Energy Plan for Roskilde Municipality with Focus on Onshore Wind Turbines

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Dorte Brandt Andersen

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Author: Dorte Brandt Andersen
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Niels-Erik Clausen
Marie Münster
Bonnie Ram

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Danmarks Tekniske Universitet
DTU Vindenergi
Nils Koppels Allé
Bygning 403
2800 Kgs. Lyngby
Telefon

www.vindenergi.dtu.dk

Preface

This thesis is made as a completion of the master education Sustainable Energy at The Technical University of Denmark. The author has a bachelor degree in Construction and Production from same university.

Several persons have contributed to this thesis. I would like to thank all my supervisors; Niels-Erik Clausen, Marie Münster and Bonnie Ram.
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Finally I would like to thank my family and friends for help and support.

Lyngby, November, 2015

Dorte Brandt Andersen

Content

List of abbreviations

Abbreviation	Definition
SEP	Strategic Energy Plan
EIA	Environmental Impact Assessment
BAU	Business As Usual
AEP	Annual Energy Production
a.g.l.	Above Ground Level
CHP plant	Combined Heat and Power plant
VEKS	Vestegnens Kraftvarmeselskab. (CHP company)
KARA/NOVEREN	Waste management company.
GHG	GreenHouse Gasses
STEPS	Strategic Energy Plans
LULUCF	Land Use, Land Use Change and Forestry
PV	Photo Voltaic
DH	District Heating
STREAM	Sustainable Technology Research and Energy Analysis Model
WAsP	Wind Atlas Analysis and Application Program
NPV	Net Present Value
IRR	Internal Rate of Return
OPEX	Operational Expenditure
CAPEX	Capital Expenditure
WACC	Weighted Average Cost of Capital
PSO	Public Service Obligation

Abstract

The global temperature is increasing, which has resulted in numerous climate changes all over world. It is believed that one of the main contributors to this increase in temperature is the emission of CO_2 as a consequence of human actions. Therefore it has politically been decided that in order to slow down the increase in temperature, the level of CO_2 emissions in the energy sector must be reduced. To meet this target, different sectors in the energy sector should cooperate, e.g. the modelling of energy systems and siting and planning of wind turbine is critical.
Especially the siting of wind turbines is a hot topic in the political debate. As for the present regulations in Denmark, a minority voices or “5%” of the vocal residents can stop a wind project or a single church. Churches have a right to veto in a distance of 28 times the total height of the wind turbine. In Denmark there are 2350 churches; with a 4km radius the total area will be higher than the area of Denmark. Off course these zones will overlap a lot in the densely populated areas, leaving few very small pockets for sitting of wind turbines outside these veto zones. In the last three years 6 out of 10 dioceses in Denmark have used the veto against wind projects. Taking the influence of the local churches on the siting discussion of future wind turbines into account it is surprising that this topic has not been investigated. In this thesis the communication with local churches is included as a natural part of the communication plan.

The strategic energy plans have increased the collaboration between the municipalities, despite the fact that the energy plans has been realized in different ways. A large collaboration projects could for instance be a large wind turbine at a municipality border. In this thesis a wind turbine (3MW) close to the border between Solrød and Roskilde. In the present thesis the repowering of old wind turbines inside Roskilde municipality has been threated throughout and through this analysis it was seen than when the cost of CO_2 emission is included in the calculations the project would be feasible for society, and has a private net present value at 2.1 mill DKK.

At the location of the wind turbine there are 6 churches in the range of 28x total height. These should be included in the planning process to decrease the use of veto’. The visualization of the wind turbines is most important for the ecclesiastical sector, therefore this could be included in the planning process earlier to start the communication with the local church council and diocese. As this is traditionally not included in the planning process this topic has been investigated thoroughly.

The local change in the energy system is on a voluntary level, there are a national target for 2035. In Roskilde there are 5 projects for change the energy system, by upscaling this with a geographical method Roskilde (almost) reach the national target. However, both with a number of citizens and energy demand the target is not reached. With wind projects nonresidential areas are needed, this is used as arguments for using geographical upscaling method, but the heating source for the residential sector outside the grid still require projects towards change from fossil fuels.
For changing the energy system several factors are needed to be included. There is a need for modeling to research the energy system for low hanging fruits, but it is also required to include analysis of siting and planning of different renewable energy projects, e.g. wind turbines. In the planning process it is important to include the different stakeholders.

1. Introduction

In recent years, global temperature has increased, with environmental changes as a result. It is believed that one of the major contributors to this rise in global temperature is the elevated levels of CO_2 in the atmosphere. Therefore, to limit the change in temperature it is critical that the emissions of CO_2 (primarily from fossil fuels) are decreased. The reduction of CO_2 emissions is also becoming a political issue and in order to limit the effects of the temperature induced climate changes it has been decided both on the national level and in Roskilde municipality to have a fossil free electricity and heat sector in 2035 (Energy Scenario 2014, Roskilde Municipality 2015 A). To meet this goal it will be necessary to initiate a whole range of activities. One of the major contributors to the CO_2 emissions is the energy sector. Therefore this sector must reduce the emissions even further. In this reduction strategy renewable energy sources are a vital part. And in particular wind turbines have a very important role to fill in this desire for the reduction of the CO_2 emissions.

Wind turbines require wind in order to generate electricity and since it is expected access to both heat and electricity at any time of the day there is a clear need for a thorough independent analysis of the energy sector before any changes are made. The result of this analysis is a plan of the entire energy sector that will be an important element in the planning process for the adoption of an expanded contribution for, the renewable energy sources. Furthermore, this plan can also provide an estimate of the total level of CO_2 emissions. This level will provide an indication of the contribution from renewable energy sources to the entire energy system.

Throughout the past decades, wind turbines have contributed to the total energy production in Denmark. In the recent years, the level of the wind capacity has increased from 1990-2013 with 4484MW (Energy statistic 2013). The size of each wind turbine has also been increased from an average at 225kW in 1995 to 3MW in 2009 (The Danish Energy Agency 2009 A).
Over the years the ownership of the wind turbines has changed towards companies instead of local citizens (The Danish Energy Agency 2009 A).
Coinciding with this change of ownership, the public attitude about these wind turbines have changed. Whether or not the change in attitude is related to the change in ownership, the increased size of the turbines or other effects will not be the focus of this thesis. Regardless of the underlying reasons towards the increased resistance against the construction of new wind turbines, it indicates the importance for public engagement in the planning process of new turbines.

In general, energy planning models are not taking the siting and planning process of the wind turbines into account (Connolly et al. 2009). It may not be possible to include all aspects of the siting and planning process of wind turbines in an actual energy planning model. However, failing to treat the siting issue with enough effort may prevent the realization of the plan, due to lack of information about community concerns and vocal local protests. Therefore a plan for the decision process regarding the actual siting of the turbines is an essential part of realizing the total energy plan despite it not being an integral part of the modelling effort. In contrast to traditional centralized power plants the production of the wind turbine highly depends on the local siting conditions and in particular the general wind speed over the area in question. To provide a realistic energy level the siting and planning of the wind turbines should be included in the energy system models. Furthermore, a more comprehensive approach to energy models should also consider the attitude of the local citizens towards the turbines for a better understanding of community concerns and attitudes (Nielsen and Karlsson 2007).

The public's attitude towards wind turbines has been explored in several industry and scientific analysis (VidenOmVind 2012 A, Bakker et el. 2011 and Delta 2011), together with several experiences documented as a neighbor to a wind turbine (National organization for neighbors 2014 A, C and National Wind Facts). Minority voices or "5%" of the vocal residents can stop a wind project (Ortwin 2015) or one church. This thesis will show one important example of why attitudes of particular local stakeholders, e.g. churches, are very important to understand in the planning process and need to complement the energy modeling approach.

In Denmark there are 2350 churches. Each of the churches have the right to veto with a radius of 4km radius (Aalborg Diocese 2013). This gives a higher area (118135 km^2) than total of Denmark (42924km^2). On Figure 1-1 the location of the churches in Denmark can be seen.

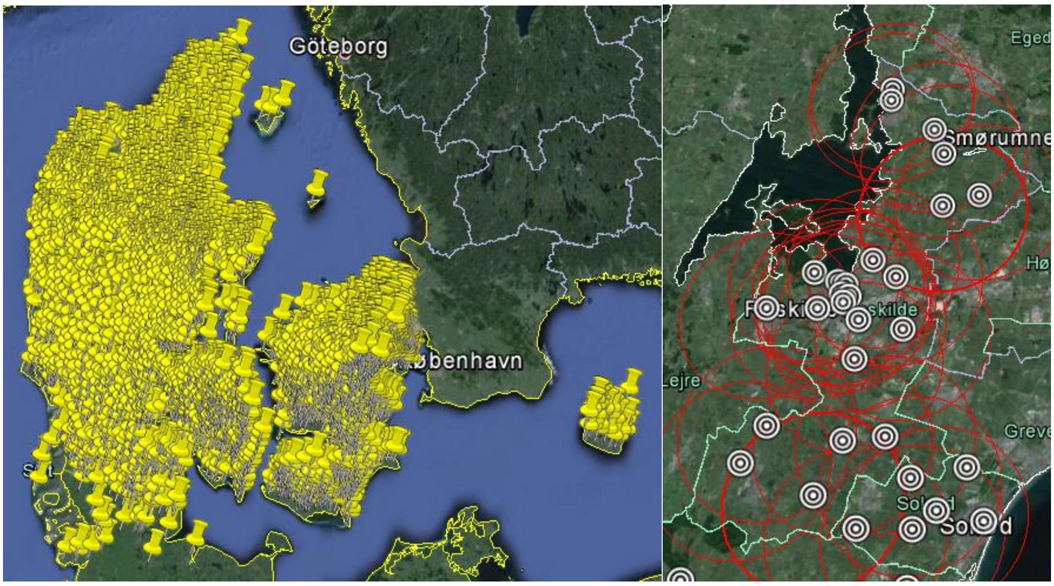

Figure 1-1 Location of 2350 churches in Denmark and churches in Roskilde
Left figure: The churches in Denmark are spread out over the country. This indicates the need for including churches in the wind planning.
Right figure: Churches in Roskilde with circles with a radius at 4.8km (28 times the total height of the investigated wind turbine in the thesis).
From (Google Earth)

There is, however, nothing written about siting of wind turbines where the local churches are included in the process. In Denmark the churches have a high impact on the local environment, and have been the visual benchmark for different villages for hundreds of years. The wind turbines can change this landscape, as they are high structures as well, and can become new visual benchmarks (Aalborg Diocese 2013). From 2011-2014 6 out of 10 dioceses have used the right to veto against a wind project (Kristeligt Dagblad 2014 A)This indicates one of the key challenges when siting and planning wind turbines near a church.

The municipality is the planning authority for onshore wind turbines. Therefore, any thorough study of the contribution from wind turbines on the overall energy plan must be linked to a specific local case. In this thesis, Roskilde municipality is used as a base for the research. For comparison, examples from Høje Taastrup municipality is included when relevant.

There seems to be a difference between the agreed climate targets and the direct actions and the energy plan in Roskilde municipality. Currently in the municipality, the level of renewable electricity reaches around 3% in 2014 (Rambøll 2014). This is in sharp contrast to the agreed upon policy not to invest in fossil fuels from 2015 and on. (Politiken 2015 B).
With this project, it is wanted to illuminate the required considerations that must be taken into account for a successful transformation from energy based on fossil fuels to renewable energy sources. Namely, it is wanted to illustrate the importance of a full energy plan for Roskilde municipality to meet the political goals of ending investments in fossil fuels by 2015. Finally, it is wanted to emphasize the importance of including the siting process of wind turbines as an important part of the realization of the energy plan. In this implementation process, the inclusion of local citizens and other local organizations (in particular the churches) in the actual siting planning of the turbine is critical for a successful implementation.

1.1 The Thesis

This thesis is an interdisciplinary project, with siting, planning, economic, modeling, social impacts and system analysis. The key focus in this thesis is to research the connection between the planning of the future energy system and the wind resources. For onshore wind turbines, the thesis focused on the siting and planning process, the different stakeholders, the grid, the EIA process and the economy. Two different traditional parts of the energy sector; the energy system planning and the siting and planning of onshore wind turbines are being studied. Within the planning of onshore wind turbines the local attitude is included, with a focus on the ecclesiastical sector.

The energy system in Denmark will in the future have a high share of wind power, both onshore and offshore. This thesis is focusing on onshore wind turbines with an analysis of the local municipalities, since they have the responsibility for marking of possible areas. Therefore, this thesis uses the local level, with Roskilde municipality as base. During the thesis the focus has evolved, from a study of the historical siting of wind turbines in Roskilde municipality to research of strategic energy plans and possible repowering projects. In addition the social focus of the thesis has also changed from general neighbors to the ecclesiastical sector because of their veto power. Also this stakeholder has not been studied in terms of wind power in Denmark so it is also original research.

The energy plan in Roskilde have been based on political decisions, and not only on energy models. Therefore, the focus is also on the Strategic Energy Plan (SEP) that is prepared on the municipal level. Different SEP' are compared and analyzed, to answer the question:

Does the SEP change the energy system on a local level?

As written the thesis' focus is on onshore wind turbines. For siting and planning of the turbines different factors such as; wind resources, topographical input, Environmental Impact Assessment, project feasibility, distances, turbine selection and grid connections are required to be included. This will be described and discussed, with Roskilde municipality as base for the geographical and wind map. The wind resources is analyzed with the program WAsP.

It is known that the onshore wind turbines creates changes and impact at the local site. Therefore, the local residents are important to include in the siting process of wind turbines. A specific stakeholder is chosen to focus the analysis. There have been several scientific studies of the local attitude towards wind turbines, but this thesis is focusing on the attitudes of the churches in Denmark.

Can the ecclesiastical sector have a significant impact in the planning process of wind turbines and how?

Roskilde municipality has, before this thesis began, marked location areas for wind turbines. However, the local residents' negative reactions stopped the political will for increasing the capacity of wind turbines. In 2014 Rambøll made an analysis about possible upgrades for present wind turbines sites.

Is there enough wind in Roskilde for a new and modern wind turbine to be feasible on both a private and social level, and where should it be located?

Finally the local experience in Roskilde, is being up-scaled to a national level, as a basis for discussion of the energy system and policies in Roskilde.

