobbelsteen et al. (2007), the Second Law of Thermodynamics states that processes constantly develop towards a state of increasing entropy. As entropy embodies the non-useful waste energy evolving during processes, exergy is the useful part, the part that set things to work, a measure of energy quality. As a result, energy efficiencies of energy systems can be very high while the exergy efficiency of that system is very low. As example: if a 1500°C gas flame is used for heating a house to a temperature of 20°C the exergy efficiency is no more than 15%, but when the heat is utilized in heavy industry the exergy efficiency is close to 100% (Van den Dobbelsteen et al. 2007). From this point of view, the Low-Exergy (Low-Ex) approach is developed. The Low-Ex approach aims to reduce exergy destruction in the built environment by dealing with realizing spatial conditions to make better use of unused energy flows. It can lead to better use of the quality of energy, energy cascades, usage of residual energy and a low-exergetic energy demand (Van den Dobbelsteen et al. 2009a). Low-Ex is a very interesting approach that can be applied on regional issues that are dealing with implementing sustainable energy technologies.

Stremke et al. (2010a) have proposed a methodological framework, which can help designing sustainable energy landscapes at regional scale. This framework aims to facilitate the composition of long-term visions by integrating current projected trends and critical uncertainties into the design process. Therefore, Stremke et al. entitled it as a methodological framework for integrated visions. Stremke (2010) also emphasized that a strong necessity for long-term visions is needed when it comes to sustainable development. In this framework, the two key sources of insight for developing the designing principles, nature and thermodynamics, can be taking into account.

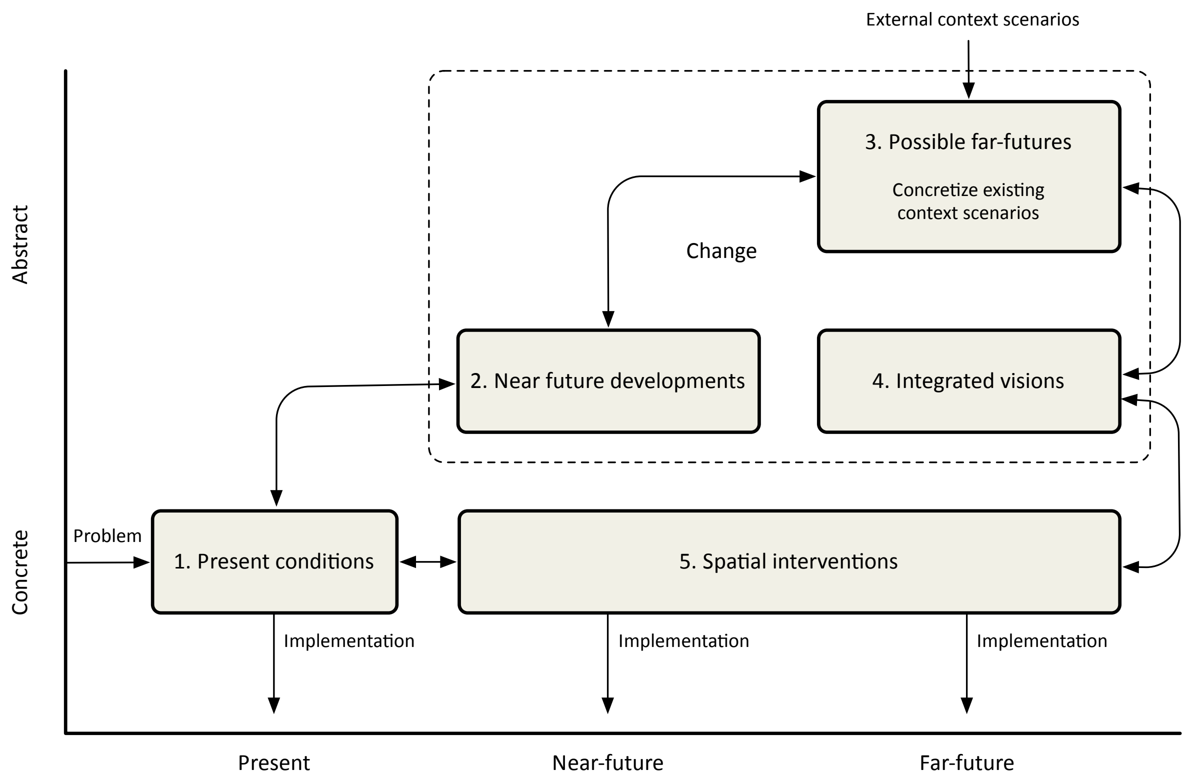


FIGURE 3 – METHODOLOGICAL FRAMEWORK FOR INTEGRATED VISIONS BY STREMKE ET AL. (2010A)

The methodological framework proposed by Stremke et al. consists of five steps, as is shown in Figure 3. The steps should be passed through twice. First, the context and scope have to be defined after which maps and data will be gathered and stakeholders will be invited to participate. In the second cycle the actual visions will be composed and the design process will be carried out. In the first step of the framework, the present conditions will be defined in which both the landscape and the present energy system will be analyzed. Also, renewable energy potentials should be identified. In the second step, near-future developments will be described in which current, projected trends and policies in the region will be analyzed. Next, possible far-futures will be described, which can be illustrated with help of existing national and regional scenario studies. These possible far-futures can give relevant input in constructing the visions. In the fourth step, a set of integrated visions will be composed, which are based on present conditions, current trends and possible far-futures of the landscape. Each of those visions depicts one desired future. In the last step, possible interventions will be identified for each vision after which the robustness of these possible interventions will be assessed. If an intervention appears in multiple visions, the robustness of an intervention is high. Interventions of which the robustness is considered high can be implemented in the short-term because these are less depending on critical uncertainties. However, less robust interventions are also needed for achieving a full transition to a desirable future. Less robust interventions can be seen as chances or opportunities. Only when certain developments happen, these interventions can be implemented in the short-term. Evaluating the robustness of possible interventions is an important task in this framework; it can be very useful in making decisions. Generally, using this framework does not necessarily lead to a spatial plan, but it results in a set of visions and a list of possible interventions.

The methodological framework proposed by Stremke et al. has been used for designing sustainable energy landscapes for Margraten, a large municipality in the South of the Netherlands (Stremke et al. 2010b). In this study, long-term visions were composed and interventions were identified for achieving energy self-sufficiency. The visions were based on four context scenarios: global market, global solidarity, secure region and caring region. From each of those visions a sustainable energy landscape was developed under the conditions established by the related scenario. Eventually, the possible interventions were identified for each vision after which the possible impacts of each intervention were illustrated. From this study it was concluded that energy self-sufficiency could be achieved based on the locally available renewable energy sources. In order to cope with the fluctuation in energy demand and supply, it was indicated to utilize as many renewable energy sources as possible.

In the case of Texel, a sustainable energy system needs to be developed, implemented and well integrated in the landscape design. The methodological framework proposed by Stremke et al. can provide suited principles for designing a sustainable energy landscape and can also identify possible spatial interventions. Furthermore, this framework can be useful in determining the feasibility of a desirable future. Based on the locally available renewable energy sources, it can be determined if Texel can achieve energy self-sufficiency. It can be concluded that the methodological framework for integrated visions can be very useful in this research.

2.3 Methodological framework of research

Interestingly, the steps in the framework proposed by Stremke et al. contain many similarities with the described frameworks for backcasting. The first two steps are part of the problem orientation step in which the current energy system and developments will be described. Also, the third step is part of the problem orientation step. In this step possible far-futures will be defined, which can be compared with step four of the framework proposed by Robinson in which the exogenous variables are specified. Possible far-futures can give important input for constructing visions or scenarios. In defining possible far-futures also exogenous variables will be specified. Exogenous variables describe that part of the world that is not included within the backcast itself, but these values are very important because they can offer a certain constraint to the scenarios. In the fourth step of the framework proposed by Stremke et al., a set of visions will be composed. In the proposed frameworks for backcasting also visions or scenarios will be constructed, based on the desirable future that is defined. In the last step of the framework proposed by Stremke et al. possible spatial interventions will be listed, which can be seen as necessary changes. These spatial interventions can help achieving the desirable future of each vision.

Furthermore, the described steps in the frameworks for backcasting and designing sustainable energy landscapes are not linear, iteration cycles and influences on one another are possible. Also, the described frameworks are intended for issues where the time horizon is long and in the frameworks proposed by Quist and Vergragt and Stremke et al. participation of stakeholders is recommended. The many similarities are a good starting point for developing a new methodological

framework for this research in which the described approaches for backcasting and sustainable energy landscape design will be combined.
Before developing the framework it is important to return to the goal of this research. The goal of this research 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 this research, the vision is already set: the municipality of Texel wants to be self-sufficient in terms of energy in 2020. However, scenarios can be constructed freely. As described, backcasting approaches are very useful for dealing with complex sustainability problems, such as the issue on how Wadden Island Texel can be energy self-sufficient. This also applies for the described approach by Stremke et al. for designing a sustainable energy landscape. When using backcasting different types of methods can be applied. No specific methods are prescribed and it is allowed to combine different methods (Quist 2007). This characteristic makes it possible to apply the backcasting method as a basis for developing the methodological framework in this research. In this research, the methodological framework for participatory backcasting proposed by Quist and Vergragt will be used as basis. Because of the limited timespan that is reserved for this research it is impossible to meet the criteria of broad stakeholder involvement. However, stakeholders will be interviewed for giving relevant input in the different steps of this research. The five steps of the framework for participatory backcasting are very useful. It enables the elaboration of certain scenarios and creation of possible pathways that can lead to energy self-sufficiency in 2020. It stresses also the importance of designing an action plan for the present for moving towards the desirable stage in the future. In the table below, the five steps of the methodological framework for participatory backcasting are used for allocating the tasks of this research. These tasks are based on the tasks that were represented in the two approaches for backcasting and the approach for designing sustainable energy landscapes. Therefore it is indicated which tasks are related to which described framework.

TABLE 1 – THE STEPS AND TASKS OF THE METHODOLOGICAL FRAMEWORK OF THIS RESEARCH

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)

From this table it must be noted that Robinson (1990) also emphasizes the necessity of implementation requirements for decision-making. However, Robinson indicates this not as a single

step in his framework. In addition, Stremke et al. indicate also implementation into their framework, but not as a single step. Stremke et al. emphasizes evaluating the robustness of possible interventions, which help decision makers with respect to implementation. As previously described, interventions of which the robustness is considered high can be implemented in the short-term because these are less depending on critical uncertainties. Furthermore, Stremke et al. focus on composing several visions in which each vision depicts one desirable future. These visions are based on existing context scenarios. Each vision thus identifies possible spatial interventions under the conditions established by the respective scenario (Stremke et al. 2010a). In this research, recent context scenarios will also be used for constructing scenarios.
Moreover, in the table it is indicated that in the first step exogenous variables will be defined which needs further explanation. In this research, exogenous variables describe that part of the world that is not included within the backcast itself (Robinson 1990). These exogenous variables can be seen as possible far-futures or assumptions that can offer a certain constraint in constructing the scenarios. So although these exogenous variables are seemed more connected to forecasting, they are part of the backcasting approach. As example: the overall economic growth is an exogenous variable that offers a certain constraint, while it is not included within the backcast itself.

As can be seen in Table 1, the methodological framework consists of many steps. Before using this framework, it is necessary to describe what is meant by these tasks. Table 2 provides descriptions of the tasks that comprise the methodological framework. The descriptions of these tasks are based on the tasks that were represented in the two approaches for backcasting and the approach for designing sustainable energy landscapes.

TABLE 2 – DESCRIPTION OF THE TASKS THAT COMPRIMISE THE METHODOLOGICAL FRAMEWORK OF THIS RESEARCH

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

2.4 Framework linked to research questions

In the previous section the methodological framework of this research was developed. This means that the first research sub question is answered. For applying the developed framework in this research, it is necessary to explain how this framework will be used for dealing with the other research questions. As was described in Chapter 1, the main research question is formulated as follows:

What are the opportunities, potentials and barriers for developing and implementing a sustainable energy system that can make Wadden Island Texel energy self-sufficient in 2020?

For answering the main research question the following sub questions are derived:

- Which present conditions can be identified concerning energy self-sufficiency?
- What are the current developments concerning energy self-sufficiency?
- Which desirable scenarios can be developed for achieving energy self-sufficiency in 2020?
- Which spatial interventions can be identified for optimal developing and implementing a sustainable energy system?
- Which technological, structural, institutional, organizational and cultural changes are needed for achieving energy self-sufficiency in 2020?
- What are the main drivers and barriers for achieving energy self-sufficiency in 2020?
- What could different stakeholders do and what should be on their action agenda?

These sub questions are linked to the steps of the developed framework, as can be seen in Figure 4. The first step in the methodological framework is the strategic problem orientation step, which is quite extensive. In this step first the goals, constraints and targets will be specified which is already done in Chapter 1. The goal of this research 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. Furthermore, the boundaries of this research are already determined by defining the starting points. An important starting point is that for achieving energy self-sufficiency on Wadden Island Texel, the focus in this research will be on the municipal area or the municipality of Texel. This means that energy generation must take place inside the municipal boundaries to achieve energy self-sufficiency. To involve stakeholders into this research, important stakeholders will be interviewed for giving relevant input in the different steps of the methodological framework of this research.

For identifying the present conditions in the municipality of Texel, first the landscape characteristics will be analyzed after which the current energy supply and demand will be determined. Furthermore, the renewable energy potentials will be identified in which will be indicated which renewable energy sources have a large potential in the municipality of Texel. Next, the current developments will be defined concerning energy self-sufficiency in the municipal area, which include current technological, economic, cultural and spatial trends and policies. In addition, stakeholders will be identified after which their interests and influences regarding energy self-sufficiency will be defined. Eventually, exogenous variables will be defined, which can offer a certain constraint in constructing the desirable scenarios. This comprises assumptions or far-future developments in and outside the municipal area. For defining these assumptions and far-future developments, recent context scenarios are used.

In the second step, two desirable scenarios will be constructed based on present conditions, current trends and exogenous variables concerning the municipal area. The backcasting analysis will be carried out in the third step. In this step, it will be indicated which spatial interventions should be implemented in the municipality of Texel after which the technological, structural, institutional, organizational and cultural changes that are necessary will be defined. Based on these spatial interventions and necessary changes, the main drivers and barriers for achieving energy self-sufficiency can be identified, which will be done in step four. In this step, also possible pathways for achieving energy self-sufficiency will be defined. Eventually, a follow-up agenda will be constructed in which is described what different stakeholders should do to continue working on achieving energy self-sufficiency.

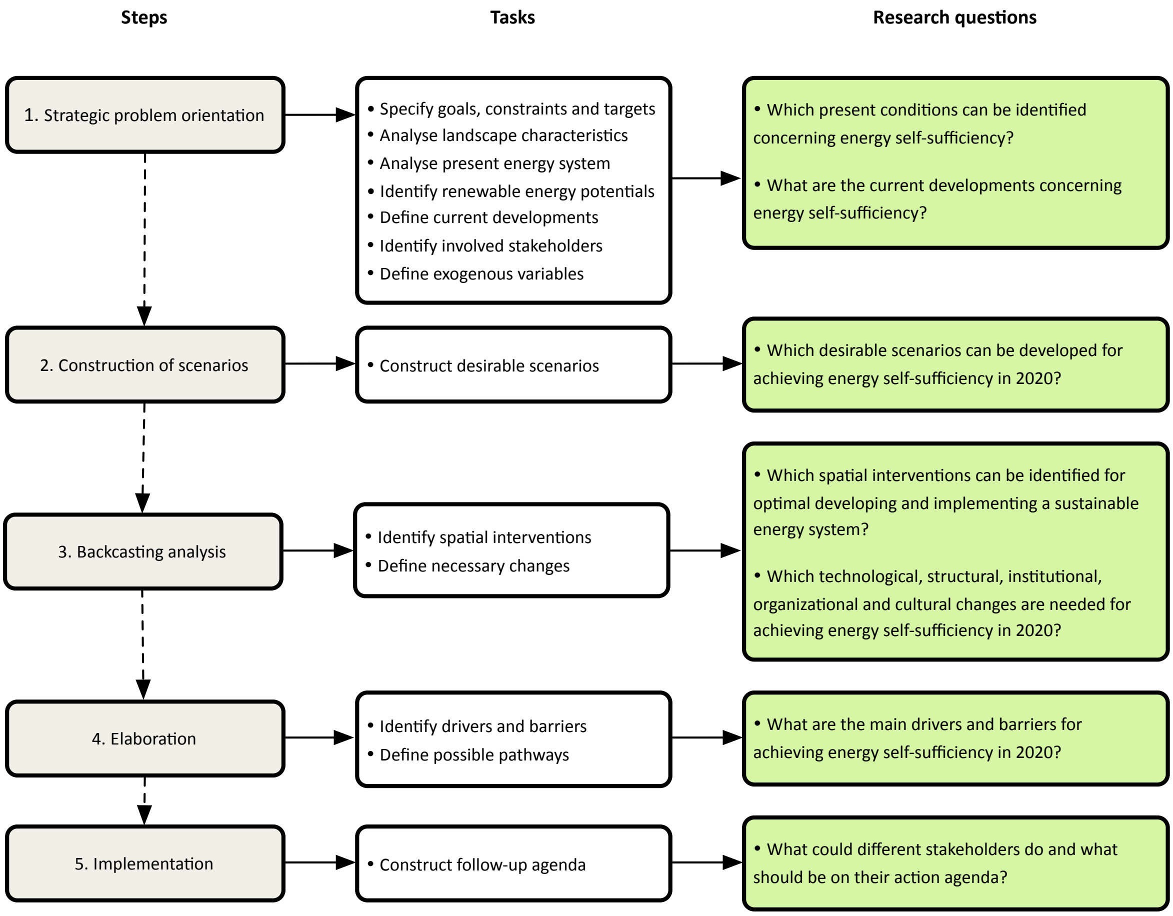


FIGURE 4 – METHODOLOGICAL FRAMEWORK LINKED TO RESEARCH QUESTIONS

3. Present conditions in the municipality of Texel

In this chapter the present conditions in the municipal area will be identified. In order to identify the present conditions, first the landscape will be analyzed, which will be done in section 3.1. In the next section the energy system will be analyzed in which the current energy supply and demand will be determined. Eventually, the renewable energy potentials will be identified in which will be indicated which renewable energy sources are interesting. As can be noted, these are important tasks in the strategic problem orientation step of this research.

3.1 Landscape characteristics

In this research, the definition of landscape is used in a broad sense. It comprises visible and non-visible features of the area, including physical elements of landforms, soil properties and different forms of land use, buildings and infrastructures. For implementing sustainable energy technologies in an area or region, it is important to analyze the landscape characteristics. Analyzing these characteristics can give relevant input for defining necessary changes and identifying spatial interventions. First, the topography and land use of Texel will be described. Subsequently, the characteristics of the built environment and infrastructure will be described and eventually the natural qualities and soil qualities will be indicated.

3.1.1 Topography and land use

Texel is the largest island in the Netherlands and is part of the Wadden Islands, also known as West Frisian Islands, which are located in the Wadden Sea. Besides being an island, Texel is also a municipality of the province of North Holland, which also includes the uninhabited sandbank Noorderhaaks. The island includes seven villages: Den Burg, Oudeschild, De Koog, Oosterend, De Cockdorp, Den Hoorn and De Waal. Furthermore, there are several hamlets, such as 't Horntje and Zuid-Eierland. Originally, Texel consisted of two islands: Texel in the south and Eierland in the north. In the seventeenth century these islands were connected together. The landscape of the island can be classified into three types: coastal zones in the west, marine clay areas in the northeast and in the south and sandy terrains in the middle (PBL 2011a). In contrast to the other Wadden Islands, the island Texel has a hard core of boulder clay, which is a mixture of sand, clay, loam and boulders that was deposited during the Ice Age (Texel 2011). The most notable impoundment of this boulder clay is 'De Hoge Berg' of which the highest point is 15.3 meter above sea level. This impoundment is located between Den Burg and Oudeschild. The villages Den Burg, Oosterend and Den Hoorn are also located on impoundments of boulder clay. The altitude on the island varies from circa 20 meters above sea level, which dunes can reach, to 2 meters below sea level.

The total area of the municipality of Texel is 46,327 hectares, of which 34.8 percent is land area (In Cijfers 2012). As a result, the municipality consists largely of water. Most land area, approximately 63 percent of the total land area, is used for agriculture. In particular cultivation of potatoes, wheat, sugar beets and corn, sheep farming and cultivation of bulbs. Furthermore, natural areas, including forest, dunes and heaths, cover approximately 28% of the total land area. Only, 5% is covered by urban and recreation areas. Surface water and roads cover the rest of the total area. Based on the GEO portal of Waddenzee (2011), a topographic map of the municipality of Texel in Figure 5 is shown.

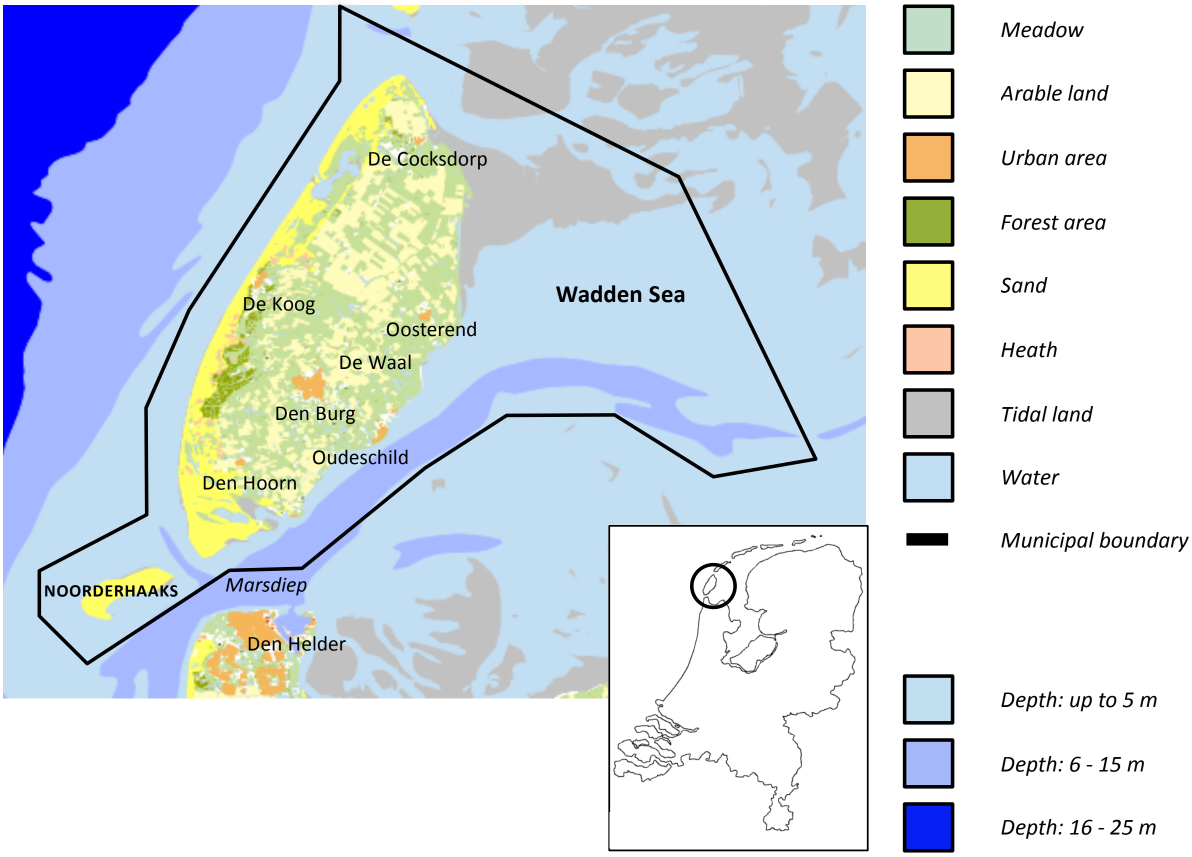


FIGURE 5 – TOPOGRAPHIC MAP OF THE MUNCIPALITY OF TEXEL

3.1.2 BUILT ENVIRONMENT AND INFRASTRUCTURE

With a population of 13,720 people, Texel has the highest population density of the Wadden Islands (In Cijfers 2012). More than half of the inhabitants live in Den Burg, which makes it by far the largest village of Texel. Based on In Cijfers (2012), in Figure 6 an overview is given of the population of Texel.

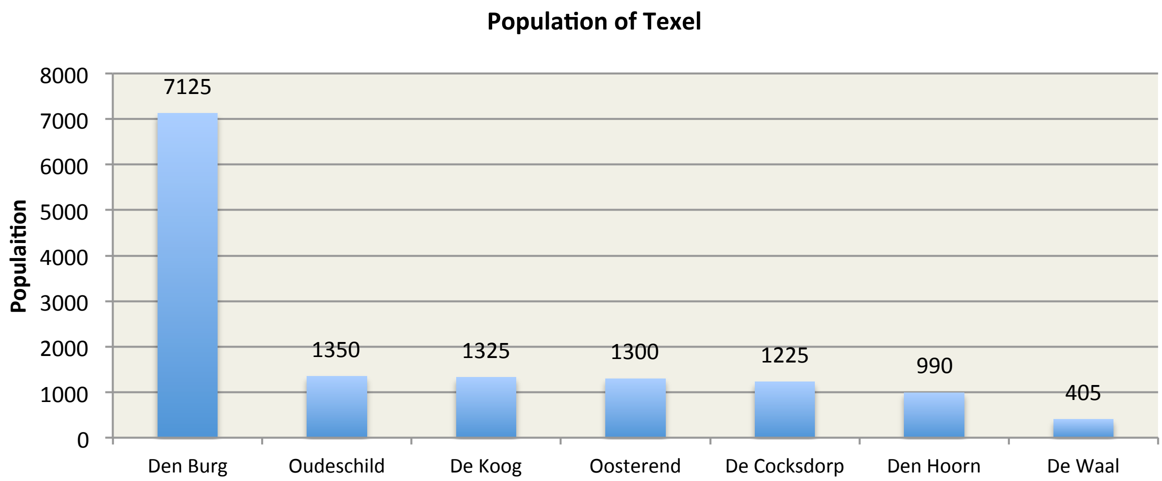


FIGURE 6 – POPULATION OF TEXEL SUBDIVIDED BY VILLAGE

At this moment, the residential housing stock of Texel is 6105 of which 72 percent are privately owned and 28 percent are rented (CBS Statline 2012). About a half is located in Den Burg. The special purpose housing stock is 423, representing complexes and buildings purpose-built for permanent housing by an institutional household, such as retirement homes. Next to the residential and special purpose housing stock, there are 3688 holiday homes on the island of which most are located around De Koog (CBS Statline 2012). In Figure 7, an overview is given of the number of residential homes, special purpose homes and holiday homes on the island. In addition, the age of the residential housing stock is shown. The average age of this stock is 49 years, which is relatively old.

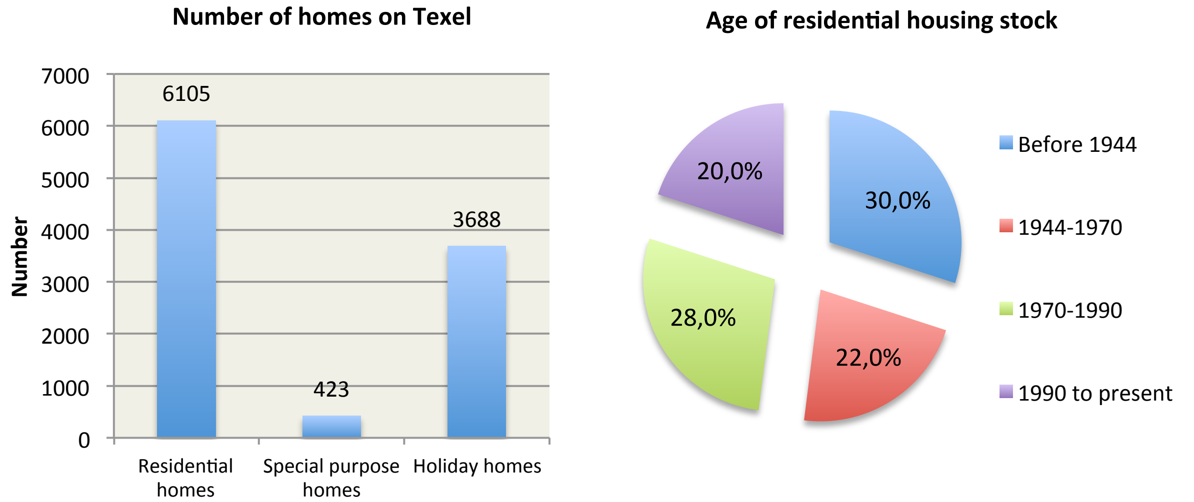


FIGURE 7 – THE NUMBER OF HOMES IN THE MUNICIPALITY OF TEXEL, INCLUDING AGE OF THE RESIDENTIAL HOUSING STOCK

The main economic activities on Texel are agriculture, fishery and tourism. As described in the previous section, most land area is used for agriculture. As a result, relatively many farms are present in the municipal area. Although agriculture and fishery are important economic activities on Texel, tourism is the main source of income. Around 850,000 tourists visit Texel every year, which are responsible for around 5.5 million overnight stays (VVV Texel 2011).

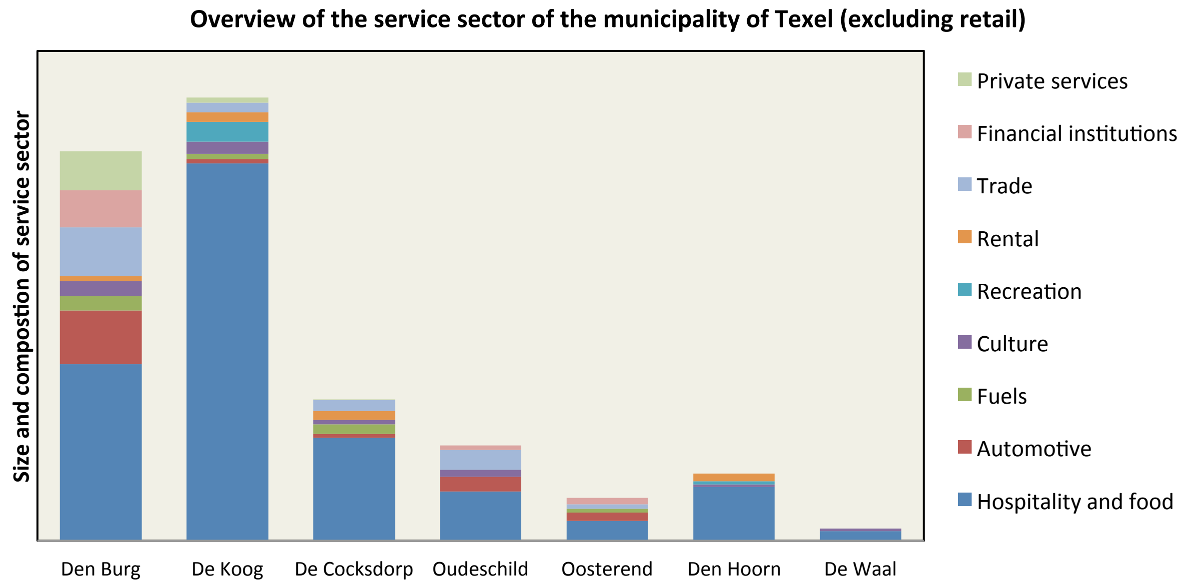


FIGURE 8 – AN OVERVIEW OF THE COMPOSITION OF THE SERVICE SECTOR OF TEXEL BY VILLAGE (EXCLUDING RETAIL)

Den Burg is the economic center of the island. In this village the retail and service sector (excluding hospitality and food) is most strongly represented (Bureau Stedelijke Planning 2009). Approximately

70% of the retail sector is located in Den Burg, which covers an area of around 24 hectares, and approximately 50% of the service sector (excluding hospitality and food). However, the hospitality and food sector is most strongly represented in De Koog, which makes De Koog the touristic center of the island (Bureau Stedelijke Planning 2009). Approximately 50% of all hospitality and food companies on Texel are located in De Koog, which are around 77 companies. Based on data from Bureau Stedelijke Planning (2009), the composition of the service sector of Texel by village is shown in Figure 8. It should be noted that in this figure the retail sector is excluded.

The municipality of Texel has indicated six industrial sites or business parks, which cover an area of 35 hectares (Gemeente Texel 2008a). In these areas both offices and light industry can be present. The locations of these areas are indicated in Figure 9. The largest industrial sites are located in Den Burg and Oudeschild. In Den Burg there are two industrial sites of respectively 9 and 3.5 hectares and in Oudeschild there is one industrial site of 8 hectares. Other industrial sites are located in De Koog, Oosterend and De Cocksdorp, which varies from 2 to 1 hectares. The industrial sites on Texel are relatively small compared to other industrial sites in the Netherlands. The industrial site in Oudeschild has an environmental category of 4 (on a scale from 1 to 6). On this industrial site the waste transfer station 'De Hamster' is located. The other industrial sites have an environmental category of 3. This concludes that in the municipality of Texel no heavy industry is present and that heavy industrial activities cannot take place, which is also indicated in the zoning regulations.

FIGURE 9 – THE MUNICIPALITY OF TEXEL

Texel is connected to the mainland by a ferry that navigates between Den Helder, a city in the north of the province North Holland, and t 'Horntje. At this moment there are two ferries, which can navigate at the same time if needed. Other gateways to the island are Texel International Airport and the harbor of Oudeschild. Texel International Airport is a small airport, which is located between De Koog and De Cocksdorp. Unlike the name suggests, there are no international flights and it is mainly used for sport and sightseeing flights. The harbor of Oudeschild is home to the fishing fleet of Texel, but there is also a marina with 250 berths. The main thoroughfare on the island is the N501, which begins from the ferry terminal and ends in De Koog. In Figure 9, the seven villages, main infrastructures and industrial sites in the municipality of Texel are shown. Furthermore, the national park is indicated, which will be described in detail in the next section.

3.1.3 Natural qualities

Texel has a diverse natural landscape. Texel has forest, dunes, heaths, wide sandy beaches, polders, meadow and marshes. Furthermore, Texel is surrounded by great waters. In particular the dunes on Texel are a great habitat for wildlife, especially for birds. These landscape characteristics have resulted in several protected areas, including a national park, Natura 2000 sites, protected natural monuments, grassland bird habitats and a World Heritage site. The characteristics and boundaries of these areas will be indicated below.

National park

As already is shown in Figure 9, about one third of the island Texel has been declared as protected national park, called Nationaal Park Duinen van Texel. This national park comprises the dune, beach and forest areas on the western side of Texel and the large coastal plains on the northern and southern side of Texel. National Park Duinen van Texel is one of the twenty national parks in the Netherlands. These national parks are characterized by their exceptional landscapes, rare plants and rare animal species. The aim of these national parks is to preserve these characteristics.

Natura 2000 sites

In the municipality of Texel there are three Natura 2000 sites, which are shown in Figure 10 (Ministerie van Economische Zaken, Landbouw en Innovatie 2011a). These sites, including Duinen en Lage Land Texel, Waddenzee and Noordzeekustzone, are part of the Natura 2000. The Natura 2000 is a network of protected areas in the European Union, which is formed from the Birds Directive and the Habitats Directive. The Birds Directive requires the establishment of Special Protected Areas (SPAs) for birds and the Habitats Directive requires Special Areas of Conservation (SACs) to be designated for other species and habitats (Natura 2000 2011). These areas together make up the Natura 2000 sites in the European Union. The aim of this network is to protect vulnerable habitats, which in turn protect the animals and plants in these habitats.

Protected natural monuments

In the Netherlands a protected natural monument is a natural landscape of unique value. There are two protected natural monuments in the municipality of Texel, which are shown in Figure 10 (Ministerie van Economische Zaken, Landbouw en Innovatie 2011a). These sites, including Polder Ceres and Oude Dijk van Waal en Burg, are not covering a large area in the municipality.

Ecological network (EHS)
At this moment natural areas in the Netherlands are very fragmented. To connect and enlarge these areas the government of the Netherlands is working on a construction of an ecological network, also known as Ecologische HoofdStructuur (EHS). This ecological network consists of natural parks, Natura 2000 sites, great waters, agricultural areas with potential for agri-environment, nature development areas and ecological corridors. In the municipality of Texel this network is also present, both on land and water. The ecological network on the island is shown in Figure 10. The great waters around the island are also part of the ecological network.

Key Planning Decision/World Heritage site (UNESCO)
The light blue area in Figure 10, which shows the Natura 2000 site Waddenzee, is also a protected area of the Dutch Wadden Sea, which has been designated in the Key Planning Decision Wadden Sea, 3rd Policy Document Wadden Sea (VROM 2007). The areas under the Key Planning Decision are part of the trilateral cooperation area, which also consists of the German National Parks, the German protected areas under the Nature Conservation Act and the Danish Wildlife and Nature Reserve (Common Wadden Sea Secretariat 2011). In 2009 the Dutch and German areas were added to the UNESCO's World Heritage List.

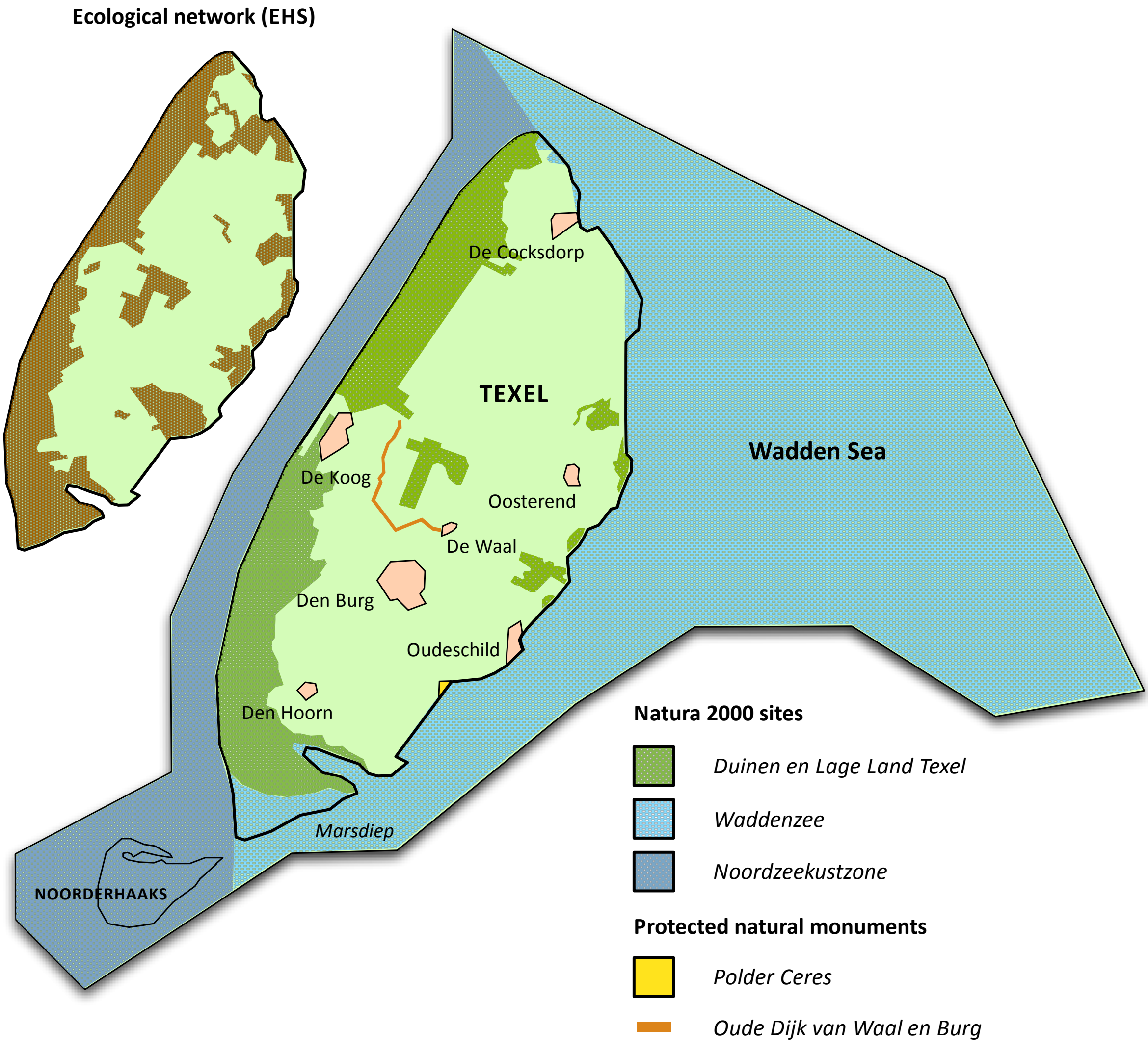


FIGURE 10 – ECOLOGICAL NETWORK, NATURA 2000 SITES AND PROTECTED NATURAL MONUMENTS IN THE MUNICIPALITY OF TEXEL

Grassland bird habitats

In the province of North Holland live many grassland birds, such as the black-tailed godwit and the lapwing. However, in recent years the grassland bird population has declined. Therefore, the province of North Holland has designated grassland bird habitats for protecting these bird species. Based on a GIS viewer of the province of North Holland (2011b), the grassland bird habitats have been identified and are indicated in Figure 11.

FIGURE 11 – GRASSLAND BIRD HABITATS IN THE MUNICIPALITY OF TEXEL

It can be concluded that there are many protected natural areas in the municipality of Texel, which affects the implementation of sustainable energy technologies in the area. To which extent these areas affect the implementation of sustainable energy technologies is described in section 4.4.4.

3.1.4 Soil qualities

The protected areas that have been indicated in the previous section are related to the natural landscape of Texel. There are also other protected areas in the municipality of Texel, which are specifically related to the soil and subsoil characteristics of the area, including geological monuments, archaeological values and groundwater protection areas. Like the natural protected areas, the characteristics and boundaries of these areas will be indicated.

Geological monuments

Geological values are qualities of a landscape, which can say something about the origins of an area or region and the forces that played a role, such as wind, water and ice. To protect these geological values in the Netherlands, provinces have designated many geological monuments. The province of North Holland has also designated several geological monuments in the municipality of Texel. Based on a GIS viewer of the province of North Holland (2011b), the geological monuments have been identified and are indicated in Figure 12. As can be seen, the geological monuments cover a large area of the island.

Archaeological values

Archaeological values are qualities that can say something about the history and bonds that traditionally existed between human activities and the properties of the soil. The province of North Holland has indicated possible locations of archaeological values in the municipal area. Based on a GIS viewer of the province of North Holland (2011d), these possible locations are indicated in Figure 12.

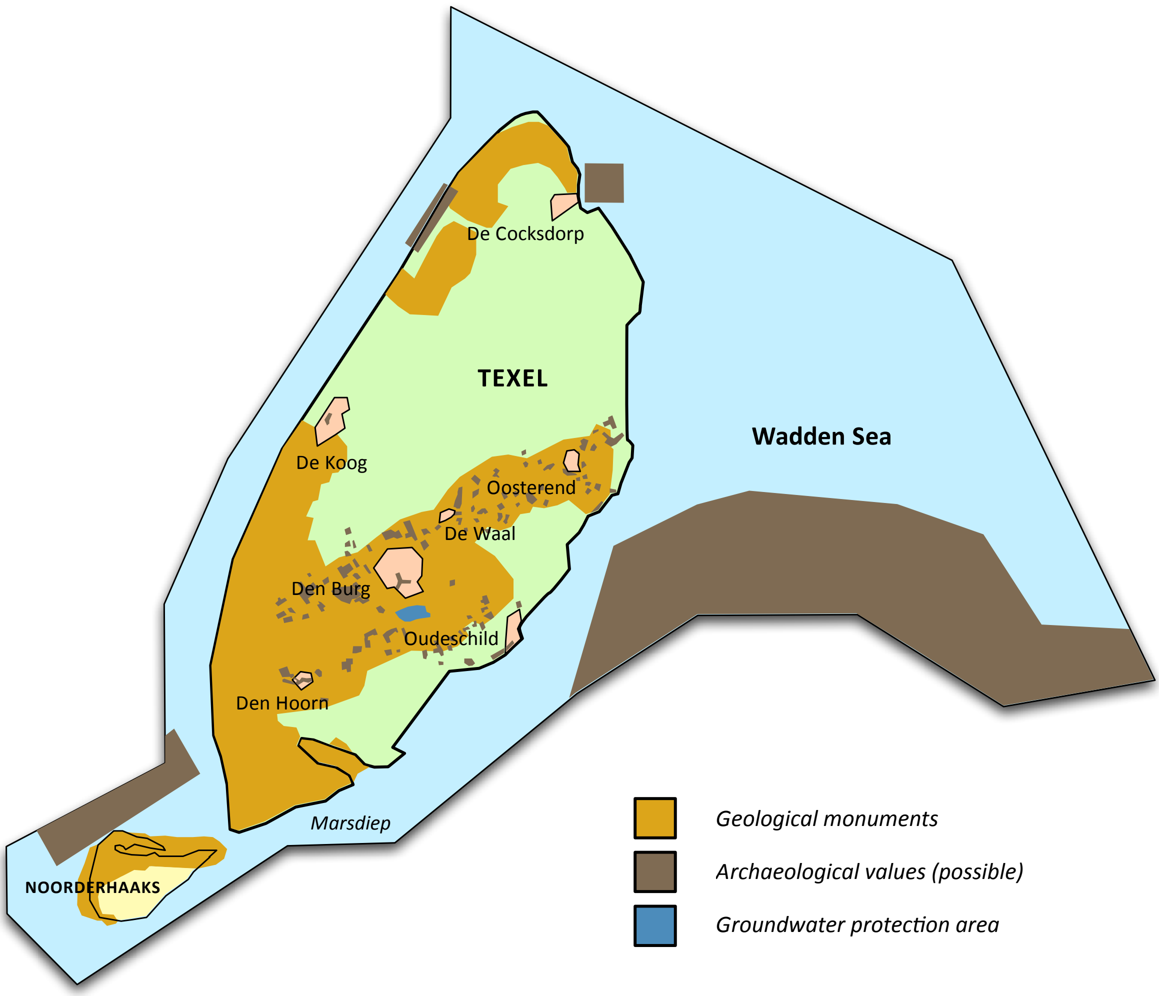


FIGURE 12 – GEOLOGICAL MONUMENTS, ARCHEOLOGICAL VALUES AND GROUND WATER PROTECTION AREAS IN THE MUNICIPAL AREA

Groundwater protection areas

For obtaining fresh water, groundwater is extracted from several areas in the Netherlands. To protect these areas from pollution, provinces have designated groundwater protection areas. The province of North Holland has designated one groundwater ground water protection area in the municipality of Texel, which is located at De Hoge Berg. Based on a GIS viewer of the province of North Holland (2011d), this ground water protection area is shown in Figure 12.

Important to indicate is that soil qualities can affect the implementation of sustainable energy technologies. In section 4.4.4, the consequences for the implementation of sustainable energy technologies in these areas will be given.

3.2 Present energy system

Analyzing the present energy system is an important basis for determining the amount of renewable energy that eventually is needed. First, the current energy supply will be determined in which will be indicated which energy technologies are currently present in the municipal area. Subsequently, the current energy demand will be determined, which will be subdivided by sector.

3.2.1 Energy supply

The current supply of Texel is physically characterized by the supply of electricity and gas through power lines and gas pipes from the mainland to the south of Texel. Alliander, one of the largest network companies in the Netherlands, manages and controls these lines and pipes. Furthermore, fuels are delivered by means of transportation from the mainland. Before the power lines and gas pipes were realized, electricity was generated on the island. In 1927 the municipality of Texel founded a local energy company called Texelsche Elektricteitsmaatschappij (TEM), which was responsible for supplying electricity to all residents of Texel. However, Texel's own electricity supply was expensive, due to many underground infrastructure and few customers. Also, the last diesel power plant, which was located in Oudeschild and at that time operated by the energy company of the province of North Holland (PEN), was not cost-efficient enough. In 1995 it was decided to close the power plant and connect Texel to the mainland (Urgenda 2009).

Although the diesel power plant was closed many years ago, some amount of energy is still generated in the municipal area. Renewable energy sources are responsible for this amount. At this moment there is one wind turbine on Texel, which is located in Oudeschild. Furthermore, solar panels, solar thermal collectors and heat and cold storage systems (combined with geothermal heat pumps) are installed in the municipal area. Based on information from the municipality of Texel and TexelEnergie (Struick 2011; Interview De Graaf 2011), the energy technologies that are currently present have been identified. Using the energy technologies that are currently present, the annual amount of electricity and heat that is generated and the annual amount of natural gas that is saved are determined. The outcomes are shown in Table 3.

