RENEWABLE ENERGY IN ZAANSTAD: FROM THEORY TO PRACTICE

RESEARCH INTERNSHIP (9 ECTS)

Author: Michel Verburg
Student number: 0728060
Organization: Eindhoven University of Technology
Education: Sustainable Energy Technology (MSc)
Specialization: Electrical Power Engineering
Department: Electrical Engineering
Supervisors: prof. J.F.G. Cobben (TUe)
Drs. Hugo Niesing (Resourcefully)
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# TABLE OF CONTENTS

**EXECUTIVE SUMMARY** .................................................................................................................. 4

1. **INTRODUCTION** .......................................................................................................................... 6

2. **MUNICIPALITY OF ZAANSTAD** ................................................................................................. 7
   2.1 **INTRODUCTION** ......................................................................................................................... 7
   2.2 **ENERGY POLICY** ......................................................................................................................... 7
   2.3 **ENERGY DEMAND** ....................................................................................................................... 8
   2.4 **VISION AND STRATEGY** ............................................................................................................. 9
   2.5 **BOUNDARIES** .............................................................................................................................. 10

3. **POTENTIAL OF RENEWABLE ENERGY IN ZAANSTAD** ............................................................. 11
   3.1 **INTRODUCTION** ........................................................................................................................... 11
   3.2 **ENERGY REDUCTION** ................................................................................................................. 11
   3.3 **BIOMASS** .................................................................................................................................... 12
   3.4 **SOLAR ENERGY** ........................................................................................................................... 12
   3.5 **WIND ENERGY** ............................................................................................................................ 13
   3.6 **GEOTHERMAL ENERGY** ............................................................................................................. 15
   3.7 **INFRASTRUCTURE** ...................................................................................................................... 16
   3.8 **CONCLUSION** ............................................................................................................................ 18

4. **SMART GRIDS** ............................................................................................................................. 19
   4.1 **INTRODUCTION** ........................................................................................................................... 19
   4.2 **DISTRIBUTED GENERATION** ....................................................................................................... 19
   4.3 **DEFINITION OF SMART GRIDS** ............................................................................................... 20
   4.4 **DEMAND RESPONSE** .................................................................................................................. 22
   4.5 **INTEGRATION OF RENEWABLE DISTRIBUTED GENERATION** ................................................. 23
   4.6 **VIRTUAL POWER PLANT** ........................................................................................................... 23

5. **SMART GRID PILOT PROJECT: RELOADIT** ............................................................................. 25
   5.1 **INTRODUCTION** ........................................................................................................................... 25
   5.2 **DEFINITION AND OBJECTIVES** ............................................................................................... 25
   5.3 **PARTNERS** .................................................................................................................................. 27
   5.4 **TECHNICAL SPECIFICATIONS** ................................................................................................... 28
   5.5 **FUTURE SMART GRID IN ZAANSTAD** ...................................................................................... 29

6. **RENEWABLE DISTRIBUTED GENERATION IN ZAANSTAD BY 2020: FROM THEORY TO PRACTICE**. 31
   6.1 **INTRODUCTION** ........................................................................................................................... 31
6.2 RESEARCH OBJECTIVE .................................................................................................................. 31
6.3 METHODOLOGY ............................................................................................................................ 31
6.4 ORGANIZATION ............................................................................................................................. 32
6.5 PRECONDITIONS AND EXPECTED RESULTS ............................................................................... 33
7. LITERATURE ........................................................................................................................................ 34
EXECUTIVE SUMMARY

Zaanstad is a Dutch municipality located in the region North-Holland with 143,000 inhabitants. The municipality has set the ambitious goal of being a CO₂ neutral municipality by 2020. Zaanstads reasons for this transition are global warming, depletion of fossil fuels, security of energy supply and providing a healthy environment for its residents.

The total energy consumption within its municipal boundaries currently is estimated at 11.1 PJ/year. The energy consumption by Zaanstad exists for a large part out of natural gas (49%), transport fuels (28%) and electricity (21%). Several investigations have been done of how Zaanstad can achieve its goals. First of all, the energy consumption needs to be reduced. Energy can be saved in the building environment and in the local industries. By applying hard measures in these sectors, Zaanstad can reduce its energy demand to 9.2 PJ/year. This amount of energy needs to be generated locally with renewable generation.

Research has shown that in theory the most suitable renewable energy sources for Zaanstads energy plans are biomass, solar energy, wind energy and geothermal energy. The investigations has shown that biomass in theory has a lot of potential. In practice however, most of the biomass already other has destinations. Zaanstad needs to negotiate with local companies in other to make biomass a suitable candidate for its energy plans. Zaanstad is planning to invest in renewable distributed generation on a large scale. This includes an investment of 76 MWp in PV cells and an investment of 74 MW in wind turbines. The energy production by these generators together is estimated at 2.9 PJ per year. Since the current electricity consumption of Zaanstad is 2.4 PJ per year, the renewable energy sources will cover the electricity demand. Nevertheless an increase of electricity is expected because of the increasing population and the increase of electric vehicles and heat pumps. For the replacement of natural gas as a heat supplier by a renewable energy sources, geothermal energy is an important candidate (besides biomass). In the northern region deep geothermal energy can be used for spatial heating. The availability of deep geothermal energy in the area of Krommenie and Wormerveer is 5.9 PJ/km². In the southern region of Zaanstad can use ATES or BTES systems in combination with ground source heat pumps. Further research needs to be done on the possibility of the practical implementation and financial aspects of these techniques in Zaanstad.

The implementation of renewable energy in Zaanstad requires a change in the current energy infrastructure. For the heat supply a district heating network needs to be installed in order to realize the possibility to connect biomass CHP units and geothermal energy techniques to this system. Also the electricity infrastructure needs to be reviewed closely in order to realize Zaanstads plans. The large scale implementation of distributed generators as PV and wind turbines can have a negative impact on the distribution grid in terms of grid reliability and power quality. Further research needs to be done in this subject. If possible problems and bottlenecks are identified, the addition of Smart Grid techniques to Zaanstads network should be investigated. The implementation of Smart Grid techniques can reduce the impact on the distribution network. Zaanstad is currently developing a Smart Grid pilot project called REloadIT, which is the showcase of the European project e-harbours in which Zaanstad is leading partner.

The REloadIT project is a step towards a possible future Smart Grid in Zaanstad. In order to realize a Smart Grid rollout over the whole municipality, further research needs to be done. If Zaanstads
wants to realize a large scale implementation of renewable distributed generators as PV and wind turbines, it should consider the option of participate or create a cooperative to trade energy by itself. Smart Grid capabilities as Virtual Power Plant can help to make financial and technical optimal decisions. This requires further research.

In the context of the master education Sustainable Energy Technology at the Eindhoven University of Technology the student will carry out an eight month research assigned by Zaanstad. The research will focus on the practical implementation of renewable distributed generators in Zaanstad. The objective of the research is to answer the following research question:

“How can Zaanstad realize the practical implementation of the renewable distributed generators by 2020 and what is the potential contribution of Smart Grid technologies to achieve this?”