If all municipalities in Denmark had the same energy policies would the 2035 targets be reached?

1.2 The Danish Energy System

In this section, the energy system in Denmark will be described, to provide an overview of the Danish system. Roskilde municipality is part of the national energy system, therefore an understanding between the local and national systems and objectives is required. As the emphasis of the work is analyzing the local energy systems, this is the focus in the thesis. For the interested reader a short description of the national energy system can be found in Appendix A.

1.2.1 Energy Politics in Denmark

In this section, the national targets for 2020 will be listed to give an indication of the level of onshore wind required to fulfill the politically set targets.

Denmark is a member of the European Union (EU), and therefore has a legal binding commitment of the 2020 goals (Europe 2020 Target A). In Denmark the national target (in the energy sector) are set to 20% reduction in CO_2 emissions, compared to the level in 1990, and 30% renewable energy production (Europe 2020 Target B). In addition to these targets, the Danish parliament has increased the targets to a 37% reduction in emissions compared to 1990 (Energy and Climate Projection 2014). The level of renewable energy in Denmark, is set to 35.8%, where in the electrical sector, the renewable energy will produce 70% of all electricity (The Danish Energy Agency 2015 H). It is assumed, that the offshore wind capacity, will increase with 1000MW, and near-shore with 500MW (compared to the level in 2012) (The Danish Energy Agreement 2012). The wind capacity onshore should increase with 500MW (1800MW should be erected and 1300MW should be taken down) (The Danish Energy Agreement 2012). The national energy target in Denmark is to decommission some of the oldest onshore wind turbines, and repower them with new larger ones.

More about the national energy politics can be seen in Appendix B.

1.3 Roskilde Municipality

In this section, the basic background of the Roskilde municipality will be described, both with a short geographical introduction and with the local energy system.

1.3.1 The Geographical Location of Roskilde

Roskilde is a municipality in the middle of Zealand, Denmark. The municipality is a part of the Region Zealand[1]. It has an area of 212km^2, and a population of 84,219 in 2012 (Gyldendal 2015 A). The municipality can be seen in Figure 1-2.

Figure 1-2 The location of Roskilde municipality.
From (Google Map)

Part of Roskilde municipality became, in March 2015, a national park (Skjoldungelandet 2015). For the energy system, this does not have a direct impact, although it could limit the areas of siting of wind turbines (Danish National Parks). For further information regarding the national park see Appendix C.

1.3.2 The Energy System in Roskilde

In this section, the present energy system in Roskilde is shortly described to give an understanding of the present situation the municipality is in. For a larger description see Appendix D.

The municipality is part owner of two different associations, VEKS[2] and KARA/Novoren[3] . These two associations are the main part of the district heating and electricity production in the municipality, by running different Combined Heat and Power (CHP) plants (Roskilde Municipality 2014 A and 2015 B).

[1] http://www.regionsjaelland.dk/english/sider/default.aspx

[2] Vestegnens Kraftvarme selskab, is owned by 12 municipalities: ALbertslund, Brøndby, Glostrup, Hvidovre, Høje-Taastrup, Ishøj, Rødovre, Vallensbæk, Greve, Køge, Roskilde and Solrød

[3] KARA/Novoren is owned by 9 different municipalities: Solrød, Holbæk, Greve, Kalundborg, Køge, Roskilde, Lejre, Stevns and Odsherred

The heating sources

The location of Roskilde municipality, and the cooperation of the two associations of CHP plants, compels the district heating in Roskilde to be in cooperation with neighboring municipalities. Therefore, it is difficult only to focus on district heating in Roskilde (Rambøll 2014). The use of fuels is thereby not solely for Roskilde to decide.

The electricity sources

The energy in Roskilde from renewable sources in 2013 was 3% of the electricity demand both from wind and solar (Rambøll 2014).
The municipality is buying electricity from the neighboring municipalities (Roskilde Municipality 2014).

1.3.3 The Energy Politics in Roskilde

To decrease the CO_2 emission a plan for the energy system in the municipality is needed. In 2011 the first climate policy for Roskilde municipality was made (Roskilde Municipality 2014 A). It is a political target for 2020 to decrease the CO_2 emissions with 35% compared to 2008 (Roskilde Municipality 2014 A). In 2015 Roskilde municipality made a Strategic Energy Plan (SEP), see section 2.1.6 for an analysis of the plan. In 2035 it is wanted to be 100% fossil free in electric and heat sector (Roskilde Municipality 2014 A).

2. The Energy System

In this part of the thesis, the energy system of Roskilde will be presented. The way to plan for the future strategic energy will be investigated with two municipalities, together with a discussion of the best structure, to increase the renewable energy.

2.1 Strategic Energy Analyse

In this section, the definition of a Strategic Energy Plan (SEP) is investigated, together with the general energy analysis in municipalities. The overall goal, for setting a strategic energy plan, is to decrease the use of fossil fuels, and increasing the renewable energy in each municipality (The Danish Energy Agency 2015 F).
Before setting an energy plan for the future, it is necessary to research the present energy system.

2.1.1 The Present System

In this section the analysis of the present energy system will be described.
The research of the present energy system, includes the electricity, the heat and the transport. Both the production of electricity and heat, together with the consumption should be mapped (The Danish Energy Agency 2015 E).
Before the study of the present system, it should be discussed, what the focus should be. By having a clear target for the analysis, a difference in the collection of the data for each sector can be made (The Danish Energy Agency 2012 B).

The difference in collection of data can be made by having different information levels. The different levels of information are divided into three different "Tiers"[4] (The Danish Energy Agency 2012 A). The description of the Tiers can be seen in Table 2-1.

Table 2-1 The definition of the Tier levels.
Tiers are used with energy data collection for an energy system.
From (The Danish Energy Agency 2012 B)

Level of Tiers	**Description**
The first level	The national data, divided into the share of the municipality in Denmark. By using this level, it is being estimated, that Denmark is a homogeneous area, which is not realistic.
The second level	Getting data from the specific energy producing companies. In this level, it is estimated that the production companies, can supply with the needed data. However, it have been seen, this can be difficult, especially when wanted data, are divided into different sectors e.g. residents and industry. In this level, the different demands for each municipality are included. However, it is not divided into the specific sectors and areas in the municipality.
The third level	Has included most data, as data for each house are being analyzed. When using the third Tier the data included are precise for the specific area and sectors. The collection of the data can, however, take many resources from the SEP.

The different level of Tiers should be a compromise, between the data wanted and the resources used to collect them. Different Tiers, can be used for different energy sectors, to support the decision of the main focus.
The Danish Energy Agency has made a strategy for mapping the present energy system (The Danish Energy Agency 2012 B). By investigating the different sectors, the present energy system can be collected, and mapped. The main measurement of the energy system, is connected to the CO_2 emissions, therefore, this should be calculated.

2.1.2 The Calculation of the CO_2 Emissions

In this section the calculation of CO_2 emissions for an energy system will be described.
Each energy source has a carbon footprint. Carbon footprint is an indicator, to quantify the greenhouse gases emission[5] (COWI 2014).
In the emission calculation it is required to ensure what are included, for all energy sources[6]. Therefore, it is important to make the limitation, for the calculation clear, and homogenous for all energy sources. The different calculations, can basically be divided into three levels as seen in Figure 2-1.

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[4] Stepwise increasing of investigation in the strategic energy investigation
[5] In this thesis, it is being done by calculating grammes CO_2.
[6] In some cases, fossil fuels have lower carbon footprint compared with wood biomass (COWI 2014)

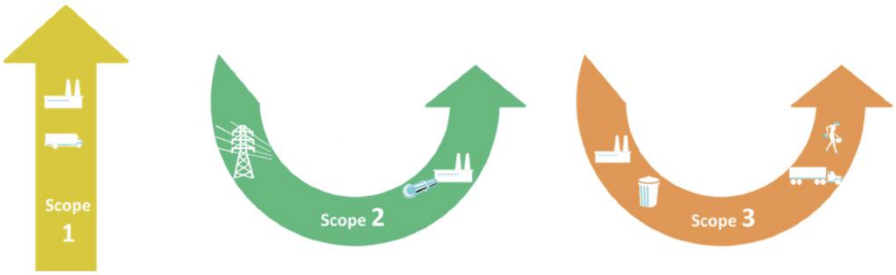

Figure 2-1 Graphic over the different levels.
Scope 1 is the direct emission from the fuels. Scope 2 is including the indirect emission from bought energy. Scope 3 is including the indirect emission from the buying of resources, transport and services.
(The Danish Energy Agency 2014 A).

The specific level for each analysis, should be clear in the calculations. For comparison the used level, should also be similar for the municipalities in Denmark, as for the national calculations.
The calculations for the CO_2 emission, are done for each energy source respectively, as each have different emission levels. The emission levels can be seen in different reports e.g. (Cowi 2014, The Danish Energy Agency 2010 B). The emission is provided in the unit g CO_2/J, it is needed to know the energy in each energy source by mass (J/g).
The greenhouse gas (GHG) emission is calculated by the equation (Damsø et al. 2011).

$$GHG\ emission = Activity \cdot Emission\ factor$$

The emission factor can be set differently according to the different Tiers.
The carbon footprint is being investigated, to see into the future, and predict the environmental consequences, for the use of each energy source.
Roskilde municipality have used scope one, as emission for the demand is calculated excluding indirect emissions. Further the emission factor is based on marginal electricity and an average for fuels in district heating (Rambøll 2014). This can give a crooked results for the specific emission level in Roskilde. The definition of marginal electricity can be seen in the next section.

Marginal Emission Level

As written, all energy sources have a specific emission level. However, the emission level for marginal electricity can be discussed. Marginal electricity, is used for import/export in the municipalities, therefore, no specific energy sources are not connected to this. See Figure 2-2 for visual explanation.

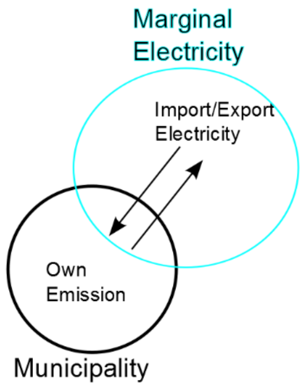

Figure 2-2 The marginal Electricity.
The marginal electricity is the imported and exported electricity in the municipality. When imported the

emission level is set to the marginal as with exported, no matter the production method. The electricity there are produced and consumed in the municipality have the specific emissions based on production method.

In Denmark the level of CO_2 emission, has been discussed (The Danish Energy Agency Note 2015). In the present calculation of the marginal electricity, the electricity is assumed to only be produced by coal (the highest CO_2 emission). This is however, being discussed, as it is not realistic for the marginal electricity in Denmark, especially not at longer term. Furthermore, it only provides incentives for export of electricity and not of import e.g. for heat pumps or electric vehicles. It is hence being debated whether, the large offshore wind parks should be included, together with 50% of the near shore wind projects. Therefore, the emission level of marginal electricity will decrease, compared to previous level (The Danish Energy Agency Note 2015). The marginal electricity is a product of the capacity of offshore and near shore wind projects, therefore, it is not a stable value, in Appendix E the recommendation, for emissions in Denmark can be seen.

2.1.3 Strategic Energy Plan

In this section the strategic energy analysis is being presented, based on the definition from the Danish Energy Agency.
A Strategic Energy Plan (SEP) is a plan, for helping the municipalities in the energy change towards renewable energy (The Danish Energy Agency 2015 F). The plan is to make the change in cooperation with the society, and to make the energy system more flexible. It is wanted, that municipalities in Denmark make a SEP, and follow the guidelines from the Danish Energy Agency[7] (The Danish Energy Agency 2012 A). When all municipalities have a SEP, it is easy to compare the different municipalities, and increase the possible cooperation.
The SEP focuses on the municipality as a geographic area. To find the best, and most social economic, solutions it is important, to investigate and include the neighbor municipalities.
In SEP the time frame is long, which is why, it is important to have a broad political agreement, as the local council election is every fourth year.
The process of the SEP can be seen in Appendix F.

From the Danish Energy Agency a definition of a SEP is given, and the needed parts can be seen in Table 2-2.

Table 2-2 The needed parts in a SEP
Individually definitions for the different parts in a SEP, based by the Danish Energy Agency. (The Danish Energy Agency 2012A)

Parts in a SEP	Definition
Time period	Long term
The present energy system	Mapping of the present energy demand in the municipality, and the present energy production. All sectors should be included (heating, electricity, cooling, process and transport)
The future energy system	Mapping of the estimated energy demand in the future, and the future energy production. This is done by use of a scenario, for the

[7] http://www.ens.dk/en

	municipality. All sectors should be included (heating, electricity, cooling, process and transport)
Potential for energy savings	Map of location and level of potential energy savings in the municipality, according to the environment and social economy. All sectors should be included (heating, electricity, cooling, process and transport)
The local energy resources	Map of the local energy resources, with the investigation of cooperation, with the neighbor municipalities.
Investigate the potential for cooperation	Explore the potential for cooperation, with the neighbor municipalities, including which sector, level etc.
Assumptions for the SEP	Map the known assumptions and preconditions for the SEP
Analysis of alternative scenarios	Make analysis of alternative scenarios in the municipality, incl. alternative demands and production. All sectors should be included (heating, electricity, cooling, process and transport)
Consequence for the alternative scenarios	Investigate the different alternative scenarios, and find the consequence for each scenario. Estimate the best scenario for the municipality.
Discussion of the main priority	Make a discussion of the municipality's priority in the energy sector. What should be priorities based on the cost, environment and the public.
Priority of the energy sources	Investigation of which energy sources are best, for the different areas in the municipality, and which technologies can use the resources most efficient. Include cooperation with neighbor municipalities. All sectors should be included (heating, electricity, cooling, process and transport)
Proposal for time line	Map a proposal for a time line, to include the different needed changes, in the energy sector. All sectors should be included (heating, electricity, cooling, process and transport)
Implementation of the plans	Implement the different needed changes in the municipality. All sectors should be included (heating, electricity, cooling, process and transport)

The level for each research can be divided into three different "Tiers" stepwise increasing of the research.
The objective of the SEP is to increase the renewable energy in Denmark, as the municipalities can plan a long-term process. The SEP can give each municipality an overview of the present energy system, and the priority in the area. When all municipalities have made a SEP the level of double counting (for renewable energy production) should be decreased[8].
The CO_2 emission should also be comparable for all municipalities.