TABLE 3 – CURRENT ENERGY SUPPLY IN THE MUNICIPALITY OF TEXEL

Energy technology	**Amount**	**Electricity**	**Heat**	
		GWh	*GWh*	*mil. m^3 of gas (saved)*
Solar panels	4500 m^2	0.47		
Solar thermal collectors	2500 m^2		1.10	0.11
Wind turbines	1	0.65		
Heat and cold storage systems	50	-0.27	0.88	0.09
Total energy supply		0.85	1.98	0.20

For determining the amount of electricity and heat that is generated (in kWh) and the amount of natural gas that is saved (in m^3) per year the following assumptions are used:

- _Solar panels_: For determining the annual amount of electricity that is generated by the solar panels or PV panels, the following data was taking into account: a yearly sum of global irradiation of 1150 kWh/m^2 on Texel, an efficiency of 12% for solar panels and an efficiency loss of 25% for solar systems. In section 3.3.1, the yearly sum of global irradiation will be described in detail. For this sum it is assumed that the solar panels were placed at an angle of 35 degrees towards the south. The choice for an efficiency of 12% has to do with the age of most solar panels on Texel. Although around 1200 m^2 of solar panels recently are installed, of which the efficiency is higher, most of the solar panels are more than 5 years old (Interview De Graaf 2011; ECN 2007). Furthermore, PV systems have an average efficiency loss of 25% (Šúri et al. 2007).
- _Solar thermal collectors_: For determining the annual amount of heat that is generated by the solar thermal collectors, also a yearly sum of global irradiation of 1150 kWh/m^2 was taking into account. According to Broersma et al. (2010), the efficiency of solar thermal collectors is between 33 and 44%. Because most of the solar thermal collectors are more than 5 years old, an efficiency of 38% is assumed. As a result, a solar thermal collector of one m^2 generates 437 kWh of heat or saves around 45 m^3 of natural gas per year (HHV).
- _Wind turbines_: At this moment, there is one wind turbine of 350 kW installed on Texel. Based on a previous study by De Beer et al. (2001), this wind turbine generates approximately 650.000 kWh or 0.65 GWh of electricity per year.
- _Heat and cold storage systems_: The capacity of the geothermal heat pumps will determine the annual amount of heat that can be generated and the annual amount of natural gas that can be saved. But before determining this amount, it should be noted that when using a heat pump the electricity demand will increase. The efficiency of a heat pump is usually expressed in the coefficient of performance (COP), which is the ratio of useful heat movement to work input (MacKay 2009). For example, a COP of 3, which is normal for a geothermal heat pump, means that 1 Joule of electricity generates 3 Joule of heat. Therefore, it can be seen in the table that the amount of electricity generation is indicated with a minus, because electricity is consumed. For determining the annual amount of heat that is generated and the annual amount of natural gas that is saved by the heat pumps, it is assumed that one geothermal heat pump can save the average gas consumption per year of one household and has an average COP of 3. The average gas consumption of one household in the municipality of

Texel is 1800 m^3 (CBS Statline 2012). Furthermore, regarding heat and cold storage, a closed system will be assumed, which will be described in detail in section 3.3.4.

In the next section, the total energy demand in the municipality of Texel will be determined. As should be noted is that the annual amount of natural gas that is saved by the solar thermal collectors and geothermal heat pumps is already drawn from the total gas demand. This also means that the additional amount of electricity per year that is needed by the heat pumps is included in the total electricity demand. Furthermore, the municipality of Texel is also a shareholder of HVC, which is a large waste and energy company that is located in Alkmaar. Waste of the municipality of Texel is brought to HVC where it is combusted in a waste incineration plant and in a biomass combustion plant. The waste incineration plant generates both electricity and heat and the biomass combustion plant generates electricity. However, this is not taken into account in determining the energy supply because this amount of energy is generated outside the municipal area.

3.2.2 Energy demand

Determining the current energy demand is essential for determining the amount of renewable energy that eventually needs to be generated to meet the total energy demand. Based on information from the municipality of Texel (Struick 2011), the total electricity and gas demand of 2009 was 74 GWh and 215 GWh (or 22 million m^3), respectively. For determining the current energy demand, the total energy demand of 2009 will be used. Although the total energy demand of 2010 would have been more recently, the energy demand of 2010 is not available and it is expected that difference between the total energy demand of 2009 and 2010 is minimal. In addition, the total electricity and gas demand of 2009 is very accurately determined by Alliander. Next to the total electricity and gas demand, the total fuel demand is determined. Based on information from the municipality of Texel (Struick 2011), the current energy demand in the municipality of Texel is shown in Table 4, subdivided by sector.

TABLE 4 – CURRENT ENERGY DEMAND IN THE MUNICIPALITY OF TEXEL SUBDIVIDED BY SECTOR

Sector	**Electricity**		**Natural gas***			**Fuel (l)****		
	GWh	*%*	*GWh*	*mil. m^3*	*%*	*GWh*	*mil. liter*	*%*
Households								
- Households	19.21	100	102.76	10.51	100			
Total	19.21	100	102.76	10.51	100			
Agriculture								
- Agriculture	3.08	100	4.69	0.48	100			
Total	3.08	100	4.69	0.48	100			
Industry								
- Industry	1.07	100	2.93	0.30	100			
Total	1.07	100	2.93	0.30	100			
Services								
- Hospitality and food	13.06	26.6	29.24	2.99	28.3			
- Retail	4.50	9.2	4.99	0.51	4.8			

- *Education*	0.26	0.5	0.49	0.05	0.5			
- *Care*	1.09	2.2	3.23	0.33	3.1			
- *Other services (e.g. recreation, culture, trade, financial institutions)*	30.18	61.5	65.41	6.69	63.3			
Total	49.09	100	103.36	10.57	100			
Municipal connections								
- *Municipal connections (e.g. public lighting, sewage)*	1.18	100	1.08	0.11	100			
Total	1.18	100	1.08	0.11	100			
Transport								
- *Motor vehicles*						72.81	7.36	61.4
Gasoline						40.83	4.20	34.5
Diesel						29.58	2.84	24.9
LPG						2.40	0.32	2.0
- *Ferries*						45.83	4.40	38.6
Total						118.64	11.76	100
Total energy demand	73.63		214.82	21.97		118.64	11.76	

* It is assumed that the HHV of natural gas is 35.2 MJ per m^3

** It is assumed that the HHV of gasoline is 35 MJ per liter; HHV of diesel is 37.5 MJ per liter; HHV of LPG is 27 MJ per liter

As can be seen in Table 4, the total energy demand is subdivided in households, agriculture, industry, services, municipal connections and transport. These are then in turn subdivided into subsectors. In Table 4, only the total fuel demand of transport is determined separately. According to Weeda et al. (2007), the amount of fuel that was tanked on the island was 7 million liters in 2006 of which 4 million liters of gasoline, 2.7 million liters of diesel and 0.3 million liters of LPG. In the period from 2006 to 2010, the amount of vehicles in the municipality of Texel is increased much with 10%, while the average number of kilometers traveled per vehicle slightly decreased and the efficiency of internal combustion engines slightly increased (CBS Statline 2012; In Cijfers 2012). Based on these findings, it is assumed that the total amount of fuel that was tanked in 2010 is increased with 5% compared the total amount of fuel that was tanked in 2006. Furthermore, according to TESO (Interview De Waal 2011), which provides the ferry service between Den Helder and 't Horntje, the total fuel consumption of the ferries was 4.4 million liters of diesel in 2010.

In Table 4 and Figure 13, it can be seen that the service sector is responsible for the largest fraction of the total energy demand. In particular, other services have a very high energy demand. Unfortunately, it is not indicated which subsectors, including recreation, culture, trade and financial institutions, are responsible for which part. However, it can be assumed that most of these services are related to tourism. Because of the many tourists that visit Texel each year, there are many holiday homes, hotels, campsites and touristic activities. Also, there are several swimming pools in the municipal area, which have usually a high energy demand. Furthermore, the service sectors trade, automotive and financial institutions are also relatively large compared to other municipal areas with the same population, because also tourists need these services. In addition to other services, the subsectors hospitality and food and retail are also responsible for a high fraction of the total energy demand in the municipal area. These subsectors are also much related to tourism.

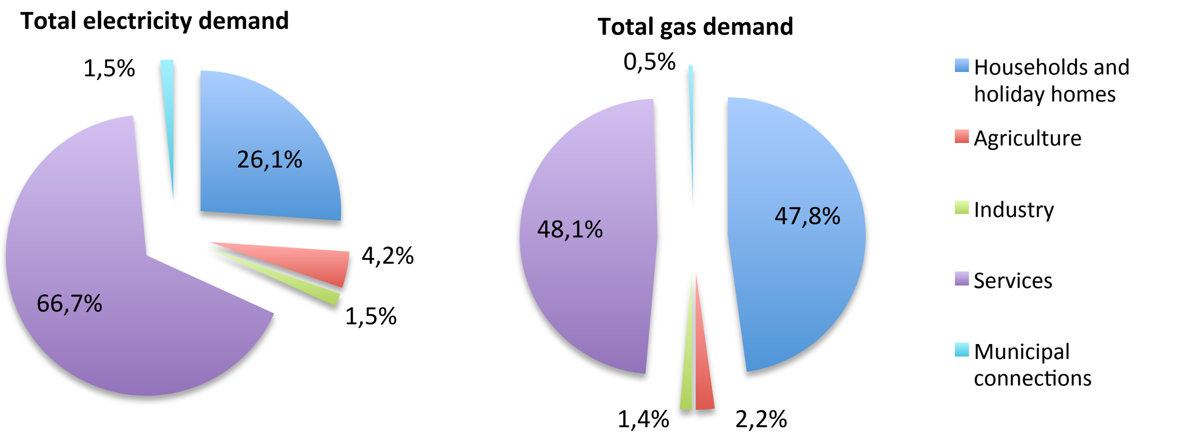


FIGURE 13 – DISTRIBUTION OF THE ELECTRICITY AND GAS DEMAND BY SECTOR

Next to the service sector, households are also responsible for a large fraction of the energy demand, in particular the gas demand as can be seen in Figure 13. Interestingly is that although most land area on the island is used for agriculture, the agriculture sector is responsible for a relatively small fraction of the energy demand. This is because there are not many greenhouses in the municipal area. In general, greenhouses have a high energy demand. The industrial sector is also responsible for a small fraction of the energy demand. This is because there are not many industrial activities and only light industry is present. Moreover, as can be seen in Table 4, the ferry service is responsible for around 40% of the total fuel demand in the municipality of Texel, which is a significant part.

TABLE 5 – CURRENT ENERGY DEMAND SUBDIVIDED BY VILLAGE (FUEL AND MUNICPAL CONNECTIONS EXCLUDED)

Village	**Electricity**		**Natural gas**	
	GWh	*%*	*GWh*	*%*
Den Burg	25.47	35.2	77.73	36.4
Oudeschild	6.20	8.6	14.57	6.8
De Koog	17.17	23.7	46.44	21.7
Oosterend	4.09	5.6	15.84	7.4
De Cocksdorp	9.87	13.6	35.49	16.6
Den Hoorn	8.35	11.5	19.07	8.9
De Waal	1.30	1.8	4.60	2.2
Total energy demand	72.45	100	213.74	100

In Table 5, the total energy demand in the municipality of Texel is shown, subdivided by village. In this table the energy demand of the municipal connections and the total fuel demand are excluded. As can be seen in Table 5, the energy demand is the highest in Den Burg and De Koog. Based on section 3.1.2, this can very well be explained. Den Burg is the economic center of the island in which the retail sector and service sector (excluding hospitality and food) is most strongly represented. Furthermore, about a half of the housing stock of Texel is located in Den Burg. De Koog is the touristic center of the island in which the food and hospitality sector is most strongly represented. Furthermore, most holiday homes on the island are located around De Koog.

Now the total energy demand is determined, it is possible to give an indication of the primary energy consumption. The primary energy consumption is the amount of primary energy that is used to generate the amount of energy that is needed to meet the energy demand. To determine this amount, the average efficiency of power plants is taken into account. Based on Essent (2012), the average efficiency of power plants is 36%. In Table 6, the energy demand is compared to the primary energy consumption.

TABLE 6 – ENERGY DEMAND VERSUS PRIMARY ENERGY CONSUMPTION

Energy demand		**Primary energy consumption**		
	Demand (GWh)	*Gas/biogas (GWh)*	*Coal/wood (GWh)*	*Fuels (l) (GWh)*
Electricity	73.63	204.53		
Gas	214.82	214.82		
Fuels	118.84			118.84

Furthermore, it is important to determine the fractions of the current gas demand that is used for space heating, hot water, cooking and processes. These different types of end-use have different energy requirements, which will be taking into account when developing a sustainable energy system. Based on data from the Dutch government, the municipality of Texel and ECN (Rijksoverheid 2012; Struick 2011; Weeda et al. 2007), these fractions are determined as can be seen in Table 7. Where it should be noted that the gas demand of industrial activities is mainly used for space heating and small processes, such as bakery and construction. In addition, the fractions of the gas demand by end-use in the sectors households, services and municipal connections are assumed to be same. By determining these fractions, the heat demand, which is the actual demand for space and water heating, and the process demand can be determined. For determining the heat demand, it is assumed that boilers have an efficiency of 90%.

TABLE 7 – FRACTIONS OF CURRENT GAS DEMAND BY END-USE AND INDICATION OF HEAT AND PROCESS DEMAND

Sector	**Gas demand**	**Space heating**		**Water heating**		**Cooking**		**Processes**	
	GWh	*GWh*	*%*	*GWh*	*%*	*GWh*	*%*	*GWh*	*%*
Households	102.76	77.07	75	22.61	22	3.08	3		
Agriculture	4.69	1.41	30					3.28	70
Industry	2.93	1.47	50	0.29	10			1.17	40
Services	103.36	77.52	75	22.74	22	3.10	3		
Municipal connections	1.08	0.81	75	0.24	22	0.03	3		
Total demand	214.82	158.28	74	45.88	21	6.21	3	4.45	2
Total heat demand	183.74	142.45		41.29					
Total process demand	10.66					6.21		4.45	

From the total energy demand in the municipality of Texel, it can be concluded that currently a small fraction of renewable energy is generated on the island. Approximately 1.5% of the electricity demand and approximately 1% of the heat demand is currently generated by renewable energy sources.

3.3 Renewable energy potentials

In order to identify which renewable energy sources have a large potential in the municipality of Texel, it is necessary to examine each source separately. For illustrating the potential of each source in the municipal area, a map will be created in which the factors affecting the potential are shown. The renewable energy sources that will be examined are solar energy, wind energy, geothermal energy, heat and cold storage, biomass energy, wave energy and tidal energy. For determining the potential of each source in the municipal area, laws and regulations and investments will not be taking into account. The section ends with a discussion in which the potentials of all renewable energy sources will be compared in order to indicate which sources are interesting in the municipal area.

3.3.1 Solar energy

In general, solar energy refers to the use of solar radiation for practical ends, which also is assumed in this research. However, it should be noted that all renewable energy sources, except geothermal energy and tidal energy, derive their energy from the sun. A distinction can be made between solar radiation that is converted in electricity and solar radiation that is converted in heat. In other words, a distinction can be made between solar power technologies, such as solar panels or photovoltaic panels, and solar thermal technologies, such as solar thermal collectors. Texel is an interesting area when it comes to sunshine. With an average amount of 1650 hours per year, Texel has the highest average amount of sunshine duration in the Netherlands (KNMI 2011a). However, for determining the potential of solar energy, it is needed to determine the yearly sum of global irradiation in the municipal area. With the yearly sum of global irradiation, the amount of energy that can be generated by solar power technologies and solar thermal technologies can be determined. Based on Šúri et al. (2007), a solar map is created in which the yearly sum of global irradiation (in GWh/ha) is indicated. This data was found for solar panels that were optimally inclined. In the Netherlands, the solar panels were placed at an angle of 35 degrees towards the south. The solar map of the municipality of Texel is shown in Figure 14.

The yearly sum of electricity that can be generated by a 1 kW-peak (kWp) PV system can be derived from the yearly sum of global irradiation. PV systems are typically measured in watt-peak (Wp), which characterizes the nominal power output of PV modules at Standard Test Conditions (STC). These conditions are a module temperature of 25°C, a solar spectrum of AM 1.5 and an irradiance of 1,000 W/m^2. However, the output of a PV system is lower than the peak power, even at an irradiance of 1,000 W/m^2 (Šúri et al. 2007). A reason is that the module temperature is often higher than 25°C. Other factors are system losses in inverters and cables and losses due to angular variation. Therefore a performance ratio of 0.75, which means an efficiency loss of 25%, will be taking into account for determining the electricity that can be generated by a 1 kWp PV system. This is also in line with Šúri et al. (2007). As a result, a 1 kWp PV system with a performance ratio of 0.75 that is installed in the municipality of Texel can generate between 860 and 900 kWh of electricity per year, which is also shown in Figure 14. However, it is important to notice that the sum of global irradiation varies by time of the day and season. The sum of global irradiation is much less in December than in May. In December the sum of global irradiation is around 23 kWh/m^2, while the sum of global irradiation in May is around 163 kWh/m^2 (European Commission JRC 2011). For a 1 kWp PV system with a performance ratio of 0.75, this corresponds to 19 kWh of electricity generation in December and 122 kWh in May.

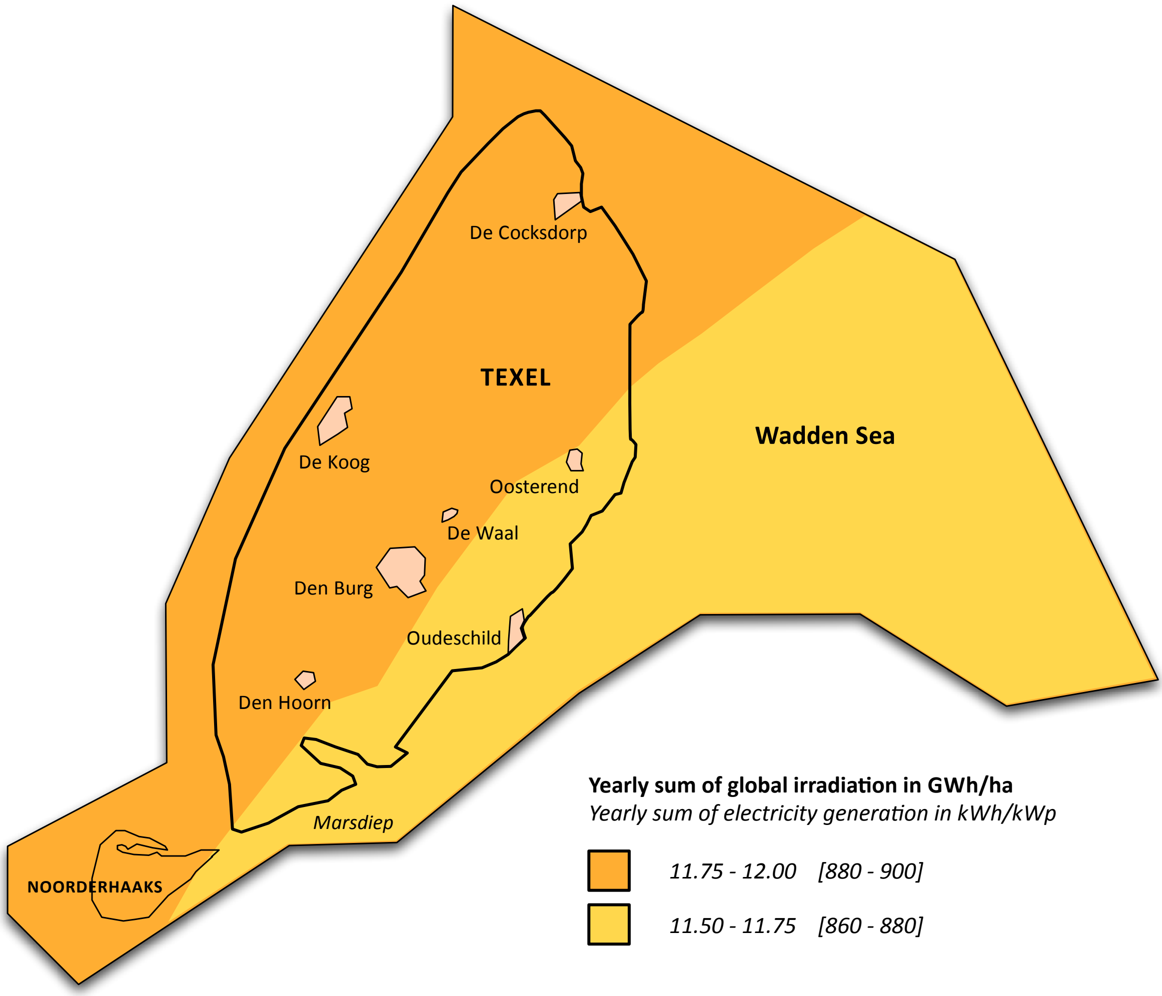


FIGURE 14 – GLOBAL IRRADIATION AND SOLAR ELECTRICITY POTENTIAL IN THE MUNICIPALITY OF TEXEL

Also, the yearly sum of heat that can be generated by a solar thermal collector can be derived from the yearly sum of global irradiation. A solar thermal collector with an area of one m^2 that has an efficiency of 44% can generate between 506 and 528 kWh of heat per year. In other words a standard solar thermal collector of 2.8 m^2 with an efficiency of 44% can save around 150 m^3 of natural gas per year (HHV). This is also in line with Agentschap NL (2011a). In general, the efficiency of solar thermal collectors is between 33 and 44% (Broersma et al. 2010).
According to Šúri et al. (2007), Texel has the highest sum of global irradiation per year in the Netherlands. This makes the municipality of Texel not only the location where the highest average amount of sunshine duration in the Netherlands is registered, but also the location where solar panels and solar thermal collectors can generate the highest sum of energy per year. As a result, Texel is a very interesting location in the Netherlands for installing solar panels and solar thermal collectors in the Netherlands. Based on IEA (2002), an indication of the total available roof area on Texel that can be used for installing solar power technologies can be given. In addition to roofs, this can also be done for façades. Based on the number of residents and the average number of tourists per day (see section 3.1), which is practically equal to the number of residents, the total available area on Texel that can be used for installing solar power technologies can be determined, as can be seen in Table 8.

TABLE 8 – INDICATION OF TOTAL AVAILABLE AREA ON TEXEL THAT CAN BE USED FOR SOLAR POWER TECHNOLOGIES

Total available area				
Buildings	*Roofs (ha)*	*Façades (ha)*	*Suitability PV*	*Suitability thermal*
Residential homes	12.3	4.8	++	++
Agriculture buildings	4.1	0.7	++	-
Industrial buildings	3.4	1.4	++	-
Commercial buildings	6.9	2.7	++	+/-
Other buildings	2.1	0.7	++	-
Touristic accommodations	8.2	3.2	++	++
Total area	37.0	13.5		

Furthermore, as can be seen in Table 8, the suitability of solar panels and solar thermal collectors is also indicated. The suitability indicates to what extent installing solar panels and solar thermal collectors on the building is useful compared to available area. In general, solar thermal collectors are installed where heat is needed directly. Although agriculture and industrial buildings need heat, a relatively small area of the total available area is useful for installing solar thermal collectors.
To illustrate the potential of solar energy when solar power technologies are installed on the total available roof area, an example will be given. In Example 1, it is assumed that 25 hectares of solar panels and 12.5 hectares of solar thermal collectors are installed in the municipal area. Because not every solar panel and solar thermal collector can be placed at an angle of 35 degrees towards the south, it is assumed that the average yearly sum of global irradiation is 20% less than the yearly sum of global irradiation that was found for solar panels that were optimally inclined.

EXAMPLE 1 – POTENTIAL OF SOLAR ENERGY IN THE MUNICIPALITY OF TEXEL

Installation of solar panels and solar thermal collectors on roofs				
	Solar panels		*Solar thermal collectors*	
Basic information				
Total area:	25 ha		12.5 ha	
Yearly sum of global irradiation (35°, south):	11.75 GWh/ha		11.75 GWh/ha	
Average yearly sum of global irradiation:	9.40 GWh/ha		9.40 GWh/ha	
Characteristics				
Efficiency:	14%		44%	
Performance ratio of PV system:	0.75			
Natural gas saved:			150 m^3/2.8 m^2	
Total energy generation		**% of total demand**		**% of total demand**
Yearly sum of electricity generation:	24.68 GWh	34%		
Yearly sum of heat generation:			51.70 GWh	24%
Yearly sum of gas savings (HHV):			5,290,000 m^3	

When Example 1 will be applied around 34% of the current electricity demand and 24% of the current heat demand can be met. However, it should be noted that Example 1 is only an indication of the potential of solar energy in the municipality of Texel. This means that it says nothing about the possibility of realization.

3.3.2 Wind energy

Wind energy is energy that is generated by converting the kinetic energy of air into a usable form, such as electricity. The amount of energy that can be generated by a wind turbine depends on many factors, including wind speed, type (horizontal or vertical axis), number of blades, rotor surface and generator. However, for determining the potential of wind energy in the municipality of Texel the wind speed has to be examined. First, it should be identified which factors affect the wind speed. Based on MacKay (2009), the wind speed depends on the area, altitude, time of the day and season. So is the wind speed higher near the coast than far inland. In addition, the wind speed at 10 meters height differs from the wind speed at 100 meters height at the same location. Furthermore, the time of the day is important because the wind speed by day is often on average higher than at night. The wind speed is also dependent on the season: in the winter is the average wind speed higher than in the summer. To take all factors into account, two wind maps are created in which the average annual wind speed at 10 meters height and the average annual wind speed at 100 meters height are indicated, as can be seen in Figure 15 and Figure 16. These figures are based on data from the Royal Netherlands Meteorological Institute (KNMI 2011b; Stepek et al. 2011).

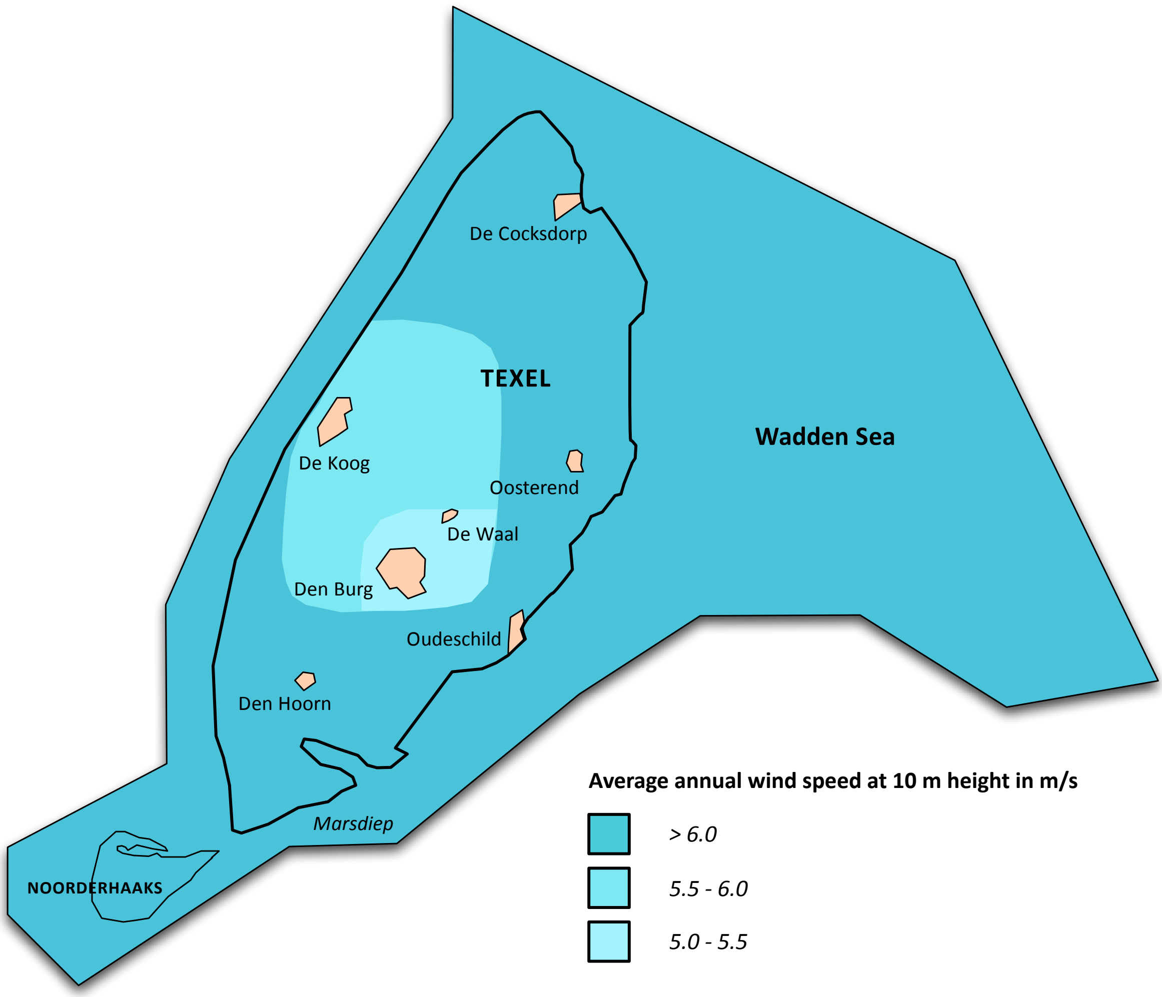


FIGURE 15 – THE AVERAGE ANNUAL WIND SPEED AT 10 METERS HEIGHT IN THE MUNICIPALITY OF TEXEL

There is also another reason for indicating the average wind speed at 10 and 100 meters. A typical wind turbine has a rotor diameter of around 54 meters, a hub height of 80 meters and a capacity between 2 to 3 MW. However, there are also small wind turbines, which are specially developed for use on or near buildings. Small wind turbines have a rotor diameter from around 1 to 10 meters, a hub height of 10 meters and a capacity of around 0.5 to 20 kW. Based on these various wind turbines, it is useful for indicating the average annual wind speed at 10 and 100 meters.

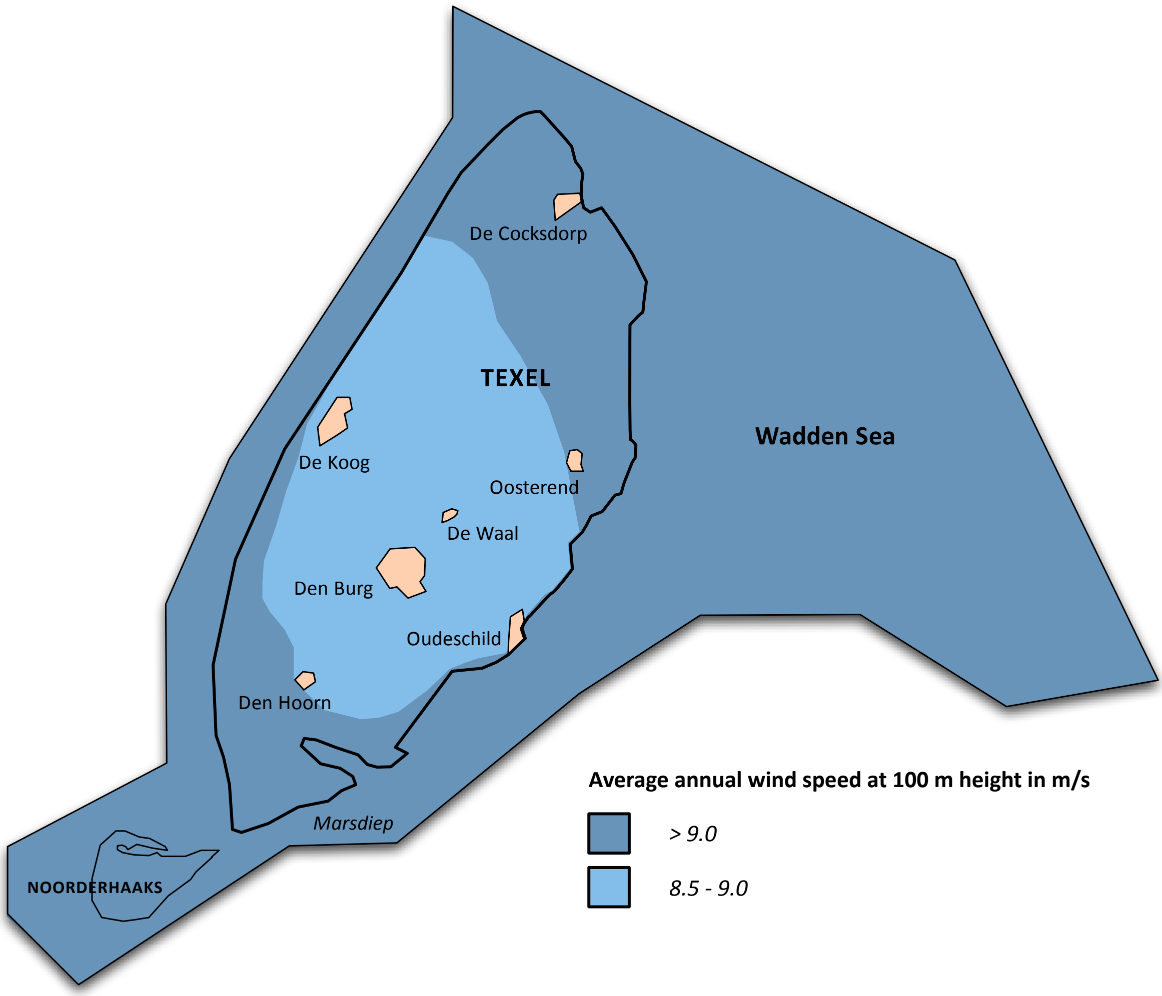


FIGURE 16 - THE AVERAGE ANNUAL WIND SPEED AT 100 METERS HEIGHT IN THE MUNICIPALITY OF TEXEL

The average annual wind speed at 10 meters height and 100 meters height in the municipality of Texel is very high compared to other regions or areas in the Netherlands or in the world. The island can be seen as one of the richest wind areas on land in the Netherlands. Because of the shallow waters in the municipal area, it is also technically possible to place offshore wind turbines. From these findings, it can be concluded that the municipal area of Texel is very interesting location for both onshore and offshore wind turbines. In addition, the amount of wind energy in terms of power is proportional to the cube of the wind speed. As a result, the wind speed can make a big difference in the amount of electricity that can be generated. For example, when the wind speed is two times higher, the electricity generation is eight times higher. However, this is only when the maximum output power not is reached. Most wind turbines have a maximum output at wind speed between 12

and 15 m/s. Furthermore, it should be noted that the larger the rotor diameter is, the more distance between the wind turbines is needed. Based on Hermans (2008), the required distance between wind turbines should be about 3 times the rotor diameter if wind turbines are placed in a row. However, if wind turbines are surrounded by other wind turbines, the required distance is 7 to 10 times the rotor diameter.
Together with the technical data of the wind turbine, the average annual power can be calculated by using the average annual wind speed. In general, the capacity of a wind turbine is given in peak power, which is the maximum amount of electricity that can be generated. However, this says nothing about the average amount of electricity that can be generated. As previously described, the wind speed is dependent on the time of the day and the season, which causes large variations in the wind speed. As a result, wind turbines do not operate full time at peak power. It is possible that the wind speed is to low so that no electricity can be generated or that the wind speed is to high so that the wind turbine has to be stopped to prevent damage. For estimating the average power the load factor, also known as capacity factor, can be taken into account. The load factor is the ratio of the average power to the peak power and is mostly determined by the average wind speed. According to MacKay (2008), the typical load factor in the Netherlands is 22%. However, Weeda et al. (2007) have estimated the load factor at 27% for onshore wind turbines and 34% for offshore wind turbines in the municipality of Texel. These estimations are based on the average annual wind speed in the municipal area. Based on the estimated load factors, the potential of wind energy in the municipality of Texel can be illustrated in an example. In Example 2, it is assumed that 6 wind turbines of 3 MW will be placed in a row both on land and in sea. Each wind turbine has rotor diameter of 90 meters and a hub height of 90 meters. As a result, the required area is 1350 meters.

EXAMPLE 2 – POTENTIAL OF WIND ENERGY IN THE MUNICIPALITY OF TEXEL

Placing 6 wind turbines on the island				
	Onshore		*Offshore*	
Characteristics of the wind turbines				
Rated power:	3 MW		3 MW	
Total power:	18 MW		18 MW	
Required area (one direction):	1350 m		1350 m	
Load factor				
Wind turbines:	27%		34%	
Total energy generation		**% of total demand**		**% of total demand**
Yearly sum of electricity generation:	42.60 GWh	58%	53.60 GWh	73%

When Example 2 will be applied around 58% of the current electricity demand can be met. However, it should be noted that Example 2 is only an indication of the potential of wind energy in the municipality of Texel. This means that it says nothing about the possibility of realization. Furthermore, also the average power of small wind turbines can be calculated. However, small wind turbines will generate proportionally less than onshore wind turbines because of the difference hub height. The load factors of small wind turbines can vary considerably and are less than onshore and offshore wind turbines.

3.3.3 Geothermal energy

Geothermal energy is natural heat that is stored in the earth at a depth of several kilometers. It comes from two sources: from radioactive decay in the crust of the earth and from heat trickling through the mantle from the earth's core (MacKay 2009). Everywhere on earth, the temperature increases with depth. In the Netherlands the temperature increases with an average of 35°C per kilometer on average (Hagedoorn et al. 2009). Geothermal energy is an attractive renewable energy source because it is continuously available and it can be used both to generate electricity and heat. Since Texel has no natural geothermal hot springs, energy has to be derived from ordinary locations in the municipal area. It is therefore necessary to drill deep into the subsoil for deriving this energy. Based on existing knowledge and experience, largely from the oil and gas industry, potential of geothermal energy is often linked to certain types of rock, which have sufficient porosity and permeability and where sufficient water is present (SREX 2011). In these layers, so called aquifers, heat can be extracted with water. Most aquifers are located at depths between 1500 and 4000 meters. In the Netherlands, the average temperature in these aquifers varies between 40 and 120°C (Agentschap NL 2011b). With a temperature of around 95°C electricity can be generated using heat exchangers with working fluid. However, in order to generate electricity using steam turbines, higher temperatures of about 175 to 220°C are needed. This is one of the reasons that much research is currently being done on extracting heat at greater depths of 4000 to 7500 meters (SREX 2011). To be able to extract enough water at these depths, it is necessary to increase holes and cracks in the layer (Hagedoorn et al. 2009). The technique used for this is called hydraulic fracturing. As a result of this relatively new technology, the geothermal potential will also be less dependent on the region or area as is the case when using aquifers.

To determine the potential of geothermal energy in the municipality of Texel, both aquifers and temperatures at great depths are indicated. Based on ThermoGIS (2011), aquifers with geothermal potential for space heating and temperatures at 5000 meters depth are visualized, as can be seen in Figure 17 and Figure 18. In Figure 17, the potential recoverable heat is shown, which is the heat that can be recovered from aquifers per year, unconstrained by techno-economic limitations and irrespective of flow properties (ThermoGIS 2011). Furthermore, this map assumes that 33% of all heat available in the porous and permeable layers between 1500 and 4000 meters is extracted for a total period of 300 years. The heat will be used for space heating, of which a minimum production temperature of 65°C is assumed and a return temperature of 40°C. Furthermore, it is also possible to create a geothermal map for other purposes, such as greenhouses, of which the minimum production temperature is lower. However, these are negligible in the municipality of Texel so this is not done. It should be noted that the heat that can be extracted from these aquifers, could also be used for generating electricity when the temperature is higher than 95°C. Compared to other regions or areas in the Netherlands, the geothermal potential from aquifers is relatively small in the municipality of Texel (ThermoGIS 2011). This is because the potential recoverable heat that can be extracted from aquifers is relatively low. Furthermore, a large area in the municipal area does not have aquifers with geothermal potential, as can been seen in Figure 17. On the island, only the north is eligible for extracting heat.

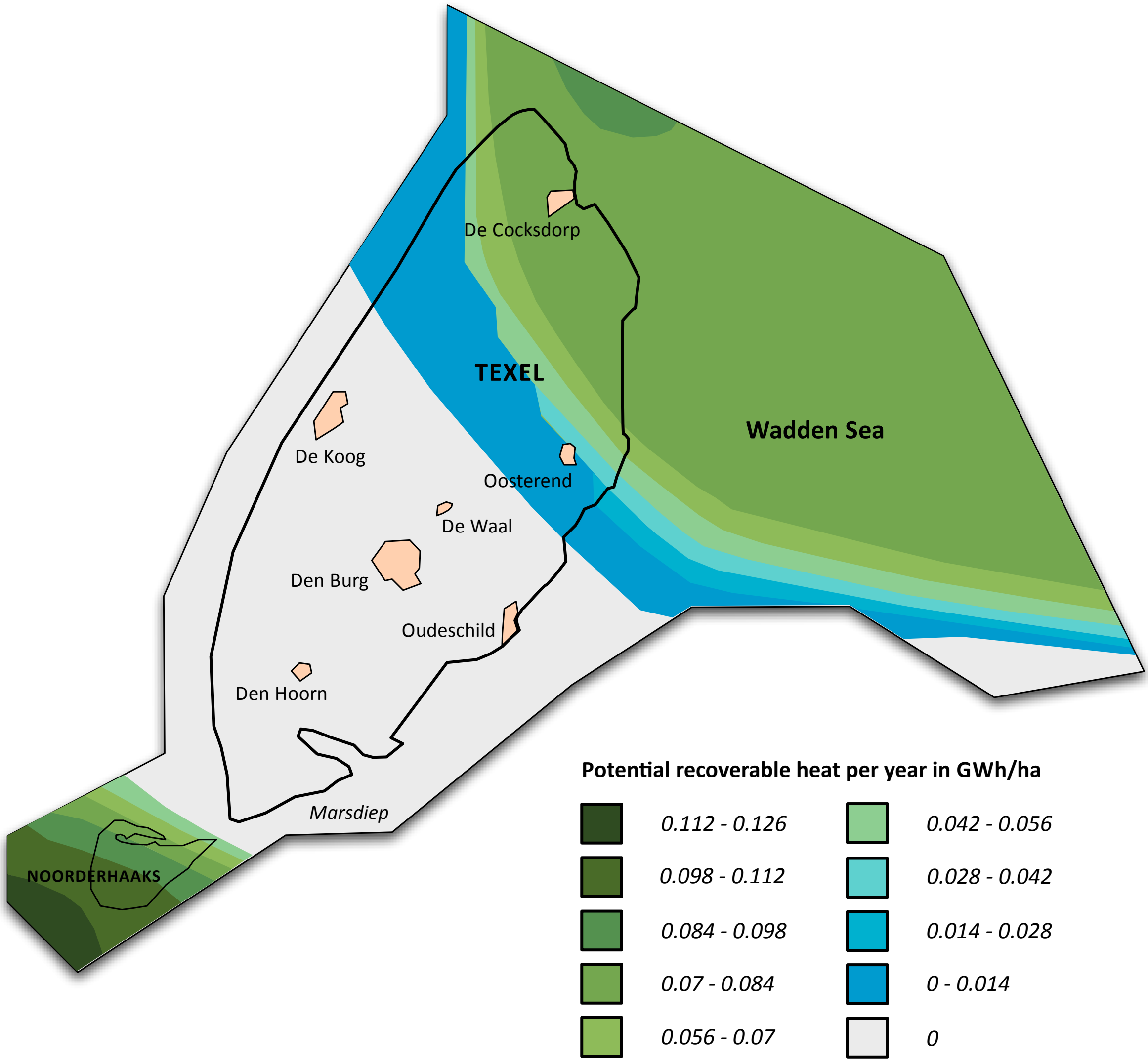


FIGURE 17 – AQUIFERS WITH GEOTHERMAL POTENTIAL FOR SPACE HEATING IN THE MUNICIPALITY OF TEXEL

As can be seen in Figure 18, the temperature at a depth of 5000 meters increases gradually from southwest to northeast in the municipal area. This is because in the western part of the Wadden Sea at this depth the temperature is relatively high compared to other areas in the Netherlands (ThermoGIS 2011). In addition, because the municipal area is close to this relatively hot area, the temperatures at 5000 meters depth are relatively high in the Netherlands. The temperatures that are indicated are high enough for generating electricity using steam turbines. However, in the north of the island the minimum production temperature that is needed can be extracted at a lower depth than in the south of the island. To be able to extract enough water at this depth, the technique hydraulic fracturing needs to be applied. According to Hagedoorn et al. (2009), there are two geological groups suitable for generating electricity in the municipality of Texel: parts of the Limburg Group (90-190°C) and the Lower Carboniferous Limestone Group (>190°C). The Lower Carboniferous Group, which is located at a depth of 5500 to 7000 meters, is the most suitable group for extracting heat that can be used for generating electricity.

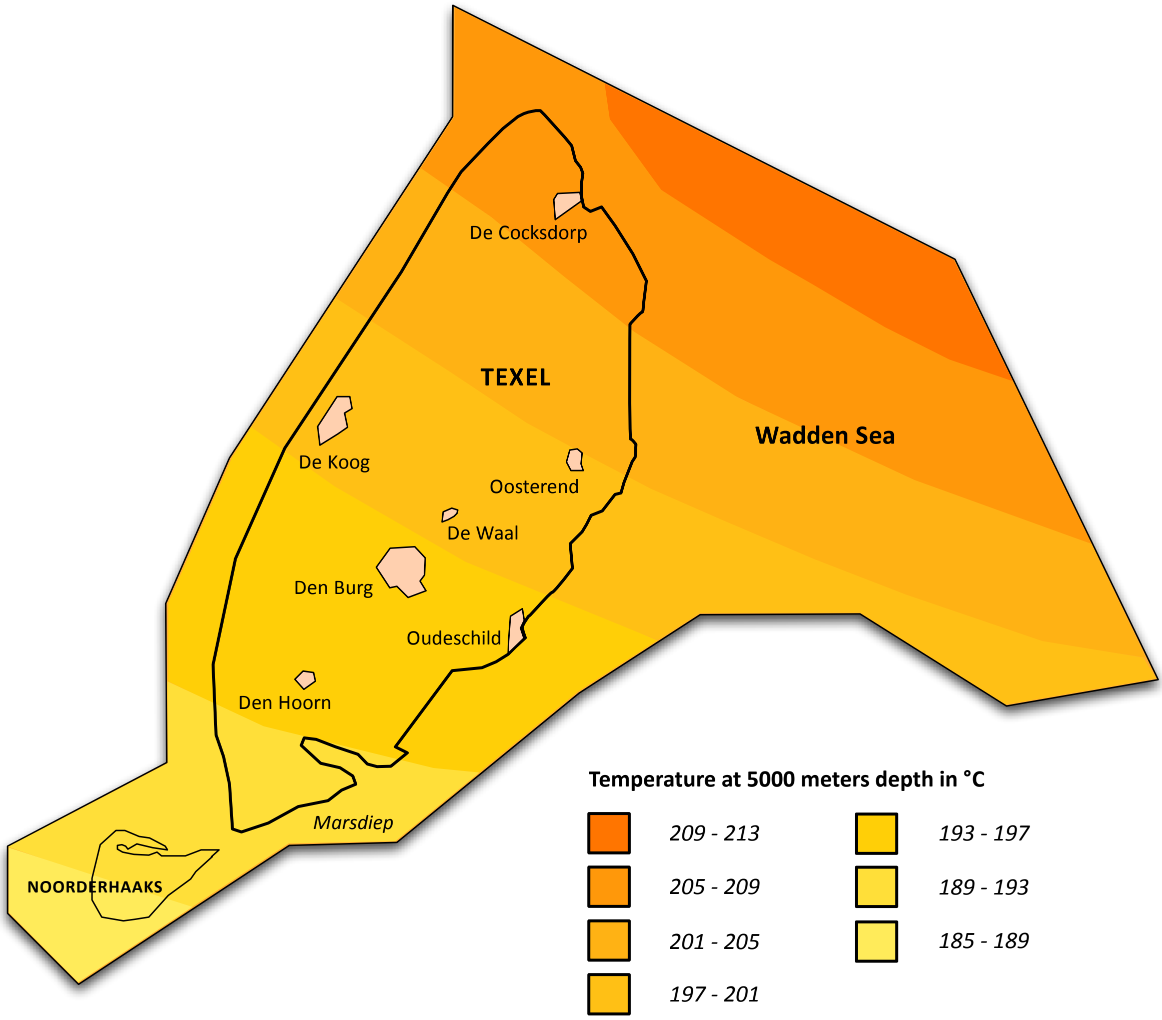


FIGURE 18 – TEMPERATURE AT A DEPTH OF 5000 METERS IN THE MUNICIPALITY OF TEXEL

It can be concluded that the geothermal potential from aquifers in the municipality of Texel is relatively small. However, the temperature at 5000 meters depth is relatively high because of the hot area in the western part of the Wadden Sea. As a result, the geothermal potential from great depths is relatively large. To be able to extract enough water at these depths, it is necessary to increase holes and cracks in the layer using the technique hydraulic fracturing. To illustrate the geothermal potential from the aquifers in the municipal area, an example will be given as is shown in Example 3. In this example it will be determined how much heat can be extracted from aquifers near De Cockdorp. It assumed that a geothermal power plant is extracting heat from one doublet, which is consists of a injection well and production well that are 1500 meters away from each other. From this doublet water is extracted at a flow rate of 150 m^3/h. The temperature of the extracted water is 65°C and the return temperature is 40°C. The heat will be used for space heating. Furthermore, the geothermal plant will operate 5500 hours per year. It should however be noted that electricity is needed for extracting water. In this example a COP of 20 is assumed, which means that 1 Joule of electricity is needed for extracting 20 Joule of heat.