In the beginning of the research, possible locations for large scale implementation of solar and wind energy will be identified. After this the local distribution network will be simulated and the impact on this network in terms of capacity and power quality will be investigated. At last the technical and financial potential of Smart Grid technologies in Zaanstad will be investigated.
1. INTRODUCTION

The energy challenge is one of the greatest tests faced by the world today. The quality of life, industrial competitiveness and the overall functioning of society are dependent on safe, secure, sustainable and affordable energy. Depletion of fossil fuels causes rising energy prices and makes countries more and more dependent on energy import. Besides this, global warming is worldwide recognized as a serious problem. Key decisions have to be taken to reduce drastically our emissions to fight climate change and to secure current en future generations of save and affordable energy supply for citizens and businesses.

The European Council in 2007 adopted ambitious energy and climate change objectives for 2020. The objectives include a reducing of greenhouse gas emissions by 20%, an increase of the share of renewable energy to 20% and an energy efficiency improvement of 20% [8]. This is a step in right direction; however, the energy challenge involves more. The worldwide increasing energy demand together with the increasing share of renewable energy causes serious challenges for the electricity infrastructure. It will require enormous investments to prepare the current transmission and distribution grids for this increase, which were installed decades ago. Besides this, the consequence of the increasing share of renewable energy is the transition from centralized electricity production in large scale power plants to distributed generation (DG). Small scale Photo Voltaic (PV) systems and onshore wind turbines are installed on the electricity distribution network. The difficulty of accurate forecasting and the variability of production can have negative impact on the current medium and low voltage networks in terms of capacity and power quality. The concept of Smart Grid can help to enable the implementation of renewable distributed generators by reduce the impact on the distribution networks.

As result of the goals set by the European Union; national governments, organizations and local municipalities are starting pilot projects to enhance the development of renewable energy and Smart Grids. The municipality of Zaanstad has set the ambitious goal of being a CO₂ neutral municipality by 2020. In the context of this energy policy Zaanstad is leading the European project e-harbours. E-harbours is a project which involves seven harbour cities who share the same objective of stimulating local renewable energy, smart mobility and Smart Grid deployment. Each of these cities is currently developing their own showcase. The municipality of Zaanstad – which is project leader – is developing the Smart Grid pilot project REloadIT. This pilot project focusses on charging electric vehicles by solar and wind energy and uses Smart Grid technologies to facilitate this in a smart way.

This report will focus on Zaanstads plan to become a CO₂ neutral municipality by 2020. In chapter 2 the energy policy of Zaanstad together with the energy consumption within the municipality will be reviewed. In chapter 3 a possible way will be described of how Zaanstad can achieve this objective. In this chapter the potential of energy savings together with the potential of renewable energy deployment in Zaanstad will be investigated. In chapter 4 the concept of Smart Grid and its capabilities will be defined according to the literature. In chapter 5 the Smart Grid pilot project REloadIT will be described. The last chapter consists of a research proposal, which exists of investigations on the practical implementation of renewable distributed generators in Zaanstad and the potential of role of Smart Grids within the municipality.
2. MUNICIPALITY OF ZAANSTAD

2.1 INTRODUCTION

Zaanstad is a Dutch municipality located in the region North-Holland. The municipality of Zaanstad was created on the 1th of January 1974 by uniting the municipalities of Assendelft, Koog aan de Zaan, Krommenie, Westzaan, Wormerveer, Zaandam and Zaandijk. Currently the municipality of Zaanstad is one of the larger municipalities of Netherlands with 143,000 inhabitants. The number of inhabitants in Zaanstad is rising. According to the expectations the number of inhabitants will be 155,000 in 2030 [9].

![Map of Zaanstad](image)

Figure 1. A geographic overview of the municipality of Zaanstad

2.2 ENERGY POLICY

Zaanstad is a community with environmental awareness and great focus on sustainability. In 2009 the municipality decided it wants to make a transition from energy consumption by fossil fuels to energy consumption by renewable energy sources. The current energy consumption exists largely out of electricity, natural gas and transport fuels. This energy is coming from centralized power plants and (petro) chemical industrial plants which are for the most part fired by fossil fuels. Zaanstad wants to produce its energy demand within its own municipal boundaries. For this transition it has several reasons.

**Global warming**

The average worldwide temperature is still increasing as result of the emission of greenhouse gasses.

**Depletion of fossil fuels**

The fossil fuels reserves are finite. The depletion of fossil fuels causes increasing electricity and fuel prices. This will cause a significant increase of costs for consumers, companies and municipalities.
Security of energy supply

The increasing amount of energy generated from renewable energy sources results in a more secure energy supply and less dependency of political instable regions.

Healthy environment

Becoming a CO₂ neutral municipality will lead to a cleaner and healthier environment for Zaanstads residents.

The Dutch government – as result of the goals set by the European Commission – wants a share of renewable energy of 14% and a reduction of CO₂ emission with 20% by 2020. Zaanstad wants its municipality to be leading in its energy policy with regard to the national policy and other communities. That is why Zaanstad has set the ambitious goal of being a CO₂ neutral municipality by 2020. This means that the yearly average CO₂ emission caused by energy consumption within the municipality should equal zero¹.

Zaanstad will be defined as climate neutral if the total yearly average CO₂-emission as result of energy consumption within its municipality boundaries will equal zero.

2.3 ENERGY DEMAND

To create a clear vision and strategy on achieving CO₂ neutrality of its energy demand, it is important to have a clear overview of the current energy consumption of Zaanstad. In this chapter an overview of the electricity and gas consumption of Zaanstads total municipality will be given, even as the energy consumption of the different sectors². Besides that the energy consumption of the municipal organization will be reviewed, which include all the municipal properties.

Municipality

The total energy consumption of Zaanstads municipality has been estimated at 11.1 PJ/year³ [1]. Figure 2 shows a distribution of Zaanstads energy consumption in different types of energy. The largest energy consumers are respectively natural gas (49%), transport fuels (28%) and electricity (21%). Figure 2 shows a distribution of the energy consumption of Zaanstad in different sectors.

![Figure 2. Overview of the distribution of the energy consumption (in PJ/year) of Zaanstad in different types of energy (left) and different sectors (right)](image)

¹ The emission of other greenhouse gasses will be neglected
² The energy demand of Zaanstad has been estimated by HVC CQ team [1].
³ This estimation is based on data from 2007 and 2008
The largest energy consumers are households (45%), industries (28%) and transport (13%). The total CO₂ emission of Zaanstad has been estimated at 950 kton/year. 75% of this CO₂ emission is caused by households and industries.

**Municipal organization**

The energy consumption of the municipal organization of Zaanstad consists of the energy usage by all the properties owned by the municipality itself. The total energy consumption and the distribution of the energy usage by the municipal organization is shown in table 1. The energy consumption of the municipal organization is 11.2 GWh per year (=0.04 PJ/year) and is very small compared to the energy consumption of the total municipality (0.4%).