When the emission level, of the marginal electricity, is decreased, as a consequence of including large offshore wind parks and 50% near shore wind projects, the emission of the municipalities will also decrease. This can give the municipalities a benefit, of increasing the

[8] Double counting can be for example when one municipality erects wind turbines in another municipality.

electrification, e.g. by increasing the number of electrical cars, heat pumps etc.
In the marginal electricity, the onshore wind turbines, and solar panels etc. is excluded. This can increase the willingness from the municipalities, to increase these renewable sources. The onshore renewable energy production is included, in the specific municipality. The difficulty is when one municipality is owner of a turbine, located outside the border. This can give double counting of the renewable energy. The calculation of renewable energy share in each municipality should be clear, both by production and included losses.

2.1.4 Models

In this thesis models have been used to show the effect in the entire system, from few specific projects. From this it will be researched if Roskilde will reach the target, and a study of the effect if Denmark has the same energy system as Roskilde. The use of models can be used to show the effect of flexible technologies such as heat pumps in the district heating sector.

In this section two different energy models are being compared and discussed.
An energy plan can be investigated by using models. There are several different kinds of energy system models. In reality, the energy system is very complex, as both technology and economics together with demand and supply are included. Because of the complexity, each model has a focus. Each model has some strengths and weaknesses, hence no model fits perfect, for all issues. Therefore, it is important to know, which issues that are most important, for each project, and base the choice of model upon that.

As the quality of life has increased so has the energy demand (Jabaraj and Iniyan 2004). To meet this increased demand, the need for organized energy systems, has increased as well. In the last ten years, the use of energy strategies has increased, as the use for energy models.

In the first versions of energy systems models, the input variables were population, income, price, growth factors and technology (Jabaraj and Iniyan 2004). The first inputs into the energy models, was from the technical and economic sectors. The first models were based on fossil fuels. As the renewable technology and energy production increased, a change in the energy models was needed, to be accepting the fluctuating energy production. With the renewable technologies, other variables are needed, e.g. the wind characteristic. For the wind characteristics a fixed value was added to the first models, with fixed value. This has however, changed to the use of Weibull probability distribution, and specific power curves for the wind turbines (Jabaraj and Iniyan 2004).
The new variables, which have been included, have improved the quality of the models. However, it is noticed, that the models do not include any social aspects. This is also noted by (Nielsen and Karlsson 2007), where the need to include both lifestyle and social development in the models is mentioned.
This increases the need for specific models for each project, as the social aspects change. People act according to emotions; thereby the modeling of the energy system incl. social aspects, will increase the complexity, of a model drastically. Ideally every person would act according to cost-benefit projection, but the ideal world does not exist.
The public support for new wind projects in a municipality should be researched, together with the modeling, such as the implemented wind capacity is realistic for the specific municipality.

The level of different grid connections between the municipalities in Denmark is high, further the cooperation across the municipality borders is wanted to increase. Therefore the modelling in this thesis is used to show the impact on the national level. To show the projects (in Roskilde) effect on the energy system, the models are used on a national level. This is the background for a small investigation of two models; Balmoral and STREAM (Sustainable Technology Research and Energy Analysis Model). Both models are free to download[9]. The limitations for each model should be known, and a discussion made to find the best fitted model, for each project.
The table of comparison by the two models can be seen in Appendix G.

STREAM is partly top-down, and the economic factor is being included in the model, however, it should be noted, that STREAM is not an investment optimization tool. As it is difficult to set the future price for each technology, level of inflation etc. the investment optimization tool, can show an offset to the most optimal scenario - this should be discussed when using Balmorel.
Both models are bottom-up, but only Balmorel includes operation optimization for the entire energy system. This indicates, that STREAM needs input for prioritizing, between the different technologies.
As Balmorel is a scenario tool, the time frame is also higher, compared to STREAM, which can implement data from one year, and give output for a future year. Balmorel can on the other hand implement data from 50 years, for calculation of future scenarios, linking analyses with e.g. five year intervals.
In Denmark, the national target for 2050 is to be 100% fossil free, which is including the transport sector. This is not included in the present Balmorel model. This needs to be included, for the energy system in 2050. There has been made Balmorel models, including transport sectors, but it is not standard (EnergyPLAN 2015). STREAM has included the transport sector.

Balmorel is good for long term scenarios, as the complexity level is higher than STREAM. STREAM is easier to learn, and to see the specific consequences for each change. Therefore, the STREAM model can be used in political discussion.
In the present political point of view the CO_2 emission has a high impact, and it should be noticed, that the CO_2 calculation in STREAM and Balmorel are not optimal. The CO_2 calculation is included in the two models, however, the models are not a CO_2 optimization tools.

All of this should be discussed before choosing a model for analyzing a specific energy system. Further, is should also be discussed, what is wanted to investigate: the predicted future, the different possible futures or the desirable future energy system (Nielsen and Karlsson 2007). This is being illustrated in Figure 2-3.

[9] Balmorel from: http://www.balmorel.com/ and STREAM from: http://streammodel.org/index.html

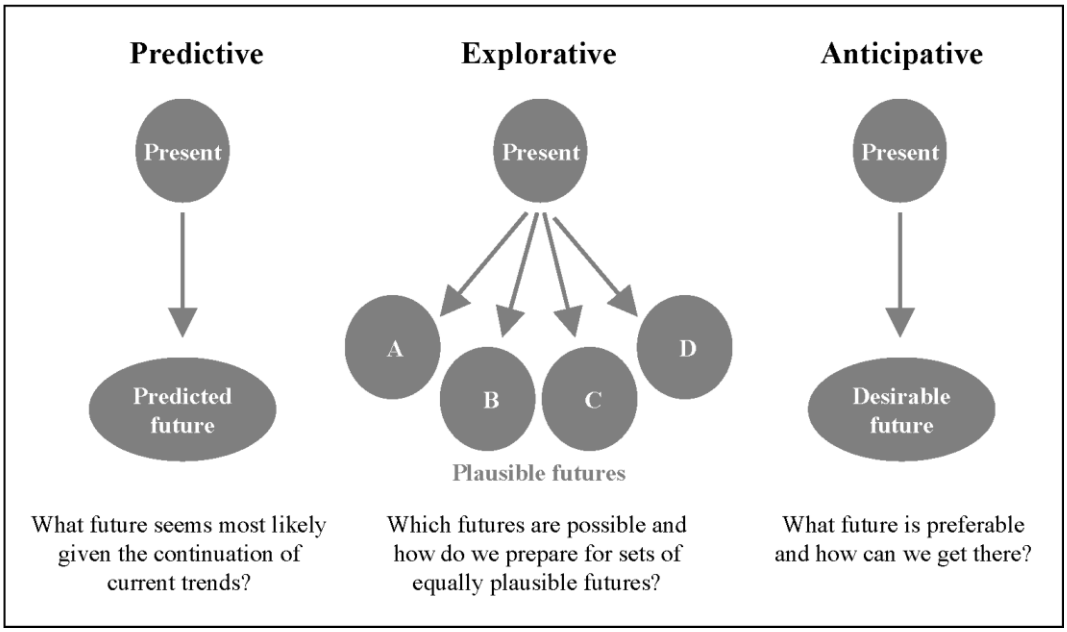

Figure 2-3 Three different scenarios.
Different scenarios studies, which can be used for analysis of future energy system. The predictive follows the previous path. The explorative investigates different future scenarios. The Anticipative has a desired future and finds the needed path towards this future.
(Nielsen and Karlsson 2007).

The predictive scenarios will describe the most likely future energy system, if nothing is changed (Nielsen and Karlsson 2007). The predictive scenario is using the Business as usual (BAU) model, this can be seen in Figure 2-4.

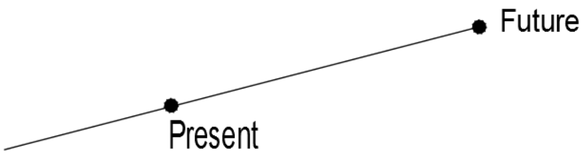

Figure 2-4 Graphic over the concept business as usual, used in energy models.

As it is seen, the path of the historic energy development is not changed towards the future energy system. The predictive scenario is used, to see the future energy system, and future CO_2 emission level, if no changes are done. This can be used during political debates.

The explorative scenario investigates different future energy systems, which are all possible, desired, feared etc. (Nielsen and Karlsson 2007). This can be used for exploring different projects impact, on the future energy system, without having a specific future energy target.

The anticipative scenario is used, when a specific future energy target is set. Both the present energy system and the future target are constant. By using back casting method, different paths to reach the target are explored. This is illustrated in Figure 2-5.

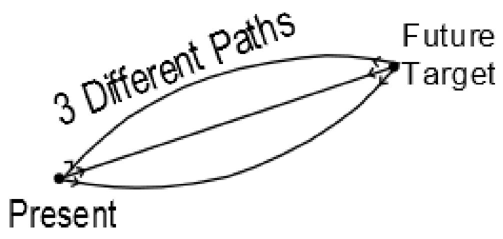

Figure 2-5 Graphic over the concept backcasting.
Backcasting is used for anticipative scenarios, where the future target is known. Backcasting explore different paths to reach this future target. Both the present path and the future target are included in the backcasting method, this can be seen with the arrows at both ends of the three different paths.

With the backcasting method, both the present path of the energy system and the desired future are included. This is being illustrated with the arrows from both the present and the future energy systems. The backcasting name is set by: A politically set future target, and afterwards the path to reach this, is being investigated backwards. The anticipative scenarios are used, for examine the needed projects to reach the political target, and the backcasting method is used to research the different project paths, towards the target. By having different paths, the decisions/consequences for the politicians are made clear.

2.1.5 Scenarios

In this section the definition for a scenario is given.
As a part of the SEP different future energy systems should be explored. This is typically done by using a model, and setting different scenarios. The different consequences, from the scenarios, can be seen in the model.
A scenario can be seen as a snap shot of the future energy system (Energy Scenario 2014). The picture is based on all the political targets, and can thereby show the effects from each political decision.
A scenario is not a window into the future, as there is much estimation for each calculation, e.g. the change of prices for the energy sources.
It is needed that the estimations are clear before any calculation, as estimations have a high influence on the output, e.g. the emission level of marginal electricity. The limitations for the scenario are also needed to be clear. As transport is used across both municipality and national borders, this sector's limitations should be discussed.
While investigating the change in the energy system, the investigation of the possible resources should be included. This is needed to avoid unrealistic scenarios.

In the SEP, both assumptions and limitations for each scenario should be included in the report. The scenarios for the municipality will help show each impact of a decision in the energy system. Therefore, the scenarios can help finding the best focus area, in the municipality, and see what is needed, to reach the political target.

2.1.6 Roskilde Municipality

In this section, the SEP for Roskilde municipality is analyzed, based on the recommendations from the Danish Energy Agency.

Roskilde municipality takes part in the Regional cooperation project "Strategic Energy Plans" (STEPS) (Energy Cluster Zealand 2015 A)[10]. STEPS has been making the strategic energy plans, for two of the municipalities (Roskilde and Odsherred) and collecting data for the 15 other municipalities in the Zealand region[11] (ENS Toftlund 2015).
The SEP should be base for political decisions in the region, with special focus on the cooperation between the municipalities. During the project, the outputs from the project have, however, changed to be inputs for SEP for each municipality (Toftlund 2015). The responsible for implementing the input from STEPS into a SEP are the different municipalities.
In 2011 the entire energy system in Roskilde, has been investigated regarding the CO_2 emission level (Damsø et al. 2011).
In the analysis, scope two (see Section 2.1.2) has been chosen, where the direct emission level from energy production, is included for all energy, used in the municipality. The system do not include loses (Damsø et al. 2011). The emission factor for all electricity, is set to the marginal electricity from (ENS 2012)[12]. The specific energy production for Roskilde is not included. As Roskilde municipality has 3% renewable electricity (in 2013), this could decrease the emission level, but will not have a large impact (Rambøll 2014).
The entire energy system, was divided into seven different sectors; (1) Electricity, (2) Heating, (3) Transport, (4) Industry, (5) Agriculture, (6) landfill and (7) Land Use, Land Use Change and Forestry (LULUCF) (Damsø et al. 2011).

In 2008 Roskilde municipality became a climate municipality, which is an agreement between the municipality and Danish Society for Nature Conservation[13]. For Roskilde municipality the decrease of CO_2 emission was set to 2%/year until 2025 (Climate Municipality 2015). The CO_2 emission reduction is for Roskilde municipality as a company.
The agreement is voluntary, and there are no consequences, if the agreement is not respected. At Figure 2-6 the CO_2 emission from 2007 to 2014 can be seen for Roskilde municipality.

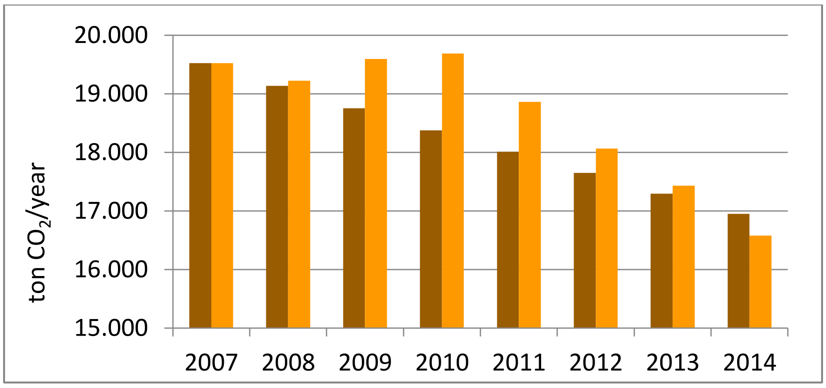

Figure 2-6 CO_2 emission from Roskilde municipality as a company.
Dark: the target from climate municipality. Light: The CO_2 emission the specific year. There was an increase of the CO_2 emissions in 2009-2010, however, from 2010 Roskilde have had a high decrease of

[10] The project is managed by the company "Energy Cluster Zealand"[10], there is a non-profit organization owned by the municipalities in region Zealand and the region (Energy Cluster Zealand 2015 B). The Energy Cluster Zealand provides managers and information regarding energy projects, including STEPS.
[11] However, both Ringsted and Stevns municipalities are both missing these data the 9th of October 2015 (ENS 2015, Ringsted and Stevns).
[12] The CO_2 emission: 2013: 318g CO_2/kWh, 2015: 242, 2020: 187, 2025: 146 and in 2030: 150 g CO_2/kWh.
[13] Danmarks Naturfredningsforening; http://www.dn.dk/. Roskilde agrees to decrease at least the CO_2 emission with 2%/year, until a chosen year (Climate Municipality 2015).

the emission, such as in 2014 the target from CoM was reached.
Figure from calculation excel sheet 2014 (Climate Municipality 2015).