EXAMPLE 3 – POTENTIAL OF GEOTHERMAL ENERGY FROM AQUIFERS IN THE MUNICIPALITY OF TEXEL

Extracting heat from aquifers with one doublet	
Characteristics of subsoil	
Location:	Near De Cocksdorp
Depth:	3000 m
Geological group:	Upper Rotliegend Group
Characteristics of geothermal power plant	
Amount of doublets:	1
Flow rate:	150 m^3/h
Temperature of extracted water:	65°C
Return temperature:	40°C
Operating hours:	5500 h/year
Total heat extracted	
Yearly sum of heat that can be extracted:	24.00 GWh
Yearly sum of electricity that is needed:	1.20 GWh

It should be noted that Example 3 illustrates how much heat can be extracted from aquifers in the municipal area and not the amount of heat that can be generated. This would be less because of efficiency losses in the process. Estimating this amount is also more complex. Furthermore, it is determined how much heat will be extracted per year. However, the extracted heat over time is becoming less because more heat will be extracted than is generated in the earth's core. Suppose that the surface is 450 hectares over which the heat is extracted than the regeneration time will be around 300 years (Broersma et al. 2010). A doublet has an average lifetime of 30 years. This means that in a total period of 300 years ten new doublets have to be constructed, which are distributed over the area.

To illustrate how much electricity and heat can be generated from greater depths, another example will be given as is shown in Example 4. This example is based on a feasibility study that is done by Hagedoorn et al. (2009). In this study it is roughly estimated how much electricity and heat can be generated by a geothermal power plant that extracts heat at a depth of approximately 5500 meters. To be able to extract enough water at this depth, hydraulic fracturing needs to be applied. The heat that is produced by the geothermal power plant is the heat that is released during the generation of electricity. Furthermore, based on IF WEP (2011), it is assumed that a geothermal power plant needs an area of 400 m^2 per GWh of electricity above ground. As a result, the total area that is needed is 1.36 ha.

EXAMPLE 4 – POTENTIAL OF GEOTHERMAL ENERGY IN THE MUNICIPALITY OF TEXEL

Generating electricity and heat by geothermal power plant based on one doublet		
Characteristics of subsoil		
Location:	Near De Cocksdorp	
Depth:	5500 m	
Geological group:	Lower Carboniferous Limestone Group	
Characteristics of geothermal power plant		
Amount of doublets:	1	
Area needed above ground:	Around 1.36 ha	
Applied technology:	2 Organic Rankine Cycle (ORC) units	
Flow rate:	200 m^3/h	
Temperature of extracted water:	200°C	
Temperature of (waste) heat produced:	70°C (that will be used for space heating)	
Return temperature:	40°C	
Total energy generation		**% of total demand**
Yearly sum of electricity generation:	34.00 GWh	46%
Yearly sum of heat generation:	53.00 GWh	25%
Yearly sum of gas savings (HHV):	5,400,000 m^3	

When Example 4 will be applied around 46% of the current electricity demand and 25% of the current heat demand can be met. However, it should be noted that Example 4 is only an indication of the potential of geothermal energy in the municipality of Texel. This means that it says nothing about the possibility of realization. Furthermore, Hagedoorn et al. (2009) indicate that more research is needed because there are still many uncertainties, such as required pumping power, achievable flow rate and the chemical composition of the geothermal water.

3.3.4 Heat and cold storage

Heat and cold storage (HCS) is often considered as geothermal energy. However, there are important differences. Where geothermal energy uses the natural heat that is stored in the earth, heat and cold storage uses the insulating effect of the subsoil (SREX 2011). Heat and cold storage systems are systems that use the earth as heat sink in the summer and as heat source in the winter. For example, heat that is deposited by a cooling system in the summer will be stored in the earth and then used in the winter when heat is needed for space heating. Heat and cold storage systems are almost always used in combination with geothermal heat pumps, or ground source heat pumps (GSHP), for bringing the temperature to the desired height. Wells and boreholes for heat and cold storage systems are usually 50 to 250 meters deep. Aquifers are also used for heat and cold storage. However, where geothermal energy uses aquifers in rocks, heat and cold storage uses shallow aquifers in water-bearing sand layers.

When shallow aquifers are used for heat and cold storage it is called an open system. An open system uses groundwater that will be pumped from the well. In the Netherlands the most applied system is a doublet system (Agentschap NL 2011c). This system consists of two wells: a cold well (heat sink) and a warm well (heat source). In the summer groundwater from the cold well can be used for cooling after which the warmed water will be pumped back into to the warm well. In the winter groundwater from the warm well can be used for space heating. Next to open systems there are also closed systems in which pipes are placed into the earth. In these pipes liquid (antifreeze) will be pumped which can extract heat or cold from the earth. This liquid comes not into direct contact with groundwater. The pipes can be applied both vertically and horizontally, with depths from 20 to 150 meters below ground level. In general, buildings that have a high cooling demand, such as offices and hospitals, use open systems because of the high energy savings on cooling that can be achieved. In practice, energy savings of 80% on cooling and 40% on heating can be achieved (Agentschap NL 2011b). Open systems have a capacity around 0.2 MW to 10 MW. In contrast to open systems, closed systems are mainly used in individual homes. When using closed systems energy savings between 30 and 50% on heating and cooling can be achieved (SREX 2011). Closed systems have a capacity of around 4 kW to 10 kW.

For determining the potential of heat and cold storage in the municipality of Texel, it is needed to examine the subsoil. Although it is difficult to determine the potential of heat and cold storage quantitatively because of the little information that is available, there is information about the suitability of the subsoil for open and closed systems in the municipal area. The main difference between open and closed systems is already described, however, there is also a difference in the suitability of these systems.

Closed systems

Closed systems can technically be used anywhere in the Netherlands. However, the varying subsoil properties can affect the performance of the system (Broersma et al. 2010). Thus, the thermal conductivity of loam and sand layers is much better than clay and peat layers. As a result, tens of percent more pipe length may be needed. In 2001, the suitability of the subsoil for closed systems in the Netherlands has been visualized (IF Technology 2001). In this map, the suitability is examined for pipes that are applied vertically with a depth between 0 to 50 meters below ground level. The suitabilities are qualified in moderate, good and very good. The qualification ‘moderate’ means that 15 to 60% more pipe length is needed compared to ‘good’. In addition, ‘very good’ means that 10 to 30% less pipe length is needed compared to ‘good’. Based on IF Technology (2001), the suitability of closed systems in the municipality of Texel is visualized, as is shown in Figure 19. In this map also groundwater protection areas are taking into account. Although it was previously indicated that laws and regulations would not be taking into account for determining the potential, these areas are also associated with the physicochemical properties of the subsoil. From this map it can be concluded that the suitability of the subsoil for closed systems is very good in and around the villages. Only the suitability in the south of Texel is moderate.

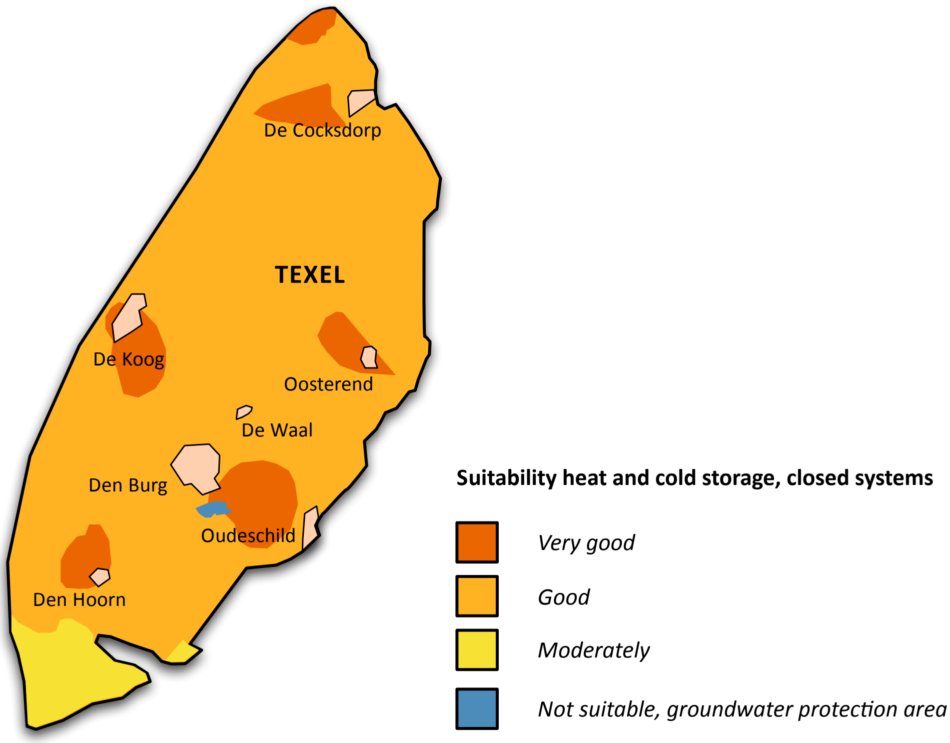


FIGURE 19 – SUITABILITY OF THE SUBSOIL FOR CLOSED SYSTEMS IN THE MUNICIPALITY OF TEXEL

Open systems

Determining the suitability of open systems is more complex. First, it is important to indicate the water-bearing layers, or aquifers, that can be used for heat and cold storage. In general, the first water-bearing layer or shallowest aquifer is less suitable for open systems. The deep water-bearing layers, however, are often very suitable (Provincie Noord-Holland 2009b). Furthermore, for determining the suitability of open systems in the municipal area, it is useful for taking into account the transition areas of brackish and fresh water and groundwater protection areas. Figure 20 shows two maps where a distinction is made between the suitability of open systems in the first water-bearing layer and in deeper water-bearing layers. This figure is based on data of the province of North Holland (2011e). As can be seen, in this figure the suitabilities are qualified in poor moderate, good and very good. These qualifications say something about the performance of the system in that particular area. Open systems that are applied in areas of which the suitability is 'poor' can extract 50% less heat than in areas of which the suitability is 'good'. In addition, the qualification 'moderate' means that between 10 to 30% less heat can be extracted and 'very good' means that between 10 to 30% more heat can be extracted. Furthermore, some areas are not suitable for open systems because of the designation of a groundwater protection area and other areas are not desired because of transition areas of brackish and fresh water. From Figure 20 it can be concluded that the suitability of open systems in deeper water-bearing layers is very good on Texel. However, the suitability of open systems in the first water-bearing layer or shallowest aquifer is moderate.

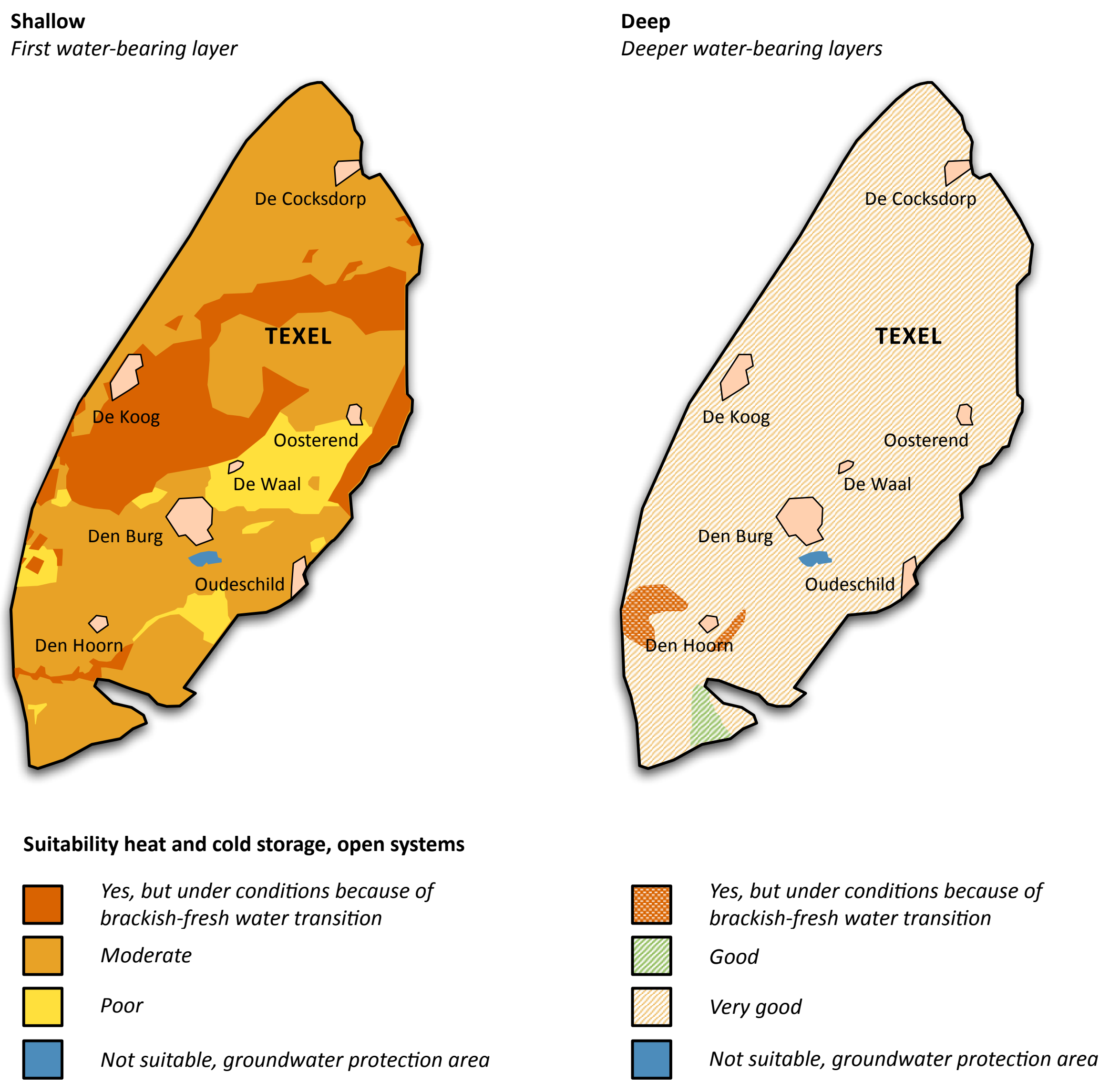


FIGURE 20 – SUITABILITY OF THE SUBSOIL FOR OPEN SYSTEMS IN THE MUNICIPALITY OF TEXEL

As previously described, it is difficult to determine the potential of heat and cold storage quantitatively because of the little information that is available. However, based on the properties of the subsoil it is possible to roughly estimate the energy potential of the subsoil for both open systems and closed systems. According to the heat map of Agentschap NL (2011b), between 1.1 and 1.4 GWh/ha of heat or cold can be extracted per year by open systems. The maximum potential of 1.4 GWh/ha per year can be achieved around Oudeschild. This is relatively high compared to other regions or areas in the Netherlands. Furthermore, between 0.44 and 0.46 GWh/ha of heat can be extracted per year by closed systems and around 0.13 kWh/m^2 of cold. These potentials are also relatively high compared to other regions or areas in the Netherlands. It shall be noted that these potentials are high compared to geothermal energy. However, these potentials are never fully recoverable because many more conditions have to be taking into account when open or closed system will be applied.

3.3.5 Biomass energy

Energy can also be generated from biomass, which is biological material that is derived from living or recently living organisms. Biomass can be used directly, usually by direct combustion, or used indirectly for generating energy. So is it possible to convert biomass into other forms, such as biofuels. The advantage of biomass in comparison to other renewable energy sources is that it can be used for producing transport biofuels, which can substitute gasoline or diesel, and biogas, which can substitute natural gas or LPG. Furthermore, biomass energy can be used when necessary. Biomass can be classified into five basic categories (Biomass Energy Centre 2011):

- *Virgin wood*: wood from forestry or wood processing
- *Energy crops*: high yield crops that can be used for energy applications
- *Agricultural residues*: residues from agriculture harvesting or processing
- *Food and green waste*: waste from food, drink and gardens
- *Industrial waste and co-products*: waste from manufacturing and industrial processes

As can be seen, there a many types of biomass, which all have different properties. As a result, there is a wide range of conversion technologies. These conversion technologies can be distinguished into two methods: thermal conversion and chemical conversion (Biomass Energy Centre 2011). Thermal processes are processes in which heat is dominant mechanism to convert biomass into another form, including combustion, gasification and pyrolysis. In addition, chemical processes can be used to convert biomass into other forms. Often biochemical processes are used in which enzymes of bacteria or other microorganisms are used to convert biomass, including anaerobic digestion, fermentation and composting.

For determining the potential of biomass energy in the municipality of Texel, first it will be examined what types of biomass are available or can be cultivated, which can be used for generating energy and for producing biofuels and biogas. Subsequently, the potentials of the various types of biomass will be determined.

Virgin wood

Once in a while, the forest area in the municipal area has to be thinned for keeping the forest varied and vital. The cut trees can be used for producing wood chips, which can be used for generating energy. In 2009, 16,000 trees were cut down, which are equal to 7000 m^3 of wood (Staatsbosbeheer 2009). If will be assumed that every 20 years 16,000 trees will be cut down then around 350 m^3 of wood is available each year. From this wood, approximately 500 m^3 of softwood chips can be produced. Based on Biomass Energy Centre (2011), the higher heating value (HHV) of softwood chips is around 900 kWh per m^3 dry weight, Using this HHV, the potential of virgin wood can be determined, as can be seen in Table 9.

TABLE 9 – ENERGY POTENTIAL OF VIRGIN WOOD IN THE MUNICIPALITY OF TEXEL

Energy potential of virgin wood per year			
Virgin wood	*Volume (in m^3)*	*HHV (kWh per m^3)*	*Heat (GWh)*
Softwood chips from cut trees	500	900	0.5
Total			0.5

From Table 9, it can be concluded that the potential of virgin wood for generating energy in the municipality of Texel is very low. In addition, it should be noted that this amount can never be fully generated because of losses during combustion.

Energy crops

At this moment, potatoes, wheat, sugar beets and corn are cultivated on Texel. These energy crops can be used for producing bioethanol, which can substitute gasoline, and for generating electricity and heat. However, it is important to indicate that these land-base energy crops are first generation feedstocks, which are controversial because they compete with food crops and valuable land. Because these energy crops can be of importance regarding the required amount of biodiesel and bioethanol, it is decided to determine the biofuel yield of these land-based energy crops and to exclude the energy yields for generating electricity and heat. Based on Kavalov (2004), in which the average biofuel yields of land-based energy crops in the EU-15 were determined, and CBS Statline (2012), the annual biofuel yields are identified in Table 10.

TABLE 10 – BIOFUEL YIELD OF LAND-BASED ENERGY CROPS THAT ARE CULTIVATED IN THE MUNICIPALITY OF TEXEL

Annual biofuel yield of cultivated crops						
Energy crop	*Used area (ha)*	*Biofuel yield (GJ per ha)*	*Biodiesel*		*Bioethanol**	
			GWh	*mil. liters*	*GWh*	*mil. liters*
Potatoes	1,170	82			26.7	4.6
Wheat	950	47			12.4	2.1
Sugar beets	550	145			22.2	3.8
Corn	500	65			9.0	1.4
Total					70.3	11.9

* It is assumed that the HHV of bioethanol is 20.8 MJ per liter

According to Table 10, approximately 70 GWh or 12 million liters of bioethanol can be produced from the amount of potatoes, wheat, sugar beets and corn that is cultivated. However, it should be noted that this is only an indication. In practice, this would be lower because different species within the identified crops are cultivated in the municipal area, most of which are used for food production. Although the amount of bioethanol that can be produced seems relatively high, a very large area in the municipal area is needed.

In addition, other land-based energy crops can also be cultivated on Texel, including rapeseed and sunflowers (Weeda et al. 2007). In contrast to the crops that are already cultivated on the Texel, rapeseed and sunflowers can be used for producing biodiesel. Next to land-based energy crops, also algae can be cultivated in the municipal area. Seaweeds, also known as macroalgae, are a promising source for producing bioethanol and can be cultivated in sea. Seaweeds are a diverse group of organisms that can achieve a length of several millimeters to tens of meters. In optimal growing conditions, the productivity of seaweed is a few times higher than most land-based energy crops. Based on Reith et al. (2005), around 20 tons per hectare of Laminaria (dry weight) can be produced in the North Sea each year. Laminaria is a seaweed specie that is native in the North Sea. Moreover, microalgae can also be cultivated in the municipal area. Microalgae are the most promising source for producing biodiesel and bioethanol and can be cultivated in various ways, including open-pond systems and photobioreactors. Microalgae can produce very large volumes of biofuel per unit of area, particularly in photobioreactors. Bioethanol from algae is possible by converting carbohydrates, while lipids from algae can be converted to produce biodiesel (Oilgae 2012). As a result, in general, microalgae species with a high carbohydrate content are used for producing biodiesel and microalgae species with a high lipid content are used for producing bioethanol. Based on Van den Dobbelsteen et al. (2009c), around 20,000 liters per hectare of biodiesel can be produced. In addition, microalgae can produce 20,000 liter per hectare of bioethanol (Guererro 2010). Based on Kavalov (2004), Reith et al. (2005), Van den Dobbelsteen et al. (2009c), Guerrero (2010) and ECN (2011a), the annual energy yields are determined, as can be seen in Table 11. It should be noted that rapeseed and sunflowers are first generation feedstocks.

TABLE 11 – BIOFUEL YIELD OF ENERGY CROPS THAT CAN BE CULTIVATED IN THE MUNICIPALITY OF TEXEL

Annual biofuel yield of energy crops that can be cultivated						
Energy crop	*Area (ha)*	*Biofuel yield** *(GJ per ha)*	*Biodiesel*		*Bioethanol*	
			GWh	*mil. liters*	*GWh*	*mil. liters*
Rapeseed	1,000	47	13.1	1.4		
Sunflowers	1,000	26	7.2	0.8		
Seaweed (Laminaria)	1,000	140			38.9	6.7
Microalgae (*lipids*)	1,000	650	180.6	20		
Microalgae (*carbohydrates*)	1,000	416			115.6	20

* It is assumed that the HHV of biodiesel and bioethanol is 32.5 and 20.8 MJ per liter, respectively

As can be seen in Table 11, from the land-based energy crops, rapeseed has the highest potential for producing biodiesel. However, a very large area is needed to cultivate enough rapeseed for meeting the demand of biodiesel, which comes at the expense of food crops and valuable land. Algae do not have to compete with food crops and valuable land. Algae can grow both in saline water and freshwater. Furthermore, a fast growth rate can be achieved and the productivity is very high (Guerrero 2010; Wijffels 2010). Another advantage is that the production of algae can be combined with nutrient removal from wastewater. As a result, algae are much more suitable for producing biofuels in comparison to land-based energy crops. It should however be noted that energy is required for both the production of biodiesel and bioethanol. This applies to all energy crops.
Moreover, algae can also be very interesting for generating energy and producing biogas. Based on Reith et al. (2005) and ECN (2011a), the average HHV of seaweed and the amount of biogas per ton is determined. Using these data, the annual heat and biogas yield of seaweed can be determined, as can be seen in Table 12.

TABLE 12 – HEAT AND BIOGAS YIELD OF SEAWEED THAT CAN BE CULTIVATED IN THE MUNICIPALITY OF TEXEL

Annual heat and biogas yield of seaweed						
Energy crop	*Area (ha)*	*Amount ($ton_{dry\ matter}$)*	*HHV (kWh per ton)*	*Biogas production (m^3 per ton_{dm})*	*Heat (GWh)*	*Biogas** *(GWh)*
Seaweed (Laminaria)	1,000	20,000	4200	280	84	34.2

* It is assumed that the HHV of biogas is 22 MJ per m^3

Agricultural residues

Because of the relatively large agricultural sector in the municipality of Texel, many agricultural residues are produced, such as animal manure and wheat straw. Each year, around 95,000 tons of animal manure is produced in stables, which mainly consists of liquid cattle manure (CBS Statline 2012). This animal manure is very suitable for generating energy and biogas. To determine the energy potential of animal manure on Texel, first the high heating value and the amount of biogas per ton will be determined. According to ECN (2011a), the HHV of liquid cattle manure is around 4100 kWh per ton. Because mainly cattle manure is produced on Texel, it is assumed that the average HHV of available animal manure is 4100 kWh per ton. In addition, based on Kool et al. (2005), around 25 m^3 of biogas per ton of liquid animal manure can be produced. These data can be used for determining the amount of heat and biogas that can be generated from the available amount of animal manure on Texel, as can be seen in Table 13.

TABLE 13 – ENERGY POTENTIAL OF ANIMAL MANURE THAT IS PRODUCED IN THE MUNICIPALITY OF TEXEL

Energy potential of animal manure per year					
Residues	*Amount (ton)*	*HHV (kWh per ton)*	*Biogas production (m^3 per ton)*	*Heat (GWh)*	*Biogas (GWh)*
Animal manure	95,000	4100	25	389.5	14.5
Total				389.5	14.5

The amount of available animal manure on Texel can generate around 389.5 GWh of heat, which is a significant amount. However, this amount can never be fully generated because of losses during combustion. In addition, the animal manure can also be used for producing 14.5 GWh or 2.4 million m^3 of biogas. From these findings, it can be concluded that animal manure is an interesting biomass source for generating energy and producing biogas. However, it should be noted that animal manure is very important for fertilizing the agricultural land on the island. In addition, animal manure needs to be imported from the mainland for fertilizing agricultural land on Texel (Interview De Graaf 2011). Therefore, it must be carefully examined how animal manure can be used. Using animal manure in combination with co-substrates, such as wheat straw, in an anaerobic co-digestion process can be a good option. From this process, digestate can be produced that can also be used as fertilizer. Furthermore, more biogas can be produced.

Next to animal manure, large amounts of wheat straw, hay, corn stover, sugar beet leaves and bulb residues are produced in the municipal area. Based on Groten (2006), Rabou et al. (2006), Van der Voort et al. (2006) and CBS Statline (2012), the available amounts of wheat straw, grass, corn stover, sugar beet leaves and bulb residues on Texel are determined, as can be seen in Table 14.

TABLE 14 – INDICATION OF THE AMOUNT OF AGRICULTURAL RESIDUES THAT ARE PRODUCED IN THE MUNICIPALITY OF TEXEL

Amount of agricultural residues produced			
	Area used (ha)	*Production ($ton_{dry\ matter}$ per ha)*	*Amount ($ton_{dry\ matter}$)*
Wheat straw	950	4	3,800
Grass	4,600	12	55,200
Corn stover	500	5	2,500
Sugar beat leaves	550	3	1,650
Bulb residues (wheat, leaves)	310	4	1,240

The residues that are indicated in Table 14 are common in the municipal area. Residues that are produced during the processing of cultivated crops, such as potato peelings and sugar beet tops, are not taken into account. These activities take place outside the municipal boundaries. Based on Kool et al. (2005), Kool 2006, Van der Voort et al. (2006) and ECN (2011a), the HHVs and the amounts of biogas per ton of wheat straw, grass, corn stover, sugar beet leaves and bulb residues (dry matter) are determined. These data are used for determining the energy potentials, as can be seen in Table 15.

TABLE 15 – ENERGY POTENTIAL OF AGRICULTURAL RESIDUES IN THE MUNICIPALITY OF TEXEL

Energy potential of agricultural residues per year					
Residues	*Amount ($ton_{dry\ matter}$)*	*HHV (kWh per ton)*	*Biogas production (m^3 per ton_{dm})*	*Heat (GWh)*	*Biogas (GWh)*
Wheat straw	3,800	5100	340	19.4	6.5
Grass	55,200	5100	300	281.5	101.2
Corn stover	2,500	5000	480	12.5	7.3
Sugar beet leaves	1,650	4700	350	7.8	3.5
Bulb residues	1,240	4900	320	6.1	2.4
Total				327.3	120.9

From Table 15, it can be concluded that the available amounts of wheat straw, grass, corn stover, sugar beet leaves and bulb residues can generate around 327 GWh of heat, which is a significant amount. However, this amount can never be fully generated because of losses during combustion. Furthermore, these residues can produce around 121 GWh or 20 million m^3 of biogas. Moreover, it is also possible to use wheat straw, grasses and corn stover for the production of second generation biofuels. Wheat straw, grasses and corn stover can be used for the production of bioethanol. There is currently much research on generating bioethanol from these crop residues (ECN 2011b). The bioethanol yield of wheat straw, grasses and corn stover, however, will be lower than the energy crops that are described above.

Food and green waste

Food and green waste can also be used for generating energy and producing biogas. Every year, an amount of food and green waste is disposed in the municipal area. This waste can be distinguished in biodegradable municipal waste, also known in the Netherlands as GFT, and bulky green waste, which is waste that is too large to be accepted by the regular waste collection, such as trunks. In 2010, around 1,500 tons of GFT was disposed (HVC 2011; CBS Statline 2012). Furthermore, in 2010, 1,500 tons of bulky green waste was disposed on Texel. Based on ECN (2011a), the average HHV of Dutch GFT and bulky green waste is determined on 2700 and 3100 kWh per ton, respectively. In addition, around 100 m^3 of biogas per ton of GFT can be produced (Agentschap NL 2011e). In contrast to GFT, bulky green waste is not suitable for the production of biogas. In Table 16, the energy potential of food and green waste is indicated. From Table 16, it can be concluded that the potential of food and green waste for generating energy and producing biogas is relatively small. According to HVC (2011), the total amount of GFT of the municipality of Texel has generated approximately 1.4 GWh of electricity in 2010.

TABLE 16 – ENERGY POTENTIAL OF FOOD AND GREEN WASTE IN THE MUNICIPALITY OF TEXEL

Energy potential of food and green waste per year					
Food and green waste	*Amount (ton)*	*HHV (kWh per ton)*	*Biogas production (m^3 per ton)*	*Heat (GWh)*	*Biogas (GWh)*
GFT	1,500	2700	100	4.1	0.9
Bulky green waste	1,500	3100		4.7	
Total				8.8	0.9

Industrial waste

Because not many industrial activities take place in the municipality of Texel and only light industry is present, there is not much industrial waste. Industrial waste that may be useful for generating energy or producing biogas is sewage sludge. At this moment, there is one wastewater treatment plant between Den Burg and De Koog, which is called 'Evertsekoog'. Based on HHNK (2012), this plant treats 2.4 million m^3 of wastewater. In addition, 1 ton of sewage sludge (25% dry matter) can be produced from 1200 m^3 of wastewater (Broersma et al. 2011). As a result, 2,000 tons of sewage sludge is produced at the wastewater treatment plant each year. Based on Broersma et al. (2011) and ECN (2011c), the energy potential of sewage sludge is determined, as can be seen in Table 17.

Moreover, although it is not really industrial waste, unwanted seaweed in fishing nets can also be allocated to industrial waste. If this seaweed can be collected and brought to shore, seaweed can be used for generating energy and for producing biogas or bioethanol (Interview Van Rijsselberghe 2011). Unfortunately, it is unknown how much seaweed each time by a fishing boat is collected. Since the fishing fleet of Texel is relatively small, it can be assumed that the potential of collected seaweed for generating energy and for producing biogas or bioethanol is very small.

TABLE 17 – ENERGY POTENTIAL OF INDUSTRIAL WASTE IN THE MUNICIPALITY OF TEXEL

Energy potential of industrial waste per year					
Industrial waste	*Amount (ton)*	*HHV (kWh per ton)*	*Biogas production (m3 per ton)*	*Heat (GWh)*	*Biogas (GWh)*
Sewage sludge	2,000	4200	140	8.4	1.7
Total				8.4	1.7

Total biomass energy potential

Now all available types of biomass on Texel are identified and the energy potentials for each are determined, the total potential of biomass energy can be determined. In Table 18, an overview is given of the energy potentials of the various types. From this table, it can be concluded that the total potential of biomass energy in the municipality of Texel is large. Biomass can be an interesting renewable energy source for achieving energy self-sufficiency. In addition, the identified types of biomass can be stored and used when necessary. As a result, biomass can assist other renewable energy sources that are not continuously available.

Agricultural residues are the most interesting source because large amounts are available in the municipal area. These agricultural residues can be interesting for generating energy and producing biogas. However, it should be noted that animal manure is very important for fertilizing the agricultural land on the island. As a result, it must be carefully examined how animal manure can be used. The best option would be to use animal manure in a co-digestion process for producing biogas and digestate, which can replace the animal manure as fertilizer. This biogas can be used in a

Combined Heat and Power plant (CHP) for generating energy. Furthermore, energy crops that are currently cultivated on Texel can be of importance when renewable transport fuels are required. However, there is a considerable amount of land area needed, which comes at the expense of food crops and valuable land. It is also important to notice that energy is needed for both the production of biodiesel and bioethanol. Next to crops that are currently cultivated on the island, also other energy crops can be cultivated. Algae are the most interesting source, which can be very useful for producing biofuels. Moreover, although the potential of virgin wood, food and green waste and industrial waste for generating energy is relatively low, it is easy to use.

TABLE 18 – POTENTIAL OF BIOMASS ENERGY IN THE MUNICIPALITY OF TEXEL

Energy potential of available biomass per year				
Biomass form	*Heat (GWh)*	*Biogas (GWh)*	*Biodiesel (GWh)*	*Bioethanol GWh)*
Virgin wood	0.5			
Energy crops				70.3
Agricultural residues	716.8	135.4		
Food and green waste	8.8	0.9		
Industrial waste	8.4	1.7		
Total	734.5	138.0		70.3

To illustrate the potential of biomass energy using agricultural residues in the municipality of Texel, an example will be given. Example 5 is based on Oei et al. (2007) and HOST (2011) in which is estimated how much electricity and heat can be generated by an anaerobic co-digestion plant and a small digestion plant. In these plants biogas is produced that is used for generating electricity and heat using a CHP. Both plants can be built next to a farm.

EXAMPLE 5 – POTENTIAL OF BIOMASS ENERGY IN THE MUNICIPALITY OF TEXEL

Anaerobic (co-)digestion				
	Anaerobic co-digestion plant		*Small digestion plant*	
Biomass input				
Animal manure (liquid):	29,630 tons		3,800 tons	
Co-substrates:	27,812 tons			
Characteristics of plant				
Digester volume:	3000 m^3		120 m^3	
Energy technology:	CHP		CHP	
Electric power:	1333 kW		62 kW	
Thermal power:	2000 kW		86 KW	
Operating hours:	8000 h/year		6000 h/year	
Total energy generation		**% total demand**		**% total demand**
Yearly sum of electricity generation:	10.50 GWh	14%	0.37 GWh	0.5%
Yearly sum of heat generation:	10.00 GWh*	5%	0.29 GWh*	0.1%
Yearly sum of gas savings:	1,000,000 m^3		30,000 m^3	

* This is the net amount of heat generation, it is assumed that 40% of the heat produced is used in the process itself

When Example 5 will be applied around 14% of the current electricity demand and 7% of the current heat demand can be met. However, it should be noted that Example 5 is only an indication of the potential of biomass energy in the municipality of Texel. This means that it says nothing about the possibility of realization.

3.3.6 Wave energy

Wave energy is energy that is obtained from harnessing the energy of ocean waves. Oceans are an enormous source of energy. When wind stirs ocean waves continually, these waves can become quite high and lot of energy can be stored in these waves (Hermans 2008). This is because waves lose little energy in deep water. To generate energy from ocean waves, different technologies can be used, which can be categorized by location and method. So is it possible to generate energy from ocean waves at open sea (offshore), near the coastline (nearshore) or at the coastline (shoreline). Furthermore, many method types can be used, including buoy, oscillating water column and overtopping (Hermans 2008). Typical wave energy technologies will generate energy with wave heights between 1.5 and 7 meters.

The potential of wave energy in the municipality of Texel is dependent on the height of the ocean waves on the west side of the island. This wave height is determined by the wind speed on the North Sea. With this in mind, it can be thought that Texel could be an interesting location for generating energy from ocean waves. However, England is too close so that the wind has not enough space for generating high waves. According to Beels et al. (2007), the average height of the ocean waves near Texel is around 1.75 meters. Furthermore, the significant wave height smaller than 1 meter occur 40% of the time. In general, the potential of wave energy in the North Sea is relatively small compared to potential of wave energy in front of the West European coast, which is 40 to 50 kW per meter (Beels et al. 2007). According to the measurement location 'Eierlandse Gat', which is the closest to Texel, the average annual available wave power is 9.9 kW per meter. The municipal boundary of Texel is around 2 kilometers from the coast, which means that energy only can be generated near the coast or at the coastline. Furthermore, the water at the west side of Texel is shallow, the water depth does not exceed 5 meters as can be seen in Figure 21. As a result, waves that passed 'Eierlandse Gat' have lost energy. From these findings, it can be concluded that the potential of wave energy in the municipality of Texel is very small.

TABLE 19 – POTENTIAL OF WAVE ENERGY IN THE MUNICIPALITY OF TEXEL

Energy potential of waves near Texel			
Location	*Annual available wave power (kW/m)*	*Mean water depth (m)*	*Shortest distance to shore (km)*
Eierlandse gat	9.9	26	31
Near the coast of Texel	Very low	5	2

To illustrate the potential of wave energy in the municipal area, an example will be given. In Example 6, it is assumed that wave energy technologies will be installed near the northwest coast of Texel. These technologies cover an area of 1000 meters and operate 2000 hours per year. Furthermore, it is assumed that the average annual available wave power is 6 kW per meter.

EXAMPLE 6 – POTENTIAL OF WAVE ENERGY IN THE MUNICIPALITY OF TEXEL

Installing wave energy technologies near the northwest coast of Texel		
Characteristics of wave energy technologies		
Required area:	1000 m (one direction)	
Efficiency:	20%	
Operating hours:	2000 h/year	
Characteristics of the ocean waves:		
Average annual available wave power:	6 kW/m	
Total energy generation		**% of total demand**
Yearly sum of electricity generation:	2.4 GWh	3%

When Example 6 will be applied around 3% of the current electricity demand can be met. However, it should be noted that Example 6 is only an indication of the potential of wave energy in the municipality of Texel. This means that it says nothing about the possibility of realization. The load factor can also be used for estimating the amount of energy generation. However, until now there is not much knowledge about the possible load factor of wave energy technologies in the North Sea. Since the potential of wave energy in the North Sea is relatively small, it can be concluded that the load factor is also relatively low.

3.3.7 Tidal energy

Tidal energy is energy that is obtained from converting the energy of tides. Compared to solar, wind and wave energy, tidal energy is interesting because of its predictability. Tides are the rise and fall of sea levels that are caused by the gravitational forces exerted by the Moon and the Sun and the rotation of the Earth. In general, areas in the ocean experience two high tides and two low tides each day. When the Moon and the Sun are in line with each other (full moon and new moon), the difference in height between high and low water is at its maximum. This is called the spring tide. Furthermore, there are also neap tides. At that moment the difference in height between high and low water is at its minimum. Due to the changing sea levels oscillating currents will be produced, also known as tidal currents. Energy can be generated from the difference in height and from tidal currents. Tidal energy can be classified into three generating methods: tidal stream generator, tidal barrage and dynamic tidal power (MacKay 2009). A tidal stream generator makes use of tidal current velocities and produces energy in similar way as wind turbines. Because water has a much higher density than air, energy generation can be more compact and at a low rotor speed. A typical tidal stream generator has a rated power between 100 and 500 kW and generates energy when the tidal current velocity is between 0.5 and 7 m/s. Furthermore, the water depth needs to be at least 5 meters or more. A tidal barrage makes use of the difference in height. Water will be let in and out at the ideal times and generate energy using turbines. Furthermore, dynamic tidal power combines both the difference in height and tidal current velocities. For applying dynamic tidal power, dams will be built in the sea, perpendicular to the coast. Making these dams very long (30 to 60 kilometers), the dams can affect the tidal movement. Using the difference in height over both sides of the dam, energy can be generated by turbines that are installed in the dam.

The potential of tidal energy is dependent on the tidal range and tidal current velocities in the area. If the tidal range is large and the tidal current velocities are high in a specific area than the potential of tidal energy in that area is large. In the Netherlands, the tidal range is small. Around Den Helder the tidal range is approximately 1 meter (Deltares 2008). As a result, tidal barrages and dynamic tidal power are not very suitable in the municipality of Texel. However, estuaries or tidal inlets in the Netherlands could be interesting because of the available tidal current velocities. In the municipality of Texel, the Marsdiep and Texelstroom can be interesting (De Vries 2011). The Marsdiep is a deep estuary between Den Helder and Texel and Texelstroom is a marine channel in the southeast of Texel. Both are shown in Figure 21. In the municipal area, the Marsdiep and Texelstroom have the highest tidal current velocities and a sufficient water depth. According to De Vries (2011), the maximum tidal current velocities are around 1.8 m/s, which can be reached during spring tide. However, this is only for a short period of time during a tidal cycle and only at the surface. The maximum tidal current velocities at average depth are between 1 and 1.5 m/s. It should be noted that the indicated velocities are site specific. From the available tidal current velocities, it can be concluded that the potential of tidal energy in the municipality of Texel is relatively small. For generating energy using tidal stream generators, higher tidal current velocities are desirable (Deltares 2008). As with wind turbines, the amount of energy that can be generated by tidal stream generators is proportional to the cube of the tidal current velocity. As a result, a small difference in the tidal current velocity can have a large impact on the amount of energy that can be generated.

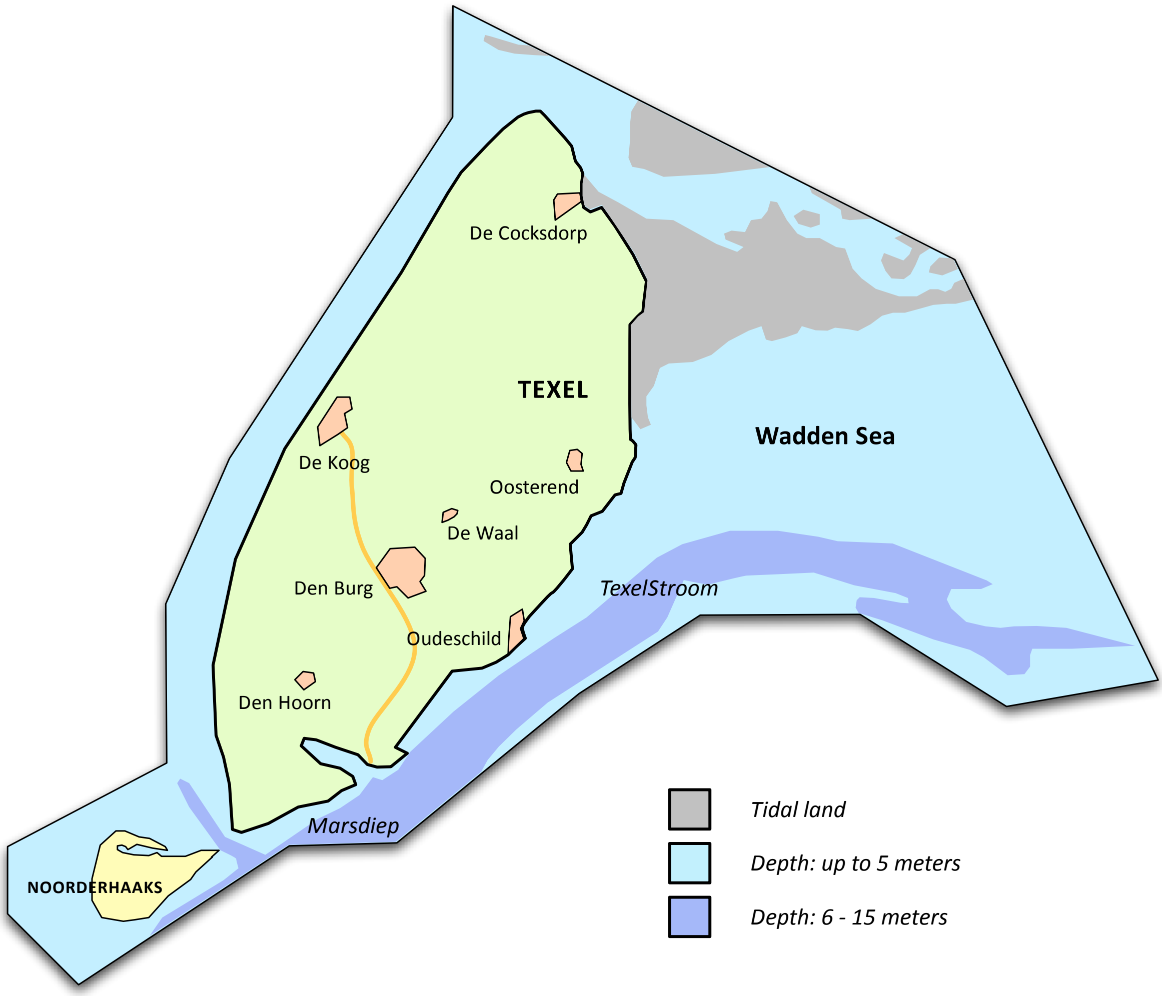


FIGURE 21 – THE WATER DEPTH AND THE MARSDIEP AND TEXELSTROOM IN THE MUNICIPALITY OF TEXEL

To illustrate the potential of tidal energy in the municipality of Texel, an example will be given. It is assumed that 10 tidal stream generators with a rotor diameter of 10 meters will be installed on a floating platform in the Marsdiep. In addition, a load factor of 15% is assumed, based on an average tidal current velocity of 1.5 m/s. Furthermore, it is assumed that the required distance between the tidal stream generators is 3 times the rotor diameter.

EXAMPLE 7 - POTENTIAL OF TIDAL ENERGY IN THE MUNICIPALITY OF TEXEL

Installing 20 tidal stream generators in the Marsdiep		
Characteristics of the wind turbines		
Rated power:	100 kW	
Total power:	1000 kW	
Length of floating platform:	270 m	
Load factor		
Tidal stream generators:	15%	
Total energy generation		**% of total demand**
Yearly sum of electricity generation:	1.31 GWh	2%

When Example 7 will be applied around 2% of the current electricity demand can be met. However, it should be noted that Example 7 is only an indication of the potential of tidal energy in the municipality of Texel. This means that it says nothing about the possibility of realization. Furthermore, there is currently much research being done on tidal current velocities in the Marsdiep (De Vries 2011). As a result, up to now there is not much knowledge about the possible load factor of tidal stream generators in the Marsdiep.

3.3.8 Conclusion and discussion

From all the renewable energy sources that are examined in the municipality of Texel, several conclusions can be drawn. In order to indicate which forms of renewable energy are interesting in the municipal area for achieving energy self-sufficiency, an overview will be given of both the electricity and heat potential of the renewable energy sources that are examined. But first, the renewable energy sources will be discussed separately. Solar energy is very interesting for generating both electricity and heat in the municipality of Texel. Texel has the highest sum of global irradiation per year in the Netherlands. Therefore, solar power technologies can generate a large amount of electricity and heat. However, where solar panels can easily be installed anywhere on the island, solar thermal collectors have some restrictions. In general, solar thermal collectors are placed where the generated heat can be used directly, because it is not practical to transport the generated heat over large distances, unlike electricity. The available area on Texel that can be used for installing solar panels is therefore higher than the area that can be used for installing solar thermal collectors. As a result, the electricity potential of solar energy in the municipal area is somewhat larger than the heat potential. In addition to solar energy, wind energy is also very interesting. Texel can be seen as one of the richest wind areas on land in the Netherlands. Also on global scale, the annual average wind speed is very high. As a result, wind turbines can generate a very large amount of electricity. Furthermore, it is technically possible to place wind turbines on land and sea in the municipality of Texel. From these findings, it can be concluded that the electricity potential of wind energy is very large.

The electricity and heat potential of geothermal energy in the municipal area is moderate. This is because the geothermal potential from aquifers in the municipality of Texel is relatively small, while the geothermal potential from greater depths (around 5000 meters) is relatively large due to the high temperatures. An important observation is that when a geothermal power plant will be built that is extracting heat from aquifers, this plant can only be built in the north of the island because of the available aquifers in that area. In addition, the best location to built a geothermal power plant that is extracting heat from greater depths is also in the north of the island. Unfortunately, the villages Den Burg and De Koog, which have the highest energy demand, are located in the middle of Texel. Furthermore, the heat potential of heat and cold storage is very large in the municipal area due to the good subsoil characteristics. From the created maps in which the suitability of heat and cold storage systems are visualized, it can be concluded that the suitability of closed systems is good to very good on the island. Especially in and around the villages, the suitability of closed systems is very good. In addition to closed systems, the suitability of open systems in deeper water-bearing layers is very good on Texel. However, the suitability of open systems in the first water-bearing layer or shallowest aquifer is moderate.