<table>
<thead>
<tr>
<th>Category</th>
<th>Consumption (kWh/year)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public lightning</td>
<td>3.140.586</td>
<td>28%</td>
</tr>
<tr>
<td>Housing and public services</td>
<td>2.691.931</td>
<td>24%</td>
</tr>
<tr>
<td>Pumps and drainages</td>
<td>1.458.129</td>
<td>13%</td>
</tr>
<tr>
<td>Firehouse</td>
<td>1.345.965</td>
<td>12%</td>
</tr>
<tr>
<td>Sports facilities</td>
<td>448.655</td>
<td>4%</td>
</tr>
<tr>
<td>Traffic control systems</td>
<td>337.330</td>
<td>3%</td>
</tr>
<tr>
<td>Bridges</td>
<td>337.307</td>
<td>3%</td>
</tr>
<tr>
<td>Remaining</td>
<td>1.458.129</td>
<td>13%</td>
</tr>
<tr>
<td><strong>Total consumption</strong></td>
<td><strong>11.216.379</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

2.4 VISION AND STRATEGY

Becoming a CO₂ neutral municipality in 2020 Zaanstad is an ambitious goal, which requires a clear vision and strategy. A common approach which is used in the transition of achieving sustainability of energy supply is the concept Trias Energetica. The Trias Energetica consists of the following steps:

1. Reduction of the energy consumption
2. Deployment of renewable energy sources
3. Increase efficiency of fossil fuels usage

The first step is to review the possibilities to reduce the energy demand within the municipality of Zaanstad. Energy reduction can for instance be achieved in the built environment and in the industry. The next step is to investigate the potential of renewable energy sources within the municipality needs to be invested. An overview of the investigations on energy reduction and renewable energy sources which have been done will be given in chapter 3.
2.5 BOUNDARIES

In the process of becoming a CO₂ neutral municipality, there are some organizational, fiscal and legislative boundaries which have to be considered. There are multiple financial and regulative preconditions that Zaanstad needs to take into account. These are stated in the Integral Climate Program 2010-2020 [2]. The most important boundaries will be summarized.

MJA
This law is signed by the government, municipalities and 20 organizations. The goal of MJA is an energy efficiency improvement of 30% by all participants together in the period 2005-2020.

Environment Preservation Law (Wet Milieubeheer)
According to this law, municipalities can force companies to reduce energy demand if investigations show that the payback of these measures is lower than 5 years.

Subsidies
By providing subsidies Zaanstad can create incentives for companies and customers to reduce energy and invest in sustainable distributed generation.

Fiscal
By applying fiscal incentives, customers and companies can be stimulated to reduce energy.

Fees
By charging fees the municipality can provide discount for parties how are evidently preserving energy and investing in sustainable energy in market activities.
3. POTENTIAL OF RENEWABLE ENERGY IN ZAANSTAD

3.1 INTRODUCTION

In this chapter the potential of the energy production from renewable energy sources in Zaanstad are reviewed. Recent years a number of investigations have been done on the potential of renewable energy in Zaanstad. A quickscan has been made of the potential of solar energy, wind energy, biomass and geothermal energy [1]. The result of this quickscan was that biomass (63%) has the largest potential of these sources, followed by geothermal (17%), solar (12%) and wind energy (8%).

This quickscan is an estimation; the extent to which this potential can be implemented depends on different factors like the development of the cost of techniques which make energy generation out of these sources possible. Besides that it will depend on national and international laws, regulations and policies which respect to sustainable energy. In this chapter the potential of each of these sources will be reviewed individually.

3.2 ENERGY REDUCTION

The first step in the Trias Energetica is to reduce the energy demand. The current energy demand of Zaanstad is 11.1 PJ/year and consists for a large part of natural gas (49%), transport fuels (28%) electricity (21%). Investigations have been done on how to achieve a reduction in this consumption [1]. Energy reduction can be realized by renovating existing buildings, making sure new buildings are delivered CO₂ neutral and saving energy in the industry by increasing the energy efficient of the consumption. The potential of energy savings in the built environment has been done (table 2), energy reduction in the industry requires further research and is not the scope of this project.

The possible routes to achieve energy reduction in Zaanstad can be separated in a business-as-usual scenario and an intensive scenario. In the business-as-usual case Zaanstad only attends the agreements made with the government on energy reduction in the building sector and the industry. The MJA agreement is an agreement between the government, municipalities and industries to increase the energy efficiency with 30% in the period 2005-2020. In the building sector an energy reduction can be achieved by decreasing the Energy Performance Coefficient (EPC) of existing and new buildings. The energy consumption in the business-as-usual scenario will drop to 10.2 PJ/year in 2020 [1].

In the intensive scenario Zaanstad goes beyond the agreements with the government and takes extra measures to reduce the energy demand within its municipality. Table 2 shows the possible measures Zaanstad can apply to reduce the energy demand.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Energy savings (PJ/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creating CO₂ neutral new buildings and houses</td>
<td>0.7</td>
</tr>
</tbody>
</table>
These measures will lead to an extra reduction of 1.1 PJ/year in the energy demand. The estimated energy consumption in 2020 as results of this intensive scenario will thus be **9.1 PJ/year**. If Zaanstad wants to reach its objective of being CO\textsubscript{2} neutral in 2020, it has to take every measure within reach. That is why in the remaining part of this investigation it will be assumed that the intensive scenario will be accomplished and the energy consumption will drop to 9.1 PJ/year in 2020.

### 3.3 BIOMASS

Biomass is the most common form of sustainable energy worldwide and with 55 EJ\textsuperscript{4} it accounted for 15% of the worldwide primary energy supply in 2010 [4]. It is mainly used for cooking and heating in rural areas in developing countries, but it can also be converted into modern energy carriers such as gaseous fuels, liquid fuels and electricity. Biomass is a term for all organic material that is coming from plants (including algae, trees and crops) and is produced in the process of photosynthesis [6]. Biomass can be considered as organic matter, in which the energy of sunlight is stored in chemical bonds. When the bonds between carbon, hydrogen and oxygen molecules are broken by digestion, combustion, or decomposition, these substances release their stored, chemical energy [6]. Biomass can be obtained from a wide range of resources such as waste streams, woody and grassy materials and all have different compositions and characteristics (moisture, ash etc.). There are three general conversion processes for biomass, i.e. thermochemical, chemical and biochemical conversion.

Zaanstad has a relatively large biomass potential and is estimated at a total of 12.3 PJ/year. Research has shown that the most promising resources for biomass in Zaanstad are [1]:

- Woody biomass (cacao shells, waste and sawdust) **1.6 PJ/year**
- Municipal waste **1.0 PJ/year**
- Waste from food industry **9.7 PJ/year**

Zaanstad has negotiated with different companies for a possible cooperation to invest in a biomass power plant. Due to economic reasons and the fact that most of the resources have already other destinations, the negotiations have not yet resulted in collaboration.