As seen on the figure, the CO_2 emission has increased in 2009 and 2010, compared to the previous year. From 2011 the emission has, however, been decreasing more than the needed 2%, according to the agreement, which is why in 2014 the CO_2 emission from Roskilde municipality, was lower compared to the targets.

In 2010, the Mayer of Roskilde, Joy Mogensen, signed a Covenant of Mayors (CoM) agreement (COM 2015 A)[14]. The target, has been increased in 2014 to 35% CO_2 emission reduction for Roskilde municipality by 2030. The signing municipalities, are demanded for emission calculation for the geographical area of the municipality, together with, an energy plan towards the 2020 targets (COM 2015 B).
Both being climate municipality and the CoM agreements are voluntary for municipalities. When the agreements are signed, the municipality can receive recommendations for larger energy savings. This can have an impact on the willingness for signing the agreements. Further, the municipality will be presented, as a “green municipality”, no matter the level of CO_2 emission reductions.

For Roskilde municipality all calculations has been done by Roskilde University[15] (Toftlund 2015). As a part of the STEPS project, the district heating area in Roskilde, has been investigated and mapped in 2014 (Hansen et al. 2014 A, B, C). Further investigations of biomass resources (for heating support) in the municipality and in landfill, have been made in different reports (Elkjær et al. 2013, 2014). These data have been used for inputs to the SEP for Roskilde municipality. It is noted, that there have not been made a study, regarding the sectors: Electricity[16], Transport, Industry, Agriculture and LULUCF.

Roskilde municipality has made an energy plan for 2011/2012, as a part of being a Climate Municipality (Roskilde Municipality 2011). In this research it was found, that other sectors requires to be implemented in the energy change to reach the target for 2030. Therefore, all the different sectors are needed to be included, in the change of the energy system.
The political energy targets is; in 2020: 35% CO_2 emission reduction, in 2035: 100% renewable energy in heat and electricity and in 2050: 100% renewable in all sectors. Therefore, the future energy system needs changes (Roskilde Municipality 2015 A).
Without an energy plan, the risk for not achieving the political target increases, as it is not known, if the projects that have already been suggested are enough (Damsø et al. 2011).
The SEP in Roskilde is based on the recommendations from the Danish Energy Agency, however, Roskilde has agreed to make some changes, compared to the recommendation because of energy resources (Magnussen 2015 B). In Table 2-3 in Section 2.1.8 a study of the SEP, compared to the recommendations can be seen.

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[14] In CoM the municipalities agree to decrease the CO_2 emission with at least 20% compared to the level in 2008 (COM 2015 B).
[15] Organized by Tyge Kjær
[16] In 2015 an application for an investigation regarding siting of wind turbines in the region Zealand (Kjær 2015).

In the SEP it is noted, that all municipalities (and citizens) in Denmark are responsible, for achieving the national political energy targets. In the SEP, 20 plans are listed for the next four years in Roskilde (Roskilde Municipality 2015 A).
These plans have been divided into whether they constitute “plans for when to start new research” (plan) or practical plans there can be implemented without a new large investigation (practical). This can be seen on Figure 2-7.

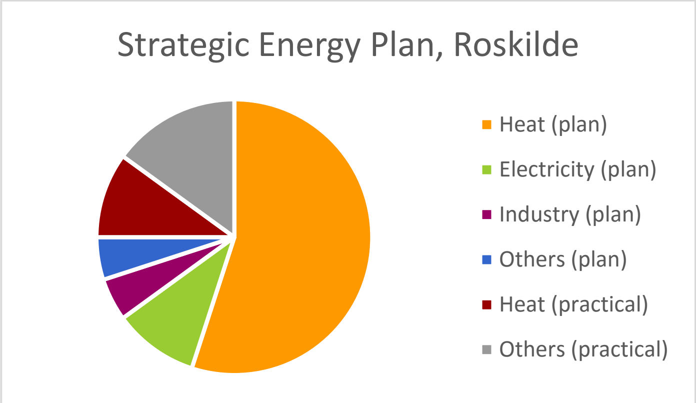

Figure 2-7 Investigation of the given plans in SEP Roskilde.
The plans in the SEP have been divided into two groups: plans for new research and practical plans which can be implemented without new analysis. The level of the first group is high, as the time plan in the SEP are not for implementing direct actions, but a plan for when to start new research.
The plans have been divided into the sectors from the Danish Energy Agency.
Data from (Roskilde Municipality 2015 A).

As seen on the figure, 75% of the plans are plans for new analysis. The included sector “Others”, is for plans, which cannot be included in the other sectors, e.g. cooperation with neighbor municipalities and energy reductions.
The analysis indicates that the SEP from Roskilde mostly is a plan for when new investigations should be done.
There are two practical plans for increasing the district heating, as has been analyzed before (Hansen et al. 2014 C).
There also are two practical plans, for increasing the cooperation with the neighbor municipalities, and finally one for reducing energy, in the buildings owned by the municipality (Roskilde Municipality 2015 A).
As written Roskilde has divided the plans into different sectors. The same study of the plans can be seen in Appendix F.
As known, it is the geographical area of the municipality, which is included in the SEP. Therefore, the plans can be divided into instruments of the municipality, e.g. the energy reduction in buildings owned by the municipality. In Figure 2-8, the plans can be seen, organized by instruments of the municipality.

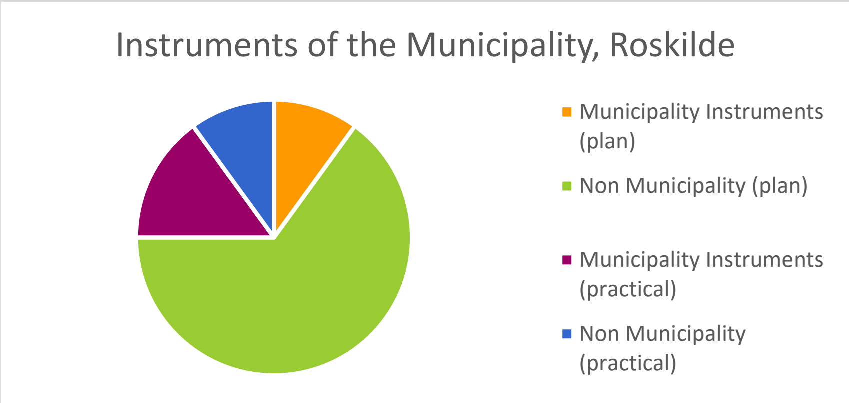

Figure 2-8 Investigation of the given plans in SEP Roskilde.
The plans in the SEP have been divided into two groups: plans new research and practical plans which can be implemented without new analysis. The level of the first group is high, as the time plan in the SEP are not for implementing direct actions, but a plan for when to start new research.
The plans have been divided into instruments of the municipality and non-municipality instruments. To explore the level of plans the municipality have a direct impact on. It is seen this level is low, therefore the municipality is depending on other partners to implement the plans.
Data from (Roskilde Municipality 2015 A).

It is seen, that most of the plans, are plans which are non-municipality instruments. This indicates the difficulties for including changes in the energy system, as there is often more than one part in the system.
Roskilde municipality has many plans for the district heating, as this has been the focus area the last couple of years (Hansen et al. 2014 A, Roskilde Municipality 2015). As written in the energy plan 2011/2012, it is needed to include other sectors to achieve the political energy target. This is missing in the SEP for Roskilde municipality.

The parts in a SEP from the Danish Energy Agency are recommendations (The Danish Energy Agency 2010 A). Therefore, it is not needed to include all parts for a local SEP. However, by the investigation of the plans in Roskilde SEP, it is wanted, to research other municipalities' SEP to be able to compare.
There are three pioneer municipalities: Ærø, Bornholm and Høje Taastrup municipality (KL 2015 B). As both Bornholm and Ærø are island municipalities, it is chosen, to compare Roskilde and Høje Taastrup, regarding the SEP.

2.1.7 Høje Taastrup Municipality

In this section the SEP for Høje Taastrup[17] municipality will being examined. Høje Taastrup municipality is a neighbor to Roskilde, as can be seen in Appendix F.
It is the general parts in the SEP that are compared.
The SEP for Høje Taastrup municipality is both an energy and climate plan towards 2020 (Høje Taastrup Municipality 2015). In the SEP, there are specific plans, for the short term (2020) and there are also, nonspecific visions for the energy system towards 2035 and 2050.
The short term plan is divided into four large sections: Transport, Energy efficiency, Electricity

[17] http://www.htk.dk/Borger.aspx

and Heating. In the timeline 44 plans are listed for the municipality. These plans, have been investigated, to find how many plans are plans for new research, and how many are practical plans, there can be implemented, without a new large study. The division of plans, in shares as the sectors recommended from the Danish Energy Agency, can be seen in Figure 2-9.

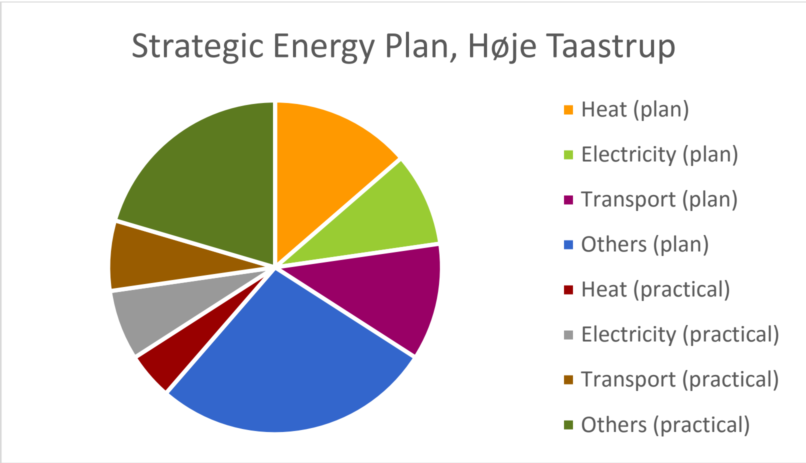

Figure 2-9 Investigation of the given plans in SEP Høje Taastrup.
The plans in the SEP have been divided into two groups: plans new research and practical plans which can be implemented without new analysis. The level of the first group is highest, as the time plan in the SEP are not for implementing direct actions, but a plan for when to start new plans.
The plans have been divided into the sectors from the Danish Energy Agency.
Data from (Høje Taastrup Municipality 2015).

It is seen, that 61% of the plans, are plans for new plans. In Høje Taastrup municipality the included sector "Others", is mainly including energy efficiency plans (43%) and plans for cooperation with neighbor municipalities (Høje Taastrup Municipality 2015). The energy efficiency plans, are mostly information campaigns, towards the residents in the municipality and the small companies located in Høje Taastrup (Høje Taastrup Municipality 2015). A figure divided into the sectors in the SEP can be seen in Appendix F.
As information campaigns are practical plans which can be implemented without major new investigations, this is included in "practical plans", however, it can be difficult to estimate/calculate/measure the direct effect from these. This also indicates the difference between which are instruments for the municipality and which are not. Again, the information plans are included in the instruments of the municipality, even though the practical change is not an instrument for the municipality. The different plans divided into instruments of the municipality, and outside the municipality' instruments can be seen in Figure 2-10.

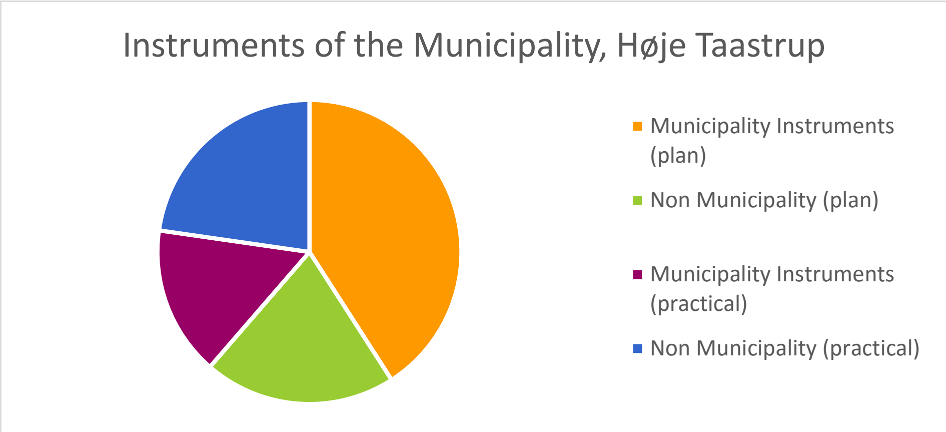

Figure 2-10 Investigation of the given plans in SEP Høje Taastrup.
The plans in the SEP have been divided into two groups: plans new research and practical plans which can be implemented without new analysis. The level of the first group is highest, as the time plan in the SEP are not for implementing direct actions, but a plan for when to start new plans.
The plans have been divided into instruments of the municipality and non-municipality instruments. To explore the level of plans the municipality have a direct impact on. It is seen this level is over 50%, however, plans for information campaigns towards companies and private are included. Therefore, the municipality still depends on the residents for a direct energy effect.
Data from (Høje Taastrup Municipality 2015)

It can be seen that the sectors with plans for new research with both municipality instrument and non-municipality instrument, have the highest share. This indicates, that there are many areas, where new studies, are needed, to reach the political set targets of the energy system. For Høje Taastrup the political target is a reduction of the CO_2 emission of 3%/year (Høje Taastrup Municipality 2015). This is increased, compared to the agreement, with the Climate Municipality.
Høje Taastrup SEP have more sectors included, compared with the Roskilde SEP. The increase of renewable energy in the electricity sector is not specific. Both for Roskilde and Høje Taastrup, it is wanted to start search, for siting of both solar and wind projects. A further comparison can be seen in the next section.