Biomass is also a very interesting source for generating energy in the municipality of Texel, in particular for the generation of heat. Agricultural residues are by far the most interesting biomass source, because of the relatively large amount of animal manure and other residues that are available in the municipal area. These agricultural residues can be used for producing biogas, which can subsequently be used for generating electricity and heat using a CHP. Agricultural residues can also be used in incineration plants for generating energy. However, it should be noted that animal manure is very important for fertilizing the agricultural land on the island. When using animal manure, the best option would be to use animal manure in combination with other agricultural residues in a co-digestion process for producing biogas and digestate, which can replace the animal manure as fertilizer. Moreover, the electricity potential of wave energy in the municipal area is very small. The average height of the ocean waves near Texel is low and the water at the west side of Texel is to shallow. As a result, the average annual available wave power is very low. From the available tidal current velocities in the Marsdiep and Texelstroom, it can be concluded that the electricity potential of tidal energy in the municipality of Texel is relatively small. Tidal stream generators can generate electricity, but higher tidal current velocities are desirable. In Table 20, an overview is given of the electricity potential of various renewable energy sources. Furthermore, in Table 21, an overview is given of the heat potential of various sources.

TABLE 20 – ELECTRICITY POTENTIAL OF VARIOUS RENEWABLE ENERY SOURCES IN THE MUNICIPALITY OF TEXEL

Form of renewable energy	**Electricity potential**				
	Very large	*Large*	*Moderate*	*Small*	*Very small*
Solar energy	✖				
Wind energy	✖				
Geothermal energy			✖		
Biomass energy		✖			
Wave energy					✖
Tidal energy				✖	

TABLE 21 – HEAT POTENTIAL OF VARIOUS RENEWABLE ENERY SOURCES IN THE MUNICIPALITY OF TEXEL

Form of renewable energy	**Heat potential**				
	Very large	*Large*	*Moderate*	*Small*	*Very small*
Solar energy		✖			
Geothermal energy			✖		
Heat and cold storage	✖				
Biomass energy	✖				

Next to electricity and heat, also transport biofuels and biogas are needed. Biomass is the only source that can produce biogas and biofuels. Energy crops that are already cultivated on Texel, including potatoes, wheat, sugar beets and corn, can be used for producing bioethanol, which can substitute gasoline. Other land-based energy crops can also be cultivated on Texel, such as rapeseed, which can be used for producing biodiesel. However, the cultivation of land-based energy crops for producing transport biofuels comes at the expense of food crops and valuable land. Next to land-based crops, also other energy crops can be cultivated, such as algae. Algae are the most interesting source for producing biofuels and biogas.

Although solar and wind energy have a large potential in the municipal area, these forms of renewable energy are not continuous available. This also applies to wave and tidal energy. The amount of energy that is generated is dependent on the time of the day and season. However, it is essential that energy can be supplied when it is needed. This means that storage of electricity and heat or other renewable energy sources, which are continuously available, are needed when sources are used that are characterized by periodic fluctuations. There are different options for electric power storage, including batteries, hydrogen storage and mechanical storage. However, in practice it will be inefficient when only electric power storage is used for assisting solar panels and wind turbines because of the large amount of electrical power that has to be stored. This also applies to thermal energy storage.
It can be concluded that a combination of different renewable energy sources is needed. This means that renewable energy sources that are not continuous available have to be combined with other sources, such as geothermal heat and biomass. Geothermal energy and biomass energy are attractive forms of renewable energy because electricity and heat can be generated when it is needed. A good match between supply and demand is possible. Furthermore, different renewable energy sources can be combined in one area. Wind turbines cover a very small area on land or sea. As a result, the area can still be used for current purposes or it can be combined with other renewable energy sources, such as the cultivation of seaweed or a geothermal power plant. Solar panels are also very flexible. For example, solar panels can be combined with other sustainable energy technologies, such as a geothermal power plant or an anaerobic co-digestion plant. Moreover, a distinction can be made between sustainable energy technologies that can be used on small scale and technologies that have to be used on large scale. Solar power technologies, small wind turbines and closed systems (heat and cold storage) can easily be applied in and on homes, while geothermal power plants and biomass incineration plants need much more space. In Table 22, an overview is given of the scale of use of various forms of renewable energy.

TABLE 22 – SCALE OF USE OF VARIOUS FORMS OF RENEWABLE ENERGY

Form of renewable energy	**Scale of use**				
	Very large	*Large*	*Moderate*	*Small*	*Very small*
Solar energy					
Wind energy					
Geothermal energy					
Heat and cold storage					
Biomass energy					
Wave energy					
Tidal energy					

It should be noted that there are also other renewable energy sources available in the municipal area. A form of hydropower that might be interesting in the municipal area is blue energy. Blue energy or osmotic power is energy that can be generated form the difference in salt concentration between seawater and river water. Each day on Texel a certain amount of fresh water is discharged into the sea. However, based on Deltares (2008), blue energy is not interesting in the municipal area because the average supply of fresh water is not high enough. In general, an average supply of at least 25 m^3 per second is needed. In addition, there are also other options of thermal energy storage or heat extraction, such as thermal energy storage in surface water or heat extraction from seawater, which can be interesting for Texel. However, the development of these options is still in its infancy and only a limited number of these options are applied, which currently are being tested. As a result, the potential of these various options can hardly be visualized quantitatively (SREX 2011).

4. DEVELOPMENTS CONCERNING ENERGY SELF-SUFFICIENCY

At this moment, many developments are taking place inside and outside the municipal boundaries of Texel concerning energy self-sufficiency. These developments can be distinguished in technical, economic, cultural, spatial trends and policies. In the first section, the motives for achieving energy self-sufficiency will be identified. Next, it will be indicated to what extent the municipality of Texel and other parties are committed to achieve energy self-sufficiency and how much progression has been made. In section 4.3, the relevant local initiatives and projects will be indicated after which the policies of the Dutch government, the province of North Holland and the municipality of Texel are determined. In section 4.5, the current technical and economical trends in sustainable energy technologies are defined. These technologies are related to the renewable energy sources that are examined in the previous chapter. Moreover, the current developments in the energy system and landscape will be defined in section 4.6 and 4.7. Eventually, the stakeholders that are involved in achieving energy self-sufficiency will be identified after which the interests and influences of these stakeholders will be determined.

4.1 MOTIVES FOR ACHIEVING ENERGY SELF-SUFFICIENCY

For many years, various parties at Texel are actively working on achieving energy self-sufficiency. It all started in 2000 when Stichting Duurzaam Texel, a local foundation that focuses on initiating and stimulating activities that support the sustainable development of the island, expressed the ambition to make Wadden Island Texel energy self-sufficient in 2030 (Interview Hordijk 2011). At that time, Stichting Duurzaam Texel emerged from Werkgroep Duurzaam Toerisme Texel, which can be freely translated as Working Group on Sustainable Tourism Texel. The main motive of Stichting Duurzaam Texel was to stimulate tourism. Subsequently, the municipality of Texel adopted the ambition and decided in 2007 to go for energy self-sufficiency in 2020 (Interview Kieft and Bakker 2011). With this ambition, Texel was at the forefront of achieving energy self-sufficiency in the Netherlands. Until now, this is still the case. In the many years that passed from the time that the ambition was first set by Stichting Duurzaam Texel, different motives to achieve self-sufficiency emerged. These motives have been identified and are described below.

Reducing the use of fossil fuels

The municipality of Texel realizes that fossil fuels are finite and that a transition is needed towards renewable energy sources. In addition, the municipality of Texel indicates that it wants to contribute to a solution to the global climate problem that is caused by the use of fossil fuels. However, currently energy is imported from the mainland that is generated from fossil fuels. To change this, the municipality of Texel has decided to deal with this issue and to go for energy self-sufficiency using renewable energy sources (Gemeenteraden Waddeneilanden 2007). With this attitude, the municipality of Texel also wants to play an exemplary role in the Netherlands.

Creating more economic activity

Achieving energy self-sufficiency can create more economic activity on Texel. This motive can be divided into two sub-motives: attracting investments and subsidies and stimulating tourism. These sub-motives will be described below:

- *Attracting investments and subsidies*: By realizing a renewable energy supply on Texel, investments from companies outside the municipal boundaries can be attracted. In addition, because Texel is at the forefront of achieving energy self-sufficiency in the Netherlands, the chances of obtaining subsidies from the Dutch government and province of North Holland are large. Texel can serve as a pilot project for many issues, including tests with technologies or policies. Investments and subsidies can lead to more jobs on the island, especially in the construction and installation sector (Interview Hercules 2011).
- *Stimulating tourism*: Achieving energy self-sufficiency using renewable energy sources can also be used as a marketing tool. By promoting Texel as a clean and energy-conscious island and as an example of how the future will look like, tourists can be attracted (Interview Hercules 2011). This motive is also based on the experiences on Danish island Samso. Samso attracted many more tourists from the moment that it became energy self-sufficient. The municipality of Texel indicates that achieving energy self-sufficiency responds to the underlying question on how tourism can be enhanced while the nature on the island can be preserved (Interview Hercules 2011; Interview Kieft and Bakker 2011; Gemeenteraden Waddeneilanden 2011). More tourists can lead to more jobs in the touristic sector, including hospitality and food sector and retail sector.

Achieving independence from the mainland

There is a deep-rooted culture of autonomy on Texel (Interview Kieft and Bakker 2011; Interview Hordijk 2011). In the earlier days, this independence was a necessity. For example, before the power lines and gas pipes were realized, electricity had to be generated on the island. However, the feeling of independence is still very much present on the island.

According to the municipality of Texel (Interview Hercules 2011), creating more economic activity on Texel is the main motive for achieving energy self-sufficiency. This applies both to the municipality of Texel and the residents.

4.2 Commitment and progression

For many years, various parties at Texel are actively working on achieving energy self-sufficiency. In this section it will be indicated to what extent the municipality of Texel and other parties are committed to achieve energy self-sufficiency. In addition, it will be indicated how much progression has been made and which difficulties are experienced.

4.2.1 Political will and public engagement

The municipality of Texel is one of the most ambitious municipalities in the Netherlands with respect to renewable energy. In 2007, the municipality of Texel decided together with the municipalities of the other Dutch Wadden Islands to go for energy self-sufficiency in 2020 (Gemeenteraden Waddeneilanden 2007). These were the first municipalities in the Netherlands that had such large ambition. However, before that time the municipality of Texel was already actively working towards achieving energy self-sufficiency. As a result, in 2007, the municipality of Texel was several steps further in achieving energy-sufficiency compared to the other municipalities of the Dutch Wadden Islands (Gemeenteraden Waddeneilanden 2007). This was not so much in the realization of sustainable energy technologies or energy conservation, but more in the development of knowledge regarding achieving energy self-sufficiency. A number of technical feasibility studies had been carried out (De Beer et al. 2001; Weeda et al. 2007). Furthermore, the municipality of Texel was involved in several local initiatives and projects, including initiatives and projects on energy awareness, solar energy and wind energy. With these initiatives and projects much experience was gained on organization and social level, including how it must deal with certain projects and which technologies experience much social resistance. Most projects were carried out in collaboration with Stichting Duurzaam Texel, which was at that time funded by the municipality of Texel. Several projects will be described in section 4.3 in which all relevant local initiatives and projects regarding energy self-sufficiency will be indicated. In the years after 2007, the municipality Texel continued to initiate, stimulate and assist local projects.

Some residents wanted to do something with the ambition and started projects in a way that they considered best. These projects ranged from small projects, in which residents decided to install solar panels on their roof, to large projects. In 2007, just after the Dutch Wadden Islands decided to go for energy self-sufficiency, residents founded the local energy company TexelEnergie. Until now, TexelEnergie has been still very active and operates as an energy cooperative, which in this case means that members are shareholder of TexelEnergie. TexelEnergie is primarily concerned with achieving a renewable energy supply on the island and focuses on buying, selling and generating renewable energy (Interview De Graaf 2011). As a result, members of TexelEnergie are committed to achieve energy self-sufficiency. At this moment, TexelEnergie has around 2600 connections and 3300 members, representing 25% of the total energy market on the island (Interview De Graaf 2011). From these findings, it can be concluded that relatively many residents are committed to achieve energy self-sufficiency. This conclusion is also shared by many other actors, including the municipality of Texel and Stichting Duurzaam Texel (Interview Hercules 2011; Interview Kieft and Bakker 2011; Interview Hordijk 2011; Interview Van Rijsselberghe 2011). However, an important observation is that most residents want to achieve energy self-sufficiency as long as it does not interfere with their vested interests.

Moreover, also a number of local companies and organizations are to greater or lesser extent committed to achieve energy self-sufficiency. So make local farmer organizations AJT and LTO Texel effort for constructing an anaerobic co-digestion plant on the island. Furthermore, the transportation company TESO, is actively working on saving fuel and replacing fossil fuels with biofuels (Interview De Waal 2011). These are just a few examples of initiatives by local companies and organizations in the municipal area. In addition, several local companies and organizations are also indirect committed. The board of Stichting Duurzaam Texel consists of representatives of various organizations on the island, including transportation company TESO, business organization TOP, touristic association VVV Texel and farmer organization LTO Texel. As previously indicated, Stichting Duurzaam Texel is already actively working towards achieving energy self-sufficiency.

The commitment of local parties has not gone unnoticed by other parties outside the municipal area. Stichting Urgenda, which is a foundation that actively deals with stimulating sustainability initiatives in the Netherlands, has declared Texel as icon project for putting sustainability on the map of the Netherlands (Interview Minnesma 2011). Stichting Urgenda has initiated several projects in collaboration with local actors. Furthermore, they have identified the local 'leaders' or 'pioneers' in the municipal area, which are residents who want to take the lead and actively work on achieving energy self-sufficiency (Urgenda 2009; Interview Minnesma 2011). This group is significantly less compared to the residents that feel committed to achieve energy self-sufficiency. Many of these local leaders are also interviewed to provide relevant input for this study. Next to Stichting Urgenda, companies outside the municipal area have also noticed the commitment of the municipality of Texel and residents, including Capgemini. These companies are also involved in several local projects as can be seen in section 4.3.

4.2.2 Progression and difficulties

Until now, only a very small amount of renewable energy is generated in the municipal area. Approximately 1.5% of the electricity demand and approximately 1% of the heat demand is generated by renewable energy sources. The amount of renewable energy that is generated in the municipal area is even reduced in the last few years, because of the removal of wind turbines in Oudeschild, which will be explained in section 4.6.1. These findings arise the question of what the underlying causes are for the poor progression of achieving energy self-sufficiency. The following causes have been identified.

Resistance

In the many years that passed from the time that the ambition was first set, social resistance took place against certain sustainable energy technologies. In particular, resistance against wind turbines and biomass power plants. In addition, there was also division in the municipality of Texel and other involved parties concerning specific sustainable energy technologies. Various types of resistance that to date have occurred in the municipal area are indicated below. These types of resistance can be distinguished in wind energy, biomass energy and solar energy:

- *Wind energy*: For many years, there is a heated discussion about placing wind turbines on the island. There is opposition from residents and local environmental organizations to place wind turbines. They indicate that wind turbines affect the natural landscape, create noise and are dangerous to birds. In particular, the local environmental organizations 10 voor Texel and Vogelwerkgroep Texel are against placing wind turbines on the island. Furthermore, in 2008, there was an incident with a wind turbine in the harbor of Oudeschild. One of the four wind turbines, which were installed at that time, broke and a part of the turbine fell down. Fortunately, no one was injured, but this incident resulted in less support among the residents. Even in the municipality of Texel and in the board of Stichting Duurzaam Texel there is division concerning wind turbines (Interview Hercules 2011; Interview Hordijk 2011). Next to resistance against wind turbines, there was even resistance in the municipality of Texel against a small wind turbine that was tested in Oudeschild (Texelse Courant 2011a).
- *Biomass energy*: There is also a discussion about constructing biomass power plants in the municipal area. A few years ago, there was much resistance in the local politics. This was due to the conception that animal manure would be imported from the mainland to use it as feedstock in a biomass power plant for generating energy (Interview De Graaf 2011). In addition, there was also a conception that animal manure would merely be used as feedstock for generating energy and not as fertilizer. However, according to the parties who want to construct a biomass power plant, including TexelEnergie, animal manure that comes from Texel will be used and digestate will be produced, which can also be used as fertilizer (Interview De Graaf 2011). This is currently also recognized by the municipal executive board of Texel (Interview Hercules 2011). Furthermore, some residents and local environmental organization 10 voor Texel indicate that biomass power plants affect the natural landscape and create an unpleasant smell and are therefore against the construction of biomass power

plants in the municipal area. The municipality of Texel recognizes this partly and indicates that biomass power plants must be well integrated into the landscape (Interview Hercules 2011). Next to resistance against biomass plants, there was also resistance against placing a wood-burning stove in Den Burg. Some residents indicated that the wood-burning stove would create an unpleasant smell in the area. However, the municipality of Texel disagreed and gave a permit for placing the wood-burning stove (Woontij 2011).

- *Solar energy*: In general, both the municipality of Texel and residents are very positive about installing solar power technologies in the municipal area. However, there is a discussion about the realization of 'solar fields', which are fields on agricultural land on which solar panels are placed. In the municipality of Texel there is division concerning solar fields (Texelse Courant 2011b). Opponents indicate that when solar fields will be realized the natural landscape will be affected.

Of the above-described types of resistance to certain sustainable energy technologies or the way it will be used, wind turbines generate by far the greatest resistance. Furthermore, in each case landscape degradation is a frequently used argument. This also indicates that conservation of the natural landscape of Texel is very important among residents. This is not remarkable: most tourists visit Texel because of the diverse natural landscape and tourism is the main source of income (VVV Texel 2011). Next to the used arguments that are indicated, there are also a lot of false arguments that are not described. This is because many residents do not have sufficient knowledge on sustainable energy technologies and energy conservation.

Change in politics

An important key person in the municipality of Texel that actively was working on achieving energy self-sufficiency was former municipal executive board member Peter Bakker. When he stopped in 2009, the ambition was slightly pushed into the background (Interview Bakker and Kieft 2011). In addition, a shift in the municipal executive board of Texel in 2010 resulted into a less active attitude of the municipality of Texel regarding achieving energy self-sufficiency. Although the ambition of achieving energy self-sufficiency maintained, at first the municipality of Texel was looking on how interpretation could be given to the ambition. At this moment, of the 180 full-time equivalents (FTEs) working for the municipality of Texel only 0.75 FTE is actively working on sustainability (Interview Hercules 2011). This is not much for a municipality that has such large ambition. Next to a change in the local politics, there was also a change in the Dutch government and province of North Holland, which affected policy on renewable energy. Political continuity is very important in achieving a goal that is many years away.

Laws and regulations

To implement sustainable energy technologies in the municipal area, the municipality of Texel must take into account the laws and regulations. The Dutch government and the province of North Holland determine most of these laws and regulations. These laws and regulation need to be observed by the municipality of Texel. Since there are many protected areas in the municipal area, it is difficult to implement certain sustainable energy technologies (Interview Hercules 2011). However, it should also be noted that the policy of the municipality of Texel does not stimulate the implementation of certain technologies. In particular parties that want to construct a wind turbine or biomass power plant have to deal with relatively many laws and regulations (Interview De Graaf 2011). The laws and regulations in the municipal area regarding the implementation of sustainable energy technologies will be described in section 4.4.4.

High investments
In recent years there has been a slight downward trend, but there are still relatively high investments required for implementing sustainable energy technologies in the municipal area (see also section 4.5). Especially a few years ago, the high investments were a major barrier for households and local companies (Interview Hordijk 2011).

Funding
This cause is related to the high investments associated with sustainable energy technologies. Funding is often a significant barrier for carrying out projects. TexelEnergie experiences many problems when they are looking for funding (Interview De Graaf 2011). In particular, commercial banks indicate that the risks are too high. Furthermore, the municipality of Texel has also not enough finances for carrying out large projects (Interview Kieft and Bakker 2011).

Agreements between the municipality of Texel and other authorities
The municipality of Texel has several agreements with other municipalities and provinces. As a result, the municipality of Texel cannot make decisions all by themselves (Interview Hercules 2011).

Difficult cooperation between the municipality of Texel and local entrepreneurs
Although the municipality of Texel has decided to go for energy self-sufficiency in 2020, local entrepreneurs are very much needed. However, the cooperation between the municipality of Texel and the local entrepreneurs is so far difficult (Interview De Graaf 2011). The municipality of Texel has often too much influence on ideas of local entrepreneurs and is often not decisive. As a result, some local entrepreneurs stopped with their plans regarding implementing sustainable energy technologies. When the cooperation can be improved, great strides can be made (Interview Kieft and Bakker 2011).

Little interest from the local construction and installation sector
Both the municipality of Texel and TexelEnergie indicate that they try as much as possible to involve local technology and engineering companies. However, until now, the interest of local technology and engineering companies is relatively small (Interview Kieft and Bakker 2011). As a result, there are currently not many local technology and engineering companies involved in initiatives and projects regarding achieving energy self-sufficiency.

Stichting Duurzaam Texel became less active
For many years, Stichting Duurzaam Texel had a very stimulating role. However, in 2009, funding from the municipality of Texel, the province of North Holland and the National Post Code Lottery was stopped (Interview Hordijk 2011). From that moment, it was funded by the various organizations that were involved in Stichting Duurzaam Texel. However, this funding was much less. As a result, Stichting Duurzaam Texel became less active.

It can be concluded that many various causes have resulted in a poor progression in the last few years. An important observation is that in recent years the municipality of Texel has done little

(Interview Minnesma 2011; Interview Kieft and Bakker 2011). This is largely due to restrictive policy and a lack of continuity, decisiveness and funding. However, at present, the municipality of Texel is much more active. This is mainly due to the subsidies obtained from the province of North Holland (Interview Minnesma 2011). In 2011, the province of North Holland has granted five million euros to the municipality of Texel for helping achieving energy self-sufficiency. As a result, new initiatives and projects are started. In addition, one million euros is allocated to TexelEnergie for stimulating the use of solar panels among residents. Furthermore, in September 2011, the municipality of Texel has presented a roadmap together with the other municipalities of the Dutch Wadden Islands (Gemeenteraden Waddeneilanden 2011). In this roadmap it is indicated that the municipalities are going to help each other in the coming years. The municipalities of the Dutch Wadden Islands have also indicated which steps are needed for achieving energy self-sufficiency, including a more active attitude from residents and local companies and more funding. This roadmap will be further discussed in section 7.4, in which a follow-up agenda will be constructed for achieving energy self-sufficiency. This roadmap also indicates that at this moment the municipality of Texel is actively working towards achieving energy self-sufficiency. According to the municipality of Texel (Interview Hercules 2011), an important observation was that Texel was still several steps further in achieving energy self-sufficiency compared to the other Dutch Wadden Islands. This was mainly due to the many efforts that the municipality of Texel had done for obtaining the subsidy of 5 million euros.

Furthermore, the municipality of Texel has appropriated a clear role. According to the municipality of Texel (Interview Hercules 2011), the task of the municipality of Texel is mainly to indicate what is possible and impossible on the island with respect to achieving energy self-sufficiency. Furthermore, they have to support the relevant actors that can contribute to the ambition, including funding and changing laws and regulations when necessary. The municipality of Texel has indicated that they should not do everything by themselves. In addition, the municipality of Texel has indicated that they should only be involved when they can add value to the project. By doing this, the municipality of Texel is trying to achieve a better cooperation with parties that are committed to achieve energy self-sufficiency.

4.3 Local initiatives and projects

In the previous section it was indicated that in the many years from the time that the ambition was first set there have been relatively many initiatives and projects in the municipality of Texel. In addition, at this moment there are many local initiatives and projects ongoing. The relevant local initiatives and projects are indicated in Table 23. In this table it is also indicated which parties are or were involved and in which period the initiative or project took place. In addition, in Appendix A, each relevant initiative or project is described in detail.

TABLE 23 – ALL RELEVANT LOCAL INITIATIVES AND PROJECTS IN THE MUNICIPAL AREA

Initiative/project	Actors	Period
Studies on achieving energy self-sufficiency	Stichting Duurzaam Texel, the municipality of Texel, Stichting Urgenda, Ecofys, ECN, CE Delft and ATO	From 2001 to 2011
Cooperation between the Dutch Wadden Islands for achieving energy self-sufficiency	The municipality of Texel and VAST-islands	From 2007 to 2011
Fairs regarding renewable energy, energy conservation and electric transport	The municipality of Texel, Stichting Urgenda, Stichting Duurzaam Texel and TexelEnergie	From 2008 to 2011
Information sessions and workshops regarding renewable energy and energy conservation	Stichting Duurzaam Texel	From 2004 to 2011
Large projects with solar panels and solar thermal collectors	TexelEnergie, Woontij and local companies	From 1995 to present
Pilot project with electric vehicles	Stichting Urgenda, the municipality of Texel and local entrepreneurs	From 2010 to present
Realization of charging points for electric vehicles	Stichting Urgenda, the municipality of Texel and local entrepreneurs	From 2011 to present
Pilot project with tidal stream generators in the Marsdiep	Tocardo International, Bluewater Energy Services, Tidal Testing Centre, NIOZ, ECN, the province of North Holland, WL, Marin, WMC and Deltares	From 2009 to 2013
Plans for constructing an anaerobic co-digestion plant	TexelEnergie, AJT and LTO Texel	From 2011 to present
Research on geothermal energy	The municipality of Texel, TexelEnergie, Development Company Holland North, the province of North Holland, Ecofys, IF WEP and Grontmij	From 2009 to present
Realization of fuel saving and reduction in greenhouse gases regarding ferry service	TESO	From 2007 to present
Pilot project with small wind turbines	The municipality of Texel, TexelEnergie and donQi	From 2010 to present
Pilot project with wood-burning stove in the residential area 'De 99' in Den Burg	TexelEnergie and Woontij	From 2011 to 2016
Heat and cold storage system for Town Hall of Texel and secondary school in Den Burg	The municipality of Texel	From 2008 to 2012
Initiative to place wind turbines at an industrial site in Oudeschild	Local entrepreneurs and De Wolff Nederland Windenergie	From 1997 to present
The development of an educational program on sustainability	Ecomare and Stichting Kopwerk (which consists of many organizations, including the municipality of Texel, Stichting Duurzaam Texel and TexelEnergie)	From 2011 to present
Energy desk in the Town Hall of Texel (Energieloket) for helping residents and tourists	The municipality of Texel, TexelEnergie and Stichting Duurzaam Texel	From 2011 to present
Implementation of smart meters throughout the municipal area	The municipality of Texel and Alliander	From 2011 to present
Pilot project with energy system Cloud Power	TexelEnergie, Capgemini, Qurrent and Alliander	From 2011 to 2013
Pilot project with LED public lighting	The municipality of Texel	From 2009 to present

From all the relevant local projects and initiatives that are identified, it can be concluded that many projects started recently. Especially the municipality of Texel is involved in many initiatives and projects that started recently. This is also consistent with the findings in the previous section: the municipality of Texel is currently more active compared to a few years ago. Furthermore, it can be concluded that TexelEnergie is involved in many projects. This is largely due to funding that they have recently received from the Dutch government and the municipality of Texel. Furthermore, TexelEnergie has gained more strength in the last few years. This is in contrast to Stichting Duurzaam Texel, which was also indicated in the previous section. Another important actor is Stichting Urgenda, which is mainly involved in projects related to electric transport. In section 4.8, an overview will be given of the stakeholders that are involved in achieving energy self-sufficiency.

4.4 National and local policy regarding renewable energy

The Dutch government, the province of North Holland and the municipality of Texel determine the national and local policy regarding renewable energy in the municipal area. The current developments of these policies are distinguished in targets and focus areas, financial incentives and subsidies and laws and regulations. First, the targets and focus areas of the Dutch government, the province of North Holland and the municipality of Texel regarding renewable energy will be identified. Furthermore, the financial incentives and subsides that are introduced by these authorities will be identified after which the laws and regulations in the municipal area regarding sustainable energy technologies will be indicated.

4.4.1 Targets

The Dutch government, the province of North Holland and the municipality have set targets regarding renewable energy. Based on information from the Dutch government, province of North Holland and the municipality of Texel (Ministerie van Economische Zaken, Landbouw & Innovatie 2011b, Provincie Noord-Holland 2009a; Interview Hercules 2011), the following targets have been identified.

Dutch government

The Dutch government has indicated that in 2020 14% of the total energy demand should come from renewable energy sources. In 2010, the share of renewable energy amounted to 4% of the total energy demand in the Netherlands. Furthermore, a 20% reduction of the CO_2 emissions has to be achieved in 2020 compared to the level of CO_2 emissions in 1990. Another target is to achieve energy savings of 20% in 2020 compared to 'business as usual'. However, this target is indicative and not binding. In addition, it is indicated that in 2020 a 10% blending of biofuels in the transport sector has to be achieved. Electric vehicles may be attributed to this target. The Dutch government has also indicated that the government aims to 200,000 electric vehicles in 2020.

Province of North Holland

The province of North Holland has indicated that in 2020 20% of the total energy demand should come from renewable energy sources. Furthermore, a 30% reduction of the CO_2 emissions has to be achieved in 2020 compared to the level of CO_2 emissions in 1990. In addition, each year energy savings of 2% has to be achieved. As for biofuels, the province of North Holland shares the same target as the Dutch government.

Municipality of Texel

The municipality of Texel has indicated that in 2020 100% of the total energy demand should come from renewable energy sources. This also applies to the transport sector. However, this target is not binding. The municipality of Texel has the ambition to be energy self-sufficient in 2020, but it is not a real problem if it appears that the ambition can be achieved somewhat later. Furthermore, the municipality of Texel wants to achieve energy savings of 30% in 2020 compared to the level of 2011.

As can be seen, the targets of the Dutch government, the province of North Holland and the municipality of Texel are quite diverse. The targets of the Dutch government are based on the minimum requirements that are set by the European Union, while the targets of the province of North Holland and the municipality of Texel go further than that. As a result, the policies regarding renewable energy are also different, as will be noted in the remainder of this section. Furthermore, it shall be noted that the targets that are indicated can change quickly. Thus, in 2010 the Dutch government indicated that in 2020 20% of the total energy demand should come from renewable energy sources. In 2011, this target is changed to 14%. Also targets concerning the reduction of CO_2 emissions and saving energy in the Netherlands were changed. In addition, the targets of the province of North Holland are described in a strategy document that covers a period of 2009 to 2012 (Province Noord-Holland 2009a). These targets are set out by an agreement between the Dutch government and the Dutch municipalities, also known as Klimaatakkoord that covers only a period from 2007 to 2011. Because the targets of the Dutch government have been changed in 2011, it is expected that the targets of the province of North Holland will also change in the next years. From the different targets, it can also be concluded that the targets of the municipality of Texel are very ambitious.

4.4.2 Focus areas

Next to the targets, the Dutch government, the province of North Holland and the municipality of Texel have also indicated focus areas in the field of renewable energy for achieving their targets. Based on information from the Dutch government, province of North Holland and the municipality of Texel (Ministerie van Economische Zaken, Landbouw & Innovatie 2011b, Provincie Noord-Holland 2009a; Interview Hercules 2011), the focus areas have been identified.

Dutch government

The Dutch government wants to provide scope for many renewable energy options. The Dutch government, however, does not focus on specific renewable energy sources. The most cost-effective sustainable energy technologies are preferred. Furthermore, the Dutch government has indicated that it wants to focus on nuclear energy, which is a non-renewable form of energy, for reducing CO_2 emissions and enhancing energy security.

Province of North Holland

The province of North Holland has indicated two forms of renewable energy where it wants to focus on in the next years. These sources are wind energy and biomass energy, in particular offshore wind energy and biomass gasification. Although the province of North Holland indicates that wind is an important renewable energy source for achieving their targets, the province does not focus on implementing wind turbines in the municipality of Texel.

Municipality of Texel

The municipality of Texel has also indicated which forms of renewable energy have the highest priority. These are solar energy and biomass energy. However, the municipality of Texel has also indicated that other forms of renewable energy are needed for achieving energy self-sufficiency. As a result, the municipality of Texel will also actively support other forms, including geothermal energy and tidal energy. However, the municipality of Texel has indicated that currently there will be no plans made for placing wind turbines in the municipal area. This does not apply for small wind turbines.

It can be concluded that the Dutch government has less priority to stimulate sustainable energy technologies compared to the province of North Holland and the municipality of Texel. This also has to do with the different targets that are set. The Dutch government even wants to focus on nuclear energy. This is in contrast with the ambition of the municipality of Texel, which has indicated that only renewable energy sources will be used for achieving energy self-sufficiency in 2020. Furthermore, at this moment there will be no effort to place wind turbines in the municipality of Texel.

The Dutch government, the province of North Holland and the municipality of Texel have all indicated that achieving saving energy is very important. When the total energy demand will be reduced, less renewable energy has to be generated for achieving their targets on renewable energy. Both the province of North Holland and the municipality of Texel emphasize the concept of the Trias Energetica, which is a 3-step approach for achieving energy savings and reducing the dependence on fossil fuels (Interview Hercules 2011; Provincie Noord-Holland 2011f). In the first step of this approach, the energy demand will be reduced by implementing energy saving measures and avoiding waste. Secondly, renewable energy sources will be used as much as possible. Eventually, when there is still demand for energy, fossil fuels will be used in the cleanest possible way. Both the province of North Holland and the municipality of Texel use this approach. However, it should be noted that the municipality of Texel is more ambitious regarding energy conservation compared to the province of North Holland. The fundamental idea is that eventually no fossil fuels will be used.

4.4.3 Financial incentives and subsidies

There are various financial incentives for stimulating the implementation of sustainable energy technologies in the Netherlands. This also applies in the province of North Holland and the municipality of Texel. In the last few years, the Dutch government, the province of North Holland and the municipality of Texel have introduced several financial incentives and subsidies. The various financial incentives and subsidies that are currently applied or that are eligible for local parties have been identified and are described below.

Dutch government

At this moment, there are several financial incentives and subsidies. The Dutch government has introduced an energy tax relief program, also known as the Energy Investment Allowance (EIA) or Energie Investeringsaftrek (Ministerie van Economische Zaken, Landbouw & Innovatie 2011b). This tax program gives a direct financial advantage to companies that invest in energy conservation or sustainable energy technologies. The budget of this tax program is from 2011 to 2013 151 million euros per year. After 2013, the budget will be increased to 161 million euro per year. Furthermore, the Dutch government has introduced a feed-in premium for renewable energy, which is known as

SDE+ or Subsidieregeling Duurzame Energie Plus (Rijksoverheid 2011a). This feed-in premium covers the extra costs on top of the wholesale energy price for several years. The premium will vary with the wholesale energy price and the type of technology. In 2012, all renewable energy sources are eligible for this feed-in premium. However, the focus will be on large projects, so this feed-in premium is primarily intended for companies. In 2011, the budget of the SDE+ regulation was around 1.5 billion euros per year and this will increase to 1.7 billion euro per year in 2012. From 2015, the budget of the SDE+ regulation (including the old MEP and SDE regulation) will be no more than 1.4 billion euros per year. In addition, from 2013 the SDE+ regulation will be funded by a surcharge on the energy bills from citizens and companies. There are also financial incentives and subsidies for innovations regarding renewable energy. SMEs can make use of the innovation fund MKB+, which will start in 2012 (Rijksoverheid 2011a). In addition, companies can also apply to new tax relief programs RDE and WBSO, which will also start in 2012. The RDE program gives a direct financial advantage to companies because of a tax deduction on the innovation investments and operating costs. The WBSO program gives also a direct financial advantage to companies because of a tax deduction on the wages of employees that carrying out R&D.

Recently, various subsidies are allocated to parties that are actively working on achieving energy self-sufficiency. In 2010, the Dutch government has designated Wadden Island Texel as pilot area for electric transport (Rijksoverheid 2011b). By doing this, the use of electric vehicles in that area will be encouraged. When an electric vehicle is purchased on Texel a subsidy will be provided. The subsidy covers 80% of the extra costs of an electric vehicle compared to a vehicle with a combustion engine (Interview Minnesma 2011). However, the main purpose of designating Texel as pilot area is to identify the advantages and disadvantages of electric vehicles. This pilot project is led by Stichting Urgenda (see also section 4.3), which also received this subsidy. In addition, in 2011, the Dutch government has also designated Texel as pilot area for implementing smart grid technologies (Rijksoverheid 2011c). In this pilot an energy system, also known as Cloud Power, will be tested in 300 households (see also section 4.3). This subsidy is allocated to various parties, including TexelEnergie. Furthermore, in the last few years feed-in premiums have been allocated to residents and local companies, including the old SDE regulation. In particular projects where solar panels were installed (Interview De Graaf 2011).

Next to the described financial incentives and subsidies, the Dutch government has introduced the Green Deal. The Green Deal is not a financial instrument, but is an incentive for companies that experience problems in their projects regarding renewable energy, including funding (Ministerie van Economische Zaken, Landbouw & Innovatie 2011b). The Green Deal is an agreement between companies and the government in which the government is going to help to eliminate the bottlenecks that companies currently experience. The government can help in several ways, including help in seeking funding.

Province of North Holland

The province of North Holland has also introduced several financial incentives and subsidies. At this moment, the province of North Holland has introduced a subsidy for homeowner associations that wants to invest in sustainable energy technologies and energy saving measures, also known as Duurzaam Renoveren, which ends in December 2012 (Provincie Noord-Holland 2011g). Furthermore, a subsidy is introduced for biomass energy projects that make use of agricultural residues. The province of North Holland is also responsible for allocating subsidies from the Waddenfonds. This is a fund for additional investments in projects in and around the Wadden Sea. Some local projects that were described in 4.3 have received funding from the Waddenfonds. In addition, in 2011, the province of North Holland has granted five million euros to the municipality of Texel for helping achieving energy self-sufficiency (Interview Hercules 2011).

Municipality of Texel
The municipality of Texel has also introduced a subsidy for residents that want to invest in sustainable energy technologies and energy conservation, also known as Subsidie Energiezuinig Wonen (Gemeente Texel 2011e). Both residential homes and holiday homes are eligible for this subsidy. Furthermore, this subsidy will also be used for making 1000 energy performance recommendations (EPA). In addition, 45 zero energy homes and 35 zero energy holiday homes will be built from this subsidy. According the municipality of Texel (Gemeente Texel 2011e), this subsidy should result in a 30% reduction of the total energy demand of households and holiday homes in the municipal area. It should be noted that this subsidy is funded from the subsidy that is received from the province of North Holland.

It can be concluded that the Dutch government currently focuses much on large projects. This is in contrast with the municipality of Texel, which focuses much on decentralized energy generation. Moreover, there are recently quite some financial incentives and subsidies allocated to the municipality of Texel and other actors for achieving energy self-sufficiency.

4.4.4 Laws and regulations regarding sustainable energy technologies
In the municipality of Texel, there are various laws and regulations regarding the implementation of sustainable energy technologies. The Dutch government, the province of North Holland and the municipality of Texel have created these laws and regulations. In this section, laws and regulations are indicated that are related to the implementation of sustainable energy technologies in the physical environment. In addition to these laws and regulation, there are also laws and regulations relating to generation transmission, supply and construction. These laws and regulations, however, will not be indicated. The laws and regulations are distinguished in zoning regulations and laws and regulations that are related to the many protected areas in the municipality of Texel.

Zoning regulations
At this moment, the municipality of Texel is determining zoning regulations regarding the implementation of sustainable energy technologies in the municipal area, both for villages and rural areas. However, in 2010, the municipality of Texel has already made a concept plan for rural areas (Gemeente Texel 2010). Many of the proposed regulations in this plan will largely match with the regulations in the new zoning plan for rural areas. In this plan, the municipality of Texel has proposed regulations regarding solar panels, solar thermal collectors, small wind turbines and digestion plants. In addition to the concept plan for rural areas, there are also some older policy documents and zoning plans for villages in which zoning regulations related to renewable energy are determined (Gemeente Texel 2009a; 2011f). Based on all these documents, the zoning regulations regarding the implementation of sustainable energy technologies in the municipal area have been identified. Laws and regulations that are related to the protected areas are not taken into account. The zoning regulations are described below.

- *Solar energy*: The installation of solar panels and solar thermal collectors on roofs and facades is already legally allowed. Both technologies can be installed without applying for a permit, except for protected buildings. Furthermore, the municipality of Texel has indicated in the concept plan for rural areas that 'solar fields' are allowed, which are fields on agricultural land on which solar panels are placed, up to a maximum of 10 hectares in total. A condition is that the solar fields are an agricultural secondary activity for the farmer. Another important condition is that these solar fields have to be integrated well into the landscape. In order to assess this, the municipality of Texel decides whether this is the case. In addition to agricultural land, solar power technologies are also allowed on dikes.
- *Wind energy*: The municipality of Texel has decided that small wind turbines are allowed in industrial sites, recreation areas and rural areas up to a maximum hub height of 15 meters. However, the municipality of Texel has indicated that so far small wind turbines are not allowed in residential areas, because of noise and safety, and protected (natural) areas. A condition is that the small wind turbine has to be functionally linked to the building. Another important condition is that the small wind turbines have to be integrated well into the landscape. In order to assess this, the municipality of Texel decides whether this is the case. There is no maximum amount determined. Furthermore, there are no zoning regulations determined for onshore wind turbines.
- *Heat and cold storage*: Open and closed systems are allowed in both villages and rural areas, except in protected (natural) areas. Closed systems can be installed without applying for a permit.
- *Biomass energy*: The municipality of Texel has also indicated that opportunities will be given for the construction of (co-)digestion plants next to the farm or on industrial sites. An important condition, however, is that the manure and co-substrates are derived from agricultural companies on the island. The municipal executive board of Texel has indicated that Texel can be seen as one system regarding the transport of manure, which makes transport of the required manure on the island easier (Interview Hercules 2011). In addition, when the produced digestate meet the requirements that are determined by the government it can be used as fertilizer. An important condition is that the digestion plants have to be integrated well into the landscape. In order to assess this, the municipality of Texel decides whether this is the case. Preference is given to industrial sites.

It should be noted that the regulations regarding solar fields and digestion plants are not yet formalized. From the zoning regulations that are identified, it can be concluded that the municipality of Texel is trying to keep all options open for achieving energy self-sufficiency. This also applies for wind turbines. Although the municipality of Texel has indicated that currently no plans will be made for placing wind turbines in the municipal area, wind turbines are not forbidden in the municipal area (Interview Hercules 2011).

Protected areas

There are many protected areas in the municipality of Texel, which have been indicated in sections 3.1.3 and 3.1.4. There are several protected parks that are related to the natural landscape, including a national park, Natura 2000 sites, protected natural monuments, grassland bird habitats and a World Heritage site. There are also other protected areas in the municipality of Texel, which are specifically related to the soil and subsoil characteristics of the area, including geological monuments, archaeological values and groundwater protection areas. All these protected areas affect also the implementation of sustainable energy technologies in the municipality of Texel. Both the Dutch government and the province of North Holland determine the laws and regulations of these areas. What laws and regulations are applied in the protected areas will be described below:

- *National park*: At present there are no specific laws and regulations concerning the implementation of sustainable energy technologies in these areas, except for wind turbines. The province of North Holland has decided that Nationaal Park Duinen van Texel is so vulnerable that wind turbines are excluded in this area (Provincie Noord-Holland 2011a). Moreover, the laws and regulations of Natura 2000 sites are also applied to the national parks in the Netherlands, which are described below (Nationaal Park 2011).
- *Natura 2000 sites*: In the Netherlands, Natura 2000 sites are protected in the Nature Conservation Act from 1998, where these areas are protected from interference and damage (Overheid.nl 2011). As a result, obtaining permits for sustainable energy technologies, which can cause interference and damage such as wind turbines or geothermal power plants, is very difficult. Moreover, Nationaal Park Duinen van Texel is part of the Natura 2000 site 'Duinen en Lage Land Texel', which makes placing wind turbines not possible in this specific area.
- *Protected natural monuments*: In the Netherlands, protected natural monuments are protected in the Nature Conservation Act from 1998. In this act is it stated that harmful activities in these areas are forbidden (Overheid.nl 2011). As a result, obtaining permits for sustainable energy technologies, where many operations are required, such as wind turbines or geothermal power plants, is very difficult.
- *Ecological network (EHS)*: Spatial interventions in the ecological network that have a can negative impact on the network are not allowed (Rijksoverheid 2011d). This means that there are very strict conditions to get permits for implementing sustainable energy technologies in these areas. Sustainable energy technologies may not disrupt the connection between natural areas.
- *Key Planning Decision/World Heritage site (UNESCO)*: There is a protected area in the municipal area that has been designated in the Key Planning Decision Wadden Sea, 3rd Policy Document Wadden Sea, and that was added to the UNESCO's World Heritage List. Placing offshore sustainable energy technologies in this area of the Dutch Wadden Sea seems impossible to be considered as a source of conservation, which is the criterion that UNESO uses. In the Key Planning Decision Wadden Sea, 3rd Policy Document Wadden Sea (VROM 2007), it is also indicated that placing offshore sustainable energy technologies, such as offshore wind turbines, are forbidden.
- *Grassland bird habitats*: To protect grassland bird habitats, the province of North Holland has decided that disturbing activities, including wind turbines, are not allowed (Provincie Noord-Holland 2011a). Other sustainable energy technologies are not specifically mentioned, but large-scale activities, such as geothermal power plants and biomass power plants, can be very disturbing. As a result, obtaining permits for these activities is very difficult.
- *Geological monuments*: Geological monuments cover a large area of the island. This will affect the implementation of sustainable energy technologies in the municipality of Texel. The province of North Holland has indicated that operations that affect the geological monuments are forbidden. This includes installing geothermal systems, construction of

underground infrastructure and earth removal, grading and digging for commercial purposes. Which makes placing sustainable energy technologies such as wind turbines, geothermal power plants, heat and cold storage systems and biomass power plants not possible (Provincie Noord-Holland 2011a; 2011c).

- *Archaeological values*: Archaeological values are protected by the Valetta Treaty in which is indicated that archaeological sites should be left undisturbed wherever possible (Provincie Noord-Holland 2009b). When activities are unavoidable in the ground, excavation is required where it should be noted that the disturber has to pay. As a result, there are very strict conditions for implementing wind turbines, geothermal power plants and heat and cold storage system in these areas. When it is expected that archaeological values may be present, research must be done. These costs are also for the possible disturber.
- *Groundwater protection areas*: In groundwater protection areas, operations are forbidden that directly or indirectly extract heat from the groundwater or add heat to the groundwater (Provincie Noord-Holland 2011c). As a result, heat and cold storage is forbidden in this area, both open and closed systems. Warming the groundwater can lead to a change in the chemical quality. Furthermore, these systems can affect the flow direction of the groundwater and an emergency can occur when liquid will leak from closed systems into the groundwater.

From the various laws and regulations related to the protected areas, it can be concluded that large-scale technologies have many restrictions in the municipal area. Small-scale technologies that are building related, such as solar panels and solar thermal collectors, have fewer restrictions. From the large-scale technologies, wind turbines have the most restrictions. Wind turbines cannot be placed in national parks, World Heritage sites, grassland bird habitats and geological monuments. Furthermore, there are very strict conditions to place wind turbines in the other areas. Next to wind turbines, geothermal power plants and heat and cold storage systems have also many restrictions. These technologies cannot be implemented in geological monuments and groundwater protection areas and have very strict conditions in other areas. Biomass power plants are not allowed in geological monuments and have also many restrictions in other areas. Furthermore, there are also very strict restrictions for ocean energy technologies, including wave energy technologies and tidal stream generators, because the waters around the island are protected, including the Dutch Wadden Sea, which is a World Heritage site. Currently, the Dutch government has given a permit for carrying out a pilot project with some tidal steam generators in the Marsdiep. However, when a tidal farm will be realized in the Marsdiep or Texelstroom, obtaining permits is very difficult.

4.5 Status of sustainable energy technologies

In the previous chapter, the potentials of various renewable energy sources were determined. These potentials are very important in order to indicate which sources are interesting in the municipal area. However, it also very important to define the latest developments regarding the sustainable energy technologies that can be implemented in the municipal area. These sustainable energy technologies are related to the renewable energy sources that are examined in section 3.3. For describing the developments, both technological and economical aspects are taken into account. The developments are briefly described below.

Solar energy

In recent years, the market for solar panels has grown strongly in the Netherlands due to international developments. An important observation is that installing solar panels is becoming more popular. In the last few years, the costs of solar panels have dropped considerably. Currently, the average price of solar panels is 2 euros per watt-peak, which also includes installation. This corresponds to around 0.10 euros per kWh of electricity. Compared to 2009 when the average price was around 3.50 euros per watt-peak, this is a significant decrease. In addition, it is expected that the prices of solar panels will decrease even further in the coming years. The average efficiency of the solar panels is also improved in the last years and it is expected that it will increase further in the coming years. At this moment, the average efficiency of solar panels is 15% and this will increase in the coming years to an average of 20%. The technical lifetime of solar panels is around 25 years.