### 3.4 SOLAR ENERGY

**Photo Voltaic**

Because of the large amount of R&D which is currently done in companies, institutions and universities, the efficiency of Photo Voltaic (PV) cells are increasing and the production costs of PV

\textsuperscript{4} EJ = Exa Joule = 10\textsuperscript{18} J
cells are becoming lower. This – and other driving forces such as sustainable awareness and depletion of fossil fuels – causes an increase in the world wide installed PV capacity. Although the world wide PV industry is still relatively small, the amount of installed PV capacity is rising. The worldwide PV market installations reached a record high of 18.2 GW in 2010, representing a growth of 139% with regard to the year before [4].

In Zaanstad, investing in the installation of PV cells is an important part of the strategy of reaching the climate objectives in 2020. Zaanstad has already installed solar panels on schools, companies and houses. In the REloadIT project the municipality uses PV cells for the charging of its electric vehicles (chapter 5). In 2011 the total installed PV capacity in Zaanstad accounted for 270 kWp. This is still a relative small part, but Zaanstad has huge plans with solar energy. The potential capacity for PV is estimated at 76 MWp, which will account for an electricity production of 2.4 PJ/year [1].

**Solar collectors**

Besides using solar energy for the production of electricity it can be used for the production of thermal energy. Solar collectors convert solar irradiation into heat and transfer the heat to a medium like water or air. There are a lot of different types of solar collectors, the most common are flat plate collectors and vacuum tube collectors. The flat plate collector is the simplest and the cheapest collector, and uses water as a medium to transport heat. Vacuum tube collectors (also called evacuated tube collectors) have in general higher efficiencies than flat plate collectors because there are no heat convection losses due to the vacuum in the absorber (pressure almost 0 Pa). The heat of solar collectors can be stored in storage systems like hot water tanks or aquifer systems (chapter 3.6) and can be used for room heating (35°C) and tap water (65°C). Heat from solar collectors can be used in Zaanstad to replace a part of the heat which is currently supplied by natural gas. It is not a part of Zaanstads strategy yet, but should be considered. Zaanstad can set an example to install solar collectors on school and buildings of the municipal organization to promote solar collectors in its municipality.

### 3.5 WIND ENERGY

The worldwide wind energy capacity is growing rapidly. Wind energy is expected to produce 495 TWh to reach over 14% of total electricity consumption in 2020 [4]. In Zaanstad, currently 6 wind turbines are installed with a capacity of 7.8 MW. Research has indicated that an extra of 25 wind turbines can be installed towards 2020, which will be an extra installed capacity of 74 MW [3]. This will account for 0.53 PJ/year [1]. The potential generated energy of these turbines of course depends on the location and turbine type.
In the development process of wind energy Zaanstad cooperates with local companies and customers. The Zaanse Energy Cooperation is a collaboration between Zaanstad and local inhabitants for the realization of a 3 MW wind turbine in the region Seandelft. Besides this, research is going on about possible collaborations with companies in other regions in Zaanstad.

Figure 4. Potential locations for the implementation of wind turbines in Zaanstad [3]
3.6 GEOTHERMAL ENERGY

Geothermal energy is thermal energy stored in the Earth. There are two main types of applications for geothermal energy: shallow and deep. The shallow applications can be separated in borehole thermal energy storage (BTES) and aquifer thermal energy storage (ATES). These types are already applied at many locations in the Netherlands. Deeper applications of geothermal energy are used for heat extraction from a depth of 1 km and deeper.

**Shallow applications**

*Aquifer thermal energy storage (ATES)*

This is a seasonal type of storage. ATES is an open system, since the heat or cold is stored in a sand layer (aquifer) between other watertight layers. The most used ATES is the storage doublet system, which consist of a cold and hot source. The heat is extracted in the winter and used for heating in the building. The heat is extracted with a ground source heat pump. This heat pump uses electricity to transfer heat in an efficient way.

*Borehole thermal energy storage (BTES)*

The closed variant of the shallow geothermal energy is called a borehole thermal energy storage system (BTES). The BTES consists of several tubes which are placed in the underground. Through these tubes runs water and the water absorbers the heat or cold from the ground. This system is most suitable when there are no aquifers available or drilling is too expensive.

**Deep geothermal energy production**

Deep geothermal energy means extracting heat from the earth from a depth of 1 km and deeper. The energy is extracted through a heat exchanger and used for spatial heating or greenhouse heating. TNO has developed software - ThermoGISTM – which can be used to locate potential spots for deep geothermal energy. The potential recoverable heat (PRH) for spatial heating in the Netherlands is estimated at 12 EJ. The software can be used to calculate the temperature of the potential energy at 2 km and 5 km. Figure 7 shows a map of the Netherlands with possible locations.
for the application of deep geothermal energy. The region South-Holland has a lot of potential with PRH. Zaanstad is less fortunately with its geothermal energy potential. The software indicates the region around Zaandam as not suitable for geothermal energy. The region around Krommenie and Wormerveer has the most potential, with a PRH of 5.9 PJ/km², a temperature of 77.5 °C at 2 km and a temperature of 176.7 °C at 5km depth.

Zaanstad

The deployment of geothermal energy can be used by Zaanstad to supply (a part of) the heat demand of its municipality in a sustainable way. Shallow applications can be used for seasonal heat storage in combination with grounds source heat pump, which consequently will lead to an increase in the electricity consumption. Deep geothermal energy has some potential, but only in the northern region of Zaanstad. In the area of Wormerveer and Krommenie a potential heat recovery of 5.9 PJ/km² is available. However, if this space is practical available and if this is cost effective requires further research.

3.7 INFRASTRUCTURE

The energy demand of Zaanstad is supplied by different energy carriers, i.e. transport fuels, natural gas and electricity. In context of Zaanstads energy policy, the municipality wants to replace the consumption of fossil fuels by energy from sustainable resources. This will inevitably lead to changes in the energy infrastructure. The impact of this transition on the heat and electricity infrastructure will now be reviewed.

Heat

The heat demand of Zaanstads residents is currently for a large part supplied by natural gas. In order to supply this heat demand in a sustainable way, Zaanstad has several options. Biomass is in theory a very promising option for Zaanstad because of its available sources, the problem however is that most of these sources are already used for other destinations. Zaanstad needs to negotiate with local
companies in order to make this work. Deep geothermal energy can be used in the northern region of Zaanstad, in the southern region solar collectors in combination with an ATES or BTES system is possible. This requires further research.

Whatever option Zaanstad chooses, there is need for an infrastructure to transport these energy sources. A heat supply distribution network is necessary to transport heat in its municipality. When this network is available, it is possible to connect different forms of renewable heat generators to this network. The heat which is generated when biomass is converted in a CHP unit can be supplied by this system to local households. Also geothermal energy can be connected to this system.

Electricity

The current electricity demand of Zaanstad accounts for 2.3 PJ per year, which is 21% of the total demand. Most of this electricity is generated in large scale power plants runned by fossil fuels. In the context of its policy of becoming a sustainable municipality, Zaanstad has already made plans to generate electricity in a sustainable way. Zaanstad plans to install 76 MWp PV cells and 74 MW wind energy. The consequence of Zaanstad energy policy will also have an impact on the demand side of electricity. The increasingly deployment of electric vehicles and heat pumps (because of geothermal energy usage) will lead to a large increase of electricity consumption.