2.1.8 Comparable Plans for Municipalities

In this section, the two municipalities SEP's are compared, with the recommendation of the Danish Energy Agency. A discussion of the plans from the two municipalities, and the emission calculations is done.
Both Roskilde (through the Energy cluster project STEPS) and Høje Taastrup have received money from the national energy agreement, for making of the SEP (KI 2015 B). In the national SEP project the collaboration between the municipalities has been a priority (KI 2015 D). The increased collaboration is seen as a success, as the municipalities have started different projects, regarding energy systems, e.g. district heating system as in Roskilde. The first step, regarding a more renewable energy system, is the SEP. However, there is a need for a new pool for economic support, for implementation of the plans.

The comparison between the SEP for Roskilde and Høje Taastrup municipalities and the recommendations from the Danish Energy Agency, can be seen in Table 2-3. For descriptions of the different parts see Table 2-2 in section 2.1.3. After contact to Høje Taastrup and Roskilde municipalities. The information in the table is based partly available information and information received directly from Høje Taastrup municipality (Lemgart 2015). This is implemented in Table 2-3.

Table 2-3 Comparison between the two SEP'.
The comparison is divided into the different parts needed for a SEP as recommended from the Danish Energy Agency.
(Høje Taastrup Municipality 2015, Roskilde Municipality 2015, the Danish Energy Agency 2012 A, Lemgart 2015*)*

Parts in a SEP	**Roskilde' SEP From May 2015**	**Høje Taastrup' SEP From May 2015**
Time line	4 years	Specific for short term: 6 years. Vision for 2035 and 2050. Calculations for changes in 2020 and 2035.
Present energy system	Have the percentage CO_2 emission for each sector.	Energy demand from 2012 is implemented. The present energy system has been investigated, with comments regarding the data.
Future energy system	In 2020, 35% CO_2 reduction compared to 2008 level. It is not specific, how the future energy demand will be.	3% reduction CO_2/year, it is not specific, how the future energy demand will be. Oil and gas changes to 1MW wind (2020) and 30MW solar Photo Voltaic (PV) and water (2035), Coal changes to biomass.
Potential for energy savings	40% energy savings, in buildings and road light, not specific how.	District heating: 40-50% reduction, by change of fuel and low temperature heat lines. Street lightning: 70%, by use of LED. Install digital electricity measurements in buildings, owned by the municipality. Inform and inspire private and companies to do energy saving. Change the cars of the municipality to electric

		vehicles. Different shares for energy savings in each sector are calculated. Furthermore COWI 2015 has made an investigation for the energy savings.
The energy resources	Cooperation in district heating, the energy source is not known.	Cooperation in district heating but the energy source is not defined. Decentralize the electricity production; across municipality borders (not specific).
Investigate the potential for cooperation	The municipality will study the cooperation with neighbor municipalities, regarding district heating.	Regarding saving in buildings, companies etc. the municipality will explore cooperation with both neighbor municipalities and local schools. Further, the municipality will increase cooperation regarding both electricity and district heating, not specific with which municipalities.
Assumption for the SEP	-	The vision, and the known conditions for the SEP are presented. The assumptions for the scenarios are discussed.
Analysis of alternative scenarios	-	The focus is to reduce the CO_2 emission, hence the estimated overall energy demand, are presented. There are made two scenarios, one BAU and one fossil free.
Consequence for the alternative scenarios	-	The scenarios are compared to the national scenario, and this is discussed.
Discussion of the main priority	The focus is the heating sector. It is not being discussed	There are four priority sectors: transport, energy efficiency, electricity and

	in the SEP. The SEP is based on Rambøll 2014, with a discussion.	heat production. These are presented, but not discussed.
Priority of different energy sources	District heating is a priority, but the fuel is not known. Electric energy sources are set to solar and wind (the level and location are not specific).	District heating is a priority, but the used fuel is not known. Both solar, heat pumps, heat storage etc. are mention (not specific). Electric energy sources are set to solar (at the municipality buildings) and wind (no specific location).
The specific planning	The plan for some expansion of district heating.	A plan towards 2020 has been made, few of the points are specific.
Implementation of the plans	-	There are some collected experiences regarding energy savings in private houses.

From the table it can be seen, that Roskilde has not included all parts, from the recommendation, whereas Høje Taastrup has.
The SEP is a political document, which needs wide agreements in the local council. Therefore the level of information and calculations are limited (Lemgart 2015). The calculations are hold outside, to get the political agreement.
It is noted especially, that future energy systems have not been investigated for Roskilde, and for Høje Taastrup one reference has been analyzed (besides the Business As Usual (BAU)).
The consequences for the different plans are not included in any of the SEP, hence, the level of impact the plans have for the CO_2 emission, is not known. This is illustrated in Figure 2-11.

Figure 2-11 The plans in the SEP for both Roskilde and Høje Taastrup municipalities.
The coming years have planned changes, however, it is not investigated, what are needed to reach the future target, as in a back casting model.
Data from (Høje Taastrup Municipality 2015, Roskilde Municipality 2015)

As seen on the figure, the plans for the nearest coming years are planned in both municipalities, but the impact from these plans are not calculated. Therefore, it is not known, if the future target can be reached, with the present plans. Both Roskilde and Høje Taastrup have plans for 2020, 2035 and 2050- from the national targets. Thereby, some stepping stones for reaching the final target are given.

Roskilde's SEP is based on Rambøll 2014, where 7 different projects CO_2 reduction was calculated. This can be a reason for the missing discussion of the different focus areas in the SEP. Roskilde municipality has had a specific focus, for areas with direct plans, which is the heating sector (Magnussen 2015 B).

The strategic energy planning is meant to be a political tool for long term investments, to change towards a renewable energy system, however both SEP' are for a short time frame. The plans given in the SEP, are not long term which indicates that short term projects are prioritized. By having a SEP for long term, different projects can be discussed, in the local council, and afterwards be prioritized. By including different scenarios, the local politicians can choose the path, which the municipality should go towards a renewable energy system.
SEP is a voluntary tool for the municipalities, as a political tool. The different parts in a SEP are also voluntary (The Danish Energy Agency 2010 A). Thereby, the definition of a SEP is not clear. This can create very different SEP's for the municipalities, and not give a comparable baseline, as wanted by the Danish Energy Agency.

In general, the different SEP's, are missing some technical calculations. This can be based on the fact that the public SEP should be easy to read for the citizens. When the calculations are missing, the background for the decisions, plans and recommendations in the SEP's cannot be recalculated or validated by a third part. This will decrease the level of discussion of the SEP in each municipality, as discussions only will be based on political point of views, and there is no possibility to discuss technical, resource and economical calculations. This can result in some missing projects in the political discussion.

An area for priority for both SEP's is the district heating sector, whereas the electricity sector has been dealt with only in the vision state. Even though, there are not specific plans for the electricity sector, it is expected that the CO_2 emission level will decrease. The reduction is thereby not from projects within the geographical area of the municipality, but due to reduced emission level from the marginal (imported) electricity (Roskilde Municipality 2010).

The national energy target, increases the large offshore wind projects therefore, the emission level for the marginal electricity, will decrease, based on the new recommendations for marginal electricity.
The marginal electricity can thereby implement a change in the energy sector without any physical changes. This indicates importance of a discussion of the calculations for CO_2 emissions. The level of geographical emission, depends on the calculations, which can be done in different scopes. It should be clear for all calculations what is included in the emissions. An example is Roskilde CO_2 calculations in 2011, where the losses in the grids were not included. To compare Høje Taastrup municipality has included 5% loss (Lemgart 2015).
A discussion of the electricity system is needed, as the offshore wind parks, can be used in all municipalities, as a plan for reducing CO_2 emissions, without having a specific local change, in the electricity system.

In the recommendation from the Danish Energy Agency, an analysis of the present energy systems is included (The Danish Energy Agency 2012 A). If all municipalities included this, and made a SEP, this could be used for a national investigation on a local level of the present energy system. This indicates that the SEP should not be voluntary. Different future scenarios are also missing[18]. If the Danish energy system is investigated on a local level, the adding of the emission for all municipalities, should ideally be equal to the emissions at national level. This could be used, for indication of the level of missing CO_2 emission, in the local calculations.

From the comparison of the different SEP's it is seen, that the municipalities are not including the long-term plans. This can be missing in the political discussions, as the politicians are presented for one path towards the renewable energy system. Together with the missing calculations for the consequence for each project, the SEP can be used for a plan for when to start new study. However, it cannot be used for discussion of impact from the different projects, as this is not included in the SEP and thereby it is not analyzed if the presented projects, will achieve the political energy target.

The long-term plans are questions on a national level by the local councils. If it becomes mandatory to develop a SEP it can be discussed if it will change the level of renewable energy, as it is "only" a plan and not direct actions. Therefore, it can be discussed if the obligation will result in enough chances in time to decrease the climate change (ENS 2015).

2.2 The Future in Roskilde Energy System

In this section, the future energy scenarios for Roskilde are being explored. As there are no scenarios in the SEP, the scenarios from 2014, made by Rambøll, are being used as base, for this analysis.

The analysis from Rambøll is desired and limited from the local council. The investigated sectors are also choose by the local council (Rambøll 2014). In the Rambøll report, a BAU scenario is being presented, for the years 2020 and 2030. The BAU scenario is used for base, and for discussions of implementation of new efforts towards reduction of the local CO_2 emission. In the BAU scenario the CO_2 reduction is 30% in 2030, for details see Appendix H.

Based on this report, the political target towards 2020 in the CoM agreement was increased to 35% reduction compared to 2008 (Magnussen 2015 B). This increase was a political signal for setting the target higher, than the BAU scenario, and therefore new projects are required to reach the 35% reduction.

The local council chose 7 projects to be researched by Rambøll, for further reduction of CO_2 emissions, in Roskilde municipality as a geographical area (Rambøll 2014). These 7 projects can be seen in Table 2-4, together with capacity of each project and comments.

Table 2-4 Presentation of the 7 chosen projects from the local council in Roskilde municipality Roskilde have in 2014 politically chosen 7 projects to be explored for CO_2 reductions. As the projects are chosen by politicians, some non-known projects can have been missed. (Rambøll 2014).

Project	Capacity	CO_2 reductions	Comments
Investment in large solar PV project	Present: 412 kW Increase: 400kW	78.4 tons/year	The capacity is a general size PV plant. It is not studied, what is best for Roskilde, or the location of the plant.

[18] This have been neglegted, because of finance in both Roskilde and Høje Taastrup Municipalities (ENS 2015 Lemgart, Magnussen 2015 B).

District cooling in Roskilde city	Present: 0 Increase: 32MW	871 tons/year	
Local onshore wind turbines	Present: 5.78 MW Increase: 3.2MW	1463 tons/year	Only repowering projects are being analyzed, with the distance to neighbors as included factor.
Solar heating in district heating	-	-	The possible capacity is not included, as it is only feasible with a heat storage, and therefore, not further analyzed.
Change of heating source in “oil villages”	Present: 9.73 MW 150-1000kW for 5-7 cities. In total average decrease with 2.6MW[19]	In average for 6 cities 1500 tons/year	It is estimated, that 5-7 villages out of 18, will change to joint renewable heating. As the renewable heating technology is not specified, the specific CO_2 reductions have not been calculated.
District heating	Present: 47.94 MW Increase: 5.2MW	6486 tons/year	The expansions of the district heating grids are in Roskilde city and Himmelev. Veddelev and Vindinge are not included, as these projects are not feasible (both in social and private analysis).
Environmental busses	Present: 0km Increase: $72 \cdot 10^4$km	808 tons/year	Change from diesel to bioethanol for the 8 city busses in Roskilde.

From the table the large reduction in CO_2 emission in the project, regarding the expansion of the district heating is clear to see. Further, it can be seen, that repowering of the present wind turbines in the municipality, will have a reduction of 1463 tons CO_2/year.
From the seven investigated projects, the arguments for the highest CO_2 emission reductions, for least money, are clear towards the expansion of district heating.

The calculations of the CO_2 reductions, are based on the present technologies, but the emission factor for each technology is not presented (Rambøll 2014). In the BAU scenario the average emission, for the technologies are used. It is estimated, that the same emission factors are used in the scenario.

In the “oil villages” project, the discussed renewable technologies are biomass and heat pumps (Rambøll 2014). As the villages are different, it should be studied, which renewable technology is most profitable, for the specific village. This indicates the need for further investigations.

[19] The total average has been calculated by the average capacity per project (425kW), for 6 cities: 2550kW.

Both solar PV and the wind turbine projects demands large areas for complement. An analysis, of the optimal capacity in Roskilde is missing. Therefore the recommended capacity of solar PV is missing in the report. To realize the solar PV project, a search for location, grid possibility, Environmental Impact Assessment (EIA) etc. is needed.
For the wind turbine projects, the distance to the neighbors has been included, however, other types of research also are needed, for example grid connections, the community attitudes and EIA process. Further, new areas for wind turbines, have not been explored in the municipality. As the average age of the present wind turbines is 14.3 years, and the average capacity is 385.7kW, the arguments for decommission of the oldest wind turbines are good. Only five locations of present wind turbines are possible for repowering (Rambøll 2014) (where two are located at Risø DTU campus, and used for scientific research. One of them has already been repowered). This indicates the need for new investigations of possible wind turbine areas.

In the Rambøll report, the investigated projects were given from the local council, and the projects were used as scenario analysis in the SEP. This can decrease the money and time spent on scenario analysis for the municipality, as the local council has located the first priority project (District heating). However, the missing analysis in the SEP, can hide some possible projects, which could have been done. In Roskilde, the CO_2 emission is being analyzed each year, as a part of the climate municipality, but new projects are not being examined.

Some projects can be overlooked as an effect, of a missing full analysis, including different scenarios, as a SEP following the recommendations of the Danish Energy Agency would.

In Roskilde, the project with the largest CO_2 emission reduction is the district heating. This has been analyzed by the municipality and is being implemented in the energy system.
The wind project has not been investigated, as the present local council has rejected any projects in this term (Mortensen 2015). Therefore, this is the focus of this thesis, including the local engagement. When the politicians do not have any interest in wind projects, the demand needs to come from the local residents, hence the local attitude is important to include.