Next to solar panels, solar thermal collectors have also undergone significant developments. In the last few years, the costs of solar thermal collectors have also dropped. Currently, the average price of a standard solar thermal collector (2.8 m^2) is 1,800 euros. Compared to 2008 when the price was around 2,400 euros for a standard solar collector, this is a significant decrease (Agentschap NL 2011a). At this moment, the costs solar thermal collectors are still higher compared to conventional technologies, such as central heating boilers. However, it is expected that in the coming years solar thermal collectors can compete with conventional technologies. Furthermore, in recent years the efficiencies of solar thermal collectors have increased. In 2008, the average efficiency was around 35%. The average efficiency is currently around 40%. It is expected that the average efficiency of solar thermal collectors will increase a few percent in the coming years. The technical lifetime of solar thermal collectors is also around 25 years.

Wind energy

To describe the developments regarding wind energy, a distinction can be made between onshore wind turbines, offshore wind turbines and small wind turbines. As described in 3.3.2, typical onshore and offshore wind turbines have a rotor diameter of 54 meters, a hub height of 80 meters and a capacity between 2 to 3 MW. In addition, small wind turbines have a rotor diameter between 1 to 10 meters, a hub height of 10 meters and a capacity between 0.5 to 20 kW. At this moment, the efficiencies of onshore and offshore wind turbines are close to the maximum that can be achieved (Hermans 2008). As a result, in the coming years there will be not much improvement on the efficiency of these turbines. However, currently there are many developments on making the wind turbines much larger, including an increase in rotor diameter and greater hub height. At this moment, the wind turbine with the world's largest rated power is the Enercon, which has a rated power of 7.58 MW (Enercon 2011). In economic terms, onshore wind energy is the most attractive. At this moment, ECN has indicated that the costs of onshore wind energy and offshore wind energy are around 0.07 and 0.11 euros per kWh of electricity, respectively (Ministerie van Economische Zaken, Landbouw & Innovatie 2011c). It is expected that these costs will decrease considerably in the coming years. According to a study that was carried out by PwC (2011), without subsidies, offshore wind energy can be profitable within 15 years. In addition, Dutch research and knowledge institute ECN is expected that onshore wind energy (in coastal areas) is becoming profitable before 2020 (Ministerie van Economische Zaken, Landbouw & Innovatie 2011c). The technical lifetime of wind turbines is currently around 20 years.

Next to onshore and offshore wind turbines, there are also small wind turbines. In the last few years, various small wind turbines have been introduced in the Netherlands. However, up to now, the market for small wind turbines is relatively small. Small wind turbines are still under development and face some large challenges. At this moment, the investment costs of small wind turbines are relatively high and the efficiencies are relatively low. Small wind turbines can be very interesting because these turbines are much easier to integrate in the landscape. It is expected that in the coming years there will be improvement on the efficiency of small wind turbines.

Geothermal energy
Up to now, there are a few small projects carried out on geothermal energy in the Netherlands. However, there are already many large geothermal power plants constructed in other countries, including USA, Italy and Philippines. As a result, there have been many developments in the field of geothermal energy. At this moment, the most common type of plant is the flash steam power plant, which uses flashed steam to drive turbines (IF WEP 2011). An advantage is the high efficiency that can be achieved when high temperatures above 200°C are used. Furthermore, a disadvantage is that the plant is vulnerable to mineral deposits because the water or steam from the geothermal reservoir comes in contact with the turbine units. Binary power plants are the most recent development and are preferred when temperatures of around 175 and 200°C are used, due to a better efficiency. In contrast to flash steam power plants, water or steam never comes in contact with the turbine units. Binary cycle power plants make use of Organic Rankine cycles (ORC) and Kalina cycles. Because of various studies that are currently carried out, it is expected that in the coming years there will be improvements on the technologies that can be used, including flash steam and ORC (IF WEP 2011).
According to Hagedoorn et al. 2009, which have carried out a feasibility study on geothermal energy in the municipality of Texel, the costs of geothermal energy are estimated at around 0.17 euros per kWh of electricity in the municipal area. In this estimation a binary cycle power plant was taking into account, which makes use of two ORC units as could be seen in Example 4. These costs are relatively high compared to solar and wind energy. The high costs of geothermal energy are largely due to the high costs of drilling and hydraulic fracturing. However, according to IF WEP (2011), it is expected that the costs will decrease in the coming years. As described in section 3.3.3, a doublet has an average lifetime of 30 years after which a new doublet has to be constructed.

Heat and cold storage
In the last few years, the use of heat and cold storage has increased significantly in the Netherlands. The technologies that used are proven and are relatively simple. In the last years, the efficiencies of ground heat exchangers and geothermal heat pumps (COP) have slightly increased. Furthermore, it is expected that developments in these technologies will continue (DHPA 2011). As previously described in section 3.3.4, there are open systems and closed systems. At this moment, the costs of open and closed systems in combination with geothermal heat pumps are still higher compared to conventional technologies, such as central heating boilers. This is largely due to the high investment costs. In practice, the costs of open systems are usually lower than closed systems. This is mainly because open systems are used on a larger scale. However, currently the cost difference is not large and it is expected that open and closed systems can directly compete with conventional technologies in the coming years. The average lifetime of a heat and cold storage system is around 20 years.

Biomass energy

At this moment, biomass energy is responsible for a large part of the amount of renewable energy that is generated in the Netherlands. Especially co-firing of biomass in power plants and combustion of organic waste in incineration plants are responsible for this large part (Agentschap NL 2011f). However, these large-scale options are less interesting for generating energy in the municipal area. Based on the findings in section 3.3, the implementation of co-digestion plants in combination with CHPs is the most interesting option for generating energy in the municipal area. According to Agentschap NL (2011f), (co-)digestion plants in combination with agricultural companies, digestion of food and green waste (GFT) and digestion of other streams have become increasingly popular. Especially the use of animal manure in combination with agricultural residues is becoming more interesting in the last years (co-digestion). This is largely due to improvement in processing of animal manure. An advantage is that digestate can be produced, which can also be used as fertilizer. However, the costs are still relatively high, especially for small-scale co-digestion plants. The high costs of co-digestion are mainly formed by the high costs of the raw materials that are needed. In addition, in recent years, wood-burning stoves have also become more popular (Agentschap NL 2011f). An important trend was an increase in the efficiency of these stoves, so that more wood-burning stoves were used. In particular, agricultural companies decided to make use of wood-burning stoves. Compared to costs of digestion plants, the costs of wood-burning stoves are relatively low.

Furthermore, at this moment the use of biofuels in the transport sector also contributes significantly to the large part of biomass energy. The advantage of biofuels is that certain amounts can easily be used in an internal combustion engines. When completely will be switched to biofuels, some adjustments are needed. However, there are currently engines that can completely use both conventional fuels and biofuels. As described in section 3.3.6, land-base energy crops that are already or can be cultivated on Texel, such as wheat, sugar beets and rapeseed, are important when biofuels are required for substituting gasoline and diesel. Biofuels derived from these crops are already commercially produced by using conventional technology. However, these energy crops are first generation feedstock, which are controversial because it does compete with food crops and valuable land. Therefore, agricultural residues, including wheat straw and hay, seaweed and other algae are much more interesting for the production of biofuels. At this moment, there is much research on generating bioethanol from wheat straw and hay (ECN 2011b). Agricultural residues use biomass to liquid technology, by thermal conversion or fermentation. These technologies, however, are still under development. Furthermore, there are several challenges, including the large areas that are required for large-scale cultivation. The production of biofuels from algae is currently also under development and faces a lot of challenges, including scaling up algae production, the low photosynthetic efficiency of photobioreactors and harvesting (Wijffels 2010). Another important trend is that other propulsion technologies are likely to compete with the internal combustion engine, such as electric motors. At this moment, there are major developments regarding electric vehicles and it is expected that the amount of electric vehicles will increase considerably in the coming years. The Dutch government also stimulates the use of electric vehicles as could be seen in section 4.4.1.

Wave energy

Although for many years research is conducted on wave energy, up to now, the developments of wave energy technologies are still in their infancy. There are so far no wave energy technologies used in the Netherlands. This is largely due to the high costs and low efficiencies. In addition, based on

Van de Berg et al. (2010), it is not expected that the use of wave energy technologies will economically viable before 2020.

Tidal energy

Up to now, tidal stream generators are still under development. Although tidal stream generators make use of a conventional technology, there are still a lot of challenges, including low efficiency and maintenance. There have been several projects with tidal stream generators. However, to date the costs of energy generating by tidal stream generators are relatively high. Based on Royal Haskoning (2009), the costs of energy generation by tidal stream generators are currently around 0.25 euros per kWh of electricity. It is expected that these costs will decline in the coming years.

Based on the findings and IEA (2011), the sustainable energy technologies that are described are so far not able to compete economically with fossil fuels in the Netherlands. The wholesale market prices (APX and TTF) of electricity and natural gas are currently around 0.05 per kWh and 0.25 euros per m^3 in the Netherlands, respectively (Nuon 2012). However, it is expected that technologies related to solar energy, wind energy, geothermal energy, heat and cold storage and biomass energy are able to compete with these market prices before 2020. This means without support from subsidies or regulations. Based on the current status and developments of sustainable energy technologies related to the renewable energy potentials, it can be concluded that solar panels and wind turbines, in particular onshore, will be techno-economically the most interesting for generating electricity in the municipal area. In addition, solar thermal collectors and heat and cold storage systems will be the most interesting for generating heat. Furthermore, co-digestion plants will be interesting for producing biogas, which can be used for generating heat and electricity. However, it is not expected that the production of biofuels from agricultural residues and algae will be techno-economically interesting before 2020. In addition, an important observation is that electric vehicles are on the rise. It should be noted that the exact break-even point of these technologies is dependent on several factors, including changes in the prices of fossil fuels.

4.6 Energy system

At this moment, there are several developments concerning the energy supply and demand in the municipality of Texel. These developments will change the current energy supply and demand in the next few years and provide important input for determining the amount of renewable energy that eventually is needed.

4.6.1 Energy supply

To define the current developments in the energy supply, developments will be considered that will have a permanent consequence on the energy supply in the municipality of Texel. Where permanent refers to energy technologies that will contribute to the energy supply for an indefinite period. As a result, pilot projects with sustainable energy technologies are not taken into account. The pilot projects that are currently carried out in the municipal area are temporary and are intended for developing knowledge on the implementation of sustainable energy technologies. At this moment, there are only concrete plans for implementing sustainable energy technologies in the municipal area. Given the ambition, this is not remarkable. In addition to the developments that will have a permanent consequence, also developments will be defined that have caused a significant decrease in the energy supply in the last few years. The developments that are identified can be distinguished in solar energy, wind energy, heat and cold storage and biomass energy.

Solar energy

At this moment, 4500 m^2 of solar panels are installed in the municipality of Texel. This amount will increase considerably in the coming years. Based on information from the municipality of Texel and TexelEnergie (Struick 2011; Interview De Graaf 2011), 10,000 m^2 of solar panels will soon be installed in the municipality of Texel. This increase is largely due to the subsidy of one million euros that the municipality of Texel has allocated to TexelEnergie for stimulating the use of solar panels among residents. As a result, next year around 1.45 hectares of solar panels will produce electricity in the municipal area.

Wind energy

Until a few years ago, four wind turbines of 250 kW were producing electricity in the harbor of Oudeschild. In 2010, these wind turbines were removed because of age. New wind turbines could have been placed because the permits remained. However, the municipality of Texel has decided that currently no plans will be made for placing wind turbines in the harbor. This is largely due to the great resistance (Interview Hercules 2011). The removal of these wind turbines has led to a significant decrease in the renewable energy supply.

Heat and cold storage

In 2008, the municipality of Texel decided to construct an open system for the new Town Hall and secondary school in Den Burg. However, up to now, this system is not realized because of frictions in the municipality of Texel while the Town Hall is already constructed. Nevertheless, it is indicated that the system will be installed. The pipes are already placed and it is expected that the system will be finished in 2012 (Texel-Plaza 2011a). Based on the counsel of the municipality of Texel (Gemeente Texel 2008b), the open system will produce around 1.2 GWh of heat per year.

Biomass energy

At this moment, TexelEnergie has plans for constructing an anaerobic co-digestion plant near Oosterend (Interview De Graaf 2011). These plans are also supported by local farmer organizations AJT and LTO Texel. The plant that they have in mind will consume 15,000 tons of animal manure and 14,500 tons of other agricultural residues per year. Both the animal manure and agricultural residues come from agricultural companies on the island. In this plant 28,000 tons of digestate will be produced, which can be used as fertilizer. Furthermore, the plant will produce 4 million m^3 of biogas, which will be used in a CHP for generating 12 GWh of electricity and 4 GWh of heat (TexelEnergie 2011a). The municipal executive board of Texel is currently supporting the construction of this plant (Interview Hercules 2011). They have indicated that they prefer to construct this plant next to the waste transfer station 'De Hamster' in Oudeschild (Texel-Plaza 2011b). It is therefore expected that this co-digestion plant will be constructed in the next few years. However, it should be noted that some reservations must be made regarding the capacity of the new plant.

From these findings, it can be concluded that particularly the amount of solar energy and biomass energy will increase considerably in the coming years. In Table 24, the current energy supply is indicated and the energy supply in the next few years. As can be seen, renewable energy sources are responsible for the energy supply in the municipal area. At this moment, approximately 1.5% of the electricity demand and approximately 1% of the heat demand is generated by renewable energy sources. A few years ago, this amount was higher due to the presence of four wind turbines in the harbor of Oudeschild. However, as can be seen in Table 24, in the next few years more renewable energy will generated in the municipal area, particularly electricity. This is increase will largely be caused by the construction of an anaerobic co-digestion plant.

TABLE 24 – DEVELOPMENTS IN ENERGY SUPPLY

Energy technology	Current energy supply		Energy supply in next few years	
	Electricity (GWh)	*Heat (GWh)*	*Electricity (GWh)*	*Heat (GWh)*
Solar panels	0.47		1.76*	
Solar thermal collectors		1.10		1.10
Wind turbines	0.65		0.65	
Heat and cold storage	-0.27	0.88	-0.57**	2.08
CHP based on biogas	0	0	12.00	4.00
Total energy supply	0.85	1.98	13.84	7.18

* It is assumed that the new solar panels that will be installed have an average efficiency of 15%

** It is assumed that the geothermal heat pump will have a COP of 4

4.6.2 ENERGY DEMAND

At this moment, several developments are taking place that will affect the energy demand in the municipality of Texel. To define these developments, developments will be considered that will have a direct impact on the energy demand in the municipality of Texel for an indefinite period. As a result, pilot projects on energy conservation and advices, information sessions, workshops and educational programs on creating energy awareness, of which it is uncertain whether these lead to a change in the energy demand, are not taken into account. The developments that are defined can be distinguished in the following categories: households and holiday homes, municipal connections and transport. It should be noted that in contrast to the developments in the energy supply, at this moment the developments in the energy demand cannot be measured quantitatively.

Households and holiday homes

At this moment, a large part of the residential housing stock in the municipal area is not well isolated (Interview Hercules 2011). Approximately two thirds of the housing stock has an energy label of D or lower (Gemeenteraden Waddeneilanden 2011). This is also not remarkable considering the average age of the residential housing stock, which is 49 years. To improve the energy efficiency of the housing stock, the municipality of Texel has introduced a subsidy for residents that want to invest in sustainable energy technologies and energy conservation, also known as Subsidie Energiezuinig Wonen (see also section 4.4.3). Both residential homes and holiday homes are eligible for this subsidy. At this moment, many residents have already applied for the subsidy (Gemeente Texel 2011e). From August 2011, 100 residential homes, of which 2 new, and 483 holiday homes were subsidized. These subsidies will lead to energy savings in the next few years. According the municipality of Texel (Gemeente Texel 2011e), the subsidy should result in a 30% reduction of the total energy demand of households and holiday homes in the municipal area by 2020.

Municipal connections
The municipality of Texel has indicated that in the next years public lighting will be provided with LED lights for saving energy on the municipal connections (Interview Hercules 2011). This goal is partly financed by the European project Cradle to Cradle Islands (C2CI) in which municipalities of the Wadden Islands in collaboration with the government, research and knowledge institutes and companies are carrying out projects related to the Cradle to Cradle philosophy.

Transport
At this moment, transportation company TESO, which provides the ferry service, is consuming 4.4 liters of diesel per year. This means that TESO is responsible for around 40% of the total fuel demand in the municipality of Texel, which is a significant amount (see also section 3.2.2). However, in the next years, a new ferry will be built that needs to be finished in 2015. As a result, TESO is currently examining how the new ferry can be more energy efficient and can make use of sustainable energy technologies (Interview De Waal 2011). The intention is to install solar panels on the ferry. Furthermore, TESO want to examine if turbosails can be used as propulsion technology, which are hollow cylinders that make use of the pressure difference between the sides of the cylinder. In addition to solar panels and turbosails, the use of batteries will also be examined, but these will not be used for propelling the ferry (Interview De Waal 2011). Another observation is that currently 20% of the total fuel amount that is consumed consists of biodiesel. TESO indicates that up to now the experiences are quite good. As a result, TESO has the ambition to increase the amount of biodiesel even further (Interview De Waal 2011). However, the biodiesel is exported and does not come from Texel.

4.7 Landscape

For defining the current developments regarding the landscape of Texel, a distinction is made between developments in the built environment and developments in the natural areas. These developments are related to the physical environment of the municipality of Texel.

Built environment
In 2009, the municipality of Texel has indicated that there is a need for 350 new homes by 2012 and a need for 400 new homes in the period from 2012 to 2022 (Gemeente Texel 2009b). Of these, 45 zero energy homes will be built, which will be funded by a subsidy of the municipality of Texel (Gemeente Texel 2011e). At this moment, 12 zero energy homes are built in Den Hoorn. Housing association Woontij is involved in this project and will be owner of these new homes. Furthermore, the municipality of Texel has indicated that until 2020 the number of sleeping places for tourists will not increase on the island (Gemeente Texel 2009b). This maximum is set on 45,000 sleeping places. At this moment, around 44,000 sleeping places are registered on the island. As a result, there is still some space for new touristic accommodations. According to the municipality of Texel (Gemeente Texel 2011e), 35 zero energy holiday homes will be built in the next few years.
In addition to the residential areas, the municipality of Texel has also indicated to upgrade the existing industrial areas and to improve the research area in ‘t Horntje, where research and knowledge institute NIOZ is situated (Gemeente Texel 2009b). In 2011, subsidies are allocated to the municipality of Texel for industrial sites in Den Burg and Oosterend and the area in ‘t Horntje for examining how these areas can be improved (Provincie Noord-Holland 2011i). Furthermore, the

municipality of Texel has indicated that it wants to preserve agricultural land as much as possible until 2020 (Gemeente Texel 2010). So has the municipality of Texel indicated that it wants to keep at least 4000 hectares of grassland by 2020 (Gemeente Texel 2009b). In order to check this, the municipality of Texel will monitor this closely.

Nature

In 2011, the Dutch government has indicated that in the next few years it wants to focus on preservation and less on improving and expanding the natural areas, particularly Natura 2000 areas (Rijksoverheid 2011e). As a result, no new Natura 2000 areas in the municipal area will be designated. However, Natuurmonumenten has indicated that it wants to expand the natural areas in the municipal area (Gemeente Texel 2009b). They want to do this by buying agricultural land and then managing these areas.

4.8 Stakeholders

In the previous sections, many stakeholders have already been mentioned. However, it is important to give an overview of the stakeholders that are involved in achieving energy self-sufficiency on Texel in 2020. Furthermore, it is needed to indicate the interests and influences of the stakeholders regarding the ambition of the municipality of Texel. This will provide important input for determining what various stakeholders could do for achieving energy self-sufficiency.

4.8.1 Overview stakeholders

To give a clear overview of the stakeholders that are involved in achieving energy self-sufficiency in the municipality of Texel in 2020, stakeholders can be divided into various stakeholder groups. These stakeholder groups can be distinguished in policy makers, research and knowledge institutes, consulting companies, technology and engineering companies, energy companies, financers, users and interest groups. In this section, the various stakeholder groups will be described, including the stakeholders that are identified.

Policy makers

The Dutch government, the province of North Holland and the municipality of Texel are important policy makers for achieving energy self-sufficiency in the municipal area. The Dutch government is capable of setting targets regarding stimulation and implementation of sustainable energy technologies. The Dutch government can come up with it own laws and regulations and frameworks. However, the Dutch government must also meet a number of treaties, such as the Kyoto Protocol, which have been agreed with other countries in the world. Furthermore, the Dutch government has to react to laws and regulation from the European Union, for example laws and regulations regarding Natura 2000 areas. As a result, the national policy of the Dutch government regarding stimulation and implementation of sustainable energy technologies is also dependent on international agreements. For achieving targets and agreements, the Dutch government can use various policy instruments, including financial incentives and subsidies. While the Dutch government is mostly concerned with the Netherlands in general, the province of North Holland is concerned with only the province. The province of North Holland has to ensure that laws and regulations that are set by the Dutch government must be observed in the region. However, the province is also capable of setting targets and making agreements, as long as they do not interfere with national policies. Also the province of North Holland can use various policy instruments for achieving targets and agreements, including financial incentives and subsidies.

The municipality of Texel is one of the most important stakeholders, as already could be noted in the previous sections. The municipality of Texel has decided to go for energy self-sufficiency in 2020. According to the municipality of Texel (Interview Hercules 2011), the task of the municipality of Texel is mainly to indicate what is possible and impossible on the island with respect to achieving energy self-sufficiency. Furthermore, the municipality of Texel supports the relevant actors that can contribute to the ambition, including financial support and changing laws and regulations when necessary. The municipality of Texel has also indicated that it is important to team up with municipalities of the other Dutch Wadden Islands. Together the municipalities are stronger in achieving energy self-sufficiency. Although the municipality of Texel can determine laws and regulations, the municipality of Texel is very dependent on laws and regulations that are created by the Dutch government and the province of North Holland. Furthermore, the municipality of Texel is dependent on agreements with other municipalities and provinces (Interview Hercules 2011).

Research and knowledge institutes

Research and knowledge institutes are important stakeholders for sharing knowledge on topics related to energy self-sufficiency. A research or knowledge institute is an organization that focuses on the development of science and performs scientific research. Institutes so far involved are ECN and a number of universities, such as Delft University of Technology and University of Twente. ECN, also known as Energy Research Centre of the Netherlands, is one of the largest research organizations in Europe and focuses on developing knowledge and technology in the field of renewable energy and energy efficiency. In 2007, ECN has done a feasibility study on achieving energy self-sufficiency on Texel (Weeda et al. 2007).

Important local research and knowledge institutes are NIOZ and Ecomare. NIOZ, also known as Royal Netherlands Institute for Sea Research, is an organization that focuses on scientific knowledge on seas and oceans. NIOZ conducts research on cultivating seaweed that can be used for generating energy and is involved in a pilot on tidal energy (Interview Van Rijsselberghe 2011; De Vries 2011). Although Ecomare is a natural museum that is very popular among tourists, it is also a knowledge institute. Ecomare has developed an educational program on sustainability for increasing this knowledge among children at primary schools in the municipality of Texel (Interview Hercules 2011). In addition, Ecomare is also discussing topics on sustainability in the museum, which can increase knowledge among residents and tourists.

Consulting companies

Consulting companies are important for assisting other stakeholders by providing them of professional advice on topics related to energy self-sufficiency, including sustainable energy technologies, environment and finance. These companies can be distinguished in profit and non-profit. An important consultant company that is involved is Development Company Holland North, also known as Ontwikkelingsbedrijf Noord-Holland Noord (NHN). Development Company Holland North is a non-profit company that assists and supports everyone who wishes to start a company or wants to invest in or develop businesses in the north of the province North Holland. Their goal is to attract economic activity to the region and to maintain the established industries. Development Company Holland North is involved in a few projects at Texel, including research on geothermal energy, and has close links with the municipality of Texel (Interview Hercules 2011).

Other consulting companies so far involved are Ecofys, CE Delft, IF WEP, Grontmij and non-profit consultancy company ATO. These companies have provided other stakeholders of professional advice, including the municipality of Texel and TexelEnergie (De Beer et al. 2001; Leguijt et al. 2008; Hagedoorn et al. 2009; Elswijk 2010). Furthermore, there are also companies involved that provide both consultancy and technology. At this moment, Capgemini is involved in a project in the municipality of Texel in which an energy management system is tested. Capgemini is seen as a consulting company, because it mainly provides professional advice. From all these findings, it can be concluded that the involvement of local consulting companies is negligible.

Technology and engineering companies

This stakeholder group consists of technology producers and engineering companies. Technology producers are important for providing the necessary sustainable energy technologies or power infrastructure for achieving energy self-sufficiency. In addition, engineering companies are important for designing, constructing and installing these necessary technologies or power infrastructure. Furthermore, like research and knowledge institutes, both technology producers and engineering companies are very important in providing technological developments. In general, there are many companies that are both a technology producer and engineering company. As a result, technology producers and engineering companies, which are involved in achieving energy self-sufficiency, are both described in this stakeholder group.

Most companies that are currently involved are companies that provide, design, construct and install sustainable energy technologies and power infrastructure. So is Tocardo International involved in a pilot project on tidal energy in which it provides, designs, constructs and installs the tidal stream generators. The same applies for donQi but than with small wind turbines. This company was involved in a pilot project on small wind turbines. Furthermore, at this moment SolarTotal is an important supplier and installer of solar panels in the municipal area (Interview Kieft and Bakker 2011). In addition, General Electric has also indicated to the municipality of Texel that it wants to cooperate (Interview Hercules 2011). However, it should be noted that these companies come and go. Especially in the field of renewable energy, there is much change in technology and engineering companies that are involved.

Although local companies can also be of importance, currently there are no local technology producers and few engineering companies involved in achieving energy self-sufficiency. However, other stakeholders that need these companies, including the municipality of Texel and TexelEnergie, have indicated that they try as much as possible to involve local technology and engineering companies (Interview Kieft and Bakker 2011). As a result, it can be concluded that the interest of local technology and engineering companies is small. This was also described in section 4.2.

Energy companies

This stakeholder group can be divided in retail companies, generation companies and network companies and retail companies. Retail companies are important for supplying the amount of energy and fuels that is needed. Generation companies are important for generating the amount of energy and for producing the amount of fuels that is needed. Furthermore, network companies are managing and controlling the power infrastructure. In general, there are many energy companies that both do retail and energy generation. In contrast to retail and generation companies, network companies are operating independent.

TexelEnergie is one of the most important stakeholders in achieving energy self-sufficiency in the municipality of Texel, as already could be noted in the previous sections. TexelEnergie was founded in 2007 and operates both as retail company and generation company. However, it differs from many other retail and generation companies. TexelEnergie is a local energy cooperative that focuses on buying, selling and generating renewable energy. It is owned by members most of whom are customer that are very attracted in achieving energy self-sufficiency. Anyone can become a member of the company and in return they become shareholder. This means that also people that are not living in the municipal area can become member. According to TexelEnergie (Interview De Graaf 2011), TexelEnergie is a non-profit company that is primarily concerned with achieving a renewable energy supply on the island. However, formally TexelEnergie is a for profit organization. TexelEnergie supplies not only energy to users in the municipality of Texel; it can also supply energy to the mainland. At this moment, TexelEnergie has around 2600 connections and 3300 members, representing 25% of the total energy market on the island (Interview De Graaf 2011). Furthermore, TexelEnergie is also involved in many local initiatives and projects as could be seen in section 4.3. It should be noted that in the Netherlands, energy users are free to choose a retail company. As a result, users in the municipality of Texel have contracts with various retail companies.

Another local retail company is RAB Groep, which is a large supplier of fuels on Texel, including gasoline and diesel. Furthermore, generation company HVC, which is located outside the municipal area, is a stakeholder. The municipality of Texel is one of the shareholders of HVC, which collects the waste in the municipality of Texel at a waste transfer station in Oudeschild, including food and green waste. The waste is then transported to the mainland where it is used for generating energy. Alliander, one of the largest network companies in the Netherlands, manages and controls the electricity lines and gas pipes in the municipality of Texel. Alliander is owned by provinces and municipalities, including the province of North Holland.

Financers

A small stakeholder, but an important group, is formed by financers. This group consists of banks, investors and subsidy providers. Since the implementation of energy technologies and power infrastructure usually requires lots of capital, financers are needed. However, as was described in section 4.2, it is relatively difficult to find financers that are willing to cooperate.

Users

The most important stakeholder group consists of the users. This group can be distinguished in direct and indirect users. Direct users are defined as actors that make directly use of electricity, gas and fuels. In addition, indirect users are defined as actors that make indirectly use of electricity. Indirect users are for example actors that can decide by whom energy is supplied and how the energy is generated but that are not using the energy by themselves.

Direct users can be subdivided in residents, tourists and professional users. Where professional users refer to companies in the agricultural, service and industrial sector and transportation companies. The transportation companies consist of the TESO, Connexxion and taxi and touring car companies. The TESO provides the ferry service between the mainland and Texel. This is the only way for motor vehicles to go to Texel. Furthermore, Connexxion provides the public transport on the island. The interest of these direct users is that if electricity, gas or fuel is needed it can be supplied.

Indirect users can be subdivided in touristic accommodations and housing associations. Because many tourists visit Texel each year, there are many hotels, campsites and bed and breakfasts in the municipal area. Furthermore, Woontij is the only housing association in the municipality of Texel. However, Woontij owns around 1700 residential homes in the municipal area, which is a relatively large share of the total housing stock of Texel.

Interest groups

There are many interest groups both in the municipal area and outside the municipal area. These interest groups can be distinguished in foundations, governmental organizations, tourism associations and organizations, farmer organizations, environmental organizations and partnerships. A very important stakeholder in the municipality of Texel is Stichting Duurzaam Texel. Stichting Duurzaam Texel is a foundation that focuses on initiating and stimulating activities that support the sustainable development of the island (Interview Hordijk 2011). It focuses not only on the environmental aspects but also on the economic and social aspects. The board of Stichting Duurzaam Texel consists of representatives of various organizations on the island, including transportation company TESO, business organization TVO, farmer organization LTO Texel. Stichting Duurzaam Texel was the first stakeholder who expressed the ambition to achieve energy self-sufficiency on Texel. From that time, the foundation was involved in several local initiatives and projects. In 2009, the foundation became less active because funding from the municipality of Texel, the province of North Holland and the National Post Code Lottery was stopped. At this moment, it is funded by the organizations that are involved in Stichting Duurzaam Texel. With respect to achieving energy self-sufficiency, Stichting Duurzaam Texel focuses currently on increasing awareness on saving energy and on connecting various organizations (Interview Hordijk 2011; Interview De Waal 2011).

Another important stakeholder outside the municipal area is Stichting Urgenda, which is a foundation that focuses on making the Netherlands as sustainable as possible. For achieving this goal, Stichting Urgenda has developed a list of actions that is covering many years (up to 2050) and in which many targets are indicated. Furthermore, several icon projects are indicated that serve as communication to show what sustainability means in practice. Stichting Urgenda has declared Texel as icon project for putting sustainability on the map of the Netherlands (Interview Minnesma 2011). As a result, Stichting Urgenda helps initiating and stimulating activities on the island with respect to sustainability of which achieving energy self-sufficiency is an important goal. Stichting Urgenda is involved in several local initiatives and projects. Furthermore, they have identified the local 'leaders' in the municipal area that can help Texel moving forward in making Texel more sustainable (Interview Minnesma 2011; Urgenda 2009). Many of these local leaders are also interviewed for this research.

There is also a business organization and tourism association in the municipality of Texel. TOP is a business organization of which many local companies are member. TOP represents the interests of their members, such as retail companies, hotels and campsites. TOP is working close together with VVV Texel, which focuses on informing tourists and promoting Texel as holiday island. VVV Texel is a tourism organization that operates as foundation. Furthermore, several farmer organizations are active in the municipal area: LTO Texel, De Lieuw and Agrarische Jongeren Texel (AJT). These organizations can be of importance regarding biomass energy. AJT was important in changing the view of the municipal executive board members of Texel on realizing an anaerobic co-digestion plant in the municipal area (Interview Kieft and Bakker 2011). These members are currently in favor of an anaerobic co-digestion plant (Interview Hercules 2011). There are also environmental organizations active in the municipality of Texel. The most important environment organization is Natuurmonumenten, which is a society for preservation of nature monuments in the Netherlands.

Natuurmonumenten manages many natural areas in the municipality of Texel. Local environmental organizations are 10 voor Texel and Vogelwerkgroep Texel. The environmental organization 10 voor Texel is an organization that focuses mainly on the conservation of the natural landscape and cultural values on the island. This organization is against constructing wind turbines and biomass power plants in the municipal area. Vogelwerkgroep Texel is an organization that focuses on the protection of birds and bird populations and their habitat on Texel. This organization is against placing wind turbines in the municipal area.
Moreover, there are also different partnerships or collaborations between various actors in the municipal area and outside the municipal area that are more or less involved in achieving energy self-sufficiency. An important stakeholder is the collaboration between the other Wadden Islands Vlieland, Ameland, Schiermonnikoog and Terschelling, also known as the VAST-islands. These islands have also the ambition to become self-sufficient in terms of energy by 2020. As previously described, the municipality of Texel has indicated that it is important to cooperate with these islands. Furthermore, there is a local collaboration called Nationaal Park Duinen van Texel, which is also the name of the natural park in the municipal area. This collaboration consists of various actors, including the municipality of Texel and Stichting Duurzaam Texel, and focuses mainly on the conservation and protection of the natural park.

4.8.2 Overview interests and influences stakeholders regarding vision

In the previous section, some of the interests and influences of the stakeholders with respect to achieving energy self-sufficiency on Texel in 2020 are already described. However, it is useful to determine the interests and influences of each stakeholder separately. First, the general interests of the stakeholder groups will be identified after which the specific interests of the stakeholders with respect to achieving energy self-sufficiency will be identified. This is done in Table 25.

TABLE 25 – GENERAL INTERESTS OF THE STAKEHOLDER GROUPS AND SPECIFIC INTERESTS OF THE STAKEHOLDERS

Stakeholder group	General interest	Stakeholders	Specific Interest
Policy makers	Achieving targets and agreements, ensuring that laws and regulations are obeyed	Dutch government	Achieving targets and agreements related to renewable energy and energy conservation
		Province of North Holland	Achieving targets and agreements related to renewable energy and energy conservation
		Municipality of Texel	Achieving energy self-sufficiency to reduce the use of fossil fuels, create more economic activity and achieve independence from the mainland
Research and knowledge institutes	Development of science, performing scientific research, providing education	Research and knowledge institutes (e.g. Universities, ECN)	Developing technology and knowledge related to achieving energy self-sufficiency, including technological, economic, cultural and institutional aspects
		Local institute NIOZ	Developing knowledge on seas and estuaries around the island, including Marsdiep and TexelStroom.
		Local institute Ecomare	Increasing knowledge on sustainability among residents and

			tourists in the municipality of Texel
Consulting companies	Assisting and providing professional advice	Development company Holland North (non-profit)	Attracting economic activity, such as renewable energy generation companies, to Texel and maintaining the established industries on Texel.
		Other non-profit consulting companies (e.g. ATO)	Assisting other stakeholders and providing them of professional advice to support these stakeholders in achieving energy self-sufficiency
		Consulting companies (e.g. Ecofys, IF WEP, CE Delft)	Assisting other stakeholders and providing them of professional advice to generate revenue, developing new knowledge
		Consulting/technology companies (e.g. Capgemini)	Assisting other stakeholders and providing them of professional advice to generate revenue, gaining experience with new concepts for their own gain
Technology and engineering companies	Providing, designing, constructing and installing technologies and infrastructure	Technology producers	Selling sustainable energy technologies and power infrastructure to generate revenue, gaining experience with new concepts for their own gain
		Engineering companies	Designing, constructing and installing sustainable energy technologies and power infrastructure to generate revenue
		Technology and engineering companies (e.g. General Electric, Tocardo)	Selling, designing, constructing and installing sustainable energy technologies and power infrastructure to generate revenue, gaining experience with new concepts for their own gain
Energy companies	Generating, supplying and transporting energy	Local company TexelEnergie	Achieving a renewable energy supply on the island by buying, selling and generating renewable energy
		Local company RAB Groep	Anticipating on possible changes in fuels
		HVC	Continuing with collecting food and green waste in the municipality that will be burned in incineration plants for generating energy
		Alliander	Proper management and control of the electricity lines and gas pipes in the municipality of Texel
		Other retail companies	Buying and selling renewable energy and fuels to generate revenue
		Other generation companies	Generating renewable energy and producing renewable fuels to generate revenue
Financers	Investing, lending, giving financial advice, providing transactions,	Banks and investors	Generating revenue from investments and loans that are provided to stakeholders for realizing the necessary sustainable

	encouraging		energy technologies and power infrastructure
		Subsidy providers	Encourage activities regarding energy self-sufficiency
Users	Making use of electricity, gas and fuels when needed	Residents	Most resident want to achieve energy self-sufficiency as long as it does not interfere with their vested interests, including conservation of the natural landscape and reliable and cheap supply of energy
		Tourists	Gaining experience and knowledge with new technologies, however, the natural landscape and quietness, which are the most important reasons for visiting Texel, should not be disturbed
		Professional users - Transportation companies (e.g. TESO and Connexxion) - Companies in agricultural, service and industrial sector	Reliable and cheap supply of renewable fuels and energy security so that activities are not disturbed
		Indirect users - Touristic accommodations - Woontij	Reliable and cheap supply of renewable energy and fuel and energy security
Interest groups	Initiating and stimulating activities, representing interests of their members, conservation and protection of certain areas, stimulating collaboration	Stichting Duurzaam Texel	Increasing awareness on saving energy and connecting various organizations that can help in achieving energy self-sufficiency
		Stichting Urgenda	Initiating and stimulating activities on the island with respect to achieving energy self-sufficiency
		Business organization TOP	Representing the interests of their members (local companies) regarding achieving energy self-sufficiency
		Touristic association VVV Texel	Boosting tourism by promoting Texel as a clean and energy-conscious island
		Farmer organizations - LTO Texel - De Lieuw - AJT	Helping agriculture companies that want to sell their agricultural residues that can be used for generating renewable energy and producing digestate
		Natuurmonumenten	Protecting the managed areas from sustainable energy technologies and power infrastructure that can damage or disturb these areas
		10 voor Texel	Preventing that sustainable energy technologies and power infrastructure, including biomass energy plants and wind turbines, that affect the natural landscape and cultural values are implemented in

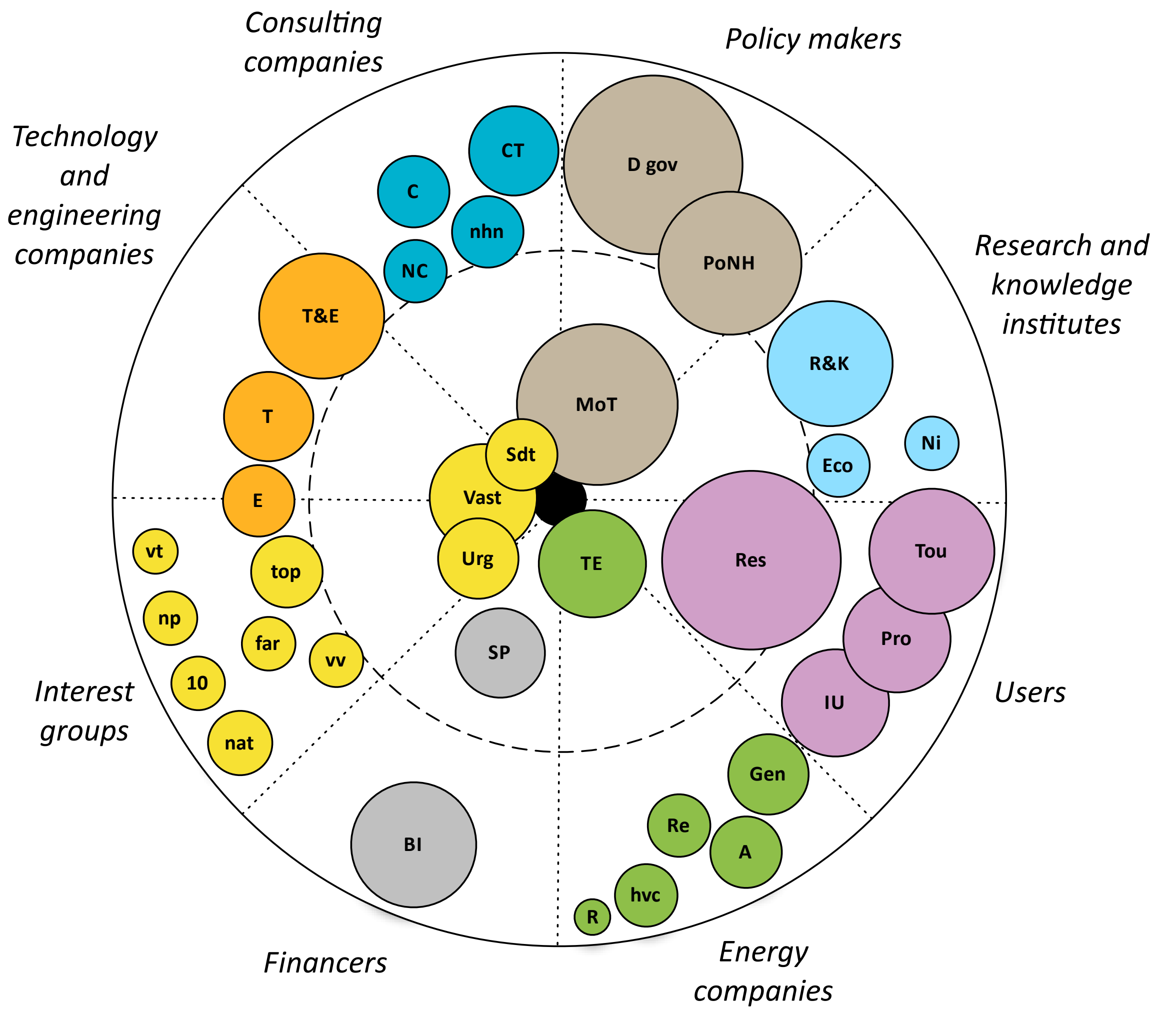
			the municipal area
		Vogelwerkgroep Texel	Protecting birds and their habitats from placing wind turbines and other disturbing sustainable energy technologies or power infrastructure
		VAST-islands	By working together, energy-sufficiency can be achieved more quickly.
		Nationaal Park Duinen van Texel	Protecting the natural park from sustainable energy technologies and power infrastructure that can damage or disturb the park

Now that the interests are identified, it is very useful to determine the influence of each stakeholder. In the previous sections, it could already be noticed which stakeholders have much influence on achieving energy self-sufficiency in the municipality of Texel. Of all stakeholder groups, policy makers have the most influence on achieving energy self-sufficiency, particularly the Dutch government. Next to policy makers, users also have very much influence. In this stakeholder group, residents have a considerable influence. Most residents have voted on political parties that had the ambition to achieve energy self-sufficiency. The municipality of Texel must constantly prove to the residents otherwise there is a chance that residents are going to vote on other political parties that do not have this ambition (Interview Kieft and Bakker 2011). Residents can also decide to deal with ambition by themselves. Tourists have also much influence. Currently, tourism is the main source of income in the municipality of Texel. When there are less tourists visiting Texel, because of damage to the natural landscape and disturbance, then this will have a huge impact on the local economy. As a result, tourists play an important role in achieving energy self-sufficiency. In addition to direct users, indirect users, including touristic accommodations and Woontij, also have much influence due to the many holiday homes, hotels, campsites and social housing units in the municipal area.

Local energy company TexelEnergie can also be much influential. At this moment, TexelEnergie has around 2600 connections and 3300 members, representing 25% of the total energy market on the island. When TexelEnergie gain more strength, larger projects can be carried out and more influence can be exerted on the municipality of Texel. Furthermore, financers, technology and engineering companies and research and knowledge institutes also have much influence. As previously described, to date sustainable energy technologies require relatively high investments. To carry out large projects, financers are very much needed. Technology and engineering companies can provide a breakthrough in technology, which can result in lower costs and higher efficiencies. The same applies for knowledge and research institutes. Moreover, the VAST-islands can also play an important role in achieving energy self-sufficiency in the municipality of Texel. The municipality of Texel has indicated that it is important to team up with municipalities of the other Dutch Wadden Islands. Together the municipalities are stronger in achieving energy self-sufficiency. Also, Stichting Duurzaam Texel and Stichting Urgenda can be important in stimulating activities and increasing awareness.

To give a good overview of the interests and influences of all stakeholders, it is very useful to create a map in which the interests against the influences of the stakeholders are visualized, as can be seen in Figure 22. In this figure, the size of the sphere indicates the degree of influence on achieving energy self-sufficiency. In addition, the distance to the center (black dot) indicates the commitment of the stakeholders in achieving energy self-sufficiency, which is based on the specific interests of the stakeholders. The closer this point, the greater the commitment.

Interest versus influence



Policy makers
D gov = Dutch government
PoNH = Province of North Holland
MoT = Municipality of Texel

Research and knowledge institutes
R&K = Research and knowledge institutes
Ni = NIOZ
Eco = Ecomare

Consulting companies
nhn = Development Company Holland North
NC = Other non-consulting companies
C = Consulting companies
CT = Consulting/technology companies

Technology and engineering companies
T = Technology companies
E = Engineering companies
T&E = Technology and engineering companies

Energy companies
TE = TexelEnergie
R = RAB Groep
hvc = HVC
A = Alliander
Re = Other retail companies
Gen = Other generation companies

Financers
BI = Bank and investors
SP = Subsidy providers

Users
Res = Residents
Tou = Tourists
Pro = Professional users
IU = Indirect users (e.g. Woontij)

Interest groups
Std = Stichting Duurzaam Texel
Urg = Stichting Urgenda
top = Business organization TOP
vv = Touristic association VVV Texel
far = Farmer organizations
nat = Natuurmonumenten
10 = 10 voor Texel
vt = Vogelwerkgroep Texel
Vast = VAST-islands
np = Nationaal Park Duinen van Texel

FIGURE 22 – INTEREST VERSUS INFLUENCE REGARDING ENERGY SELF-SUFFICIENCY

5. Construction of future scenarios

In this chapter, first the total energy demand on Texel in 2020 will be determined based on exogenous variables and current trends concerning energy self-sufficiency. Exogenous variables can be seen as possible far-futures or assumptions that will offer a certain constraint in constructing the two scenarios. So although these possible far-futures and assumptions seemed more connected to forecasting, they are part of the backcasting approach. Next, exogenous variables will be defined that affect the development and implementation of the sustainable energy system. Eventually, two scenarios will be constructed, which is done in section 5.3. First, a scenario will be considered in which the growth trend of the total energy demand in the period from 2010 to 2020 will be maintained. Subsequently, a scenario will be considered in which energy conservation is essential for achieving energy self-sufficiency.

5.1 Energy demand on Texel in 2020

Based on possible far-futures, assumptions and current trends concerning energy self-sufficiency, which are described in the previous chapter, the development of the energy demand in the municipality of Texel in the period from 2010 to 2020 will be determined. For defining possible far-futures and assumptions, recent context scenarios from ECN and government institute PBL will be used (ECN 2010; PBL 2011b). The developments that are defined will be distinguished in various sectors: households, agriculture, industry, services, municipal connections and transport. The current energy demand is also subdivided into these sectors, as could be seen in section 3.2.2.

Households

The change in the energy demand of households will be the result of several developments, including developments in the housing stock and implementation of energy saving measures. According to ECN (2010), the existing housing stock in the Netherlands will become more energy efficient in the next years. In particular, high efficient boilers, double-glazing, roof insulation, floor insulation and cavity wall insulation will be more applied, which will affect the heat demand. Because until now gas is mainly used to meet the heat demand in the Netherlands, the gas demand of the existing housing stock will decrease. On the other hand, new homes will be built in the next years, which will result in an increase in the energy demand. The energetic requirements of these new homes, however, will be much higher. According to ECN (2010), the influence of these new homes on the heat demand is much less than the implementation of high efficient technologies and energy saving measures in the next years. As a result, the gas demand of households will decrease in the Netherlands with approximately 9% in the period from 2010 to 2020. In contrast to the gas demand, the electricity demand will increase slightly in this period. This is due to a slight increase of the housing stock and the rise of several technologies that will play a more important role in the next years, including information and communication technology, ventilation systems and water heaters. Based on ECN (2010), the electricity demand will increase with approximately 5%. It is assumed that these national trends will be largely consistent with the development of the energy demand of households in the municipality of Texel. However, because the municipality of Texel has an incentive policy regarding the implementation of energy saving measures, which mainly affects the heat demand, it is expected that more energy saving measures will be applied in the next years compared to the national trend. Therefore it is assumed that the gas demand of households in the municipality of Texel will decrease with 12%. The development of the electricity demand, however, is assumed to be consistent with the national trend. The development of the energy demand of households in the municipality of Texel is shown in Figure 23.