The question is if the current electricity distribution network (MV and LV) is suitable for a large increase in distributed generation. Distribution generation by renewable energy resources generally have a negative impact on grid reliability due to their variability of production, low correlation with the load profile and relatively high forecasting errors [7]. If the grid is not ready for this increase in renewable distributed generation, reinforcement is necessary. This however includes high investment costs. Another possibility is to balance supply and demand in a smart way by means of a ‘Smart Grid’. By reducing the impact on the distribution network by Smart Grid technologies,
investments for reinforcements of the grid can be avoided. The Smart Grid technologies however requires investments too, so a business case needs to be developed and investigated. The concept of Smart Grid will be explained in chapter 4.

3.8 CONCLUSION

The current energy demand of Zaanstad is 11.1 PJ per year and consists for a large part of natural gas (49%), transport fuels (28%) electricity (21%). As result of the MJA agreement and an intensive collaboration with the built environment and industries, Zaanstad can reduce its demand to 9.1 PJ per year in 2020.

According to Zaanstads energy policy, the energy consumption of Zaanstad needs to be generated in a sustainable way within its municipal boundaries by 2020. The available renewable energy sources to supply this demand are biomass, solar energy, wind energy and geothermal energy.

The electricity can be generated by biomass (CHP unit), PV cells and wind turbines. Biomass has a lot of potential in theory but in practice less, since most of the biomass has already other destinations. In order to use this potential Zaanstad needs to negotiate with local companies. For solar and wind energy Zaanstad has already made plans. Zaanstad plans to install 74 MWp of PV cells and 76 MW of wind turbines. This will be an electricity generation of 2.93 PJ per year. This is larger than the current electricity consumption. The electricity demand however is expected to increase because of the rising population and the deployment of electric vehicles and heat pumps.

The current heat demand is for the most part supplied by natural gas. In order to supply the heat demand in a sustainable way, Zaanstad can invest in geothermal energy. Deep geothermal energy can be used in the northern region; in the southern region an ATES or BTES system can be applied. This requires further research. The released heat from a biomass CHP plant can also be used, but as said this requires further negotiation with local companies.

The changes in electricity and heat supply have consequences for the current energy infrastructure. A heat distribution network needs to be installed to support the local heat production. This way geothermal energy and biomass can be connected to this system. The increasing distributed generation by solar and wind energy has possible consequences for the electricity distribution network. The impact of renewable distributed generation on the distribution network will be reviewed in the next chapter, together with the concept of Smart Grid.
4. SMART GRIDS

4.1 INTRODUCTION

Since its discovery, electricity has mainly been generated in large centralized power plants runned by fossil fuels. The generated electricity is transported by the high voltage electricity grid and flows one directional, from the power plant to the end user. The information flow is the other way around, from end users to higher operational centers.

![Figure 9. Traditional way of energy generation and supply: from large scale power plants to end user [12]](image)

The increasing deployment of renewable energy sources like solar and wind energy will cause a transition from the current centralized electricity generation to a decentralized generation, or distributed generation (DG). This transition will have a large impact on the current electricity infrastructure. Distribution generation by renewable energy resources generally have a negative impact on grid reliability due to their variability of production, low correlation with the demand profile and relatively high forecasting errors [7]. These aspects along with the increasing load profile will cause serious problems in the future in terms of congestion management and power quality. These problems will probably not occur in the next few years, but if the share of renewable distributed generation increases significantly (like nowadays in Germany) these can problems become reality.

4.2 DISTRIBUTED GENERATION

In general, distributed generation can be defined as electric power generation within distribution networks or on the customer side of the network [Ackerman et al]. DG technologies include PV systems, wind turbines, fuel cells, micro CHP units and so on. The advantage from a utility point of view is that the increase of these DG technologies reduce the impact on the transmission (HV) network, which means lower losses [11]. However, the increase of distributed generation can cause problems on the distribution network in terms of stability, reliability and power quality. The main issue is that generation by renewable energy sources as solar and wind energy is hard to predict on
short term and have high short term fluctuations. As a consequence, their connection to the utility network can lead to grid instability or even failure, if these systems are not properly designed or controlled [5]. Among others, important aspects to consider with the implementation of distributed generation into the distribution network are:

- Protection (tripping, fault levels, blinding of protection, etc.)
- Voltage limits
- Frequency
- Flicker
- Harmonic distortion

The impact of the implementation on the distribution grid has different effects for PV cells compared to wind turbines. PV cells are connected on the low voltage network; wind turbines are usually connected to the MV or sometimes even HV network. The injection of power from wind turbines and PV cells affects both the voltage quality. Because the voltage level should be within limits at all times, this is an important requirement and should be considered when plans are made for the implementation of large quantities of solar and wind energy on the distribution network.

Although the current grids have evolved over more than a hundred year and have been performing well, the implementation of large quantities of distribution generation on the distribution network can cause problems in terms of reliability and power quality. A lot of research has been going on in the field of automation of the current grid by communication and information technologies. A common term used in this field of research is ‘Smart Grid’. Smart Grid however is a very broad term and used in different contexts and different definitions. This is why it is important to define Smart Grid and review the different concepts of Smart Grids. In the next section the definition, concepts and capabilities of Smart Grid will be reviewed.

### 4.3 DEFINITION OF SMART GRIDS

The term Smart Grid has a lot of different definitions in the literature. Below are some examples given.

‘A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.’ (The European Technology Platform Smart Grids)

‘A smart grid is the electricity delivery system (from point of generation to point of consumption) integrated with communications and information technology for enhanced grid operations, customer services, and environmental benefits. (US Department of Energy)

Although a lot of different definitions can be found in the literature, there are some basic similarities. Integrating the key themes, a Smart Grid can be defined as the integration of ICT to the current electric grid to enhance the sustainability, economic efficiency and security of electricity supply. A Smart Grid is not really a new technology; it is rather a new combination of different existing
concepts. It is basically adding information and communication technologies to the existing grid with the following objectives:

- The integration of large amounts of distributed renewable energy systems on the grid
- Reducing peak load on grid by balancing electricity supply and demand
- Reduce the costs for wholesale operations
- Improvement of efficiency, security and reliability of the power supply by the grid
- Improvement of power quality
- Provide ancillary services

The increasing penetration of renewable generation has a negative impact on the reliability of the distribution system because of its mismatch with the load profile and its high short term variations in production. This increases the need for a regulation system which can balance the electricity supply and demand. The advantage of this is that the peak load on the grid will be lower, which improves the financial efficiency of the system even as the reliability of the power supply.

In the current electricity market the Transmission System Operator (TSO) maintains and controls the power supply and demand. To keep this balance, many services – beyond power production – are provided by power plants to keep the grid in a stable and reliable condition. These services are called ancillary services. Examples of ancillary services are participation in frequency regulation, providing spinning and non-spinning reserves and reactive power supply. These services are traded on the real
time electricity markets. A Smart Grid will enable retail consumers – or prosumers – to participate on this market [13].