3. The Siting of Onshore Wind Turbines

In this section different aspects of the planning process that are needed for location of wind turbines are being introduced. This includes a map of the wanted area, with both topographical input and wind data. Afterwards the electric grid, the economics, the specific turbines and the wanted wind farm design needs to be mapped for each of the interested area. In addition the environmental impact should be documented for each area.
All parts of this planning process are important for siting of wind turbines. Siting, means the location for an object (e.g. a wind turbine) especially with the environmental impacts examined (Directory 2015 B). When siting wind turbines, it is wanted to find the best location, in relation to both the local geography, the wind resources, the environment and public acceptance.
When siting wind turbines the map, both geographical and wind map, are important factors. Different software programs can accomplish this and for this thesis the program WAsP (Wind Atlas Analysis and Application Program) has been used.

3.1 WAsP- The Wind Atlas Analysis and Application Program

In this section the program WAsP is being introduced, and will be discussed for pros and cons. When siting wind turbines, the exact location is very important, according to both the wind, the obstacles, roughness etc. These factors are all important, and to be able to calculate the correct electricity production in the specific period.

"What you need is a way to take the wind climate recorded at the meteorological station, and use it to predict the wind climate at the turbine site. That is what WAsP does." (WAsP11 Help).

WAsP cannot model the wind atlas very close to obstacles (Mortensen 2015). This limitation of WAsP has a small impact, as siting of wind turbines close to large obstacles, such as large buildings, are not favorable because of the high wind impacts.
The different types and heights of wind turbines can also be included in WAsP. Different siting for each wind turbine can be investigated, by calculating the Annual Energy Production (AEP). There can also be included several wind turbines in one map, to explore future wind farms. In a wind farm wakes have a significant impact for the other turbines. The wakes are decreasing the AEP, this can be seen in WAsP. In Roskilde the largest area has two wind turbines. Therefore the wake impact is limited in this project.
WAsP is developed in Denmark. A limitation of the program is correlated to the orography, and complex terrain (Bowen and Mortensen 1996). In Denmark the terrain is not complex, therefore, this limitation is not relevant for this thesis. For more information regarding the limitations in WAsP see Appendix I.
The measured data used to calculate the wind atlas in WAsP, is also very important. An error in the measured data will give an error in the calculated wind atlas and AEP. To ensure the data used for the program is realistic for a wind turbine technical lifetime, the measurements should at least include 3 years of data. The meteorological mast (met mast) should be close to the wanted location for the new wind turbine, and be no lower than 2/3 of the hub height.

WAsP is an engineering tool, to make it more commercial, and easy to access, WAsP online has been made, for calculation with small and medium size wind turbines. WAsP online is easy to use for private, municipalities and others, who does not have the high technical background, but want to make the first rough investigation of potential sites in their area (DTU 2014 A).
In the program Windpro[20] the map and wind atlas is based on WAsP calculations (Mortensen 2015). The Windpro program can further also calculate the environmental impact as noise and shadow flickering, visualization and economics for each project (EMD 2014). Windpro is used by several institutes e.g. Roskilde University for siting of wind turbines in Roskilde municipality (Kjær 2015).

The Geographical and Wind Map

In this section the geographical and wind resource map is being introduced.
For an analysis of the wind turbines in Roskilde municipality, a map of the area is needed in WAsP.
To understand the flow of the wind, it is needed to have a basic understanding of fluid dynamics. The definition of a fluid is any substance that deforms continually under shear stress

[20] http://www.emd.dk/

(Fox et al. 2010). Fluids can both be as liquids and gases. As air is a fluid, the flow is depending on the topographical input.

3.1.1 The Topographical Input

In this section the different impact on the topographical input is described.
The topographical input is the elevation of the land, the different roughness areas and the sheltering obstacles close to the met mast and/or the wind turbines (WAsP11 Help). All three have a significant input on the wind.
The wanted area in WAsP is the municipality, but as the wind does not "start" at the municipality border, the map is increased with 6 minutes (11.1km[21]) in each direction (Mortensen 2015).

Elevation

The elevation of the ground has a high impact on the wind. The increase in height of the ground will change the speed of wind. At Figure 3-1 a drawing of the flow can be seen over a hill.

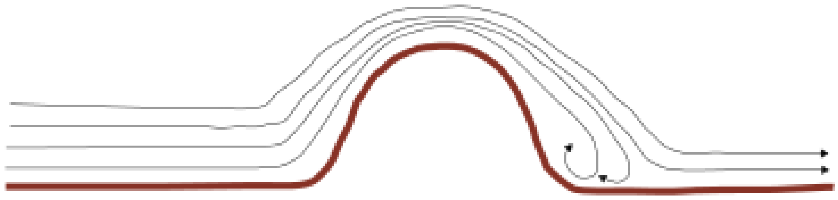

Figure 3-1 Wind flow over a steep hill.

Drawing of the flow over a hill. The distance between the wind lines indicates the wind speed. Highest wind speed at top hill. Separation at downside of the hill there are turbulence wind. It is seen the location of wind turbines should not be behind the hill, because of the level of turbulence. As the wind direction changes, the best location for a wind turbine is on the top of the hill.

The closer the wind lines are at each other the faster is the wind speed. It is seen that the velocity is highest at the top of the hill. At the downside of the hill the wind is not following the elevation of the terrain. For steep slopes there can be turbulence wind both at the downside and the upside of the hill (Wood 1995).
In Denmark there are no high mountains, but hills still have an impact on the wind. The elevation is included in the map by using the Shuttle Radar Topographic Mission (SRTM)[22] (WAsP11 Help). The elevation map of Roskilde municipality can be seen in Appendix J.
From the analysis, it is seen that the elevation is low in Roskilde municipality, as the separation of the wind flow does not have an impact in this area.

Roughness

The roughness of the land cover has a high impact on the wind. The speed of wind is different, whether there is a forest or a flat field on the ground. This roughness effect can be seen visually in Appendix J.
The roughness can be calculated by equation:

$$Z_0 = 0.5 \cdot \frac{h \cdot S}{A_H}$$

[21] 1 minute = 1 nautical mile = 1.852km

[22] http://srtm.usgs.gov/

Where h is the height of the roughness elements, S is the cross-section for the wind and A_H is the density for the area (the average horizontal area) (Troen and Petersen 1989). To calculate the roughness length all these values needs to be known, and this can be difficult and time consuming for each project. Therefore the roughnesses have been simplified, based on the land cover surface.
The different roughnesses are dividing into five classes, as seen in Table 3-1.

Table 3-1 Roughness classes

As the roughness of the surface are changing, different roughness classes are used in the wind turbine siting, to calculate the wind speed and turbulence.

From (WAsP11 Help)

Roughness class	Terrain surface characteristics (Examples)	Physical Z_0 [m] (Specified in WAsP Z_0 [m])
0	Water areas Sand and snow surfaces	0.0001 (0.0) 0.0003 (0.0003)
1	Farmland w. few buildings/trees Farmland w. open appearance	0.03 (0.03) 0.05 (0.05)
2	Farmland w. closed appearance	0.10 (0.10)
3	Many trees and/or bushes Suburbs Forest	0.20 (0.20) 0.50 (0.50) 0.80 (0.80)
4	City Tall forest	1.00 (1.00) >1 (>1)

To show the roughness impact on the wind, the ground is divided into different areas of roughness. The roughness map from the analyzed area can be seen in Appendix J.

Sheltering obstacles

When high buildings, trees etc. are close to the site, these have a different impact on the wind than roughness. The close high buildings and trees are sheltering obstacles.
The obstacles should be in the area within 50 obstacle heights, and the point of interest should be no higher than three obstacle heights (WAsP11 Help). This indicates that the number of obstacles should be low, as the limits are very low. If the obstacles are lower than the limitations, they should be included in the roughness description.
Each obstacles has to be included separately in the map in WAsP, therefore each site of interest have to be investigated for obstacles.
By investigating each area of interest in Roskilde municipality, it is seen, that there are no obstacles for the present wind turbines.

3.1.2 The Wind Data

In this section the wind data for Roskilde municipality is described and calculated.
The calculations done in WAsP are based on measurements from a meteorological mast (met mast), therefore it is important to analyze the measured data.
In Roskilde municipality there are several met mast' located, but one large at Risø campus is used in this project.
The Risø met mast can be seen in Figure 3-2.

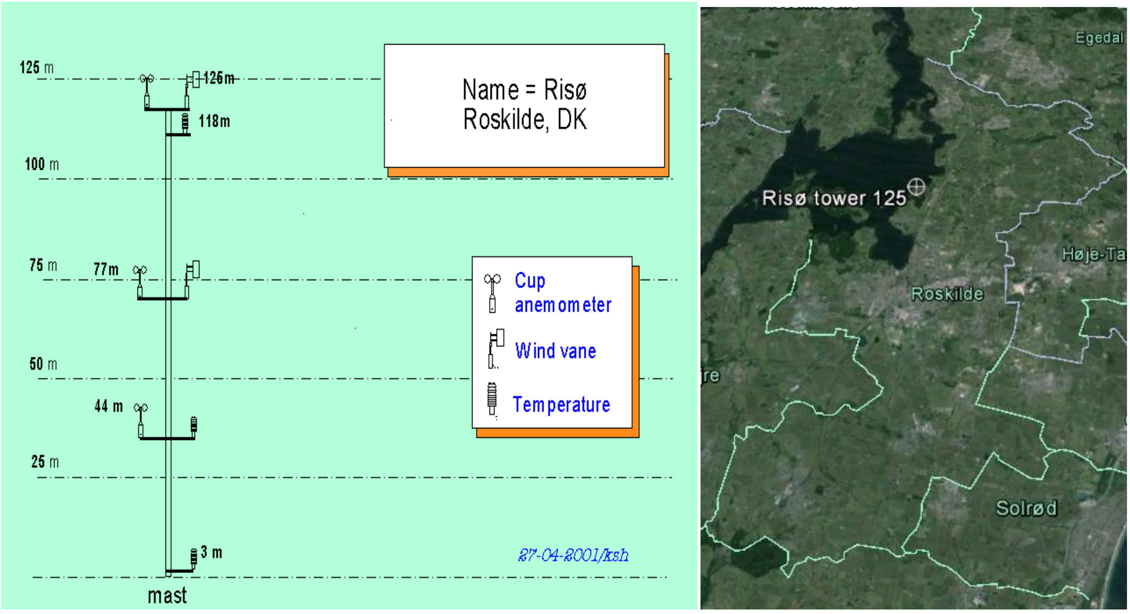

Figure 3-2.The meteorological mast sited at Risø campus.

(Left) As the present wind turbines in Roskilde are low, the measurements done in 44m above ground level are used in this thesis. It is seen all measurements are done outside of the mast, to decrease the impact of high mast on the measured wind.

(Right) The location of the met mast in Roskilde municipality.

Figure from (Risø met mast 2001) and (Google Earth)

It is seen that both cup anemometer, wind vane and thermometer are located in different heights. All obstacles have influence on the wind, therefore the measuring met mast also has an influence. To decrease this influence on the measuring, they are located outside the mast, to measure as “clean” wind as possible.

The ideal height of measuring the wind is the same as the hub height, as is the wind at this height that is being used for power production. But as one met mast can be used for several sites, the height of measurements should at least be 2/3 of the height of the wind turbine. This is to decrease the level of transformation of wind velocity in the different heights. The wind does not have the same velocity in all heights.

For the Roskilde case some measurements are higher than the hub heights of the present wind turbines. To investigate the impact of the measurements heights both from the 44m above ground level (a.g.l.) and 125m a.g.l. will be explored.

The researched wind data is from 1995-2004, where the data is studied manually to ensure the lack of data to a minimum. The study is done visually in the program WAsP Climate Analyst 2.0. A figure of the wind data in 2004 from 125m a.g.l. can be seen in Figure 3-3.

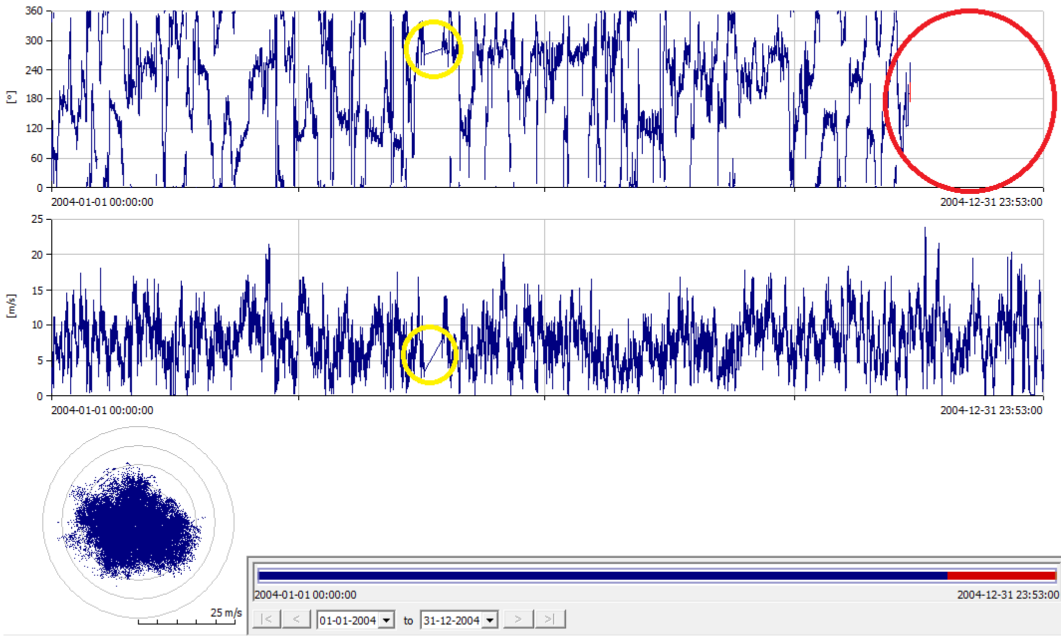

Figure 3-3 Visually investigation of wind data.

Wind data from 2004 height 125m a.g.l., visually study in WAsP Climate Analyst, where both a long and short lack of data be seen. Short lacks can be accepted, see the two yellow circles, the data is missing on both direction and sped. Several years of data are including, therefore, short lacks can be accepted. However, long lacks of data cannot be accepted, as this will change the result see the red circle, the missing data is the direction.