Agriculture

According to ECN (2010), the development of the energy demand in the agricultural sector in the Netherlands in the next years will be mainly determined by developments in horticulture, especially greenhouses. However, although there are relatively many farms present in the municipal area, there are not many greenhouses. As a result, the national trend is not representative for the development of the energy demand in the agricultural sector on Texel. For determining the development of the energy demand in the next years, the development of agricultural land in the municipal area and the development of technologies used will be taken into account. At this moment, around 10,150 hectares is used for agriculture. In the last years, the total area used for agriculture on the island remained unchanged (In Cijfers 2012). In addition, the municipality of Texel has indicated that it wants to preserve agricultural land as much as possible until 2020 (see also section 4.7). Based on these findings, it is assumed that the total area used for agriculture in the municipal area will remain unchanged until 2020. Next to this development, however, it is expected that mechanization and automation will play a more important role in the agricultural sector in the next years, which will mainly affect the electricity demand (ECN 2010). Based on these findings, it is assumed that the gas demand will slightly increase with 1% and the electricity demand with 3% in the period from 2010 to 2020. The development of the energy demand in the agricultural sector is shown in Figure 23.

Industry

Not many industrial activities take place in the municipality of Texel. Furthermore, only light industry is present and no heavy industry can take place because of zoning regulations. Therefore, the industrial sector in the municipality of Texel cannot be compared with the industrial sector in the Netherlands. As a result, the national trend of the energy demand in the industrial sector has no significance for Texel. In the industrial sector on Texel, gas is mainly used for space heating and small activities, such as bakery and construction (Weeda et al. 2007). Due to a number of new industrial activities that will take place in the next years, it is assumed that the gas demand will increase with 3% in the period from 2010 to 2020. Moreover, electricity is mainly used for the distribution of water, gas and electricity (Weeda et al. 2007). Because the total energy demand will not change much (as also can be seen in Table 26) and the water demand will increase slightly (Deltares 2011), it is assumed that the electricity demand will increase with 2% in the period from 2010 to 2020. The development of the energy demand in the industrial sector is shown in Figure 23.

Services

The service sector includes local companies that are in active in the subsectors hospitality and food, retail, education, care and other services, particularly recreation. The change of the energy demand in the service sector on the island will be the result of several developments, including the growth of employees and the implementation of energy saving measures. According to ECN (2010), the gas demand of the service sector in the Netherlands will decrease in the next years with approximately 9%. This is largely due to the implementation of energy measures, a smaller growth of employees compared to the past and a shift from gas to electric applications. In addition to the gas demand, ECN is expecting that the electricity demand of the service sector in the Netherlands will increase with approximately 7%, which is largely due to a slight growth in the number of employees, a shift from gas to electric applications and an increasing use of information and communication technology. Although these national trends are largely consistent with the development of the energy demand in the service sector on Texel, the energy demand will undergo a somewhat different development as the national trend. Many services in the municipality of Texel are related to tourism, which is different compared to the Dutch service sector in general. As a result, the change in the energy demand of the service sector in the municipal area is much dependent on the development in the number of sleeping places and occupancy of touristic accommodations, which largely determine the growth of the service sector on Texel. The municipality of Texel has indicated that until 2020 the number of sleeping places for tourists, which is set on 45,000, will not increase on the island. At this moment, around 44,000 sleeping places are registered on the island. As a result, it is expected that few touristic accommodations will be added to the existing amount in the period from 2010 to 2020. This assumption is also based on the development of touristic accommodations in the period from 2000 to 2010. In this period, the number of touristic accommodations was increased with 2% (CBS Statline 2012). Moreover, the occupancy of touristic accommodations is expecting to increase in the next years, which will be largely caused by a broadening of the season (Bureau Stedelijke Planning 2009). This is also reflected in the upward trend of the number of overnight stays on Texel (VVV Texel 2010). Next to a slight growth in the number of sleeping places and growth in the occupancy rate, however, there will be more energy saving measures applied in the next years compared to the national trend. This is because the municipality of Texel has an incentive policy for holiday homes regarding energy saving measures. The influence of these energy saving measures on the energy demand, however, will be less than the growth in the number of sleeping places and occupancy rate. Based on these findings, it is assumed that in the next years the gas demand will decrease less and the electricity demand will increase more in comparison to the national trend. Therefore, it is assumed that the gas demand in the service sector will decrease with 7% in the period from 2010 to 2020. In addition, the electricity demand will increase with 9%. The development of the energy demand in the service sector is shown in Figure 23.

Municipal connections

The municipal connections on Texel consist largely of municipal buildings, public lighting, sewage pumping stations and public toilets. According to ECN (2010), it can be assumed that the development of the energy demand of municipal connections in the Netherlands will be equal to the development of the Dutch service sector in the next years. As a result, it is assumed that the gas demand of municipal connections will decrease with 7% in the period from 2010 to 2020. However, the development of the electricity demand of municipal connections will have a different development. The municipality of Texel has indicated that it will provide public lighting with LED lights in the next years. Based on information from the municipality of Texel (Struick 2011), public lighting accounts for more than 50% of the electricity demand of municipal connections, which is a significant part. As a result, it is expected that the electricity demand will decrease in the next years. Based on Agentschap NL (2012), it is assumed that LED lights will result in energy savings of 15%. In contrast to public lighting, however, it is expected that in the next years the electricity demand of municipal buildings, which account for 28% of the total electricity demand, will increase with approximately 7% (ECN 2010). Based on these findings, it is determined that the electricity demand of municipal connections will decrease with 6% in the period from 2010 to 2020.

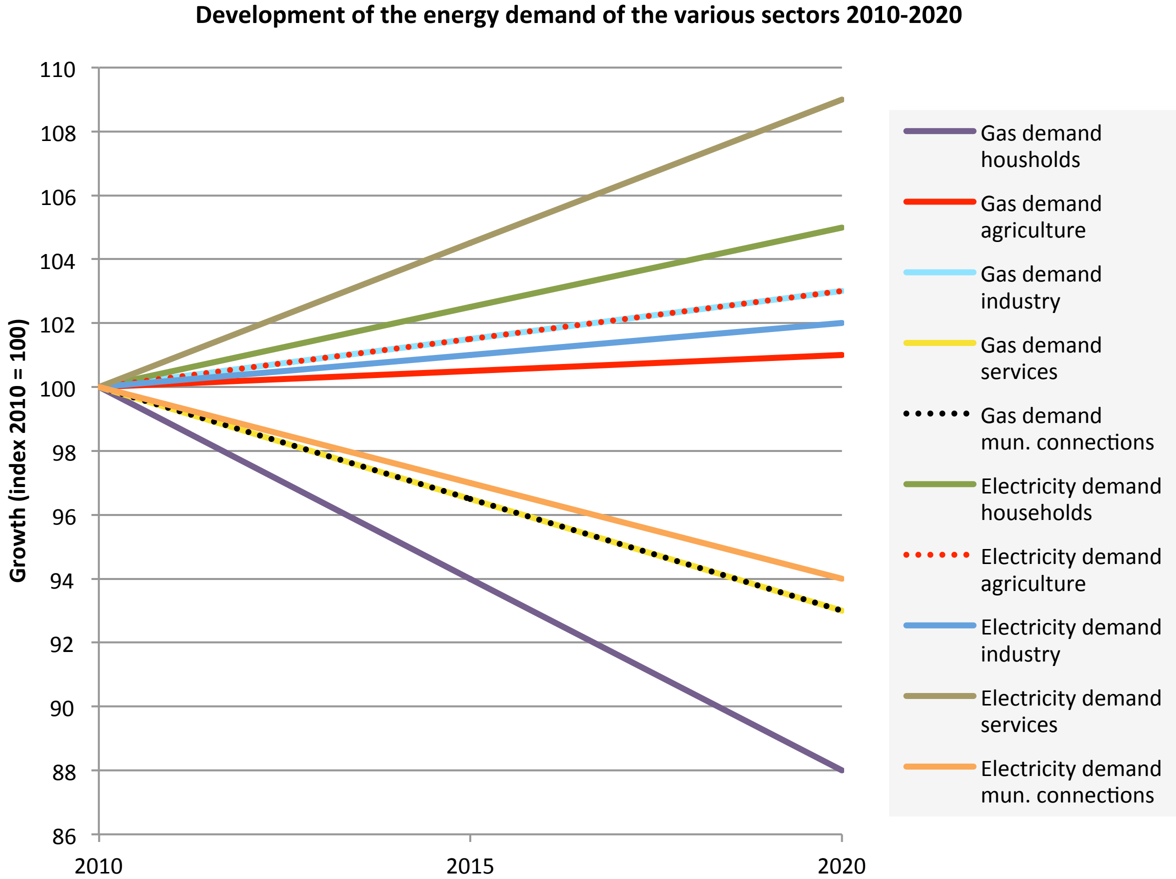


FIGURE 23 – DEVELOPMENT OF THE ENERGY DEMAND OF VARIOUS SECTORS IN THE MUNICIPALITY OF TEXEL

Transport

The change in the fuel demand of motor vehicles in the next years will be the result of several developments, including developments in the number of kilometers travelled by vehicles and technological developments related to internal combustion engine vehicles (ICEVs) and electric vehicles (EVs). According to the context scenarios from PBL (2011b) and ECN (2010), it is expected that the number of kilometers travelled by vehicles will increase in the Netherlands. Based on PBL (2011b), the number of kilometer travelled by vehicles will increase in the municipality of Texel with approximately 10% in the period from 2010 to 2020. Another important trend is that internal combustion engine vehicles will become more energy efficient in the next years. Based on ECN (2010), the average efficiency of these vehicles will go up with 5% in the period from 2010 to 2020. It is assumed that this national trend will be consistent with the development of transport in the municipality of Texel. As a result, the fuel demand of motor vehicles on the island will increase less than the number of kilometers travelled by vehicles. However, there is a significant development going on regarding electric vehicles that needs to be taken into account. In the next years, the market share of electric vehicles will increase, which results in a decline in the demand of gasoline, diesel and LPG and an increase of the electricity demand. Based on a study from D-incert (2010), also known as Dutch Innovation Centre for Electric Road Transport, it is expected that electric vehicles will account for 5% of the total vehicles in the Netherlands in 2020. As with the efficiency improvement, it is assumed that this national trend will be consistent with the development of transport in the municipality of Texel. Based on these findings, the fuel demand of gasoline, diesel and LPG will decrease slightly with 0.7% in the period from 2010 to 2020. In addition, there will arise a demand for electricity. Based on the average kilometers travelled by vehicles in the municipal area and an average electricity consumption of 16 kWh per 100 kilometers at this moment (CBS Statline 2012; Zimmer et al. 2009), this electricity demand is estimated on 1 GWh in 2020. The development of the fuel demand of motor vehicles in the municipality of Texel is shown in Figure 24.

Next to a change in the fuel demand of motor vehicles, there will be also a change in the fuel demand of the ferries. This change is also dependent on developments in the number of kilometers travelled by vehicles and technological developments. Moreover, developments in the number of tourists that are travelling by bike or on foot can also affect the fuel demand of the ferries. As previously indicated, both the number of kilometers travelled by vehicles and overnight stays of tourists will increase in the municipal area. It is not expected, however, that these developments will affect the fuel demand of the ferries considerably in the next years. At this moment, the average occupancy rate of the ferries is around 34%, which is relatively low (TESO 2011). Therefore, the ferries can largely accommodate this growth of passengers. An important development, however, which will affect the fuel demand of the ferries in the next years, is the advent of a new ferry in 2015. TESO indicates that they are currently actively examining how the new ferry can be more energy efficient and can make use of sustainable energy technologies (Interview De Waal 2011). This development will decrease the fuel demand of the ferries in period from 2010 to 2020. Based on these findings, it is assumed that the fuel demand of the ferries will decrease with 5%.

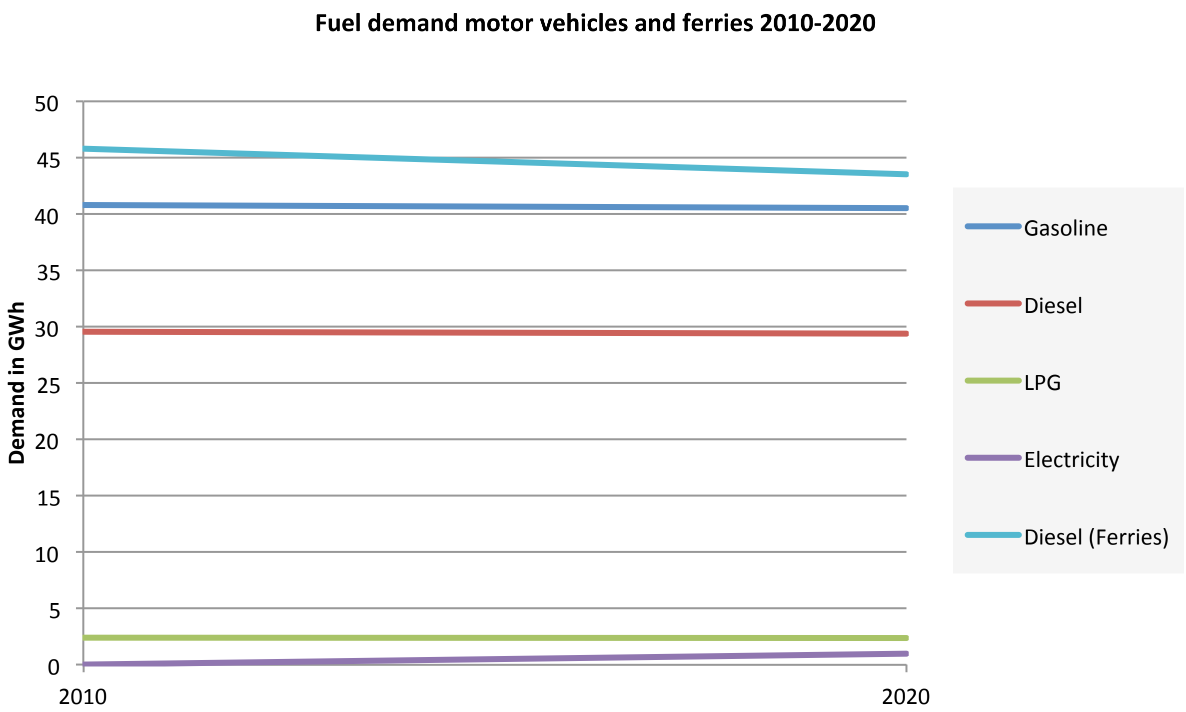


FIGURE 24 – DEVELOPMENT OF THE FUEL DEMAND OF TRANSPORT IN THE MUNICIPALITY OF TEXEL

Based on the developments of the energy demand in the various sectors, the total energy demand on Texel in 2020 is determined, as can be seen can in Table 26. As is indicated, the electricity demand will increase with 8.7%, while the gas and fuel demand will decrease with 9.1% and 1.5%, respectively.

TABLE 26 - THE DEVELOPMENT OF THE TOTAL ENERGY DEMAND ON TEXEL IN THE PERIOD FROM 2010 TO 2020

	2010			2020		
Sector	**Electricity**	**Gas**	**Fuel (l)**	**Electricity**	**Gas**	**Fuel (l)**
	GWh	*GWh*	*GWh*	*GWh*	*GWh*	*GWh*
Households						
- *Households*	19.21	102.76		20.17	90.43	
Total	19.21	102.76		20.17	90.43	
Agriculture						
- *Agriculture*	3.08	4.69		3.17	4.74	
Total	3.08	4.69		3.17	4.74	
Industry						
- *Industry*	1.07	2.93		1.09	3.02	
Total	1.07	2.93		1.09	3.02	
Services						
- *Hospitality and food*	13.06	29.24		14.23	27.19	
- *Retail*	4.50	4.99		4.91	4.64	
- *Education*	0.26	0.49		0.28	0.46	
- *Care*	1.09	3.23		1.19	3.00	
- *Other services (e.g. recreation, culture, trade, financial institutions)*	30.18	65.41		32.90	60.83	
Total	49.09	103.36		53.51	96.12	
Municipal connections						
- *Municipal connections (e.g. public lighting, sewage)*	1.18	1.08		1.11	1.00	
Total	1.18	1.08		1.11	1.00	
Transport						
- *Motor vehicles*			72.81			72.28
Gasoline			40.83			40.54
Diesel			29.58			29.37
LPG			2.40			2.38
Electric vehicles	-			1.00		
- *Ferries*			45.83			43.54
Total	-		118.64	1.00		115.82
Total energy demand	73.63	214.82	118.64	80.05	195.31	115.82
Change in demand				+8.7%	-9.1%	-1.5%

5.2 Exogenous variables concering sustainable energy system

In addition to exogenous variables that affect the development of the total energy demand on Texel in the period from 2010 to 2020, there are also exogenous variables that affect the development and implementation of the sustainable energy system in the same period. It is important to define these exogenous variables and their influence before constructing the scenarios so that these can take into account. Based on the findings in section 4.5, the sustainable energy technologies that are described are so far not able to compete economically with fossil fuels in the Netherlands. However, it is expected that solar energy, wind energy, geothermal energy, heat and cold storage and biomass energy are able to compete with fossil fuels before 2020 without the need for subsidies or regulations. The break-even point of these forms of renewable energy is dependent on several exogenous variables, including changes in the prices of fossil fuels and international technological developments regarding renewable energy.

Based on CBS Statline (2012), it can be concluded that fossil fuel prices have increased much in recent decades. At this moment, the prices of oil, natural gas and coal are considerably high. Also, transport fossil fuels, including gasoline and diesel, have reached new record heights. The increases are largely caused by an increasing demand for energy (CBS Statline 2012). Moreover, economical developments, major disasters and tensions between countries have contributed to this. Because it is expected that the demand for energy will continue to increase, it is assumed that the prices of fossil fuels will continue to increase until 2020. This has a positive impact on the implementation of sustainable energy technologies. Renewable energy sources become more attractive and can sooner compete with fossil fuels. In addition to an increase in fossil fuel prices, more technological developments regarding renewable energy are expected. According to UNEP (2011), in recent years, global investments in research and development concerning renewable energy have increased and are expected to continue increase further. Solar energy has attracted the most support and was followed by biomass energy and wind energy. Due to an increase of global investments in research and development, it is assumed that more technological developments will take place in the next years. Both the development of the fossil fuel prices and international technological developments regarding renewable energy will be taking into account when constructing scenarios.

5.3 Scenarios for achieving energy self-sufficiency

In this section, two scenarios will be constructed. These scenarios will be based on present conditions, current trends and exogenous variables concerning the municipal area, which are defined in the previous sections. First, a scenario will be considered in which the trend growth of the total energy demand on Texel in the period from 2010 to 2020 will be maintained. In this scenario, which is called scenario A, economical efficiency, technological innovations, large-scale technologies and centralization will play an important role. Subsequently, a scenario will be considered in which the total energy demand will be reduced considerably in the period from 2010 to 2020. In this scenario, which is called scenario B, solidarity, energy saving measures, small-scale technologies, decentralization, community building and nature and environment will play an important role. As a result, two very different scenarios will be constructed. An overview of the main characteristics of the scenarios is shown in Table 27.

TABLE 27 – MAIN CHARACTERISTICS OF THE TWO SCENARIOS

Scenario A: Trend growth	Scenario B: Energy conservation
• Economical efficiency • Technology driven • Large-scale • Centralization	• Solidarity • Energy saving measures • Small-scale • Decentralization/community • Nature and environment

In the next sections, the two scenarios will be described in detail. For doing this, first the background of the scenarios will be outlined after which the scenarios are described in the following categories: energy demand, energy supply, storage, power infrastructure, organization, policies, finance and culture.

5.3.1 Scenario A: Trend growth

This scenario builds itself on the assumption that energy self-sufficiency can be achieved, while the trend growth of the total energy demand on Texel will be maintained. In this scenario, the market economy plays a very important role. As a result, the main focus will be on developing an energy system that is economically efficient. Where economic efficiency refers to the use of renewable sources that generate energy at the lowest cost possible and that are able to compete economically with fossil fuels. For doing this, economies of scale are important, which means that cost advantages can be obtained when renewable energy sources will be used on large scale in the municipal area. To realize an economically efficient sustainable energy system, TexelEnergie has taken the lead in cooperation with the municipality of Texel and local entrepreneurs. Based on the development of fossil fuel prices and international technology developments regarding renewable energy, which are described in the previous section, it is expected that in this scenario solar energy, wind energy, geothermal energy, heat and cold storage and biomass energy are able to compete economically with fossil fuels before 2020 without the need for subsidies or regulations. Moreover, in this scenario, energy conservation plays no significant role.

An important observation is that the desire of achieving energy self-sufficiency among residents is more important than the conservation of nature and environment. Moreover, residents attach great importance to reliable and cheap supply of energy. They consider that reliable and cheap supply of energy can be realized by making a centralized energy system in which economies of scale is important. As a result, residents tolerate the implementation of large-scale technologies in the municipal area. TexelEnergie is managing the sustainable energy technologies and trades the amount of renewable energy that is generated. Although residents are free to choose their own retail company, residents want to choose for TexelEnergie. This is due to the deep-rooted culture of autonomy that is present on Texel and the confidence that TexelEnergie keep the prices as low as possible. Although TexelEnergie is a for profit organization, residents consider TexelEnergie as a non-profit company of which they know that it is owned by members most of whom are residents. As a result, households and local companies, which mainly are owned by residents, join TexelEnergie.

The most important stakeholders in this scenario are policy makers, research and knowledge institutes, technology and engineering companies, energy companies, financers and users. Policy makers, including the Dutch government, the province of North Holland and the municipality of

Texel, facilitate and stimulate the implementation of sustainable energy technologies on large scale. Research and knowledge institutes and technology and engineering companies play a major role in providing technological developments. Moreover, in cooperation with the municipality of Texel and local entrepreneurs, local energy company TexelEnergie has taken the lead in realizing the new energy supply. Where it should be noted that technology and engineering companies from outside the municipal area provide, construct and install the technologies. TexelEnergie is also responsible for managing the renewable energy supply and sells the amount of generated energy. Alliander, which is owner of electricity lines and gas pipes in the municipal area, provides the necessary changes in the power infrastructure. Financers are important for providing investments and loans that are needed for the implementation of sustainable energy technologies and power infrastructure. Moreover, where residents tolerate the implementation of large-scale technologies, tourists also take the view that these technologies are not disruptive and do not affect the natural landscape.

Energy demand
In this scenario, the growth trend of the total energy demand on Texel will be maintained. Although the trend indicates that some energy saving measures will be applied, as can be seen in section 5.1, there will be no additional measures applied that will affect the trend growth. As a result, the electricity demand will increase with 8.7% in the period from 2010 to 2020, while the gas and fuel demand will decrease with 9.1% and 1.5%, respectively, as can be seen in Table 28.

TABLE 28 – THE DEVELOPMENT OF THE TOTAL ENERGY DEMAND IN SCENARIO A

Development of energy demand 2010-2020						
	Electricity demand (GWh)		*Gas demand (GWh)*		*Fuel demand (l) (GWh)*	
2010						
Total energy demand	73.63		214.82		118.64	
2020		*Change*		*Change*		*Change*
Total energy demand	80.05	+8.7%	195.31	-9.1%	115.82	-1.5%

Energy supply
Large-scale technologies related to solar energy, wind energy, geothermal energy, heat and cold storage and biomass energy are widely used in the municipal area. To describe the energy supply in scenario A, a distinction will be made between technologies that are implemented for meeting the electricity, heat and process demand. Besides indicating what technologies are used, it will also be indicated for which shares the renewable energy sources are responsible. These shares are based on providing a resilient and diversified system in the municipal area.

Electricity demand
To generate electricity in the municipal area, wind turbines, solar fields, a geothermal plant and CHPs based on biogas are realized on Texel. In this scenario, onshore wind turbines are techno-economically the most interesting. As a result, 4 onshore wind turbines of 3 MW are placed and generate around 35% of the total electricity demand in the municipal area. However, onshore wind turbines are characterized by periodic fluctuations. Therefore, other sources are used in order to create a diversified system. Next to onshore wind turbines, solar fields are realized with a total area

of 10 hectares. A solar field is a field on agricultural land on which solar panels are installed. Whereas the average wind speed is higher in winter than in the summer, the sum of global irradiation is higher in the summer than in the winter. Due to technological developments, solar panels have an average efficiency of 20%. Through realizing this field, solar energy accounts for around 22% of the electricity demand. Furthermore, a geothermal power plant is constructed based on one doublet, which extracts heat at a depth of approximately 5000 meters (Carboniferous Limestone Group). Based on IF WEP (2011), it is assumed that the costs per kWh of electricity generated are the lowest at this depth. To be able to extract enough water at this depth, hydraulic fracturing is applied. With a share of around 35% of the electricity demand, the geothermal plant generates a significant amount of electricity on Texel. In contrast to onshore wind turbines and solar fields, this geothermal power plant generates electricity when it is needed. In order to further increase the diversity of the energy system, 3 CHPs are constructed, which make use of biogas to generate electricity. These CHPs will account for 28% of the electricity demand. Because a relatively high share of the electricity demand (17%) was already generated by existing sustainable energy technologies in the municipal area, more capacity is realized than is needed. This is done for providing a resilient system in the municipal area and for economic reasons related to electric power storage and export of energy, which will be explained below (see 'storage'). Moreover, it is important to realize more capacity for providing the amount of electricity that geothermal heat pumps need for generating heat. An overview of the technologies that are implemented to meet the electricity demand can be seen in Table 30.

Heat and process demand
To indicate which technologies are responsible for meeting the heat and process demand, first it is needed to determine the fractions of the gas demand in 2020 that is used for space heating, hot water, cooking and other activities. With these fractions the actual heat demand and process demand can be determined, which are important for indicating which technologies are needed. Based on section 3.2.2, in 2010, 95% was used for space and water heating and 5% for cooking and processes. In this scenario, it assumed that these fractions are unchanged in 2020. As a result, space and water heating are largely responsible for the total gas demand. Space and water heating have less energy requirements than cooking and processes, such as bakery and construction. From energy point of view, it is unwise to burn gas for only space and water heating, which is done by boilers. In order to create an efficient energy system, technologies are implemented that are based on the fractions of the different types of end-use. However, it should be noted that also other factors, such as existing protected areas, are taken into account. In Table 29, the heat demand, which is the actual demand for space and water heating, and the process demand of scenario A are shown. For determining the heat demand, it is assumed that boilers have an efficiency of 90%.

TABLE 29 - HEAT AND PROCESS DEMAND IN SCENARIO A

	Demand	Space heating		Water heating		Cooking		Processes	
	GWh	*GWh*	*%*	*GWh*	*%*	*GWh*	*%*	*GWh*	*%*
Total gas demand	195.31	144.53	74	41.01	21	5.86	3	3.91	2
Total heat demand	**166.99**	130.08		36.91					
Total process demand	**9.77**					5.86		3.91	

The geothermal power plant that is constructed generates also much heat, which is the residual heat from electricity generation. The residual heat from the geothermal power plant, which generates a water temperature of 65°C, is very suited to meet the desired temperature for space and water heating. By using this plant, geothermal energy accounts for 36% of the heat demand. In order to diversify the system, also technologies related to heat and cold storage and biomass energy are used. Open systems are constructed, which are used for space and water heating and cooling in residential and commercial areas that are not receiving geothermal heat. Moreover, although the costs of open systems are lower compared to closed systems, closed systems are also constructed. These individual heating systems are very suitable in not densely built areas. Due to technical developments, it is assumed that the average COP of geothermal heat pumps is 5. Heat and cold storage systems account for 45% of the heat demand. Next to geothermal energy and heat and cold storage, also biomass is used to meet the heat demand. Three anaerobic co-digestion power plants are constructed for producing biogas. In addition, wastewater treatment plant 'Evertsekoog' is upgraded to produce biogas. The major part of the produced biogas is used in three CHPs that, besides the supply of electricity, also generate a significant amount of heat. Next to the CHPs, also a small amount of boilers, which are adjusted or bought new, generate heat. These boilers provide heat in rural areas where no heat and cold storage systems and heating grids can be constructed due to laws and regulations. Biogas that is not used by the CHPs is used for processes. The constructed co-digestion plants, CHPs, wastewater treatment plant account and adjusted boilers account for 20% of the heat demand. Furthermore, the co-digestion plants and wastewater treatment plant account for 100% of the process demand. Because a relatively low share of the heat demand (4%) was already generated, some additional capacity is realized. This is done for providing a resilient energy system. An overview of the technologies that are implemented to meet the heat and process demand can be seen in Table 30.

Fuel demand

In 2020, electric vehicles account for 5% of the total amount of vehicles in the municipality of Texel. ICEVs are still widely used and make use of bioethanol, biodiesel and biogas, which can be refueled on the island. This also applies to tourists. Moreover, the ferries of transportation company TESO make use of biodiesel. To meet the demand of bioethanol and biodiesel, microalgae are produced in photobioreactors for producing the required amount. However, producing biofuels from microalgae is still under development and faces a lot of challenges. Until now, the investments costs are very high. Therefore, it is considered that a major breakthrough has occurred. It is assumed that photobioreactors can produce 60,000 liters per hectare in 2020. This applies both to the production of bioethanol and biodiesel. In addition, biofuels from microalgae are able to compete economically with fossil fuels. Moreover, cars that make use of LPG will be replaced by cars that make use of biogas. Produced biogas is upgraded to make it suitable for use in ICEVs.

TABLE 30 – ENERGY SUPPLY IN SCENARIO A

Energy supply

	Technology	Characteristics and information	Electricity
Electricity demand	Solar panels (field)	Total area: 10 hectares Average efficiency: 20% Yearly sum of global irradiation: 11.75 GWh/ha	17.6 GWh
	Wind turbines	Amount: 4 Total rated power: 3 MW*4= 12 MW Load factor: 27%	28.4 GWh
	Geothermal power plant	Doublet: 1 (space between wells is 1500 m) Depth: 5000 m Applied technology: double ORC Temperature extracted water: 175°C Operating hours electricity generation: 8500	28 GWh*
	HCS open and closed systems	Capacity of open systems: 0.2 – 5 MW Capacity of closed systems: 4 – 10 kW Coefficient of performance (COP): 5	- 15 GWh
	CHPs based on biogas	Amount: 3 Total electric power: 3.8 MW Total amount of biogas used: 60 GWh Thermal efficiency: 38%	22.8 GWh
	New supply		81.8 GWh
	Existing supply		13.8 GWh
	Total supply		**96 GWh**

	Technology	Characteristics and information	Heat	Biogas
Heat and process demand	Geothermal plant	Temperature of heat produced: 65°C Operating hours heat generation: 6000	60 GWh*	
	HCS open and closed systems	Capacity of open systems: 0.2 – 5 MW Capacity of closed systems: 4 – 10 kW Coefficient of performance (COP): 5	75 GWh	
	Anaerobic co-digestion plants	Amount: 3 Total manure: 66,000 tons Total co-substrates: 66,000 tons Digestate produced: 123,000 tons		80 – 70.4 = 9.6 GWh
	CHPs based on biogas	Amount: 3 Total thermal power: 5 MW Total amount of biogas used: 60 GWh Thermal efficiency: 50%	30 GWh	
	Wastewater treatment plant	Total digested sludge: 2,000 tons		1.7 – 1.5 = 0.2 GWh
	Adjusted/new boilers	Total amount of biogas used: 6.9 GWh Thermal efficiency: 90%	6.2 GWh	
	New supply		171.2 GWh	9.8 GWh
	Existing supply		7.2 GWh	
	Total supply		**178 GWh**	**9.8 GWh**

	Technology	Characteristics	Bioethanol	Biodiesel	Biogas
Fuel demand (I)	Photobioreactors	Reactor area: 120 ha Used area: 12 ha	42 GWh		
	Photobioreactors	Reactor area: 135 ha Used area: 13.5 ha		73 GWh	
	Gas cleaning	Biogas used: 5 GWh			5 GWh
	New supply		42 GWh	73 GWh	5 GWh
	Total supply		**42 GWh**	**73 GWh**	**5 GWh**

* Based on IF WEP (2011) and ThermoGIS (2012)

Storage

By making the energy system diversified and larger than needed, storage of energy will be minimized. Electric power storage, including batteries, hydrogen storage and mechanical storage, is considered as not economically viable. It is assumed that realizing more capacity is economically more efficient than realizing electric power storage. Heat and cold storage, however, is widely used. This is an effective strategy to mitigate periodic fluctuations in the heat supply and demand (Stremke 2010). As described, open systems are used, which make use of aquifers. Moreover, residual heat from the geothermal power plant is of little use for heating homes during the summer. However, this heat is very useful in the winter (high exergetic quality). Therefore, residual heat from the geothermal power plant will also be stored in aquifers during the summer and used in times of need, which is usually in the winter and autumn. Next to heat and cold storage, also amounts of biomass, including agricultural residues, are stored and used when necessary. Furthermore, biogas can be stored in the present gas grid.

Power infrastructure

Because more capacity is realized and wind turbines and solar panels are characterized by periodic fluctuations, it frequently happens that more energy is generated than is needed. This excess energy will be exported to the mainland. Furthermore, a low-temperature district heating grid is constructed. This grid distributes geothermal heat and heat from CHPs to residential and commercial areas, which is used for space and water heating. Also, a small district heating grid is constructed for distributing heat that is generated by a CHP. Moreover, the gas infrastructure on the island is improved so that it can handle the produced biogas.

Organization

TexelEnergie is managing the sustainable energy technologies and trades the amount of renewable energy that is generated. Although many large-scale technologies are constructed on commercial level, there are also heat and cold storage systems constructed on household level. To be able to manage these technologies, TexelEnergie has provided these technologies and residents lease the system.

Policies

Specific laws and regulations regarding the implementation of sustainable energy technologies in protected areas are obeyed as much as possible. However, when information indicates that certain spatial interventions are inevitable, the Dutch government and the province of North Holland are flexible in giving permits. Policies are focused on large projects and large-scale technologies. There is no oriented policy on energy conservation and decentralized energy generation.

Finance

TexelEnergie, the municipality of Texel and local entrepreneurs have attracted investments from outside the municipal area to implement energy technologies and the required power infrastructure in the municipal area. This means that financers outside the municipal area are highly involved in the energy supply and that local parties not fully own the energy supply. Furthermore, TexelEnergie and the municipality of Texel want to make revenue by exporting energy and commissions.

Culture

In this scenario, costs are the decisive factor when choices are made. Because residents consider that reliable and cheap supply of energy can be realized by making a centralized energy system in which economies of scale is important, residents support the implementation of sustainable energy technologies on large scale. Residents consider small-scale sustainable energy technologies as too expensive and are therefore not installed in, on and around their homes. The same applies for energy saving measures. Moreover, most residents are afraid of change and prefer to stick to the familiar. Therefore, electric vehicles are still not widely accepted in 2020. Furthermore, most residents are not changing their current behavior and habits in order to save energy.

5.3.2 Scenario B: Energy conservation

In this scenario, it is assumed that energy self-sufficiency can only be achieved when energy will be saved considerably. Residents have decided to deal with the ambition by themselves. For doing this, energy is saved as much as possible and renewable energy is generated locally. In this scenario, solidarity plays a very important role. To achieve energy self-sufficiency, residents of the municipality of Texel act as a community. This means that the residents actively work together towards this goal. It should be noted that this cooperation take place not only at household level, but also on company level. For generating the amount of renewable energy that is needed, small-scale technologies are used, which can be easily applied in, on or around homes or companies. Cultural and environmental aspects are more important among residents than financial aspects. This is also necessary because in this scenario it is assumed that not all renewable energy sources are able to compete economically with fossil fuels. Residents attach great importance to nature and environment in the municipal area. They take the view that large-scale technologies affect the natural landscape, while small-scale technologies can be integrated well into the landscape. An important observation is that residents are willing to pay more for their energy as long as the natural landscape is not affected.

To stimulate decentralized energy generation, it possible to exchange energy with other households or companies. As a result, excess energy can be delivered back to grid and can be retrieved when necessary. Local energy company TexelEnergie takes care of this so that households and companies will join TexelEnergie. In this scenario TexelEnergie has a very different role compared to scenario A. Whereas in scenario A TexelEnergie has taken the lead for realizing the renewable energy supply in the municipal area, in scenario B TexelEnergie is primarily responsible for trading the generated energy and matching the energy supply and demand.

The most important stakeholders in this scenario are users, policy makers, technology and engineering companies, energy companies and interest groups. Residents are by far the most important. They have decided to deal with the ambition by themselves and to take the responsibility for realizing the energy supply. The municipality of Texel facilitates and stimulates the implementation of small-scale technologies in the municipal area. Technology and engineering companies are constructing and installing most technologies. Most residents do not have enough knowledge to do this al by themselves. In this case, a major role is reserved for local technology and engineering companies. In cooperation with Alliander, TexelEnergie applies measures that make it possible to deliver energy back to the grid and to balance the energy supply and demand. Interest groups that stimulate achieving energy self-sufficiency, such as Stichting Duurzaam Texel and Stichting Urgenda, are convincing residents to join and to work together. This is especially important in the initial phase.

Energy demand

To achieve energy self-sufficiency, energy conservation is essential. As a result, residents are actively working on saving energy and have applied many energy saving measures for reducing the energy demand in the municipal area. To describe the developments of the energy demand in this scenario, a distinction will be made between the electricity, gas and fuel demand.

Electricity demand

To reduce the electricity demand, energy efficient appliances and lighting are used. Modern appliances use significantly less energy than older appliances. Therefore, many residents change their old appliances for new energy-efficient appliances. In addition, new homes that are constructed are zero energy homes, which do not affect the electricity demand. However, due to a shift from gas to electric applications and the implementation of more ventilation systems and ICT, which is needed to balance the energy supply and demand, these measures reduce the electricity demand only with 5%.

To save energy in the transportation sector, residents are switched from internal combustion engine vehicles (ICEVs) to electric vehicles. In addition, tourists can only visit Texel when they own or rent an electric car. However, not all ICEVs are replaced by electric vehicles. Due to the limited range of electric vehicles and long distances outside the municipal area, trucks make use of bioethanol. The transition to electric vehicles has a major impact on the electricity demand. Based on the average kilometers travelled by vehicles in the municipal area and an average electricity consumption of 14 kWh per 100 kilometers in 2020 (CBS Statline 2012; Zimmer et al. 2009), the electricity demand of electric vehicles is determined on 15 GWh in 2020. Hereby is assumed that research and development have improved the batteries and efficiencies of the drivetrain. Moreover, for propelling the ferries, batteries are used. These batteries are not installed in the ferries, but are attached on trucks, which makes them mobile. Each time that the truck comes on board, the truck can quickly be connected to the ferry. When the batteries are discharged, the truck leaves the ferry and another loaded truck takes its place. The discharged batteries are being recharged on land. This idea is also proposed by Wubbo Ockels, which is professor at the Delft University of Technology (Texelelectric 2012). Based on TESO (2011), each year there are around 13,500 departures. For each trip between the mainland and Texel, the engines of the ferries use around 1 MWh (Texelectric 2012). In this scenario, it is considered that the amount of departures will remain constant in the period from 2010 to 2020 and that the average efficiency of electric motors is around 90%. As a result, the electricity demand of the ferries is assumed to be 15 GWh in 2020. This brings the electricity demand in the transport sector on 30 GWh in 2020, which is a significant decrease compared to scenario A. From these findings, the influence of the transition to electric vehicles on the electricity demand is much greater than the implementation of measures for reducing the electricity demand. As a result, it is assumed that the electricity demand will increase with 37% instead of 8.8% in the period from 2010 to 2020, as can be seen in Table 31.

<u>Gas demand</u>

To reduce the gas demand, many insulation measures are applied that have much impact on the gas demand. Cavity wall, outer wall, window, roof and floor insulation are applied where possible. Furthermore, good ventilation is realized and low-temperature heating (LTH) systems are applied. These measures have also a significant impact on the gas demand. Another observation is that a shift from gas to electric applications has taken place. Moreover, new homes that are constructed on Texel are zero energy homes, which do not affect the gas demand. In this scenario, it is assumed that the gas demand in the period from 2010 to 2020 will decrease with 30% instead of 8.7%.

<u>Fuel demand:</u>

As described, to reduce the fuel demand, ICEVs are replaced by electric vehicles. However, trucks and are not replaced by electric vehicles and make use of bioethanol. Based on the amount of kilometers travelled by trucks and an average fuel consumption of and 25 liters of gasoline per 100 kilometers in 2020, the required amount of fuel is assumed on 3.9 GWh or 670,000 million liters of bioethanol in 2020 (CBS Statline 2012). As a result, in 2020, the fuel demand in the transport sector is decreased with 97%.

TABLE 31 – THE DEVELOPMENT OF THE TOTAL ENERGY DEMAND IN SCENARIO B

Development of energy demand 2010-2020						
	Electricity demand (GWh)		*Gas demand (GWh)*		*Fuel demand (l) (GWh)*	
2010						
Total energy demand	73.63		214.82		118.64	
2020		*Change*		*Change*		*Change*
Efficient appliances and lighting	- 3.63	-5%				
Insulation, good ventilation, LTH			- 64.82	-30%		
ICEVS are replaced by EVs	+ 15	+20%			- 68.91	-58%
Ferries make use batteries	+ 15	+20%			- 45.83	-29%
Total energy demand	100	+37%	150	-30%	3.9	-97%

Energy supply

Small-scale technologies related to solar energy, wind energy, heat and cold storage and biomass energy are widely used in the municipal area for meeting the electricity, heat and process demand. As in scenario A, next to indicating what technologies are used it will be also indicated for which shares the renewable energy sources are responsible. These shares are based on providing a resilient and diversified system in the municipal area.

Electricity demand

In order to meet the electricity demand for a large part, households and companies have installed solar panels and small wind turbines on their roofs. For installing solar panels on roofs in the municipal area, a total roof area of 15 hectares is used. It should however be noted that not every solar panel can be placed at an angle of 35 degrees towards the south. It is therefore assumed that average yearly sum of global irradiation is 20% less than the yearly sum that was found for solar panels that were optimally inclined, which is in line with IEA (2002). Next to solar panels on roofs, solar panels are installed on dikes, which cover an area of 5 hectares. Due to technological developments, solar panels have an average efficiency of 20%. The solar panels on roofs and dikes that are placed generate for around 30% of the electricity demand. Small wind turbines are also used because these are much easier to integrate in the landscape compared to onshore and offshore wind turbines. These turbines are placed both on roofs and in yards. An important observation is that the efficiencies of small wind turbines have improved. The small wind turbines generate around 18% of the total electricity demand. In order to create a diversified system, also sixteen small-scale CHPs (container size) are constructed in and around villages, which generate a large amount of electricity. Although micro-CHPs, which are CHPs that can be used in homes, would be more suitable for decentralized energy generation, micro-CHPs generate primarily heat and deliver electricity as by-product. As a result, container sized CHPs are used, which can generate much more electricity. However, a small amount of micro-CHPs are used for providing heat in rural areas, which will be explained in the next item. The CHPs make use of biogas, which is produced by new small-scale co-digestion plants and the wastewater treatment plant. The constructed CHPs and wastewater treatment plant generate around 50% of the electricity demand. Because 14% of the electricity demand was already generated by existing sustainable energy technologies in the municipal area, it seems that more capacity is realized than is needed. However, this is done for providing the amount of electricity that geothermal heat pumps need for generating heat. An overview of the technologies that are implemented to meet the electricity demand can be seen in Table 33.

Heat and process demand

As is in scenario A, first it is needed to determine the fractions of the gas demand by end-use in 2020. With these fractions the actual heat demand and process demand can be determined. In this scenario, it is assumed that 95% of the gas demand is used for space and water heating and 5% for processes. Because there is no longer cooked with gas, there is no gas demand for cooking. In Table 32, the actual heat demand and the process demand are shown. For determining the heat demand, it is assumed that boilers have an efficiency of 90%.

TABLE 32 – HEAT AND PROCESS DEMAND IN SCENARIO B

	Demand	**Space heating**		**Water heating**		**Processes**	
	GWh	*GWh*	*%*	*GWh*	*%*	*GWh*	*%*
Total gas demand	150	111	74	31.5	21	7.5	5
Total heat demand	**128.25**	99.9		28.35			
Total process demand	**7.5**					7.5	

In order to generate a large amount of heat, residents have installed solar thermal collectors. These solar thermal collectors cover a total roof area of 10 hectares. As with solar panels, not every solar thermal collector can be placed at an angle of 35 degrees towards the south. Due to technological developments, solar thermal collectors have an average efficiency of 44%. The installed solar thermal collectors generate around 32% of the heat demand. Next to solar thermal collectors, open and closed systems are widely used. In most homes, closed systems are installed for generating heat, which is used space and water heating. Open systems are mainly used in commercial areas where companies are located that have a high cooling demand, such as companies in the retail and hospitality and food sector. Due to technical developments, it is assumed that the average COP of geothermal heat pumps is 5. Heat and cold storage systems account for 35% of the heat demand. Moreover, twenty small-scale anaerobic co-digestion plants are constructed next to farms for producing biogas. Also, three small-scale digestion plants are constructed. To provide enough feedstock for the digestion plants, seaweed is cultivated in sea. In total 300 hectares is used for producing 6,000 tons of Laminaria (dry weight). Seaweed is a third generation feedstock that does not compete with food crops and valuable land. The largest part of the produced biogas is used by CHPs for generating heat. Next to sixteen small-scale CHPs, also a small amount of micro-CHPs are realized for providing heat in rural areas. These are realized in areas where no heat and cold storage systems and heating grids can be constructed due to laws and regulations. The co-digestion plants, digestion plants, wastewater treatment plant and CHPs account for 32% of the heat demand. In addition, the co-digestion plants, digestion plants and wastewater treatment plant account for 100% of the process demand. Because a relatively low share of the heat demand (4%) was already generated, some additional capacity is realized. This is done for providing a resilient energy system. An overview of the technologies that are implemented to meet the heat and process demand can be seen in Table 33.

Fuel demand

To meet the fuel demand, seaweed is cultivated in sea. Next to the 300 hectares that is already used for producing Laminaria in order to provide enough feedstock for the digestion plants, another 100 hectares is used for producing Laminaria. The amount of Laminaria that is produced is used for producing bioethanol in a fermentation plant. The bioethanol yield is assumed on 140 GJ per hectare.

TABLE 33 – ENERGY SUPPLY IN SCENARIO B

Energy supply			
	Technology	**Characteristics and information**	**Electricity**
Electricity demand	Solar panels on roofs	Total area: 15 ha Average efficiency: 20% Yearly sum of global irradiation: 9.4 GWh/ha	21.2 GWh
	Solar panels on dikes	Total area: 5 ha Average efficiency: 20% Yearly sum of global irradiation: 11.75 GWh/ha	8.8 GWh
	Small wind turbines	Amount: 6000 Total rated power: $2.25*10^{-3}$ MW*6500 = 13.5 MW Load factor: 15%	17.7 GWh
	HCS open and closed systems	Capacity of open systems: 0.2 – 0.5 MW Capacity of closed systems: 4 – 10 kW Coefficient of performance (COP): 5	- 9 GWh
	CHPs based on biogas	Amount: 16 Total electric power: 8.4 MW Total amount of biogas used: 100 GWh	50 GWh

		Electric efficiency: 50%		
	Micro-CHPs based on biogas	Total amount of biogas used: 3.4 GWh Thermal efficiency: 10%		0.4 GWh
	New electricity supply			89.1 GWh
	Existing electricity supply			13.8 GWh
	Total electricity supply			**103 GWh**
Heat and process demand	**Technology**	**Characteristics and information**	**Heat**	**Biogas**
	Solar thermal collectors	Total area: 10 ha Average efficiency: 44% Yearly sum of irradiation: 9.4 GWh/ha	41.4 GWh	
	HCS open and closed systems	Capacity of open systems: 0.2 – 0.5 MW Capacity of closed systems: 4 – 10 kW Coefficient of performance (COP): 5	45 GWh	
	Anaerobic co-digestion plants	Amount: 20 Total manure: 80,000 tons Total co-substrates: 80,000 tons Digestate produced: 150,000 tons		98 – 91.3 = 6.7 GWh
	Digestion plants	Amount: 3 Total seaweed: 6,000 tons dry weight		10.3 – 9.6 = 0.7 GWh
	CHPs based on biogas	Amount: 16 Total thermal power: 6.4 MW Total amount of biogas used: 100 GWh Thermal efficiency: 38%	38 GWh	
	Micro-CHPs based on biogas	Total amount of biogas used: 2.5 GWh Thermal efficiency: 85%	2.1 GWh	
	Wastewater treatment plant	Total digested sludge: 2,000 tons		1.7 – 1.6 = 0.1 GWh
	New supply		126.5 GWh	7.5 GWh
	Existing supply		7.2 GWh	
	Total supply		**134 GWh**	**7.5 GWh**
Fuel demand	**Technology**	**Characteristics and information**		**Bioethanol**
	Bioethanol plant	Total seaweed: 2,000 tons dry weight Bioethanol yield: 7 GJ per ton dry weight		3.9 GWh
	New supply			3.9 GWh
	Total supply			**3.9 GWh**

Storage

Small wind turbines and solar power technologies, which are characterized by periodic fluctuations provides a large share of the energy demand. Furthermore, not much additional capacity is realized. As a result, power storage plays a very important role in this scenario. By using the batteries of electric vehicles and the ferries, a significant amount of electricity can be stored on the island. When electric vehicles are not used, most of the vehicles are connected to the grid to help balance the energy demand and supply. Electric vehicles can provide electricity to the grid when it is needed, which is usually during peak hours, and can be recharged when excess energy is generated, which is usually during off-peak hours. The same applies for the batteries of the ferries. Furthermore, also aquifers are widely used for heat and cold storage.