Because of the different objectives for different participants in the electricity markets the meaning of Smart Grid is easier to understand if different Smart Grid concepts are distinguished [13]:

- **Market Oriented Smart Grid**: This is concept of Smart Grid from the prosumers perspective. A Smart Grid gives prosumers insight in their real time electricity consumption and enables them to actively participate on the electricity market by trading electricity and provide ancillary services.

- **Grid Oriented Smart Grid**: This is the meaning of Smart Grid from a grid operator perspective. Their objective is to reduce the peak load demand to reduce investment and maintenance costs concerning the electric infrastructure.

- **System Oriented Smart Grid**: The system orientated Smart Grid aims at optimizing the system as a whole, both from the perspective of keeping the energy balance as well as from the perspective of grid operation. It is the integration of the market orientated and the grid orientated concept.

![Figure 12. Overview of the system orientated Smart Grid concept [13]](image)

So far the Smart Grid and its different concepts are defined. Now some of the capabilities of Smart Grids will be reviewed. Through Smart Grid deployment different objectives can be reached. This can be for instance to optimize the use of distributed generation. Besides that the objective of a Smart Grid can be to reach a financial optimum.

### 4.4 DEMAND RESPONSE

One of the capabilities of a Smart Grid can be Demand Response (DR). DR can be defined as the changes in electricity consumption by customers from their normal consumption patterns in response to changes in the price of electricity over time [14]. Information systems – for instance
smart meters – give consumers real time insight in their electricity consumption and the electricity prices. The consumers adjust their energy consumption as a result of this information. In other words, consumers become prosumers.

There are different examples of demand response. A consumer can reduce their energy consumption at peak hours. This can for instance be achieved by turning off the heater or air conditioning, hereby giving up thermal comfort. Another way is to shift activities to off peak hours, like dish washing. This way there is no energy conservation, but a reduction in peak load demand: peak shaving. The last example is the deployment of renewable distributed generation like solar or wind energy at peak hours. This usually means the need for electrical storage devices like batteries or electric vehicles because of the mismatch between renewable energy supply and peak hour demand.

4.5 INTEGRATION OF RENEWABLE DISTRIBUTED GENERATION

Another capability of a Smart Grid is to increase the integration of renewable energy and/or the deployment of electric vehicles. One of the issues with the implementation of renewable energy sources is the mismatch in the electricity supply with regard to the demand of consumers. Although Demand Response can be seen as the capability of a Smart Grid to manage the demand side of this problem, there is still a need to manage the supply side. The supply needs to be matched with the demand and the grid reliability and power quality needs to be maintained at all times.

A possible solution for the supply mismatch is the deployment of electrical storage devices or the next generation plug-in electric vehicles with vehicle-to-grid (V2G) capability. V2G technology is an energy storage technology that has capability to allow bidirectional power flow between a vehicle’s battery and the electric power grid [15]. The advantage of the deployment of these storage systems is that besides the capability to match supply and demand, it is also possible to increase the economic efficiency of the system. From the Market Orientated Smart Grid perspective, the prosumer can store the surplus of renewable generated electricity at off peak hours and sell it when the prices are high at peak hours. Distributed energy storage has the advantage to solve the mismatch in locally electricity supply and demand. It has to be stated however that the current battery devices have relative high losses, so the overall energy efficiency will be lower. So the energy efficiency of these storage devices needs to increase through further research to be a real solution.

4.6 VIRTUAL POWER PLANT

Besides environmental reasons Smart Grids can be deployed for financial reasons, i.e. to increase the benefits. This can be reached with the concept of a Virtual Power Plant (VPP). The VPP concept is based on controlling renewable distributed generators and operating them from a central control point [10]. The idea is to connect the distributed generators through information and communication technologies with a central control system. This way the control system has information on the profile characteristics – like schedule of generation, generation limits, costs characteristics – of the involved DGs. Using this profile, the system can interact directly with other market participants to trade power and services (like ancillary services) on the whole sale markets.
The VVP concept has the following capabilities [16]:

- Individual renewable distributed generators will be able to gain access and visibility across all the energy markets, and will benefit from VPP market intelligence in order to optimize their position and maximize revenue opportunities.
- System operation will benefit from optimal use of all available capacity and increased efficiency of operation.

![Diagram of Virtual Power Plant](image1)

*Figure 13. Detailed (left) and general (right) overview of the concept of Virtual Power Plant [10]*

From the Market Orientated Smart Grid perspective this concept has a lot of benefits. First of all, since the system trades in the energy market itself consumers no longer have to pay energy companies to do this. Besides that, consumers can profit by providing ancillary services like reactive power control and balancing power.
5. SMART GRID PILOT PROJECT: RELOADIT

5.1 INTRODUCTION

In the previous chapters Zaanstads objective of being CO$_2$ neutral in 2020 is shown and a possible way of achieving this objective. Also the impact of distributed renewable generation on the distribution network and the general concept of Smart Grids have been reviewed. Zaanstad realizes that if it wants to invest in renewable energy on a large scale, changes have to be made in the energy delivering infrastructure. That is why Zaanstad is taking a leading role in the European project e-harbours; which is a cooperation of different harbour cities around the North-Sea and focusses on smart grids and smart mobility. The objective of e-harbours is to stimulate renewable energy in the harbour cities by developing Smart Grid and smart mobility pilot projects. The different partners of e-harbours are all developing their own unique showcase.

The showcases of Antwerp and Hamburg focus on matching energy demand and supply in a smart way by combining solar and wind energy production with energy storage. Hamburg is developing a Virtual Power Plant called ‘NegaWatts’. The municipality of Amsterdam is creating a show case which focusses on charging electric boats with electricity generated by renewable energy. The Swedish harbour city Uddevalla combines renewable energy sources with CHP units. Another Swedish partner, Malmö, creates ‘Smart Houses’ in the harbour with deployment of VPP technologies. All houses will be equipped with smart grids where also price adjusting solutions will be examined for steering of electric cars charging, freezers and laundry machines [17]. In the Shetlands Islands in Scotland the objective of the showcase is to provide the harbour with sustainable energy. Also the Robert Gordon University is partner in e-harbours, which is developing a Smart Grid benchmarking methodology.

The municipality of Zaanstad is project leader of e-harbours. The showcase of Zaanstad is called REloadIT. The objective of REloadIT is to charge the electric vehicles of the municipal organization by PV cells and visualize how supply and demand can be matched by Smart Grid technologies. The objective of REloadIT together with the technical specifications will be reviewed in this chapter.