From (WAsP Climate Analyst 2.0)

It is seen on the figure, the direction data is missing from 12^{th} of November (red circle). Further, it can be seen that in May, there are some interruptions on the data (yellow circles). This is seen, as a straight line both in the direction and in the wind speed. When the missing data is a small limited period, the program can accept the missing data, as several years of data are including. When the missing data is a large coherent period, the result will not be realistic for the area (Mortensen 2015). This indicates that it is not only the number of missing data, but also whether the period is coherent or if there are many small periods that has an influence in the wind calculations.

The available data is imported to the program in Appendix L the data comments can be seen. The data in the different years, have different quality, to research the influence different years are excluded, and the results are being compared in Appendix L. A cross-prediction between the two heights are also been done, to see the effect of the height on the mean wind speed. See Appendix L for the analysis.
Based on the investigation, it can be seen, that the mean wind speeds are higher for measurements in 125m a.g.l. compared to measured data in 44m a.g.l.
For small wind turbines it is wanted to use the measurements from the lowest height, as this height will fit better to the hub height.
When investigating the different calculations for the wind climates, it is seen, the results are very similar, as all data are good. However, it have been chosen to use measurements in 44m a.g.l. with excl. years 01 + 03-04. This results in a mean wind at 6.2m/s at 44m a.g.l.

WAsP Climate Analyst can calculate both the mean wind speed and the extreme wind speeds. The mean wind speed is used in WAsP to calculate the Average Energy Production (AEP), and the extreme wind speed is used for categorizing a wind turbine for the specific area. For more about the mean and extreme wind see Appendix K.

3.2 Wind Farm Design

In This section the basic guidelines for wind farm designing is being introduced. The focus will be on wind farms with two wind turbines, as this is relevant for Roskilde Municipality.

When a wind turbine is being erected in an area that has present wind turbines, the distance to these should be investigated. For new wind turbines with a distance less than 28 times the total height (from the present or coming wind turbine), the developer need to state the new impact on the environment. It should be argued, for the low impact of the new wind turbine in the area (Law regarding location of WT 2013).
For large wind farms, the design of the wind turbines shall follow a simple pattern, compared to the specific environment. For Roskilde municipality the areas have one or two wind turbines, thereby this regulation is not relevant for this thesis.

A wind turbine creates wakes, therefore the wind speed is less behind a wind turbine. This indicates the need for a distance between wind turbines in a wind farm, to maximize the energy production. In Denmark the recommended distance is set to 3-4 times the rotor diameter (The Danish Energy Agency 2009 A), as illustrated in Figure 3-4.

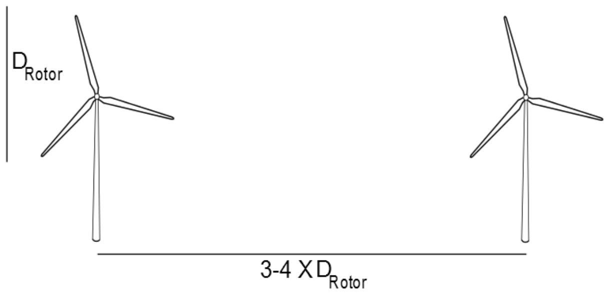

Figure 3-4 Recommend distance between the wind turbines in a Danish wind farm.
To decrease the wake impact on the EAP the distance between two wind turbines should be 3-4 times the rotor diameter. This is the recommended distance; however, a higher distance can be preferred, to decrease the wake impact further.
Data from (The Danish Energy Agency 2009 A)

The specific impact of the wake loss for each wind farm, is decreasing the AEP from the turbines. The general distances to neighbors etc. should be obeyed for all wind turbines in a wind farm.

The Electric Grid

In this section the needed electric grid for a wind turbines is being presented.

To transport the electricity, the electric grid is needed. The basic functionality of the grid is connecting the production sites and the consumers by transporting the electric (The Danish Energy Agency 2014 B).

There are some basics the grid must obtain (Energinet 2008):

- Obtain the safety of supply
- Ensure the free market on the electricity market
- Ensure the integration of renewable energy and other energies
- Minimize the environmental impact
- Create stable grid, for the future change in the electricity production

The grid in Denmark is divided into three grids:

- The national grid which is connected to the neighboring countries and the large CHP plants. The national grid has a voltage level at 400 kV.
- The regional grid which is connected to the neighboring countries, large offshore wind parks, and smaller CHP plants. The regional grid has a voltage level between 132-150 kV.
- The local grid which is connected to the onshore wind turbines and the consumers. The local grid has a voltage level between 10-60 kV.

The national and regional grid is owned by Energinet.dk[23], while several contributors own the local grid (Energinet 2014 A). A visualization of the different grids can be seen on Figure 3-5.

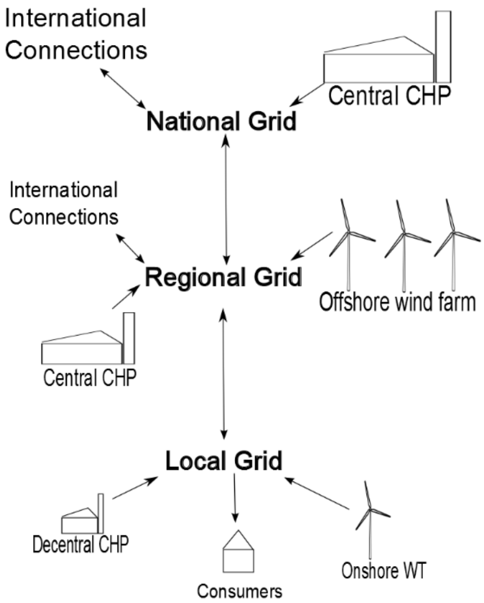

Figure 3-5 The three different grids in Denmark

The national grid connects the two grids in Denmark (East and West), have a voltage at 400kV. The Regional grid have a voltage level between 132-150kV, there are connecting central CHP plants and offshore wind farms with the grid. The local grid, is connecting all consumers to the grid, together with decentral CHP plants and onshore wind turbines. The local grid have a voltage level between 10-60kV. From (Energinet 2014 A)

[23] http://www.energinet.dk/DA/Sider/default.aspx

As seen on the figure, the grid for onshore wind turbines is the local grid (60-10kV). For siting of wind turbines this grid is needed, for connection to the national grid, and thereby the income for the project. For more information on the electric grid in Denmark, see Appendix N.

3.3 Wind Turbine Selection

In this section the different impacts on the turbine selection is being introduced, for later in the thesis to find the specific wind turbines for Roskilde municipality.

For each wind project the specific wind turbines should be decided. In Roskilde the most important part is to comply with the distance to the neighbors. The distance is set to be minimum 4 times the total height of the wind turbines (The Nature Agency 2015), as can be seen in Figure 3-6.

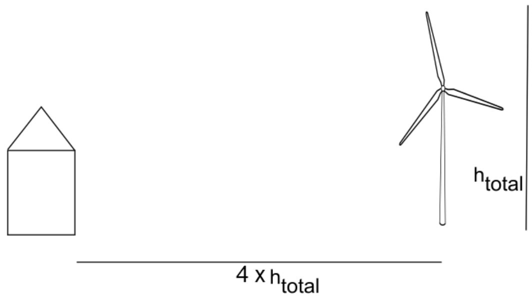

Figure 3-6 The min. distance between wind turbines and neighbors.
The minimum distance between residential buildings and wind turbines is set by law to minimum four times the total height of the wind turbine. This is used to decrease especially the noise impact for neighbors. From (The Nature Agency 2015).

The law has a high impact on old wind turbine sites, as the height of wind turbines have increased steeply in the last years.

Two wind turbines of the same height can have been designed towards two different wind classes (IEC 2008), causing two different designs. To avoid over engineering, it is important to study the wind class for the specific site. The wind class is based on both the maximum 50 year wind speed and the turbulence. The wind turbines are therefore both marked with a number and a letter, as can be seen in Table 3-2.

Table 3-2 The wind classes for design of wind turbines.
Each wind turbine have both a number and a letter, to mark the designed construction. This is used to decrease the overdesign.
Both the 50 year extreme wind and the turbulence have an impact on the loads on a wind turbine, therefore, these are used to mark each wind turbine.
(IEC 2008)

Wind turbine Clas	I	II	III	S
V_{ref} [m/s]	50	42.5	37.5	Values specified by the designer
A I_{ref} [-]	0.16			
B I_{ref} [-]	0.14			
C I_{ref} [-]	0.12			

The research of the correct wind class, is to ensure that the technical lifetime can be hold at 20 years (Madsen 2008). Further the different wind turbines are designed to increase the power production, for the specific wind climate in each wind class (IEC 2008).

For Roskilde municipality both the extreme wind and the turbulence have been calculated, this can be seen in Section 6.1.

3.4 Wind Farm Economics

In this section the economic analysis for a wind project is being introduced. Both the private and social feasibility will be introduced, to later in the thesis calculated for a project in Roskilde. Further the different support mechanisms for renewable energy will be discussed in relation to the Danish energy system.

3.4.1 Project Feasibility

In this section the basic analysis for feasibility for a project will be explored. There are several analysis which can be used to find if a project is feasible. The different analysis, have different advantages.

For investment projects, a cash flow analysis, gives an overview, whether the project will give a profit or will have a negative output. General the cash flow analysis is investigating all the different flows of money in a project, from the investment in year 0, to the end of the project lifetime in year n.
For projects with a relative long lifetime, as wind projects (lifetime of 20 years), it is important to include the different value for money, according to the time. The money today is basically worth more than the same value of money tomorrow (Levy and Sarnat 1994). The time value can be calculated by equation:

$$V_n = V_0(1+r)^n$$

Where V is the value, n is the number of years and r is the annual rate of return which is possible. Further, the inflation of money should also be included in the calculations, for the future income. In Denmark the inflation is average 2% from 1990- 2014 (Danish Statistic 2014). The Net Present Value (NPV) can be calculated by the equation:

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+k)^t} - C_0$$

Where the n is the number of years, R_t is the estimated net cash flow from the project in each n year, k is the discount rate and C_0 is the initial cost of the project (Salvatore 2012).
By using the NPV equation, it can be analyzed, whether the project is feasible or not when the NPV is higher than zero the project is feasible.
As seen from previous equation the discount rate [k] is very important for a project's feasibility. The value for the maximal discount rate can be estimated, by using next equation. Where NPV is set to 0 and with k as the variable value Internal Rate of Return (IRR) (Salvatore 2012).

$$0 = \sum_{t=1}^{n} \frac{R_t}{(1+IRR)^t} - C_0$$

If IRR is higher than the discount rate, the project is feasible, and it can be seen, how high a discount rate the project can accept, and still being feasible.

The rate of return consist of two parts, one which is the risk free and another that is the risk premium (PropertyMetrics 2013 A), this also indicates the complexity of the IRR and discount rate.
The discount rate is not a fixed value for wind projects, and it is important to investigate the discount rate for each project. There are four questions which have to be answered, to estimate the discount rate (PropertyMetrics 2013 B):

1) How much money is invested?
2) When are the money invested?
3) How much is the outcome from the investment?
4) When does the outcome come?

It is seen that both the level of outcome and investment, and the time for this, is important to know the discount rate. For individual investors this will be the desired rate of return, whereas for corporate investors it is typically the Weighted Average Cost of Capital (WACC).
The WACC[24] is a represent of the opportunity cost for taking a risk with the project (Investopedia 2015). To calculate the WACC, both the cost of equity and the specific project's equity and value is added with the debt for the project and the borrowing rate. Therefore both the specific project, and the company's finance, are included in the equation.
To calculate the discount rate, the risk for the project has a high impact, whereas the calculation of this is an estimation, and can change during the project. To decrease the discount rate, the risks for each project have to be decreased. This can e.g. be done by stable technology and stable political agreements.

For wind project the risk is high, as the market prize for electricity is not constant. This requires to be included in the finance calculations. The production of electricity is based on the wind, which cannot be estimated correctly 20 years into the future.
To make wind projects attractive for investors, the level of risk needs to decrease.

"… we make environmental policy to reduce the current risk in favor of a new lower level of risk"
(Hanley et al. 2013)

The quotation indicates the importance of a stable political goal, to decrease the risk for an unstable energy market and unstable production. The political goals should be stable, during the different governments, as a lifetime for wind projects is 20 years, and is dependent on the policy during the entire lifetime.
There are different risk in a wind project, a projects starts before the accept of the wind turbines, as it is required that an Environmental Impact Assessment (EIA) report is made before the decision can be made.

For wind projects the income will be the sale of electricity, produced by the wind turbines. The electricity in Denmark is mostly sold on day ahead market. In Denmark the renewable energy is prioritized. Since the wind is unstable there is a high risk connected to wind projects. This high risk is being decreased, by different political decisions, as support mechanisms. In Section 3.4.2 the different support mechanisms are being discussed.

[24] The WACC is calculated by: $WACC = Re \cdot \frac{E}{V} + Rd \cdot (1 - corporate\ tax\ rate) \cdot \frac{D}{V}$, where Re is the cost of equity, E is the equity of the project, V is the value of the project, Rd is the borrowing rate and D is the debt of the project (Investopedia 2015).

There are some projects which are economic feasible, but not feasible for the society. Therefore it is important to investigate the project both for social and private economics.
For the private economic analysis it is the market price which has a high impact on the level of income. Therefore it is also important, to use the nominal prices for long term projects, where the inflation is included. The boundaries for the private analysis can be seen in Figure 3-7.

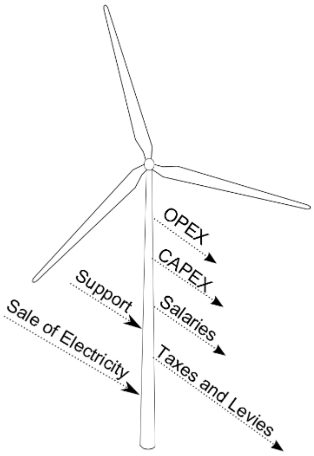

Figure 3-7 The Private Economic Analysis
Boundaries for the private economic analysis is set to the direct input/output of a project, examples can be seen on the figure.
Data from (Münster et al. 2014).

For socio economic analysis it is the real cost there is important, how much does the project cost, without including the inflation. For most sectors the market price and the real price, is identically, but some sectors are regulated by e.g. taxes and support. There are given economic support to renewable energy, and in Denmark the consumers are paying extra taxes for the use. The boundaries for the socio economic analysis can be seen in Figure 3-8.