Power infrastructure

Energy management systems are widely used in the municipal area. These systems can monitor, control and optimize the performance of local energy systems. In addition, a smart grid is realized on the island, which balances the energy supply and demand and makes it possible to exchange energy between households or companies. Furthermore, this grid can communicate with electric vehicles to balance supply and demand, which is also known as vehicle-to-grid (V2G). Although the energy supply and demand are often well matched, there may be cases where energy is urgently needed but that it is not available. Therefore, the grid connection with the mainland is served as back-up to provide energy security. Moreover, the gas infrastructure on the island is improved so that it can handle biogas. Furthermore, small district heating grids are constructed for distributing heat that is generated by CHPs. Where possible, cascading of heat is realized, in particular between holiday homes and swimming pools.

Organization

In this scenario, residents has taken the lead for realizing the new energy supply and TexelEnergie is primarily responsible for trading the generated energy and matching the energy supply and demand. To make this possible, TexelEnergie provides the technologies that can balance the supply and demand and ensures that households and companies can sell back their energy for a price that is equal to the price that they pay from the grid.

Policies

Sustainable energy technologies cannot be implemented in protected areas. Furthermore, the province of North Holland and the municipality of Texel take the view that large-scale technologies affect the environment in the municipal area. As a result, large-scale technologies are not tolerated. In order to facilitate the implementation of small-scale technologies, there will be oriented policy on energy conservation and decentralized energy generation.

Finance

Residents are willing to invest in energy saving measures and sustainable energy technologies. However, there are occasions where residents cannot afford these measures, even though they are willing. In this case, the municipality of Texel is going to help so that these residents can also contribute to achieving energy self-sufficiency.

Culture

Energy conservation is become an integral part of the community. Residents have changed their behavior and habits in order to save energy as much as possible and to reduce peak demand. In addition, electric vehicles are wisely used. Residents connect their electric vehicle to the grid when these are not used so that electric vehicles can help balance the energy supply and demand. Moreover, when implementing sustainable energy technologies, costs are not the decisive factor but the preservation of nature and environment in the municipal area.

5.3.3 Scenario comparison

In the previous sections, both scenarios are described. As can be noted, the constructed scenarios are significantly different. Although both scenarios have the same goal, energy self-sufficiency will be achieved in a different way. In order to compare both scenarios, first a comparison of the energy system of scenario A an B will be given, as can be seen Table 34. Next, the organization of the system, policies, finance, costs and culture of both scenarios will be compared, which is done in Table 35.

TABLE 34 – COMPARISON ENERGY SYSTEM OF SCENARIO A AND B

	Scenario A: Trend growth		**Scenario B: Energy conservation**	
Energy conservation	- No focus on energy conservation		- 37% increase of electricity demand (due to transition to electric transport) - 30% reduction of gas demand - 97% reduction of fuel demand	
Energy supply	*Centralized energy system*		*Decentralized energy system*	
	Electricity demand: 80.10 GWh	Share	Electricity: 100 GWh	Share
	Solar: solar panels (field)	*22%*	*Solar*: solar panels	*30%*
	Wind: onshore wind turbines	*35%*	*Wind*: small wind turbines	*18%*
	Geo: geothermal power plant	*35%*	*Bio*: CHPs based on biogas	*50%*
	Bio: CHPs based on biogas	*28%*		
	Heat demand: 167.78 GWh	Share	Heat demand: 128.25 GWh	Share
	Geo: geothermal power plant	*36%*	*Solar*: solar thermal collectors	*32%*
	HCS: open and closed systems	*45%*	*HCS*: open and closed systems	*35%*
	Bio: anaerobic co-digestion plants, CHPs based on biogas, wastewater treatment plant	*20%*	*Bio*: anaerobic co-digestion plants, digestion plants, CHPs based on biogas, wastewater treatment plant	*32%*
	Process demand: 9.81 GWh	Share	Process demand: 9.5 GWh	Share
	Bio: anaerobic co-digestion plants, wastewater treatment plant	*100%*	*Bio*: anaerobic co-digestion plants, digestion plants, wastewater treatment plant	*100%*
	Fuel demand (l): 115.82 GWh	Share		
	Bioethanol: photobioreactors	*35%*		
	Biodiesel: photobioreactors	*63%*		
	Bio-LPG: conversion of biogas	*2%*		
Storage	- No electric power storage - Heat and cold storage (aquifers)		- Electric vehicles - Batteries of the ferries - Heat and cold storage (aquifers)	
Power infrastructure	- Export excess energy to mainland - Low-temperature district heating grid - Small district heating grid for CHP - Gas network suitable for biogas		- Management systems and smart grid - Connection with mainland as back-up - Small district heating grids for CHP - Gas network suitable for biogas	

TABLE 35 – COMPARISON OF ORGANIZATION, POLICIES, FINANCE, COSTS AND CULTURE OF SCENARIO A AND B

	Scenario A: Trend growth	**Scenario B: Energy conservation**
Organization	- Local parties have take the lead - TexelEnergie manages technologies - TexelEnergie trades generated energy	- Residents have take the lead - Residents manage technologies - TexelEnergie primarily trades energy - TexelEnergie balances supply-demand
Policies	- No focus on energy conservation - Focus on large projects - Flexible in giving permits	- Focus on energy conservation - Focus on decentralized generation - SET not allowed in protected areas
Finance	- Attracting investments from outside - Financers are interested	- Residents are willing to invest - Financial help for residents
Costs	- Energy generation at the lowest cost	- Costs of generation are relatively high
Culture	- Costs decisive factor among residents - No change in behavior and habits - Prefer to stick to the familiar	- Preservation of nature is crucial - Changing behavior to save energy - Changing behavior to reduce peak

6. Backcasting analysis

Now that the scenarios are constructed, the spatial interventions for achieving the constructed desirable scenarios can be identified, which will be done in the first section. Furthermore, the robustness of these possible interventions will be evaluated. In section 6.2, the backcasting analysis will be carried out in which the necessary technical, structural, institutional, organizational and cultural changes for achieving the constructed desirable scenarios are defined.

6.1 Spatial interventions

To indicate the spatial interventions for each scenario, a map of the municipality of Texel is created in which suitable locations or search areas of energy-conscious interventions are shown. These spatial interventions are based on considerations, which are related to make better use of energy qualities and to gain energy from local energy potentials as much as possible. These considerations will also be indicated in this section.

6.1.2 Interventions for scenario A

In Figure 25, the spatial interventions in the municipality of Texel for scenario A are indicated. The indicated search area for solar fields is based on the yearly sum of global irradiation, the existing protected areas and areas used for agriculture in the municipal area. As can be seen, the search area for solar fields is relatively large. To indicate 10 hectares, a black square is shown. Furthermore, taking into account the average annual wind speed at 100 meters height and the existing protected areas in the municipal area, several search areas for wind turbines have been identified. The geothermal power plant provides heat to residential and commercial areas in Den Burg and De Koog, which are responsible for the largest part of the gas demand on Texel. To minimize the losses and costs of the low-temperature district heating grid, the geothermal power plant is constructed between the villages Den Burg and De Koog. Although the potential of geothermal energy is somewhat larger near De Cocksdorp, the heat distribution is the decisive factor. An important observation however is that a part of the grid affects geological monuments, which is inevitable. In order to minimize the damage to the underground, the grid is constructed next to the main road (N501). Excess heat from the geothermal power plant is stored near the geothermal power plant. The indicated search area for storage of geothermal heat in aquifers is based on the suitability of the subsoil and the existing protected areas around the geothermal power plant. Moreover, the suitability of heat and cold storage is good to very good on Texel, in particular in and around villages. This applies both to open and closed systems. Taking into account the existing protected areas, the search areas for heat and cold storage are indicated. Also, based on the existing protected areas, it is indicated in which area boilers have to be adjusted or applied for generating heat using biogas. This area seems large but it only covers rural areas where not many homes are located. Furthermore, three CHPs are constructed in Den Burg, De Koog and De Cocksdorp due to the relatively high heat demand in these villages. For distributing the generated heat to residential and commercial areas in De Cocksdorp, a small district heating grid is constructed. In addition, to distribute the generated heat from the CHPs in Den Burg and De Koog, the low-temperature district heating grid is used.

Scenario A

Electricity demand:
Solar: 18 GWh
Wind: 28 GWh
Geo: 28 GWh
HCS: - 15 GWh
Biomass: 23 GWh +
82 GWh

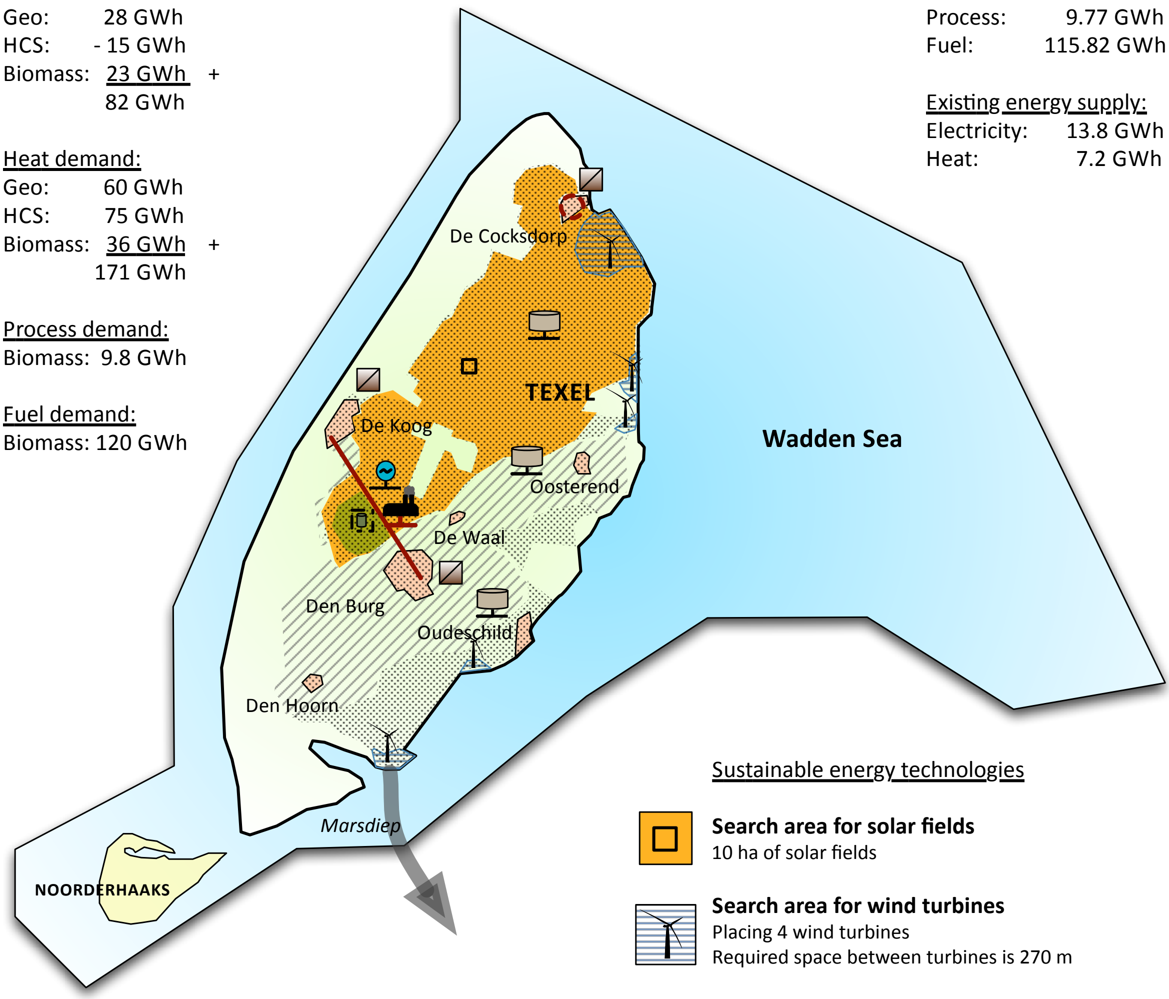
Heat demand:
Geo: 60 GWh
HCS: 75 GWh
Biomass: 36 GWh +
171 GWh

Process demand:
Biomass: 9.8 GWh

Fuel demand:
Biomass: 120 GWh

Energy demand:
Electricity: 80.05 GWh
Heat: 166.99 GWh
Process: 9.77 GWh
Fuel: 115.82 GWh

Existing energy supply:
Electricity: 13.8 GWh
Heat: 7.2 GWh



Storage

Search area for storage of geothermal heat
Storing excess heat in aquifers near geothermal plant

Power infrastructure

Low-temperature district heating grid
Distributing heat to areas in Den Burg and De Koog

Small district heating grid
Distributing heat to areas in De Cocksdorp

Exporting energy to mainland
Excess energy is exported via existing grid connection

Sustainable energy technologies

Search area for solar fields
10 ha of solar fields

Search area for wind turbines
Placing 4 wind turbines
Required space between turbines is 270 m

Geothermal power plant
One doublet (1500 m) near Den Burg and De Koog
Used area above ground is 1.12 ha

Search area heat and cold storage
Open systems in residential and commercial areas
Closed systems in not densely built areas

Anaerobic co-digestion plants
3 plants in Oudeschild, near Oosterend and Cocksdorp

CHPs based on biogas
3 CHPs in Den Burg, De Koog and De Cocksdorp

Wastewater treatment plant
Upgrading wastewater treatment plant Evertsekoog

Boilers based on biogas
Adjusting or applying new boilers in rural areas

Photobioreactors
Production of microalgae for bioethanol and -diesel
Used area is 25.5 ha

FIGURE 25 – INDICATION OF THE SPATIAL INTERVENTIONS IN THE MUNICIPALITY OF TEXEL FOR SCENARIO A

Because of the collection point for organic waste at the industrial site in Oudeschild (De Hamster), an anaerobic co-digestion plant is constructed near this point. Furthermore, an anaerobic co-digestion plant is constructed near Oosterend and another between Oosterend and De Cocksdorp. These locations are favorable for transport of agricultural residues, because relatively many agricultural companies are present is these areas. The production of microalgae takes place near the geothermal power plant and wastewater treatment plant. This is because heat from the geothermal plant and nutrients from wastewater can very well be used for algae production.

6.1.3 Interventions for scenario B

In Figure 26, the spatial interventions in the municipality of Texel for scenario B are indicated. Although most roof area is present in residential and commercial areas, there is roof area available in the whole municipal area. Therefore, search areas for solar panels and solar thermal collectors cover almost the whole island, except nature areas. The same applies for small wind turbines. Hereby should be noted that although small wind turbines perform better in rural areas compared to residential areas, all types of areas are needed for placing turbines due to the large amount. In addition, taking into account the yearly sum of global irradiation and existing protected areas in the municipal area, the search area for solar panels on dikes is indicated. As can be seen, this search area located in the northwest of the island. The indicated search areas for heat and cold storage are based on the existing protected areas. This also applies to the indicated search area for micro-CHPs. Hereby should be noted that although the search area seems large, the search area covers only rural areas where not many homes are located. Moreover, many small-scale CHPs are constructed near villages to provide heat directly to residential and commercial areas. The distribution of the CHPs on the island is based on the heat demand of each village. For distributing the heat to residential and commercial areas, small district heating grids are constructed in all villages except De Waal. Because several swimming pools are located in and around Den Burg, De Koog and De Cocksdorp, heat cascades are realized between homes and swimming pools in these areas. Furthermore, anaerobic co-digestion plants are constructed where much agricultural activity occurs so that transport of agricultural residues is minimized. Moreover, seaweed cultivation is taking place near the Texelstroom. This is because the water is relatively deep near the Texelstroom so that more seaweed can be cultivated. Furthermore, in the Texelstroom the highest tidal current velocities are present, which minimizes sedimentation of degraded fragments of seaweed (Reith et al. 2005). The digestion plants, which are making use of seaweed, are constructed in Oudeschild where the cultivated seaweed is delivered so that transport is minimized. The same reasoning applies to the construction of the bioethanol plant in Oudeschild. Because most electric vehicles are located in the villages, public charging points for electric vehicles are realized in all villages. The charging station of the batteries of the ferries is situated in ‘t Horntje near the ferry terminal in order to keep the distance for the trucks as small as possible.

Scenario B

Electricity demand:
Solar: 30 GWh
Wind: 18 GWh
HCS: - 9 GWh
Biomass: 50 GWh +
89 GWh

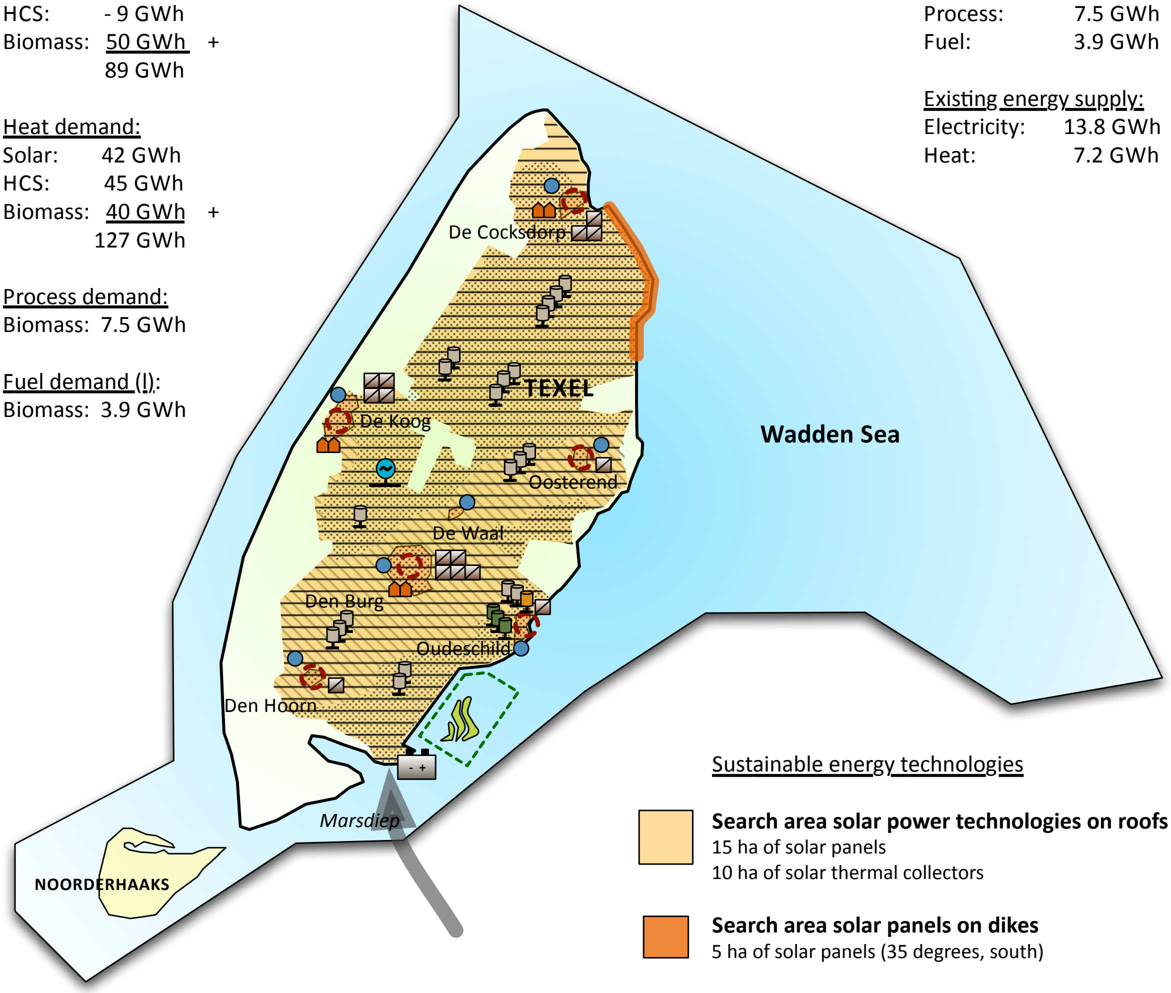
Heat demand:
Solar: 42 GWh
HCS: 45 GWh
Biomass: 40 GWh +
127 GWh

Process demand:
Biomass: 7.5 GWh

Fuel demand (l):
Biomass: 3.9 GWh

Energy demand:
Electricity: 100 GWh
Heat: 128.25 GWh
Process: 7.5 GWh
Fuel: 3.9 GWh

Existing energy supply:
Electricity: 13.8 GWh
Heat: 7.2 GWh



Storage

Public charging points for electric vehicles
Charging points are realized in all villages

Charging station batteries of ferries
Charging station in 't Horntje near the ferry terminal

Power infrastructure

Small district heating grid
Heat that is generated by CHPs is distributed

Heat cascading
Cascades between homes and swimming pools

Back-up
Grid connection with mainland is served as back-up

Feedstock

Seaweed production
Seaweed is cultivated in Wadden Sea
Used area is 400 ha

Sustainable energy technologies

Search area solar power technologies on roofs
15 ha of solar panels
10 ha of solar thermal collectors

Search area solar panels on dikes
5 ha of solar panels (35 degrees, south)

Search area small wind turbines
Placing 6000 small wind turbines on roofs and yards

Search area heat and cold storage
Open systems used in commercial areas
Closed systems for individual households

Anaerobic co-digestion plants
20 small-scale plants distributed over the island

Digestion plants
3 small-scale digestion plants in Oudeschild

Bioethanol plant
1 small-scale bioethanol plant in Oudeschild

Wastewater treatment plant
Upgrading wastewater treatment plant Evertsekoog

CHPs based on biogas
16 CHPs distributed over all villages except De Waal

Search area micro-CHPs based on biogas
Micro-CHPs in rural areas

FIGURE 26 - INDICATION OF THE SPATIAL INTERVENTIONS IN THE MUNICIPALITY OF TEXEL FOR SCENARIO B

6.1.4 Robustness of interventions

Now that the spatial interventions are identified, the robustness of the possible interventions will be assessed. If an intervention appears in both scenarios, the robustness of an intervention is high. Interventions of which the robustness is considered high can be implemented in the short-term because these are less depending on critical uncertainties. However, less robust interventions are also needed for achieving a full transition to a desirable future. Less robust interventions can be seen as chances or opportunities. Only when certain developments happen, these interventions can be implemented in the short-term. In Table 36, the robustness of the possible interventions is assessed.

TABLE 36 – ROBUSTNESS OF POSSIBLE INTERVENTIONS

Possible interventions	Scenario A	Scenario B	Robust-ness
Search area heat and cold storage	All villages, rural areas	All villages, rural areas	2
Constructing co-digestion plants	3 plants	20 small-scale plants	2
Upgrading wastewater treatment plant	1 plant	1 plant	2
Constructing CHPs based on biogas	3 CHPs	16 small-scale CHPs	2
Constructing small district heating grid	1 village	6 villages	2
Search area solar fields	10 hectares		1
Search area solar panels on roofs		15 hectares	1
Search area solar panels on dikes		5 hectares	1
Search area solar thermal collectors on roofs		10 hectares	1
Search areas wind turbines	4 wind turbines		1
Search area small wind turbines		6000 turbines	1
Constructing geothermal power plant	1 doublet		1
Search area for storage of geothermal heat	1 system		1
Digestion plants (seaweed)		3 small-scale plants	1
Fermentation plant (seaweed)		1 small-scale plant	1
Production of microalgae	25.5 hectares		1
Seaweed production		500 hectares	1
Low-temperature district heating grid	2 villages		1
Public charging points for electric vehicles		7 villages	1
Charging station batteries of ferries		1 station	1

From Table 36, it can be concluded that the robustness is high of the following interventions: constructing heat and cold storage systems, constructing anaerobic co-digestion plants, upgrading existing wastewater treatment plant, constructing CHPs based on biogas and constructing small district heating grids. These are interventions that appear in both scenarios. This means that these interventions are less depending on critical uncertainties and can be implemented in the short-term. Heat and cold storage, anaerobic co-digestion plants and CHPs are very much needed to achieve energy self-sufficiency. Besides the large amount of energy that these technologies can generate, the scale of use of these technologies can vary considerably, which is a very important characteristic. Moreover, it should be noted that due to the construction of only two scenarios, the assessment of the robustness of the interventions is limited. When more scenarios will be constructed, the robustness can be assessed much better. However, due to the construction of very different scenarios, it is possible to see which interventions have the highest robustness.

6.2 Backcasting analysis

In this section, the backcasting analysis will be carried out for both scenarios. To define the changes that are necessary for achieving the two future scenarios, the changes are distinguished in technological, structural, institutional, organizational and cultural changes.

6.2.1 Necessary changes for scenario A

Technological changes

To describe the technological changes, the changes are classified in following categories: sustainable energy technologies, transport, power infrastructure and process equipment and appliances.

Sustainable energy technologies:

- Reducing costs of sustainable energy technologies

A reduction in the costs of sustainable energy technologies is very important to make renewable energy sources economically competitive with fossil fuels without the need for subsidies or regulations. To reduce these costs, technological developments are needed. Research and knowledge institutes and technology and engineering companies are important in providing these technological developments.

- Efficiency improvements of solar panels and geothermal heat pumps

The efficiencies of solar panels need to be improved so that the average efficiency of solar panels increases to 20%. Next to the efficiency of solar panels, also the efficiencies of geothermal heat pumps need to be improved for increasing the average COP to 5. To increase these efficiencies, technological developments are needed. Research and knowledge institutes and technology and engineering companies are important in providing these technological developments.

- Development of large-scale production of microalgae using photobioreactors

To produce 60,000 liters of bioethanol per hectare in 2020, technological developments are needed, including improvements in the photosynthetic efficiency, scaling up the production and harnessing. The same applies for the production of biodiesel. Research and knowledge institutes and technology and engineering companies are important in providing these technological developments.

- Upgrading wastewater treatment plant

For producing biogas from sewage sludge that is produced by wastewater treatment plant 'Evertsekoog', the plant has to be upgraded. Governmental authority Hoogheemraadschap Hollands Noorderkwartier, which is owner of this plant, can provide this upgrade.

Transport:

- Modifying internal combustion engines of vehicles and ferries

Internal combustion engines of vehicles need to be modified so that it can completely use both conventional fuels and biofuels. This makes it possible that users can refuel their vehicle both with conventional fuels and biofuels. To provide these modifications, technology and engineering companies in the automotive sector are very important. In addition to vehicles, the engines of the ferries need also be modified for completely using biodiesel. TESO, which is responsible for these ferries, can provide these modifications.

Power infrastructure:

- Upgrading existing gas grid

To inject the produced biogas into the existing gas grid, the gas grid has to be upgraded for handling biogas. Alliander, which manages and controls the gas pipes in the municipal area, can provide this upgrade.

- Upgrading electrical infrastructure

Due to the implementation of large-scale technologies that generate large amounts of electricity, the electric infrastructure has to be upgraded on Texel. In addition, the electric infrastructure must also cope with periodic fluctuations. Alliander, which manages and controls the electricity lines in the municipal area, can provide this upgrade.

Process equipment and appliances:

- Adjusting process equipment and boilers

If necessary, process equipment need to be adjusted so that it can make use of biogas. Furthermore, also some boilers have to be adjusted to make use of biogas. Technology and engineering companies can provide these adjustments.

Structural changes

- Increase of fossil fuel prices

The prices of fossil fuels need to increase to make renewable energy sources economically competitive with fossil fuels without the need of subsidies and regulations. Market forces can cause this increase.

- Economies of scale as key strategy for achieving energy self-sufficiency

To develop a local energy system that generates energy at the lowest cost possible, economies of scale are essential for obtaining cost advantages. The municipality of Texel has to take the lead for carrying out this strategy.

- Grid connection with the mainland used for export

The function of the existing grid connection with the mainland has to be changed. Whereas the connection currently is currently being used for the import of energy, the existing grid connection will be used for exporting energy to make revenue. Local energy company TexelEnergie can use the grid connection for trading energy with the mainland.

- Improving cooperation between the municipality of Texel and local entrepreneurs

To be able to realize the new energy supply in the municipal area, the cooperation between the municipality and local entrepreneurs has to be improved.

- Increasing interest from financers from outside the municipal area

The interest from financers, such as banks and investors, to invest in sustainable energy technologies has to increase so that funds are available for implementing sustainable energy technologies in the municipal area.

Institutional changes

- Facilitating the implementation of large-scale technologies in the municipal area

To facilitate the implementation of large-scale technologies in the municipal area, large-scale technologies need to be allowed in areas that are not protected. In addition, conditions should be made more flexible for constructing technologies and power infrastructure in protected areas when information indicates that spatial interventions in these areas are inevitable. The Dutch government, the province of North Holland and the municipality of Texel must take care for this.

- Oriented policy on large projects and large-scale technologies

To stimulate the implementation of sustainable energy technologies on large scale in the municipal area, both national and local policies are needed that are focusing on large projects and large-scale technologies. The Dutch government, the province of North Holland and the municipality of Texel must take care for this.

- Need for political continuity

Energy self-sufficiency cannot be achieved in the short-term. It is a long-term vision with 2020 as end-point. Political continuity is therefore essential for achieving energy self-sufficiency and is needed both at national and local level. This gives TexelEnergie, local entrepreneurs and companies outside the municipal area confidence to invest.

Organizational changes

- TexelEnergie in charge of managing technologies and energy trading

TexelEnergie should be made responsible for managing the new sustainable energy technologies and for trading the generated amount of energy. The municipality of Texel, local entrepreneurs and technology and engineering companies, which are realizing the energy supply in cooperation with TexelEnergie, will have to agree with this.

- Households and companies should join TexelEnergie

Each household and local company should join TexelEnergie so that generated renewable energy can be supplied to each household and company on Texel.

- Increasing the amount of FTEs at the municipality of Texel that is working on sustainability

The municipality of Texel has to increase the amount of FTEs that is actively working on achieving energy self-sufficiency to be able to assist TexelEnergie and local entrepreneurs and to provide more information to residents.

Cultural and behavioral changes

- Acceptance of large-scale technologies

In order to implement large-scale technologies in the municipal area, there should be no resistance among residents against large-scale technologies, including solar fields, wind turbines, geothermal power plants and biomass power plants. Resistance is often based on false arguments. Therefore, increasing knowledge among residents on sustainable energy technologies can be very useful. The municipality of Texel, TexelEnergie, Ecomare and organizations, including Stichting Duurzaam Texel and Stichting Urgenda, can play a very important role in providing this knowledge.

- Need for continued interest among residents

Residents should keep interest in achieve energy self-sufficiency. This is needed to support the municipality of Texel. The municipality of Texel, TexelEnergie, Ecomare and organizations, including Stichting Duurzaam Texel and Stichting Urgenda, can play a major role in this.

6.2.2 Necessary changes for scenario B

Technological changes

Sustainable energy technologies:

- Efficiency improvements of solar power technologies, small wind turbines and heat pumps

The efficiencies of solar panels and solar thermal collectors need to be improved so that the average efficiency increases to 20% and 44%, respectively. Next to solar power technologies also the efficiencies of small wind turbines need to be improved. Furthermore, geothermal heat pumps need to be improved for increasing the average COP to 5. To increase these efficiencies, technological developments are needed. Research and knowledge institutes and technology and engineering companies are important in providing these technological developments.

- Upgrading wastewater treatment plant

For producing biogas from sewage sludge that is produced by wastewater treatment plant 'Evertsekoog', the plant has to be upgraded. Governmental authority Hoogheemraadschap Hollands Noorderkwartier can provide this upgrade.

Transport:

- Improvement of drivetrain and batteries of electric vehicles

To achieve an average electricity consumption of 14 kWh per 100 kilometers in 2020, the drivetrain and batteries, including weight, higher energy density and lifespan, of electric vehicles have to be improved. Research and knowledge institutes and technology and engineering companies are important in providing these technological developments.

- Modifying internal combustion engines of trucks

The internal combustion engines of trucks in the municipal area need to be modified so that these trucks can completely use both gasoline and bioethanol. Technology and engineering companies in the automotive sector can provide these modifications.

Power infrastructure:

- Upgrading existing gas grid

To inject the produced biogas into the existing gas grid, the gas grid has to be upgraded for handling biogas. Alliander can provide this upgrade.

- Upgrading electrical infrastructure and developing smart grid

Due to the implementation of technologies that are characterized by periodic fluctuations, the electric infrastructure has to be upgraded to cope with these fluctuations. In addition, to balance the energy supply and demand and to make it possible to exchange energy, a smart grid needs to be developed. TexelEnergie, Alliander and technology and engineering companies can provide these changes.

- Development of system that can access the grid at public places

To make it possible that residents and tourists can recharge there electric vehicles at public places, a system needs to be developed that controls the access to the grid. Technology and engineering companies can provide this development.

Structural changes

- Grid connection with the mainland used as back-up

The function of the existing grid connection with the mainland has to be changed. Whereas the connection currently is currently being used for the import of energy, the existing grid connection will be used as back-up for providing energy security. TexelEnergie, which is responsible for balancing the energy supply and demand, can take care of this.

- Increasing interest from local technology and engineering companies

The interest of local technology and engineering companies has to be increased so that they can play a major role in constructing and installing small-scale sustainable energy technologies.

- Local automotive sector need to increase knowledge on electric vehicles

Because of the transition to electric vehicles, the local automotive sector needs to gain knowledge on electric vehicles so that these vehicles can be maintained. In addition, gaining knowledge on electric vehicles is essential in order to remain in business.

Institutional changes

- Oriented policy on energy conservation and decentralized energy generation

To stimulate the implementation of energy saving measures and decentralized energy generation in the municipal area, policies are needed that are focusing on energy conservation and decentralized energy generation. Introducing financial incentives and subsidies and adjusting zoning regulations regarding small wind turbines are important. The Dutch government, the province of North Holland and the municipality of Texel must take care for this.

- Need for political continuity in order to stimulate and help residents

Political continuity is essential in order to stimulate and help residents in achieving energy self-sufficiency. Long-term strategies are needed both at national and local level.

Organizational changes

- TexelEnergie in charge of balancing supply and demand and trading energy

TexelEnergie should be made responsible for balancing the energy supply and demand and for trading the generated amount of energy. Residents, which are realizing he energy supply, will have to agree with this.

- Households and companies should join TexelEnergie

Each household and local company should join TexelEnergie so that generated renewable energy can be exchanged and supplied to each household and company on Texel. For doing this, TexelEnergie provides also the technologies that are needed**.**

- Increasing the amount of FTEs at the municipality of Texel that is working on sustainability

The municipality of Texel has to increase the amount of FTEs that is actively working on achieving energy self-sufficiency to be able to help residents.

Cultural changes

- Increasing knowledge on energy conservation and decentralized energy generation

In order to increase the interest among residents to apply energy saving measures and install sustainable energy technologies, residents have to gain more knowledge on the opportunities and potentials regarding energy conservation and renewable energy. The residents themselves, the municipality of Texel, TexelEnergie, Ecomare and organizations, including Stichting Duurzaam Texel and Stichting Urgenda can play a very important role in providing this knowledge.

- Increasing sense of solidarity

To actively work together towards achieving energy self-sufficiency, it is needed that the sense of solidarity among residents increases. The residents themselves, the municipality of Texel, TexelEnergie, Ecomare and organizations, including Stichting Duurzaam Texel and Stichting Urgenda, can play a major role in this.

- Increasing environmental awareness

Residents have to be more aware of their natural environment so that financial aspects are become subordinate to environmental and cultural aspects. As a result, residents are willing to pay more for their energy as long as the natural landscape is not affected. The residents themselves, the municipality of Texel, TexelEnergie, Ecomare and organizations, including Stichting Duurzaam Texel and Stichting Urgenda, can play a very important role in increasing the environmental awareness among residents.

- Need for continued interest among residents

It is essential that residents should keep interest in achieving energy self-sufficiency so that they remain engaged with achieving energy self-sufficiency. In this scenario, the residents are the ones who have taken the lead in realizing the energy supply. The residents themselves, the municipality of Texel, TexelEnergie, Ecomare and organizations, including Stichting Duurzaam Texel and Stichting Urgenda, can play a major role in this.

7. ELABORATION AND IMPLEMENTATION

In this chapter, the results of the previous chapter, in which spatial interventions are identified and necessary changes are determined, will be elaborated and embedded. In the first sections, the main drivers and barriers for achieving the two constructed desirable scenarios will be determined. Then, possible pathways will be defined for both scenarios in section 7.3. These possible pathways can lead to achieving self-sufficiency. Eventually, a follow-up agenda will be constructed in which is described what different stakeholders should do to continue working on achieving energy self-sufficiency.

7.1 DRIVERS AND BARRIERS

By determining the main drivers for each scenario, it is possible to gain insight why one would go for the respective scenario. In addition, by determining the barriers, it is possible to gain insight what barriers need to be overcome to achieve the constructed desirable scenario. The greater these barriers, the more difficult it becomes to achieve the scenario. In the first sections, the main drivers for scenario A and scenario B will be determined. At the end of each section an overview of the drivers will be given. Next, the main barriers for achieving the constructed scenarios will be determined. These barriers will be distinguished into technological, structural, institutional and cultural barriers. Eventually, the identified drivers and barriers of both scenarios will be discussed.

7.1.1 DRIVERS FOR SCENARIO A

In scenario A, energy self-sufficiency can be achieved, while the trend growth of the total energy demand on Texel will be maintained. As a result, households and companies in the municipality of Texel do not have to adapt to achieve energy self-sufficiency. They can continue with their current activities, which is a major driver for this scenario. Next to maintaining the trend growth of the total energy demand, in scenario A the focus will be on developing an energy system that is economically efficient. For doing this, renewable energy sources are used on large scale. By following this strategy, cost advantages can be obtained so that investment costs are minimized. In addition, it is expected that wind turbines, solar panels, heat and cold storage systems, geothermal power plants and co-digestion plants, which are used in this scenario, can compete with fossil fuels before 2020. Furthermore, when implementing technologies on large scale, great strides can be made in achieving energy self-sufficiency. Large-scale technologies can generate a large amount of energy so that a large part of the energy demand can be met. For example: when a geothermal plant will be constructed on Texel, 35% of the electricity demand and 36% of the heat demand can be generated. Moreover, the implementation of large-scale technologies can create permanent jobs in the municipal area. Local jobs will be created in the maintenance and operation of these technologies. In particular, the geothermal power plant, anaerobic digestion plants and the production of microalgae can lead to new jobs on Texel. Another driver is the current policy of the Dutch government. At this moment, there is focus on the most cost-efficient sustainable energy technologies and most financial incentives and subsidies are focused on large projects and large-scale technologies.

TABLE 37 – OVERVIEW OF MAIN DRIVERS FOR SCENARIO A

Main drivers scenario A

• Energy self-sufficiency by using renewable energy sources can be achieved
• Households and companies can continue current activities
• Creating a system that generates renewable energy at the lowest costs
    o Minimizing investment costs due to economies of scale
    o Most used technologies can compete economically with fossil fuels before 2020
• Large-scale technologies can meet large part of energy demand
• Creating permanent jobs, in particular in the maintenance and operation of the technologies
• Policies of Dutch government are focused on cost-efficient technologies and large projects

7.1.2 Drivers for scenario B

In scenario B, energy self-sufficiency can be achieved through energy conservation and decentralized energy generation. In order to make this happen, residents have decided to deal with the ambition by themselves. By investing in small-scale sustainable energy technologies for meeting the energy demand, residents own the technologies and have taken much control over the supply. There are no companies from outside the municipal area that own or help managing the supply, except network company Alliander. As a result, much independence from the mainland is reached, which is a major driver for this scenario. Another major driver for this scenario is that most sustainable energy technologies can easily and quickly be implemented. There is no resistance against most small-scale technologies that are used in this scenario. In addition, many technologies can be installed without applying for a permit. Both factors facilitate the implementation of small-scale technologies in the municipal area. Furthermore, although there is no focus on developing a system that is generating energy at the lowest cost in this scenario, many used technologies become economically more interesting in the coming years. So is it expected that solar panels, solar thermal collectors, heat and cold storage systems and (co-) digestion plants are able to compete with fossil fuels before 2020. Moreover, the implementation of small-scale technologies can create local jobs, in particular in the maintenance. Many technologies that are used in this scenario have to be maintained. A major role is reserved for local technology and engineering companies.

TABLE 38 – OVERVIEW OF MAIN DRIVERS FOR SCENARIO B

Main drivers scenario B

• Energy self-sufficiency by using renewable energy sources can be achieved
• Reaching much independence from the mainland
• Easy and quick implementation of small-scale sustainable energy technologies
    o No resistance against most technologies
    o Many technologies can be installed without applying for a permit
• Many small-scale technologies can compete economically with fossil fuels before 2020
• Creating permanent jobs, in particular in the maintenance of the technologies

7.1.3 Barriers for scenario A

Technological barriers

- Uncertainties and long construction time concerning geothermal power plant

Before constructing a geothermal power plant, first seismic research is needed to gain a better understanding of the subsoil (Energeia 2011). Furthermore, although it is expected that the Lower Carboniferous Limestone Group is suitable for hydraulic fracturing, laboratory research is needed to examine whether is the case. This can take several years. When these studies have been carried out and it is decided to construct the geothermal power plant, first there must be drilled after which hydraulic fracturing needs to be applied. Drilling and hydraulic fracturing also takes much time. As a result, even when enough funding is available, constructing a geothermal power plant before 2020 is very difficult.

- Geothermal doublet has a relatively short lifetime

The average lifetime of geothermal doublet is approximately 30 years (Broersma et al. 2010). This is because after 30 years the cold front of injection well reaches the production well, which causes a significant decrease in the efficiency of the doublet. When the doublet is not used for many years, regeneration can occur after which the doublet can again be used. However, the regeneration time will be around 300 years. This means that in a total period of 300 years new doublets have to be constructed, which are spread out over the area over which the heat is extracted. Also, a new district heating grid has to be constructed. Although this is not a direct technological barrier for realizing the geothermal power plant, this information can be crucial for deciding whether a geothermal power plant is a good option.

- The production of microalgae using photobioreactors is still in experimental phase

Until now, the production of microalgae in photobioreactors is still in the experimental phase and faces many challenges. Major challenges are the low photosynthetic efficiency and difficulties with scaling up the production and harnessing (Wijffels 2010). As a result, it is unlikely that the production of biofuels from algae become economically feasible before 2020.

Structural barriers

- Not enough funding to carry out large projects

Although in this scenario the focus will be on developing an energy system that is economically efficient, there is currently not enough funding for carrying out large projects. Most large-scale technologies require very high initial investment costs. TexelEnergie experiences that is very difficult to get funding and the municipality of Texel has currently not enough funding (Interview De Graaf 2011; Interview Kieft and Bakker 2011).

- Difficult cooperation between the municipality of Texel and local entrepreneurs

Until now, the cooperation between the municipality of Texel and local entrepreneurs is not proceeding well. The municipality of Texel has often too much influence on ideas and is often not decisive.

Institutional barriers

- The Dutch government is much less ambitious than the municipality of Texel

At this moment, the Dutch government is much less ambitious than the municipality of Texel regarding renewable energy. The targets and focus areas are very different from the targets and focus areas of the municipality of Texel. Therefore, it is expected that in the next years the municipality of Texel will get limited support from the Dutch government. Moreover, it is also expected that the targets and focus areas of the province of North Holland regarding renewable energy, which are currently determined, will be less ambitious. These targets and focus areas of the province of North Holland are much based on national policies.

- The municipality of Texel focuses much on energy conservation and small-scale technologies

At this moment, the municipality of Texel pursues a strategy that is based on the concept of the Trias Energetica. As a result, the municipality of Texel focuses much on saving energy. Moreover, the financial incentives and subsidies of the municipality of Texel are focused on implementing sustainable energy technologies in, on and around homes and on applying energy saving measures.

- Placing wind turbines is not possible in the next years

The current policies of the province of North Holland and the municipality of Texel are not focused on the implementation of wind turbines on Texel. In addition, the municipality of Texel has indicated that currently there will be no plans made for placing wind turbines in the municipal area (Interview Hercules 2011). As a result, it will not be possible to place 4 wind turbines on land in the next years.

Cultural barriers

- Social resistance against wind turbines, biomass power plants and solar fields

There is much resistance against placing wind turbines in the municipal area. For many years, there is opposition from residents and local environmental organizations to place wind turbines on the island. It is therefore unlikely that the resistance against wind turbines will disappear in the next years. At this moment, wind turbines generate by far the greatest resistance. Next to wind turbines, there is also resistance against the construction of biomass power plants and the realization of solar fields.

7.1.4 Barriers for scenario B

Technical barriers

- The development of electric vehicles is still in its infancy

Until now, the development of electric vehicles is still in its infancy. Although many car manufacturers have introduced or are introducing various electric cars, the market share of electric vehicles is still negligible in the Netherlands. In addition, the existing infrastructure does not allow a fast transition to electric vehicles. This applies not only for Texel but also for the Netherlands as a whole. As a result, it is very difficult to achieve a transition to electric vehicles on Texel by 2020.

- The development of smart grids is still in experimental phase

To date there are no large smart grids realized in the Netherlands. There is still much research and development on smart grid technologies. Although an important first step is made by installing smart meters in each household and company on Texel, much more technologies have to be installed to be able to balance the energy supply and demand. Therefore, developing a smart grid on Texel before 2020 is difficult.

Structural barriers

- High investment costs of sustainable energy technologies

Although in recent years the investment costs of sustainable energy technologies have dropped, to date most residents consider that without the support of subsidies the investment costs are too high (Interview Hercules 2011; Interview Hordijk 2011). Although it is expected that this barrier will become less significant in the next years, the high investment costs can lead to a poor rate of progression in the next years, which makes achieving energy self-sufficiency in 2020 difficult.

- TESO has no intention to use batteries for propelling the ferries

TESO has indicated that the new ferry, which needs to be finished in 2015, will not make use of batteries for propulsion (Interview De Waal 2011). From their own research, TESO concludes that to date batteries are not economically feasible and not practical in use due to the short time that the ferry is stationary. As a result, it is unlikely that TESO will use batteries for propelling their ferries before 2020.

- Seaweed cultivation can disturb shipping traffic

The area that is used for seaweed cultivation is quite large and is situated in a relatively large part of the marine channel Texelstroom. This marine channel is very important for shipping traffic, including fishing and tourist boats, from and to the harbor of Oudeschild. Seaweed cultivation can disturb shipping traffic, which can have a negative impact on the harbor of Oudeschild.

Institutional barriers

- The Dutch government is much less ambitious than the municipality of Texel

This significant barrier is the same institutional barrier that is described in the previous section.

- The Dutch government focuses on the most cost-efficient technologies and large projects

The current policy of the Dutch government regarding renewable energy focuses on the most cost-efficient sustainable energy technologies. In addition, most financial incentives and subsidies of the Dutch government are focused on large projects. There is no focus on decentralized energy generation.

Cultural barriers

- Each resident should have an active attitude regarding energy conservation and generation

Although many residents are committed to achieve energy self-sufficiency, the group of residents that want to take the lead and actively work on achieving energy self-sufficiency is currently less. However, to realize a decentralized energy system that can make Texel energy self-sufficient, it is essential that each resident has an active attitude regarding energy conservation and decentralized energy generation.

- <u>Social resistance against small wind turbines can be expected</u>

Although there is currently almost no resistance against small wind turbines, it can be expected that the implementation of 6000 small wind turbines can encounter heavy resistance among residents. This is based on the existing resistance against wind turbines. A frequently used argument by opponents is that wind turbines affect the natural landscape. Implementing 6000 small wind turbines, which is a considerable amount, can have a large impact on the natural landscape.

7.1.5 Discussion of the main drivers and barriers

Now the main drivers and barriers of both scenarios are identified, it is possible to analyze and compare the drivers and barriers. First, it is useful to return to the motives for achieving energy self-sufficiency that are identified. In section 4.1, three motives were identified: reducing the use of fossil fuels, creating more economic activity and achieving independence from the mainland. When taking into account these motives and analyze the drivers, it can be concluded that in both scenarios a transition towards renewable energy sources can be achieved. Furthermore, when going for scenario A, more economic activity can be generated. Next to jobs in the maintenance, there will be relatively more jobs created in the operation of the technologies compared to scenario B. However, it should be noted that the operation of most technologies require specific knowledge and the question arises whether this knowledge is present on Texel. This also applies to the maintenance of sustainable energy technologies. Moreover, when going for scenario B, more independence from the mainland can be achieved.