5.2 DEFINITION AND OBJECTIVES

REloadIT is Zaanstads showcase in the European e-harbours project. The objective of REloadIT is to optimize the usage of solar and (future) wind energy for the charging of the electric vehicles of the municipal organization. By using Smart Grid technologies – information and communication hardware and software – Zaanstad wants to visualize the way demand and supply can be matched in a smart way. By doing this, Zaanstad will stimulate the deployment of renewable energy in Zaanstad
because of environmental and social reasons. By learning from this Smart Grid pilot project Zaanstad can gain knowledge to develop the electric infrastructure necessary to support the plans for renewable energy by 2020. This way Zaanstad can develop a business case for the possible roll-out of a Smart Grid over the municipal organization. The components on the production side consist of:

I. 10 kWp of PV cells at location ‘Fietsenpakhuis’
II. 10.2 kWp of PV cells at location ‘Van Serooskerkelaan’
III. 10.2 kWp of PV cells at location ‘Havengebouw’
IV. A wind turbine simulation model

The consumers are the 16 electric vehicles of the municipal organization. Figure 15 shows a schematic overview of the REloadIT project.

The objective is to charge the electric vehicles by solar and wind energy and do this in a smart way by using information and communication hard- and software. To achieve, the production and the consumption need to be forecasted in a detailed and accurate way. To forecast this consumption, an accurate planning of the electric vehicles usage by the municipal employees needs to be available. On the production side, a meteo forecaster will be installed to forecast the PV production as detailed as possible. The Smart Grid software will use both forecasting data to calculate ahead if supply and demand can be matched. If there will be an underproduction, the Smart Grid data center will use a virtual electricity market to suggest optimal financial decisions. This means, selling surplus electricity when the electricity prices are high, and buying shortage on electricity when the prices are low. The

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5 There are no wind turbines installed in the context of the REloadIT project yet, so this will be simulate.
total energy flows will be visualized on a public display to inform residents of Zaanstad and promote renewable energy and Smart Grid technologies.

5.3 PARTNERS

REloadIT is a pilot project which consists of several partners who all share their knowledge and work together to develop a successful project. In figure 16 an overview of the partners of REloadIT is shown.

![Overview of the partners of REloadIT](image)

Table 3 shows the role of the different partners in the project.

<table>
<thead>
<tr>
<th>PARTNER</th>
<th>ROLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zaandam</td>
<td>Project leader, in charge of: RE generation facilities; Electric fleet; SmartGrid realization and deployment</td>
</tr>
<tr>
<td>VITO</td>
<td>Smart Grid expert, providing technical support; Partner in e-harbours</td>
</tr>
<tr>
<td>Imtech</td>
<td>Delivering charging infrastructure</td>
</tr>
<tr>
<td>Q-park</td>
<td>Owner electrical vehicle parking facility</td>
</tr>
<tr>
<td>Truckland</td>
<td>Supplier electrical vehicles</td>
</tr>
<tr>
<td>University of Amsterdam</td>
<td>Advisor energy contracts and European energy laws and regulations</td>
</tr>
<tr>
<td>Alliander</td>
<td>Owner distribution network; sharing knowledge in Smart Grid area</td>
</tr>
</tbody>
</table>
In chapter 4 the concept of Smart Grid has been reviewed with the definitions and capabilities given in the literature. Smart Grid is a very broad concept with a lot of different possibilities and objectives. An objective can for instance be financial optimization within a cluster of distributed generators and energy consumers. In that case it can be characterized as a Virtual Power Plant. Whatever objective it is; a possible way of achieving a particular objective is the usage of a Multi-Agent System (MAS) technology. A MAS technology provides a way to implement complex distributed, scalable and open ICT system [18]. It consists of several software agents – device agents – which carry out programmed tasks called business rules device agents each calculate its own priority; i.e. the priority to supply or consume energy.

In the REloadIT project the objective is to optimize the production of renewable energy for the charging of the electric vehicles. In this particular case the device agents consist of distributed generators, the charging devices of the electric vehicles and a business agent for the weather forecast. The priority of all the agents is send to the priority manager, which analyzes the priorities of the agents and optimizes the business case.

![Figure 17. Technical design of the MAS system used in the REloadIT project [20]](image)

The business rules in the REloadIT project are [20]:

- Optimizing the usage of the production of the PV cells (and future wind turbines) for the consumption of the electric vehicles
- Guaranteeing the state of charge of the electric vehicles
- Financial optimization of electricity underproduction; i.e. buying at off peak hours and operating energy intensive devices.
5.5 FUTURE SMART GRID IN ZAANSTAD

The pilot project REloadIT is a step towards a possible future Smart Grid in the municipality of Zaanstad. One key objective of REloadIT is to show how distributed generation can be matched in a smart way with energy consumers to lower the impact on the distribution network. By lowering this impact a possible business case arises. For instance, a rising energy demand can cause capacity problems which then need to be avoided by investing in new cables or a new or extra transformer. If by the implementation of Smart Grid hard- and software the peaks in the distribution network can be lowered, the business case exists of the savings versus the Smart Grid costs.

In the case of REloadIT the distributed generators exists of the PV cells (now a total of 30.4 kWp) on the three different locations. The wind turbines are not yet implemented, so their contribution will be simulated. The consumers are the 16 electric vehicles in the parking storage. In figure 18 the performance and the estimated generated energy per year of the PV cells on the location Fietsenpakhuis are shown. Since the performance is somewhat lower than the expectations, the total yearly generated energy of the PV cells can be estimated at 15 MWh/year.

![Figure 18. Potential generated energy by the PV cells on location Fietsenpakhuis (10 kWp) [21]](image)

The REloadIT project shows how it is possible to use solar energy for the charging of electric vehicles by Smart Grid technologies. However, the electricity generated by the PV cells is first delivered back to distribution grid before it is supplied to the electric vehicles. This is a difference in terms of laws and finances, since Zaanstad receives less money if it supplies electricity back to the grid, compared to the money it pays to the energy company for the consumption of electricity. Zaanstad is a customer at the energy company Nuon and cannot trade directly on the Dutch electricity markets.

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6 The first 5000 kWh are the same price, so this can be equalized (dutch: salderen).
Since Zaanstad is planning to invest in solar and wind energy on a large scale; it is interesting to review a couple of scenarios.

Currently, Zaanstad pays an average of 0.07812 €/kWh for buying electricity. For the first 5000 kWh Zaanstad delivers back to the grid, Zaanstad receives the same price from the energy company, Nuon. So this can be equalized. If Zaanstad delivers more electricity back to grid – in this case an estimation of 10,000 kWh – Zaanstad actually receives 0.0588 €/kWh from Nuon.

When Zaanstad becomes a large scale producer of distributed renewable generation – i.e. solar and wind energy – and delivers this electricity back to the grid, it loses (0.0712 – 0.0588 =) 0.0193 € on every kWh it produces. The total electricity consumption of Zaanstad currently equals 2.3 PJ (=639 GWh) per year. If Zaanstad wants to supply the electricity for the demand of its whole municipality in 2020 by renewable distributed generators, Zaanstad pays 12.3 million per year € to Nuon.

A far better option is that Zaanstad creates or participates in a cooperative and trades electricity on the energy market by itself. This way Zaanstad can provide electricity for its own usage without paying an energy company fees. The surplus of energy can be traded on the APX spot market. Through Smart Grid technologies Zaanstad can create a Virtual Power Plant, which will make financially and technical favorable decisions. This way, Smart Grid technologies can be used to lower the impact on the distribution network and make financial favorable decisions.

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7 This calculation includes taxes, but excludes payments for to the distribution network owner Alliander.
6. RENEWABLE DISTRIBUTED GENERATION IN ZAANSTAD BY 2020: FROM THEORY TO PRACTICE

6.1 INTRODUCTION

In the previous chapters an overview has been given of Zaanstads objective on climate policy and a review of the possible renewable energy sources which can be implementation to achieve this objective. Zaanstads plans to invest in solar and wind energy on a large scale. In order to realize these plans, further research needs to be done on how to practically implement these renewable distributed generators within the municipality. In context of the master education Sustainable Energy Technology at the Technical University of Eindhoven, the student will carry out a research of eight months. The research will focus on the practical implementation of solar and wind energy in Zaanstad. First of all the possible locations will be identified for the large scale implementation of PV cells and wind turbines. For this matter it is important to study the local distribution network and identify potential problems in terms of capacity and power quality. The distribution network will be simulated with the simulation software DigSILENT PowerFactory. If potential problems are identified, solutions will be proposed. Hereby the potential role of Smart Grid technologies in Zaanstad will be investigated to reduce the impact on the distribution network and to optimize business cases.

6.2 RESEARCH OBJECTIVE

The research will focus on the practical implementation of solar and wind energy in Zaanstad. For this practical implementation, possible locations need to be identified and the impact of these distributed generators on the distribution network need to be investigated. The research question for this project is:

“How can Zaanstad realize the practical implementation of the renewable distributed generators by 2020 and what is the potential contribution of Smart Grid technologies to achieve this?”

The research will have the following objectives:

- Identifying potential locations for the large scale implementation of PV cells and wind turbines in Zaanstad.
- Investigating the impact of these distributed generators on the distribution grid in terms of power quality.
- Proposing possible solutions if problems or bottlenecks in the electricity distribution network are identified.
- Investigate the technical and financial potential of Smart Grid technologies within Zaanstad.

6.3 METHODOLOGY

The graduation project will take place in different phases and is therefore divided in different parts. Below and overview of the different phases is given.
1. In the first phase the theoretical plans of Zaanstad will be translated to practical plans. Possible locations for the large scale implementation of solar and wind energy will be identified. In this phase different scenarios in terms of capacity (solar/wind) will be taken into account.

2. In the second phase the distribution network of the identified locations will be reviewed. The network will be simulated with the power system analysis simulation software DgSILENT PowerFactory. After that the problems and bottlenecks in terms of power quality will be identified.

3. The third phase exists of reviewing and investigating the potential problems which have been identified in phase two. Solutions for these problems will be proposed. In this phase the potential rollout of a Smart Grid in Zaanstads municipality will be investigated. In these investigations both technical and financial aspects will be taken into account.

4. In the last phase the results of the research will be analyzed and described in the form of a report. Conclusions will be drawn and recommendations will be given to Zaanstad.

For the graduation project the following planning has been made:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Content/Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Identifying potential locations for DG</td>
</tr>
<tr>
<td>2</td>
<td>Reviewing distribution network</td>
</tr>
<tr>
<td>3</td>
<td>Simulating the distribution network</td>
</tr>
<tr>
<td>4</td>
<td>Identifying potential PQ problems</td>
</tr>
<tr>
<td>5</td>
<td>Investigation of SG potential</td>
</tr>
<tr>
<td>6</td>
<td>Writing final report</td>
</tr>
<tr>
<td>7</td>
<td>Presenting conclusions &amp; recommendations</td>
</tr>
</tbody>
</table>

![Figure 19. Planning of the graduation project](image)

### 6.4 ORGANIZATION

The student will carry out an eight month during research project – from May 2012 until December 2012 – for the municipality of Zaanstad. The student will be located at the consultancy company Resourcefully in Amsterdam, which is hired by Zaanstad. Another important organization is the project is the owner of the distribution network Alliander, which will be the supplier of information about the distribution network. Below the personal information of the student is shown. Furthermore the contact information of the other organizations is shown.

**Name**
Michel Verburg

**Organization**
Eindhoven University of Technology

**Student number**
0728060

**Education**
Sustainable Energy Technology (Master)

**Faculty**
Electrical Engineering
<table>
<thead>
<tr>
<th>Organization</th>
<th>Contact person</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical University of Eindhoven</td>
<td>Michel Verburg +31(6) 52 02 12 92 <a href="mailto:M.verburg.1@student.tue.nl">M.verburg.1@student.tue.nl</a></td>
<td>Student</td>
</tr>
<tr>
<td></td>
<td>Prof. J.F.G. Cobben <a href="mailto:J.F.G.cobben@tue.nl">J.F.G.cobben@tue.nl</a></td>
<td>Coordinator</td>
</tr>
<tr>
<td>Municipality of Zaanstad</td>
<td>Jan Schreuder <a href="mailto:j.schreuder@zaanstad.nl">j.schreuder@zaanstad.nl</a> +31(6) 26 02 78 34 Hugo Niesing <a href="mailto:H.niesing@resourcefully.nl">H.niesing@resourcefully.nl</a> +31(6) 51 73 11 90</td>
<td>Coordinator</td>
</tr>
<tr>
<td>Alliander</td>
<td>Justin Au-Yeung <a href="mailto:Justin.Au-Yeung@alliander.com">Justin.Au-Yeung@alliander.com</a> +31(6) 52 44 15 43</td>
<td>Supplier of information</td>
</tr>
</tbody>
</table>

### 6.5 PRECONDITIONS AND EXPECTED RESULTS

In order to carry out the research objectives - which are stated in paragraph 6.2 – some preconditions have to be met.

I. The student will carry out his research based on the plans of the municipality of Zaanstad stated as in this report. The information in this report in the context of Zaanstads plans on renewable energy is obtained from the documents Integraal Klimaat programma 2010-2020 and Visie op Duurzame Energie [2] [3]. If Zaanstad has suggestions or comments regarding the content of this report, it has to be made clear to the student within one week after the concept version is received.

II. If Zaanstad will adjust its policy on renewable energy, i.e. Zaanstad is planning to invest more or less in solar or wind energy or even other renewable energy sources, these changes have to be made clear to the student within two months after the start of the research (so before July 2012). Otherwise the plans for investments in renewable energy as stated in this report will be assumed to be real.

III. The student has to be provided with accurate and detailed information about the distribution network by network owner Alliander.

The expected result of the research project will be a report covering an answer on the research question. Furthermore the research objectives stated in paragraph 6.2 need be fulfilled. The conclusions and recommendations which are the results of the investigations will be presented at the end of the internship, in January 2013.
7. LITERATURE


energy sources. IET Renewable Power Generation, 2007 (1) p 10-16.


http://www2.econ.iastate.edu/tesfatsi/IntelligenceInElectricityNetworks.KokScheepersKamphuis2009.pdf