Another driver in scenario A that needs greater attention, is the development of an energy system that generates renewable energy at the lowest costs. In scenario A, renewable energy sources will be used on large scale for obtaining cost advantages. But the question arises whether this also has benefits for the users, particularly residents. Considering the organization of the energy system of scenario A, this is not the case. In scenario A, the energy supply is owned by both local parties and parties from outside the municipal area. Because the market economy plays an important role, they want to generate renewable energy at the lowest price possible and sell the generated energy for a price that is in accordance with the current market prices. As a result, residents will not benefit from the costs advantages that are obtained by using renewable energy sources on large scale. After all, they will pay the same price for their energy as they paid before. In addition, residents do not have control over the energy price. Although residents will not benefit from the cost advantages in scenario A, it should be noted that when residents own the energy supply, cost advantages could be obtained. Moreover, now this is discussed, it can be questioned whether residents pay less for their energy in scenario B in comparison to scenario A. In scenario B, the energy supply becomes a public good. Residents are the ones that have decided to install sustainable energy technologies in, on and around their homes. They have control over their own energy price. In addition, which is also indicated as a driver in scenario B, many used technologies become economically more interesting in the coming years. As a result, it can be expected that the average price of their energy will approach the market price. As a result, when comparing both scenarios, eventually there will be not much difference in the price that residents pay for their energy. Based on these findings, the organization of the energy system will influence whether users can benefit from the cost advantages that be obtained by using renewable sources on large scale.

When the main barriers from scenario A and B will be compared, several conclusions can be drawn. In both scenarios, major barriers are related to meeting the fuel demand. When focusing on scenario

A, it seems unlikely that the fuel demand can be fulfilled by biofuels. In addition, when focusing on scenario B it seems unlikely that ferries will make use of batteries and a transition to electric vehicles can be realized before 2020. As a result, it is considerably difficult to meet the fuel demand using renewable energy sources in 2020. Furthermore, a major barrier in scenario A is the large social resistance against wind turbines. In particular, landscape degradation is a frequently used argument. Based on the same argument, it is also expected that the implementation of 6000 small wind turbines can encounter heavy resistance among residents In scenario B. Therefore, although wind energy has a very large potential, it is very difficult to make use of wind as a key resource for achieving energy self-sufficiency. Moreover, in both scenarios, the same major institutional barrier is identified. At this moment, the Dutch government is much less ambitious than the municipality of Texel and it is also expected that the province of North Holland will be less ambitious in the next years. As a result, it is expected that in the next years the municipality of Texel will get limited support from the Dutch government and the province of North Holland. This will have negative consequences related to funding and laws and regulations. Also, in both scenarios, the required investments for implementing sustainable energy technologies form are a major barrier. This applies both to large-scale and small-scale sustainable energy technologies. There is insufficient funding or it is very difficult to get funding or attract investments.

7.3 Pathways

Based on the main drivers and barriers that are determined in the previous sections, pathways will be defined for both scenarios. These possible pathways can be used as a guiding line for achieving self-sufficiency. The pathways are described into three time periods: from 2012 to 2015, from 2015 to 2018 and from 2018 to 2020. In each time period it is described which actions are needed to achieve energy self-sufficiency before 2020.

Pathway for achieving scenario A

2012-2015

In this period, the municipality of Texel will change to a strategy in which economies of scale are important for achieving energy self-sufficiency. By doing this, the municipality of Texel will implementing policies that are focused on large projects and large-scale technologies, which can generate renewable energy at the lowest cost. However, most radical changes can be realized after 2014 when the elections are held due to existing agreements between the ruling parties. To be able to change the policies regarding achieving energy self-sufficiency in 2014, the support of residents is urgently needed. However, to get this support, first actions will be carried out that will increase knowledge among residents with regard to renewable energy. By doing this, the importance of economies of scale, which can result in generating renewable energy at the lowest cost, will be explained. In addition, also the importance of the use of wind turbines, solar fields and co-digestion plants will be emphasized for reducing the social resistance against these technologies.
Because of the existing local policies regarding renewable energy, in the first years of this period, implementing technologies on large scale is very difficult. In addition, most renewable energy sources are still not able to compete economically with fossil fuels. Therefore in this period, particularly preparations are being made for implementing sustainable energy technologies that can be constructed in the short term. Interventions that can be realized in the short term are solar fields, heat and cold storage systems, anaerobic co-digestion plans and CHPs based on biogas and the

upgrade of the wastewater treatment plant. Important is that research and development will be continued to improve the efficiencies and to reduce the costs of these technologies. Also, plans are being made for providing the necessary power infrastructure. Furthermore, funding will be attracted and the municipality of Texel will improve the cooperation with local entrepreneurs.

After 2104, a start will be made with upgrading the existing gas grid and electrical infrastructure. There will be also started with the construction of a district heating grid and a low-temperature district heating grid. Moreover, to be able to construct a geothermal plant before 2020, in this period seismic and laboratory research will be conducted. Also, pilot projects will be started on producing microalgae with photobioreactors. This is essential to realize large-scale production of microalgae for producing bioethanol and biodiesel before 2020.

2015-2018

In the beginning of this period, the existing gas grid is upgraded so that it can handle biogas. Also, the existing electrical infrastructure will be upgraded so that it can cope with fluctuations. Moreover, a district heating grid and a low-temperature district heating grid will be constructed, which is needed to distribute the produced heat from the CHPs and geothermal power plant. Important is that, if necessary, also process equipment and boilers will be modified or replaced so that it can make us of biogas. After the necessary power infrastructure is realized, anaerobic co-digestion plants and CHPs based on biogas will be constructed and the wastewater treatment plant will be upgraded. Furthermore, heat and cold storage systems will be implemented on large scale and solar fields will be realized. As a result, in the end of this period more than 50% of the electricity and heat demand will be generated by renewable energy sources. Furthermore, there will be started with drilling and hydraulic fracturing, which is needed for realizing the geothermal power plant. The pilot projects on producing microalgae with photobioreactors will be scaled up.

If all goes well in the local polities, there will be new elections in 2018. Important is that the strategy regarding achieving energy self-sufficiency will be maintained. This gives TexelEnergie, local entrepreneurs and companies outside the municipal area confidence to continue investing.

2018-2020

In the last period, a full transition to renewable energy sources will be realized. For doing this, first wind turbines will be placed. The reasoning behind this is that the heavy social resistance against wind turbines is weakened and that residents recognize the importance of wind turbines for generating energy at the lowest cost. Next to wind turbines, the geothermal power plant will be constructed and large-scale production of microalgae will be realized. Moreover, the internal combustion engines of vehicles and ferries will be modified so that it can completely use both conventional fuels and biofuels. After a full transition is realized, the existing grid will be used for exporting energy. In this period, each household and company has joined TexelEnergie.

Pathway for achieving scenario B

2012-2015

Because the current policies of the municipality of Texel are much focused on energy conservation and decentralized energy generation, residents are already stimulated to apply energy saving measures and install small-scale sustainable energy technologies. Residents can make use of financial incentives and subsidies, which are currently available. In addition, most small-scale technologies can be installed without a permit and other technologies can easier obtain a permit than large-scale

technologies. Another important factor is that there is no resistance against most technologies that are used in this scenario. As a result, there can be immediately started with implementing many energy saving measures and sustainable energy technologies. This is also necessary, because unlike large-scale technologies only great strides can be made when many energy saving measures and small-scale technologies are implemented.
In this period, the main focus with regard to decentralized energy generation will be on implementing solar power technologies, small wind turbines and heat and cold storage systems. Solar panels and solar thermal collectors will be installed on roofs and small wind turbines will be placed on and around homes. Heat and cold storage systems will be constructed in commercial and residential areas. Next to implementing small-scale technologies, many energy saving measures related to insulation and ventilation will be applied. In order to generate more interest among residents to actively work on achieving energy self-sufficiency, actions will be carried out that will increase the knowledge on the opportunities and potentials regarding energy conservation and renewable energy. Furthermore, actions will be carried out that will increase the environmental awareness among residents.
To be able to realize a smart grid in the municipal area before 2020, smart grid technologies will be tested. Furthermore, pilot projects on electric mobility will be scaled up and research and development on electric vehicles continues. To be prepared for a possible transition to electricity for propelling the new ferry, it is important that this will be taking into account in making the plans for the new ferry. Moreover, pilot projects on seaweed cultivation will be started so that knowledge on cultivating seaweed can be developed. In 2014, there will be new elections. It is important that the ambition remains and that energy conservation and decentralized energy generation remain the focus areas of the municipality of Texel. Also, the new policies will emphasize the need for upgrading the existing gas grid and electrical infrastructure and for constructing district heating grids. As a result, after 2014, a start will be made with upgrading the gas grid and electrical infrastructure and with the construction of district heating grids.

<u>2015-2018</u>
In the beginning of this period, the existing gas grid is upgraded so that it can handle biogas. Also, the existing electrical infrastructure will be upgraded so that it can cope with fluctuations and a start will be made with the development of a smart grid. Moreover, district heating grids will be constructed, which is needed to distribute the produced heat from the CHPs. After the necessary power infrastructure is realized, small-scale anaerobic co-digestion plants, CHPs and micro-CHPs based on biogas will be constructed and the wastewater treatment plant will be upgraded. Next to the co-digestion plants and CHPs, solar panels will be installed on dikes. Because of the many technologies that have to be installed, also in this period there will be continued with installing solar power technologies, small wind turbines and heat and cold storage systems. The same applies for applying energy saving measures related to insulation and ventilation. In addition, a shift from gas to electricity applications will take place and low-temperature heating systems will be applied. In the end of this period, more than 75% of the electricity and heat demand will be generated by renewable energy sources. Moreover, pilot projects on seaweed cultivation will be scaled up and a start will be made with implementing smart grid technologies. Also, a start will be made with making the existing transport infrastructure suitable for a transition to electric vehicles.
In this period, it is essential that residents keep interest in achieving energy self-sufficiency. Therefore, it is important that residents keep informed on the opportunities and potentials of energy

conservation and decentralized energy generation. Furthermore, in 2018, again elections are held. Here also applies that it is important that the ambition remains and that the new policies will be build on earlier polices in which energy conservation and decentralized energy generation play a major role.

2018-2020

In the beginning of this period, the existing transport infrastructure is made suitable for electric vehicles. Also, in each village public charging points are realized. In addition, a smart grid is realized on the island, which makes it possible to exchange energy and to balance the energy supply and demand. Now the transport infrastructure is upgraded and a smart grid is realized, a transition to electric vehicles can be realized. Therefore, in this period the focus will be on realizing a transition to electric vehicles. Moreover, due to pressure from the residents and the municipality of Texel, the ferries will switch from conventional fuels to electricity for propulsion. To recharge the batteries of the ferries and to use the batteries as storage for balancing the energy supply and demand, a charging station will be realized.

Also in this period, there will be continued with installing solar power technologies, small wind turbines and heat and cold storage systems. Eventually, in the end of this period, the required amount is implemented. Furthermore, all energy saving measures are applied and have caused in a significant reduction of the total energy demand. To provide enough feedstock for the digestion plants and bioethanol plant, seaweed cultivation is realized in sea. As a result, in this period, digestion plants and a bioethanol plant will be constructed. To make use of the produced bioethanol in trucks, the internal combustion engines of trucks will be modified. After a full transition to renewable energy sources is achieved, the existing grid connection with the mainland will be used as back-up.

7.4 Implementation

In this research, two very different scenarios are constructed and elaborated for gaining insight into the opportunities, potentials and barriers for developing and implementing a sustainable energy system that lead to energy self-sufficiency. These insights can be used when making decisions. It is important to note that none of the constructed scenarios represents the most suitable scenario. Both scenarios show that energy self-sufficiency can be achieved in very different ways and that the related drivers and barriers are different. Now the two constructed scenarios are elaborated, it can be discussed what different stakeholders could do and what should be on their action agenda to actively work on achieving energy self-sufficiency.

Before defining a follow-up agenda, it is very useful to understand what led to constructing these two scenarios. As could be noted, in each scenario the energy supply is very different. Although there are not many differences in the renewable energy sources that are used, there is a difference in the technologies that are used, the shares and scale of use. Furthermore, there are differences in the used technologies regarding storage and power infrastructure. In addition to the physical part of the energy system, the two scenarios also differ at organizational, political and social level. The differences of between the scenarios are not just made up. Many considerations form the basis of the development and implementation of the energy system in the respective scenario. These considerations are based on the present conditions, current developments and exogenous variables concerning energy self-sufficiency that are defined in this research.

It can be concluded that many considerations have to be taken before developing and implementing a sustainable energy system in the municipal area. Through interviews with key stakeholders, relevant input has been obtained that was used in the different steps of the methodological framework of this research. However, for getting a better understanding about the interests regarding achieving energy self-sufficiency so that good decisions can be made, broad stakeholder involvement is needed. In particular, more insight is needed into the interests of residents. As described in section 4.2.1, most residents want to achieve energy self-sufficiency as long as it does not interfere with their vested interests. An important follow-up activity would be to examine which aspects are of great importance among the residents with regard to achieving energy self-sufficiency, including financial, institutional, organizational, cultural and environmental aspects. Although energy self-sufficiency is technically feasible, the results of the research can indicate whether energy self-sufficiency is socially feasible. For carrying out this research, participatory or interactive tools can be used, for example surveys. Also, when carrying out this research, residents can become more involved in the decision-making process of making Texel energy self-sufficient. In addition to residents, it would be also very useful to examine which aspects are of importance among local companies with regard to achieving energy self-sufficiency. The same applies for tourists. After all, tourism is the main source of income on Texel.

However, before examining which aspects are important among residents and local companies, first residents and local companies have to gain more knowledge and be more aware on the opportunities, potentials and barriers. If this is not done, many of the results have little relevance and cannot be used. For example: when residents do not know that tidal energy has a small potential in the municipal area, residents can indicate that they prefer tidal stream generators for meeting the total electricity demand, while this is impossible because of the potential. As previously described in section 4.2, in September 2011, the municipality of Texel has presented a road map together with other municipalities of the Dutch Wadden Islands. In this road map, it is indicated which steps are needed for achieving energy self-sufficiency, including a more active attitude from residents and local companies and more funding. Moreover, opportunities and potentials of available renewable energy sources and energy conservation are discussed. Although this road map is a very good first step of showing opportunities and potentials, there are several shortcomings and errors. An important shortcoming is that heat and cold storage is not treated. Furthermore, not all renewable energy potentials are indicated, such as the potential of wind energy, or the potentials are incorrect, in particular solar and biomass energy. In addition, there is little attention given to the barriers. However, despite these shortcomings and errors, an important observation is that at this moment the municipality of Texel is working on achieving energy self-sufficiency. Now it is needed to extend the communication with the residents and local companies. Many forms of communication can be used, including websites, information panels or TV broadcasts (on regional channel). For example, the ferries can be provided with information panels. In this way, many residents can be reached: each resident uses the ferry service because it connects Texel with the mainland.

Increasing knowledge and awareness and examining which aspects are important is very useful but it does not ensure that new actions take place. Therefore it is important that local parties continue working on the ambition. As long as no strategic action plan is developed, the implementation of energy saving measures and sustainable energy technologies, both small-scale and large-scale, must be stimulated. This is also necessary, because the end-point of 2020 is approaching and much more effort is needed. Stimulating can be done in several ways, including financial incentives and subsidies. An important observation is that the municipality of Texel has still budget for providing subsidies to

residents for applying energy saving measures and small-scale sustainable energy technologies. In addition, TexelEnergie has received subsidy from the municipality of Texel to stimulate installing solar panels. However, when there is no more budget available for financial incentives and subsidies, other ways have to be found for stimulating the implementation of energy saving measures and sustainable energy technologies.
When it is known which aspects are of importance among residents, local companies and tourists regarding energy self-sufficiency, a strategic action plan can be developed. Hereby is it important that representatives of these stakeholders keep involved to guarantee their interests in the decision-making process as much as possible so that this plan can take into account the various demands of the stakeholders. However, it should be noted that it is unlikely that all demands of the stakeholders can be processed. The plan covers a period up to 2020 and calls for immediate action.
Based on the proposed follow-up activities that are described, a follow-up agenda is constructed in which is described what different stakeholders should do to continue working on achieving energy self-sufficiency.

1. Continue to stimulate applying energy saving measures and sustainable energy technologies
As long as no strategic action plan is developed, the municipality of Texel, TexelEnergie and organizations, including Stichting Duurzaam Texel and Stichting Urgenda, have to continue stimulating residents and local companies to apply energy saving measures and sustainable energy technologies.

2. Focus on learning and increasing awareness regarding opportunities, potentials and barriers
Residents and local companies have to gain more knowledge and be more aware on the opportunities, potentials and barriers for achieving energy self-sufficiency. The municipality of Texel, TexelEnergie, other local companies, such as TESO, Ecomare and organizations, including Stichting Duurzaam Texel and Stichting Urgenda, are needed for providing this information. Many forms of communication can be used.

3. Research on aspects concerning energy self-sufficiency
The municipality of Texel and TexelEnergie are needed to examine which aspects are of importance among residents and local companies with regard to achieving energy self-sufficiency. The municipality of Texel can reach each resident and local company. Furthermore, TexelEnergie has around 3300 members of which most are residents that can easily be reached. In addition, to examine which aspects are of importance among tourists, tourism organization VVV Texel is important. Each year, VVV Texel is carrying out surveys among tourists.

4. Developing a strategic action plan
For developing a strategic action plan, broad stakeholder involvement is needed. Therefore, it would be very useful to set up a steering committee, which consists of residents and representatives of various local parties, including the municipality of Texel, TexelEnergie, TESO, Woontij, business organization TOP, farmer organizations and environmental organizations, that can develop this plan.

5. Developing and implementing sustainable energy system
Based on the strategic action plan, various stakeholders will actively work on developing and implementing a sustainable energy system that can make Texel self-sufficient in 2020.

8. CONCLUSION AND RECOMMENDATIONS

8.1 CONCLUSION

This research is aimed at gaining 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. These opportunities, potentials and barriers can be very useful in helping the involved stakeholders in developing a new strategy, which is needed to achieve self-sufficiency in 2020. For carrying out this research, a methodological framework was developed that has combined the methods backcasting and sustainable energy landscape design. This framework could take into account technological, economic, cultural, institutional, organizational and spatial aspects. By integrating backcasting and sustainable energy landscape design into one methodological framework, the first research sub question was answered and a start could be made with identifying the opportunities, potential and barriers.
This research focuses on the municipal area. An important starting point was that for achieving energy self-sufficiency, renewable energy generation has to take place within the municipal boundaries. It can be concluded that energy self-sufficiency by using renewable energy sources is technically feasible and that it is largely dependent on economical, institutional and cultural or social aspects. Based on the present conditions, current developments and exogenous variables concerning energy self-sufficiency, two very different scenarios were constructed. The two constructed scenarios showed that energy self-sufficiency can be achieved in very different ways. In the first scenario energy self-sufficiency could be achieved, while the trend growth of the total energy demand in the period from 2010 to 2020 on Texel was maintained. In this scenario, the main focus was on developing a decentralized energy system in which renewable energy sources were used on large scale for obtaining cost advantages. Furthermore, there was no focus on energy conservation. In the second scenario energy self-sufficiency could be achieved when focusing on energy conservation and decentralized energy generation. In this scenario, solidarity played a very important role.

An important finding is that the municipal area has a large potential of renewable energy. Based on the identified renewable energy potentials and current status and developments of sustainable energy technologies, solar energy, wind energy, heat and cold storage and biomass energy are the most important forms of renewable energy for achieving energy self-sufficiency. In addition, geothermal energy can also be of importance. Solar energy is very interesting for generating both electricity and heat. Solar panels are very important for meeting the electricity demand and solar thermal collectors can be very important for meeting the heat demand. Both solar power technologies are also techno-economically very interesting. Next to solar energy, wind energy is also very interesting. Wind energy has a very large electricity potential and is very important for meeting the electricity demand. In addition, wind turbines are techno-economically the most interesting sustainable energy technologies. Moreover, heat and cold storage has a very large heat potential. Open and closed systems are techno-economically very interesting and are essential for meeting the heat demand. Biomass is a very interesting source for generating electricity and heat and for producing liquid biofuels and biogas. Anaerobic co-digestion plants and CHPs based on biogas are essential for meeting the electricity and heat demand. Furthermore, biomass is the only source that can generate biogas, which is needed for meeting the process demand.

In addition to generating renewable energy, energy conservation can also play a major role in achieving energy self-sufficiency. A large part of the housing stock in the municipal area is not well isolated. Many energy saving measures, including insulation, LTH and ventilation systems, and new regulations related to constructing homes can affect the heat demand significantly. To significantly reduce the fuel demand, electric cars can be used and batteries can be used for propelling the ferries. Furthermore, energy saving measures, such as energy efficient appliances and lighting, can reduce the electricity demand. However, when the heat and fuel demand will be reduced significantly, a shift from gas and fuel applications to electric applications takes place, which will increase the electricity demand.
Considering the motives for achieving energy self-sufficiency that were identified, several conclusions could be drawn. When developing a sustainable energy system, permanent jobs can be created in the operation and maintenance of the technologies. It should however be noted that specific knowledge is required for operating and maintaining most technologies and the question arises whether this knowledge is present on Texel. Moreover, when residents decided to deal with the ambition by themselves and take the lead for realizing the energy supply in cooperation with local parties, more independence from the mainland can be achieved.
Although in recent years the municipality of Texel has done little with regard to energy self-sufficiency, due to obtained subsidies, the municipality of Texel is currently much more active. Next to the municipality of Texel, relatively many residents are committed to achieve energy self-sufficiency. However, the group of residents that want to take the lead and actively work on achieving energy self-sufficiency is significantly less. Also several local companies and organizations are committed to achieving energy self-sufficiency. Although the amount of renewable energy that is currently generated in the municipal area is very low, a positive finding is that in the next few years more renewable energy will be generated, particularly electricity.

However, there are also major barriers for developing and implementing a sustainable energy system, which are very difficult to overcome. The following major barriers for achieving energy self-sufficiency have been identified:

- Due to technical, structural and social barriers, meeting the fuel demand by using renewable energy sources is considerably difficult. It seems unlikely that the fuel demand can be fulfilled by biofuels. In addition, it seems unlikely that the ferries will make use of batteries and a transition to electric vehicles can be realized before 2020.
- Making use of wind as key resource is extremely difficult. Due to the large social resistance against wind turbines, it is extremely difficult to implement wind turbines in the municipal area. The municipality of Texel has even indicated that there will be no plans made for placing wind turbines in the next years. In addition, when using small wind turbines, many wind turbines are needed to generate a large amount of electricity. This will have also a large impact on the natural landscape so that heavy resistance is expected.
- The required investments for implementing sustainable energy technologies form are a major barrier. This applies both to large-scale or small-scale technologies. There is insufficient funding or it is very difficult to get funding or attract investments.
- Because of the large differences in the current national and local policies, it is expected that the municipality of Texel will get limited support from the Dutch government and the province of Holland in the coming years to achieve energy self-sufficiency. This will have negative consequences related to funding and laws and regulations

Moreover, when developing and implementing a sustainable energy system in the municipal area, several technological, economic, cultural, institutional, organizational and spatial aspects need to be taken into account:

- The existing power infrastructure has to be upgraded and district heating grids have to be constructed for dealing with the sustainable energy technologies.
- To create a diversified and resilient system, renewable energy sources that are not continuous available need to combined with sources that can be used when necessary. In this way, it is possible to minimize storage and to supply energy continuously.
- Due to laws and regulations related to the protected areas in the municipal area, heat and cold storage systems cannot be implemented in a large area. In addition, there are not many search areas for placing onshore wind turbines and constructing geothermal power plants.
- The scale of use of renewable energy sources has much influence on the implementation of sustainable energy technologies, including regulations, cost, required space and resistance.
- The organization of the energy system will influence whether users can benefit from the cost advantages that can be obtained by using renewable sources on large scale.

For achieving energy self-sufficiency, a better understanding is needed on the interests regarding achieving energy self-sufficiency. Broad stakeholder involvement is needed so that good decisions can be made. To realize this, a follow-up agenda is constructed. First, residents and local companies have to gain more knowledge and be aware on the opportunities, potentials and barriers. Then it will be examined which aspects are of importance among residents, local companies and tourists regarding energy self-sufficiency. When these aspects are known, a strategic action plan can be developed. For doing this, broad stakeholder involvement is needed. Based on this plan, various stakeholders will actively work on developing and implementing a sustainable energy system that can make Texel self-sufficient in 2020. It should however be noted that the implementation of energy saving measures and sustainable energy technologies must be stimulated as long as no strategic action plan is developed.

When this thesis will be compared with the most recent technical feasibility study that was carried out by ECN (Weeda et al. 2007) in which was concluded that energy self-sufficiency cannot be achieved, several conclusions can be drawn. When analyzing the report of Weeda et al., several shortcomings can be identified. There was not much focus on heat and cold storage and the potential biomass energy was not properly identified and taken into account when constructing scenarios. In particular, the potential of agricultural residues was not properly taken into account. As could be noted, heat and cold storage and biomass energy are essential for achieving energy self-sufficiency. In addition, relatively new technology developments were not taking into account, including biofuel generation from algae and electric transport. This is understandable because in the field of renewable energy and transport many developments have taken place in the last five years. Furthermore, the potentials of geothermal energy, tidal energy and wave energy were not taking into account.

8.2 Recommendations

Currently there are relatively many initiatives and projects ongoing and an important observation is that in the next years more renewable energy will be generated. However, given the relatively short period of time there is, much more effort is needed to achieve energy self-sufficiency in 2020. This could also be seen in the pathways that were defined for both scenarios. Based on findings of this research, several recommendations are made that can help in developing and implementing a sustainable energy system that can make Texel self-sufficient in 2020.

Do not focus too much on meeting fuel demand

Meeting the fuel demand using renewable energy sources before 2020 seems too ambitious. Therefore, it is recommended not to focus too much on meeting the fuel demand. It is however important to maintain the ambition so that reducing the use of fossil fuels keeps stimulated.

Focus on energy conservation

At this moment, a large part of the residential housing stock in the municipal area is not well isolated. Approximately two thirds of the housing stock has an energy label of D or lower. As a result, when applying energy saving measures, the heat demand can be reduced considerably. When heat is saved, heat does not have to be generated. Next to reducing the heat demand, it is also useful to focus on reducing the electricity and fuel demand although this is more difficult.

Focus on solar energy, wind energy, heat and cold storage and biomass energy

Based on the identified renewable energy potentials and current status and developments of sustainable energy technologies, solar energy, wind energy, heat and cold storage and biomass energy are essential for making Texel energy self-sufficient. In addition, it is also important to combine these different forms of renewable energy for providing a resilient energy system. Solar energy and wind energy are not continuous available, while biomass energy can be generated when necessary. Moreover, heat and cold storage systems use the earth as heat sink in the summer and as heat source in the winter when the heat demand is the highest.

Focus both on large-scale and small-scale sustainable energy technologies

The scale of use of renewable energy sources has much influence on the implementation of sustainable energy technologies, including regulations, cost, required space and resistance. For each spatial intervention, different aspects have to be taken into account. Therefore it is recommended to focus both on large-scale and small-scale technologies for developing and implementing a sustainable energy system.

Increasing knowledge and awareness among residents

In order to increase the interest among residents to apply energy saving measures and install sustainable energy technologies, residents have to gain more knowledge on the opportunities and potentials of energy conservation and renewable energy. In addition, the existing social resistance on Texel is often based on false arguments. When increasing knowledge on energy conservation and renewable energy, this resistance can be reduced. Moreover, residents can only provide useful input in the decision-making process when they have enough knowledge and are aware on the opportunities, potentials and barriers concerning achieving energy self-sufficiency.

Residents need to be more involved into the decision-making process

Residents have very much influence on achieving energy self-sufficiency. Most residents want to achieve energy self-sufficiency as long as it does not interfere with their vested interests. However, more insight is needed into the interests of residents in order to make good decisions. When the interests of residents are not properly taken into account, much social resistance can be expected. Therefore, residents need to be more involved into the decision-making process.

Setting up a steering committee to facilitate implementation

This recommendation is actually a continuation of the previous recommendation. It would be very useful to set up a steering committee that consists of residents and representatives of various local parties, including the municipality of Texel, TexelEnergie, TESO, Woontij, business organization TOP, farmer organizations and environmental organizations, to facilitate the implementation of sustainable energy technologies and energy saving measures. As can be noted, many of these parties are also represented in Stichting Duurzaam Texel. However, where Stichting Duurzaam Texel focuses on initiating and stimulating activities that support the sustainable development of the island, the steering committee will focus specifically on decision-making with regard to energy self-sufficiency and can develop a strategic action plan. Moreover, by setting up a steering committee, the cooperation between the municipality of Texel and local entrepreneurs can be improved.

Political continuity

Energy-self sufficiency cannot be achieved in the short term. It is a long-term vision so that political continuity in the municipality of Texel is essential. Especially when new elections are held, it is important that the ambition and chosen strategy will be maintained. This gives TexelEnergie, local entrepreneurs and companies outside the municipal area confidence to invest.

Increasing the amount of FTEs at the municipality of Texel that is working on the ambition

To achieve energy self-sufficiency much more effort is needed. The municipality of Texel can make an important first step by increasing the amount of FTEs that is actively working on achieving energy self-sufficiency so that residents, TexelEnergie and other local parties can get more help in setting up initiatives and projects.

Stichting Duurzaam Texel should be more active

Until a few years ago, Stichting Duurzaam Texel had a very stimulating role. However, due to a lack of funding, the foundation became less active in 2009. Currently, only one person is working for Stichting Duurzaam Texel. Based on past activities, Stichting Duurzaam Texel can be very important for providing knowledge and creating more awareness among residents and local companies.

8.3 Methodological reflection and recommendations

By combining the methods backcasting and sustainable energy landscape design, the methodological framework of this research was developed. This framework provided useful tools and methods that could take into account technological, economic, cultural, institutional, organizational and spatial aspects. However, also some limitations were experienced. To discuss the methodological framework of this research, first the used methods will be discussed separately after which the overall use of these methods will be discussed.

Backcasting

In this research, the methodological frameworks for backcasting by Quist and Vergragt (2006) and Robinson (1990) were used for developing the methodological framework of this research. Both approaches have proved their worth in this research, particularly the five-step methodological framework for participatory backcasting by Quist and Vergragt. This framework provided a very useful basis for developing the methodological framework of this research. An important characteristic of using backcasting is that no specific methods are prescribed so that it is possible to combine different methods. What is interesting about using the framework of Quist and Vergragt is that it encourages applying creativity when constructing the scenarios because no constraints are prescribed. In addition, the framework enables the elaboration of the constructed scenarios and stresses the importance of a follow-up agenda for the present. Also, Quist and Vergragt emphasize broad stakeholder involvement. Although it was impossible to meet the criteria of broad stakeholder involvement, in this research key stakeholders were interviewed for providing input.

The methodological framework of Robinson was also used, which provided a good addition. Robinson specifically refers to exogenous variables. By defining exogenous variables a certain constraint could be offered to the scenarios. In this research, these exogenous variables were important in determining the development of the energy demand in 2020 and in defining exogenous factors that affect the development and implementation of a sustainable energy system in the coming years. However, attention must be paid when defining exogenous variables, because it must not constrain the scenarios too much. There is otherwise a danger that the line between forecasting and backcasting is crossed.

In this research, also weaknesses could be identified when using backcasting. In backcasting studies end-points are usually chosen between 25 to 50 years into the future. In this research, the end-point was 2020, which is not far into the future. Although necessary changes could be defined, it is the question whether there is enough time for making conscious decisions. When the time period is longer, the potential to influence developments is much larger. There is a large risk that necessary changes cannot be achieved, which makes the results of the backcasting analysis less useful. In addition, many changes are necessary in a relatively short period of time. This can discourage stakeholders to actively work on achieving energy self-sufficiency, because they think it is not feasible beforehand.

Sustainable energy landscape design

The methodological framework for integrated visions proposed by Stremke et al. (2010a), provided very suited principles for designing a sustainable energy landscape. By analyzing the landscape characteristics and identifying the renewable energy potentials, a very good overview could be given of opportunities, potentials and spatial barriers for generating renewable energy in the municipal area. Furthermore, by identifying possible spatial interventions on the map of the municipality of Texel, a clear view could be given of suitable locations and search areas of energy-conscious interventions. Also, the most robust interventions could be indicated. These findings can be very useful for decision-makers.

However, some limitations were experienced. When identifying the renewable energy potentials, it would be also very useful to identify the energy conservation potential. Although the potential of energy conservation was taken into account in this research, it would be useful to identify the energy conservation separately. This potential, which is much related to the building environment, can be determined relatively easy and can be very useful for decision-makers. Furthermore, although is assessed which proposed spatial interventions had the highest robustness, the robustness of proposed interventions could be assessed much better when more scenarios were constructed. For example, as could be seen in Table 36, the robustness of installing solar panels on roofs is as high as constructing a geothermal power plant. However, installing solar panels on roofs has fewer uncertainties in comparison with constructing a geothermal power plant regarding implementation in the municipal area. As a result, the robustness of installing solar panels on roofs is higher. This can however not be seen because only two scenarios were constructed.

Moreover, a weakness was identified. Whereas the framework for participatory backcasting by Quist and Vergragt provides much creativity in constructing scenarios, until now, in studies where the framework for integrated visions is used there is much emphasis on using storylines of existing context scenarios, in particular WLO scenarios. This does not encourage the researcher for being creative when constructing scenarios.

Combination of both methods

Interestingly, the steps in the methodological framework proposed by Stremke et al. contained many similarities with the frameworks for backcasting proposed by Quist and Vergragt and Robinson. By using the framework of Quist and Vergragt as basis, an effective framework could be developed, which could take into account technological, economic, cultural, institutional, organizational and spatial aspects. By using only one method it would not be possible to take all these aspects into account. When using only backcasting, not enough attention would be paid to the spatial aspects. However, when only using sustainable energy landscape design, not enough attention would be paid to the economical, cultural, institutional and organizational aspects.

The framework of this research consisted of five steps and each tasks consisted of several tasks. In the first, third and fourth step there was a certain order maintained in the tasks, which proved to be good. In the first step, first the present conditions were identified. It was very useful to take into account these present conditions when identifying the current developments concerning energy self-sufficiency. In the third step, it is good to first identify the spatial interventions after which the necessary technological, structural, institutional, organizational and cultural changes will be defined. By identifying the spatial interventions, a clear view can be given of suitable locations and search areas of energy-conscious interventions so that necessary changes can be better understood. Furthermore, in the fourth step first the main drivers and barriers were identified so that these could be taking into account when defining pathways.

However, when carrying out this research also a pitfall was experienced. The first step of the methodological framework, which is the strategic problem orientation step, is quite intensive. Herein lies the risk that too much time will be invested into the first step and that less attention will be given to the other steps. This may finally lead to unsatisfied results. Moreover, the large quantity of information that was found when carrying out the first step could be an overkill to readers who are only interested in the different scenarios and the outcomes of these scenarios.

Recommendations

Now the used methods and the overall use of these methods are reflected, several recommendations can be made for further studies. These recommendations are described below.

- When using backcasting a longer time horizon is recommended

Using backcasting would be more useful when the time horizon is long. When the time period is longer, the potential to influence developments is much larger. This can have also a positive impact on the commitment of stakeholders.

- Constructing more scenarios would assess the robustness of interventions much better

The robustness of possible spatial interventions can be assessed much better when more scenarios are constructed. When constructing more scenarios, more insight can be obtained in the degree of robustness of possible spatial interventions.

- Identify energy conservation potential when analyzing present conditions

When analyzing the present conditions, it would be useful to identify the energy conservation potential separately.

- Do not invest too much time in the strategic problem orientation step

The first step of the methodological framework is quite intensive. However, do not invest too much time in this step. There is otherwise a danger that the other steps will not be carried out properly.

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Appendix A – Local initiatives and projects

At this moment there are many local initiatives and projects ongoing. To describe all relevant local initiatives and projects, a brief description of each relevant initiative or project will be given. Furthermore, it will be indicated which parties are or were involved and in which period the initiative or project took place.

Studies on achieving energy self-sufficiency

Actors: Stichting Duurzaam Texel, the municipality of Texel, Stichting Urgenda, Ecofys, ECN, CE Delft and ATO

Period: From 2001 to 2011

Summary: In the last few years several feasibility studies have been carried out. From 2001 to 2007, several studies were carried out, which were mainly taking into account the technical aspects and considered 2030 as end-point (De Beer et al. 2001; Weeda et al. 2007). In 2007, the municipality of Texel had decided to go for achieving energy self-sufficiency in 2020. In the years after 2007, CE Delft and ATO carried out new studies on behalf of the municipality of Texel (Leguijt et al. 2008; Elswijk 2010). Next to these studies, Stichting Urgenda had identified the local leaders in the municipal area, which are residents that can be of importance regarding achieving energy self-sufficiency (Urgenda 2009).

Cooperation between the Dutch Wadden Islands for achieving energy self-sufficiency

Actors: The municipality of Texel and the municipalities of the other Wadden Islands (VAST-islands)

Period: From 2007 to 2011

Summary: In 2007, the municipalities of the Dutch Wadden Islands have decided to go for energy self-sufficiency in 2020. They have this ambition set out in a manifesto (Gemeenteraden Waddeneilanden 2007). In addition, in 2011, the municipalities have presented a road map together (Gemeenteraden Waddeneilanden 2011). In this roadmap it is indicated that the municipalities have to help each other in the coming years. Furthermore, the municipalities of the Dutch Wadden Islands have indicated which steps are needed for achieving energy self-sufficiency.

Fairs regarding renewable energy, energy conservation and electric transport

Actors: The municipality of Texel, Stichting Urgenda, Stichting Duurzaam Texel and TexelEnergie

Period: From 2008 to 2011

Summary: In the last few years there have been various fairs regarding renewable energy, energy conservation and electric transport on Texel. In 2008, the municipality of Texel and Stichting Duurzaam Texel had organized a fair (Interview Kieft and Bakker 2011). This fair, also called Energiebeurs, was held for informing residents and local companies on renewable energy and energy conservation. In 2011, Stichting Urgenda had organized 'Texelectric day', which was a day where residents could gain experience with electric vehicles (Texelectric 2012). Furthermore, a fair was held on renewable energy and energy conservation, also called Energiebespaarbeurs. The various fairs were well attended (Interview Hercules 2011; Interview Kieft and Bakker 2011; Interview Minnesma 2011).

Information sessions and workshops regarding renewable energy and energy conservation

Actors: Stichting Duurzaam Texel

Period: From 2004 to 2011

Summary: For many years, Stichting Duurzaam Texel is actively working on achieving energy self-sufficiency. It had organized several information sessions and workshops for resident and local companies on renewable energy and energy conservation. Already in 2004, Stichting Duurzaam held information sessions on the 'milieubarometer', which was a certification mark that indicated that a company was actively working on improving the environment. This proved a great success and many local companies applied (Interview Hordijk 2011). In 2007, Stichting Duurzaam Texel had organized a trip to Danish island Samso, which is already energy self-sufficient by using renewable energy sources. In 2008, Stichting Duurzaam Texel organized information sessions on various topics related to renewable energy and energy conservation (Stichting Duurzaam Texel 2011). Furthermore, in 2009, Stichting Duurzaam Texel held information sessions at schools and also workshops for companies on Energy Investment Allowance (EIA).

Large projects with solar panels and solar thermal collectors

Actors: TexelEnergie, Woontij and local companies

Period: From 1995 to present

Summary: In the last few years several local companies have installed many solar panels and solar thermal collectors on their roofs. Already in 1995, 440 m^2 of solar thermal collectors were installed on the roof of swimming pool Molenkoog in Den Burg. Another example of a large project is a project in 't Horntje, where in 2011 186 solar panels on the Potvis were installed. This was also the first project of TexelEnergie, which was carried out in cooperation with Woontij. TexelEnergie is currently carrying out more large projects regarding solar panels (Interview De Graaf 2011).

Pilot project with electric vehicles

Actors: Stichting Urgenda, the municipality of Texel and local entrepreneurs

Period: From 2010 to present

Summary: The Dutch government has allocated a subsidy to Stichting Urgenda for gaining experience with electric vehicles. For carrying out this pilot project, Stichting Urgenda is working together with 19 local entrepreneurs (Agentschap NL 2011d). The intention is to purchase 26 electric cars and gaining experience with these cars.

Realization of charging points for electric vehicles

Actors: Stichting Urgenda, the municipality of Texel and local entrepreneurs

Period: From 2011 to present

Summary: In 2011, two charging points for electric vehicles are realized on the island. The first charging point was realized at the Town Hall of Texel and the other charging point at Profile Tyrecenter Texel (Gemeente Texel 2011a). The intention is to realize a total of 40 charging points on the island in the next years. These charging points can be realized through the subsidy that is obtained by Stichting Urgenda.

Pilot project with tidal stream generators in the Marsdiep

Actors: Tocardo International, Bluewater Energy Services, Tidal Testing Centre, NIOZ, ECN, the province of North Holland, WL, Marin, WMC and Deltares

Period: From 2009 to 2013

Summary: This project is part of the ‘Kansen voor West’ program in which 4 provinces and 4 cities, including the province of North Holland, stimulate knowledge development in the Randstad. In this project several technology companies and knowledge institutes are working together for developing knowledge on tidal stream generators (Kansen voor West 2011). It will examine the problems occurring when tidal stream generators are placed in estuaries. For doing this, 6 tidal stream generators with a rotor diameter of 9.2 meters and a peak power of 80 kW each will be installed on a floating platform in the Marsdiep. For carrying out this project in the Marsdiep, which is a protected area, the Dutch government has issued a permit. Local research and knowledge institute NIOZ provides the measurements (De Vries 2011).

Plans for constructing an anaerobic co-digestion plant

Actors: TexelEnergie, AJT and LTO Texel

Period: From 2011 to present

Summary: TexelEnergie and local farmer organizations AJT and LTO Texel are actively working together for constructing an anaerobic co-digestion plant on the island (Interview De Graaf 2011). The plant that they have in mind will consume 15,000 tons of animal manure and 14,500 tons of agricultural residues per year. Both the animal manure and agricultural residues comes from agricultural companies on the island. In this plant 28,000 tons of digestate will be produced, which can be used as fertilizer. Furthermore, the plant will produce 4 million m^3 of biogas and 12 million kWh of electricity each year (TexelEnergie 2011a). The municipal executive board of Texel is currently supporting the construction of this plant (Interview Hercules 2011).

Research on geothermal energy

Actors: The municipality of Texel, TexelEnergie, Development Company Holland North, the province of North Holland, Ecofys, IF WEP and Grontmij

Period: From 2009 to present

Summary: In 2009, Ecofys and IF WEP have carried out a feasibility study on geothermal energy in the municipal area on behalf of the municipality of Texel, TexelEnergie, Development Company Holland North and the province of North Holland. This study has been partially made public (Hagedoorn et al. 2009). In this study it is roughly estimated how much electricity and heat can be generated by a geothermal power plant that extracts heat at a depth of approximately 5500 meters (see also Example 4). It was concluded that geothermal energy can be an important source for achieving energy self-sufficiency. In 2011, the Dutch government has issued a permit to search for geothermal energy on the island (Energeia 2011). As a result, more specific research can be carried out and new progress is made in the realization of a geothermal power plant. However, until now, funding is very difficult.

Realization of fuel saving and reduction in greenhouse gases regarding ferry service

Actors: TESO

Period: From 2007 to present

Summary: In recent years, transportation company TESO, which provides the ferry service, has taken several measures for realizing fuel savings and for reducing greenhouse gases and pollutants. In 2007, a pilot project was carried out with GTL (Gas to Liquid), which resulted in a reduction of pollutants. However, the fuel was too expensive. As a result, TESO did not continue with this fuel (Interview De Waal 2011). Furthermore, a part of the fuel is replaced by biodiesel. At this moment, 20% of the total fuel amount consists of biodiesel, which does not come from Texel (Interview De Waal 2011). TESO also encourages tourists to come on foot and by bike. To achieve this, TESO has reduced the rates for pedestrians in the last few years. In the next years, a new ferry will be built that needs to be finished in 2015. As a result, TESO is currently examining how the new ferry can be more energy efficient and can make use of sustainable energy technologies (Interview De Waal 2011). The intention is to install solar panels on the ferry. Furthermore, TESO want to examine if turbosails can be used as drive technology, which are hollow cylinders that make use of the pressure difference between the sides of the cylinder. Batteries can also be applied, but these will not be used for propelling the ferry.

Pilot project with small wind turbines

Actors: The municipality of Texel, TexelEnergie and donQi

Period: From 2010 to present

Summary: The municipality of Texel is carrying out a pilot project with small wind turbines. These small wind turbines can be realized through a subsidy from the Waddenfonds, which is a fund for additional investments in projects in and around the Wadden Sea. Up to now, only one small wind turbine (donQi) is tested at the harbor in Oudeschild, which was no success. Because of the high wind speed in the harbor, both the construction and the turbine broke down (Interview Hercules 2011). Soon, another small wind turbine will be tested. Furthermore, the budget that was determined for carrying out this pilot project was not enough for testing 25 small wind turbines (Interview Hercules 2011).

Pilot project with wood-burning stove in the residential area 'De 99' in Den Burg

Actors: TexelEnergie and Woontij

Period: From 2011 to 2016

Summary: TexelEnergie and Woontij are placing a wood-burning stove in the residential area 'De 99' in Den Burg (Woontij 2011). It will be a pilot project for 5 years in which wood chips will be burned in a stove for heating the residential area 'De 99'. The municipality of Texel has given a temporary permit for placing the wood-burning stove.

Heat and cold storage system for Town Hall of Texel and secondary school in Den Burg

Actors: The municipality of Texel

Period: From 2008 to 2012

Summary: In 2008, the municipality of Texel decided to construct a heat and cold storage system for the new Town Hall and secondary school in Den Burg. However, up to now, this system is not realized because of frictions in the municipality of Texel while the Town Hall is already constructed. Nevertheless, it is indicated that the system be installed. The pipes are already placed and it is expected that the system will be finished in 2012 (Texel-Plaza 2011a).

Initiative to place wind turbines at an industrial site in Oudeschild

Actors: Local entrepreneurs and De Wolff Nederland Windenergie

Period: From 1997 to present

Summary: For many years, local entrepreneurs are actively working on placing wind turbines at an industrial site in Oudeschild. In 2000, one wind turbine of 350 kW was placed, which is currently the only wind turbine on Texel. However, local entrepreneurs wanted to place two other wind turbines next to this turbine. Although the province of North Holland has giving permits to place these turbines, the municipality of Texel does not want to cooperate (Gemeente Texel 2011d). As a result, up to now no wind turbines are placed.

The development of an educational program on sustainability

Actors: Ecomare and Stichting Kopwerk (which consists of many organizations, including the municipality of Texel, Stichting Duurzaam Texel and TexelEnergie)

Period: From 2011 to present

Summary: Ecomare has developed an educational program on sustainability in cooperation with Stichting Kopwerk. This educational program is developed for increasing the knowledge on sustainability among children at primary schools in the municipality of Texel (Interview Hercules 2011; Ecomare 2011).

Energy desk in the Town Hall of Texel (Energieloket) for helping residents and tourists

Actors: The municipality of Texel, TexelEnergie and Stichting Duurzaam Texel

Period: From 2011 to present

Summary: In 2011, the municipality of Texel has opened an 'energy desk', also known as Energieloket (Gemeente Texel 2011b). At this information desk residents can ask for advice on saving energy and they can get help in applying for subsidies for various sustainable energy technologies. For providing good advice and help, the municipality of Texel is working together with TexelEnergie and Stichting Duurzaam Texel.

Implementation of smart meters throughout the municipal area

Actors: The municipality of Texel and Alliander

Period: From 2011 to present

Summary: Texel is the first municipality in the Netherlands where smart energy meters will be installed (Gemeente Texel 2011c). This applies for all households and companies in the municipal area. In 2012, it will be possible to connect the smart energy meter to a computer. As a result, residents and companies can gain insight in their energy consumption.

Pilot project with energy system Cloud Power

Actors: TexelEnergie, Capgemini, Qurrent and Alliander

Period: From 2011 to 2013

Summary: In this pilot project an energy system will be tested in 300 households, which have a contract with TexelEnergie (TexelEnergie 2011b). This energy system, also known as Cloud Power, is a developed by Capgemini, which can match the energy supply and demand. Cloud Power aims to unite a relatively small group of consumers with a common approach to their energy supply, and enable them to define and jointly pursue their individual goals (Capgemini 2011). Furthermore, Qurrent is delivering the control. This pilot project in funded by the Dutch government.

Pilot project with LED public lighting

Actors: The municipality of Texel

Period: From 2009 to present

Summary: The municipality of Texel is involved in the European project Cradle to Cradle Islands (C2CI) in which municipalities of the Wadden Islands in collaboration with the government, research and knowledge institutes and companies are carrying out projects related to the Cradle to Cradle philosophy. The municipality of Texel is carrying out a pilot project in De Koog in which public lighting will be provided with LED lights (Struick 2011). By doing this, energy will be saved on public lighting. Eventually, the goal is to apply LED lights in all public lighting in the municipal area.