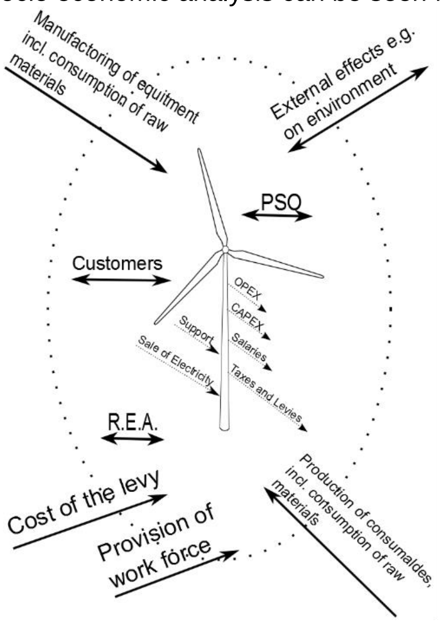

Figure 3-8 The Socio economic analysis
Boundaries for a socio economic analysis, is marked with the dotted circle. The crossing points are

including in the socio economic analysis, whereas points within the dotted circle are not included in the calculations, as it is within the boundaries.
Data from (Münster et al. 2014).

The arguments for this high level of support can be given by the externalities. The externalities are the areas, which are not naturally included in the market price, e.g. the environment. For the society, it is wanted to have a good environment, hence the support for renewable energy.
For wind projects the visualization is another externality. This is not an area with a natural market price, but is very important for the neighbors to wind projects.
To include these externalities, there are some extra renewable energy arrangements, as extra support for renewable projects (Energinet 2015 H). This extra support is included in the law regarding renewable energy in Denmark, where the four points can be seen in Table 3-3.

Table 3-3 The externalities for wind projects in Denmark.
The different sections used in wind projects in Denmark are described, the externalities are used to decrease the negative impact from a wind turbine, especially for neighbors.
(Law regarding Renewable Energy 2013 and Energinet 2015 C, D, E, F).

Name:	**Description**
The Guaranty Fund	For local groups of min. 10 people, it is possible to get guaranties for up to 500,000 DKK, for starting analysis of new wind projects, such as an EIA analysis, technical and economic analysis and siting of wind turbines.
The Green Arrangement	This arrangement gives economic advantages for project, increasing the local acceptance for wind energy. There is also given support for project decreasing the negative effect from the building period.
The Value Loss Arrangement	For buildings at a distance from a wind turbine in the range of 6 times total heights of new wind turbines, the decrease in value of the building have to be paid by the developer. It is the local citizens, which have to apply for the value loss, and the level has to set by the citizens and the developer.
The Arrangement for Buy of Projects Parts	20% of a wind project should be set for sale. For locals in a range of 4.5km, the price for the project parts, should be the same as for sale of the total project. If the parts have not been bought by the neighbors, the sale is increased to the whole municipality.

As seen from the table some externalities have impact on the private feasibility, as the developer has to pay for these. The level of these is dependent on the number of neighbors there applies, therefore it is specific for each project, and difficult to estimate.

3.4.2 Support for Renewable Energy Technologies

In this section the different support mechanisms for renewable energy are described and discussed.
The renewable technology receive economic support, to decrease the level of risk in the projects (Pade and Jacobsen 2012). The support mechanisms are a political tool, used to increase the level of renewable energy. The different mechanisms can be seen in Figure 3-9.

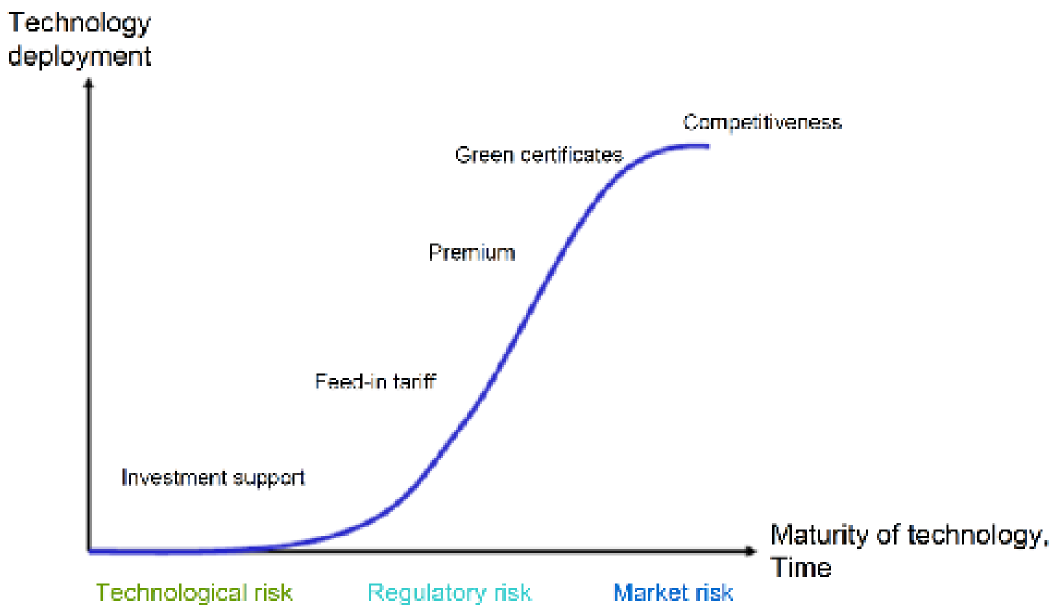

Figure 3-9 The different support mechanisms based on the level of technology development. When the technological risk are high, the support is high as well such as investment support. When the technology are being developed, and the risk are decreasing the level support decreases as well, in Denmark it decreases to feed-in premium.
Figure from (Pade and Jacobsen 2012)

As seen on the figure, the different support mechanisms have different advantages, and are used for different stages of maturity of renewable energy technology. A definition of each mechanisms can be seen in Table 3-4.

Table 3-4 The different support mechanisms
The four different support mechanisms as illustrated in Figure 3-9, are being described. (Pade and Jacobsen 2012).

Support mechanism	**Definition**
Investment support	For new technologies the investment support is used, to increase the technology used, to be more reliable.
Feed-in tariff	When the technology is reliable and ready for being exposed to the market, it is supported by feed-in tariff. There is a fixed level of support, outside the market, for a specific number of years or electricity produced.
Feed-in premium	For stable technologies feed-in premium is used. This support gives an extra income, upon the market price for the produced electricity.
Green certificate	When it is wanted to have a high competition for the renewable energy technologies, green certifications are used. This however, has a high risk, as both the level of market price and green certification is variable.

A graphic definition of the different support technologies can be seen in Appendix O.

In Denmark onshore wind project is supported by feed-in premium, where the technology behind is well known, and proven to be competitive with fossil energy production (EA Energy 2014). For new wind projects, the level of support is set to 25 øre/kWh, with a max of total income at 58 øre/kWh for specific number of years (The Danish Energy Agency 2015 J) see Appendix O for visualization. The number of years is calculated by the equation:

$$Capacity\ [MW] \cdot 6{,}600h + rotor\ areal\ [m^2]\ \cdot 5.6\ ^{MWh}/_{m^2} = time\ for\ support$$

As the political support can increase a specific renewable technology, it can also increase the risk in the energy sector.
The political support is not fixed, this can increase the risk for some projects. This was seen with large solar PV plants (Ingeniøren 2015 E). Another example of the politics influence on the energy sector is with the small CHP plants. There are present given a base support for having the capacity of all CHP plants, however, this is analyzed in 2014. The report is not yet finished. Therefore, there is no political agreement for the further support to the small CHP plants. This has resulted in that the small CHP plants are not changing the fuel, as all are waiting for the new political agreement regarding the different fuels (Ingeniøren 2015 F).

In Denmark, each technology has a specific support system (AA 2013, Kitzing et al. 2012). Therefore, the level of the different technologies is “decided” by the politicians. This can increase, the different technologies in the energy system, but the cost can also increase, as the cheapest technologies are not prioritized.
To decrease the cost of support (with increasing the “clean” market), green certificates can be used. This can be done nationally, as done in Great Britain, or as a Nordic cooperation as Sweden and Norway (AA 2013, Kitzing et al. 2012).

In Denmark, the consumers finance the support by the PSO tariff[25] (Energinet 2015 G). The tariff is based on the market prize for electricity, and is set each quarter. The tariff is used for support of national renewable energy production. The European Union criticizes this, as it makes a difference between energy production in the EU states and Denmark. Therefore Denmark is demanded to change the tariff in the future (Ingeniøren 2015 G).
A change could be a Nordic certificate cooperation, where the cost for support could be decreased with ¼ of the prize (Ingeniøren 2015 G). The certificates are not controlling the technologies used, which will not increase new technologies. As onshore wind turbines have low cost for CO_2 reduction, the capacity will increase, and other technologies will not be feasible with the same certificates (Ingeniøren 2015 G, H). The Nordic cooperation requires an agreement between the countries, for the number of certificates for each country. The development of the renewable technologies will not be specific to each nation. The local impact from the projects, is not divided between the nations. This can increase the opportunity to the cooperation across the borders, and set the national politicians under pressure.
The certificate has only one size for all renewable projects. Therefore, the level of support can be high for developed technologies (such as onshore wind), and too low for new technologies (such as wave energy) (Ingeniøren 2015 G).
In Denmark, the use of biomass is not included in the PSO tariff (Ingeniøren 2015 I). Therefore the use of heat pumps cannot compete with the wood pellets, because of the difference of the tariff for the two technologies. A variable tariff for the electricity could increase the competition as the heat pump could use the electricity when the tariff is low. The variable tariff should be based on the production of wind and solar electricity. For consumers that do not change consumptions, the variable tariff will not change the price from the present. Unlike consumers

[25] Public Service Obligation (PSO)

that do change their consumptions, the decrease in the cost of electricity, will be a positive effect. By implementing the variable tariff, the criticizing from the EU will not change. Another aspect of the variable tariff is the consumer's change, which can be discussed. How large should the price change be before, consumers are changing the use of electricity? And how large are the effect by changing consumer's use, compared to companies?
The present support system in Denmark should be changed, as the country is a part of the EU. However, it is important to make the change public, and make it transparent, for both the public and further developers for energy projects.
At the present technology level, the need for support to renewable technologies, is present. For increasing the green energy. The onshore wind projects, is the only renewable technology there can compete with fossil fuels (Ingeniøren 2015 H). This can indicate that the operating support could be decreased. The support for the local society could be increased with the same level. Thereby the cost for onshore wind projects will not change for the nation, but the profit for the developer will be decreased, and the locals will achieve more for being neighbors to a wind turbine.

3.5 Environmental Impact Assessment

In this section the Environmental Impact Assessment (EIA) analysis is briefly introduced. Later in the thesis, this is used to make a short EIA analysis of a project in Roskilde.
For large infrastructure projects, an EIA is required to investigate the impacts the projects may have on the local environment. In Denmark, an EIA is required for wind projects, when the turbine has a total height above 80m, or the project has more than three turbines (The Danish Energy Agency 2009 A).
In the EIA many topics are analyzed, including the effect on neighbors and community (noise, visualization and shadow flickering), culture historical areas (e.g. churches), flora and fauna and birds and bats.
The EIA process allows the local citizens to see the potential impact a future wind project may have on the environment. The developer and municipality try to ensure the project has no high negative impact on flora and fauna and birds and bats.
The electromagnetic impact should also be described in the EIA, due to transmission lines. However, this has not been an issue for onshore turbines in Denmark, therefore, it is not included in this thesis. See Appendix M for further describing of the EIA including the electromagnetic impact.

3.5.1 Community and Neighbor Impact

This section will introduce briefly an important part of the EIA report that is to illustrate the impact on the community and neighbors.

Visualization

The visualization of the turbines is used to show the impact on the environment. The visual impact is one of the highest factors regarding the siting of wind turbines (Molnarova et al. 2011). The specific number of turbines and height has a high impact. Therefore it is important, to show the visual impact of the exact number and heights of turbines for each project.

Shadow Flicker

As a part of the visual impact, the shadow flicker is important to examine, as this can have a high impact on the environment. The shadow flicker is the interruption of the sunlight by the turbines blades. In Denmark there is a 10h rule per year with flicker impact on residential houses, however this is not a law (The Danish Wind Turbine Owners' Association). The level of flicker is calculated for each neighbor in the EIA for each wind project.

Noise

Another important impact from the wind turbines is the noise. The noise has been shown to be one of the main disturbances from wind turbines, and one of the highest fear for new projects (Pedersen and Waye 2004, Bolin et al. 2011). Therefore, it is important to include the level of noise, at each neighbor, in the EIA.

In Denmark the noise from wind turbines have a specific limit at 44 dB(A) (at 8m/s) and 42 dB(A) (at 6m/s) (Law regarding Wind Turbine Noise 2011). For noise sensitive areas the limitation is 39 dB(A) (at 8m/s) and 37dB(A) (at 6m/s). This should be calculated before the erection of the turbines. In cases of problems with the noise after the erection, the level of noise must be measured according to the IEC- standard 61400-11 (2012).

3.5.2 Birds and Bats

The impact wind turbines have on the birds and bats are being introduced in this section.

As wind turbines are large moving constructions, the impact of these, for the birds and bats is expected to be high. Human activity are increasing the pressure on birds in general (Birdlife 2015). The decreasing of forestry and habitat areas are an increasing threat for the life of birds. For wind turbines it is clear to see the number of killed birds, therefore the big question is the level of the impact, which can be measured by killed bird per turbine per year.

For the EIA, it is important to explore, the different spices of both the birds and the bats in the area. It is needed to have at least one year of survey, as some spices only are present in some month (Kuvelsky et al. 2007).

This indicates that the EIA work is a time challenges, and cannot be pushed forward, to speed up the process.

3.5.3 Flora and Fauna

In this section the research of the flora and fauna in an EIA is being described.

In the EIA, the area should be studyed for protected species of plants, protected areas etc. (Law regarding the EIA). The analysis must be done both by a Geographic Information System (GIS), and by site visits.

All the protected areas, should be avoided for the turbines. The protected areas in Roskilde can be seen in Figure 3-10.

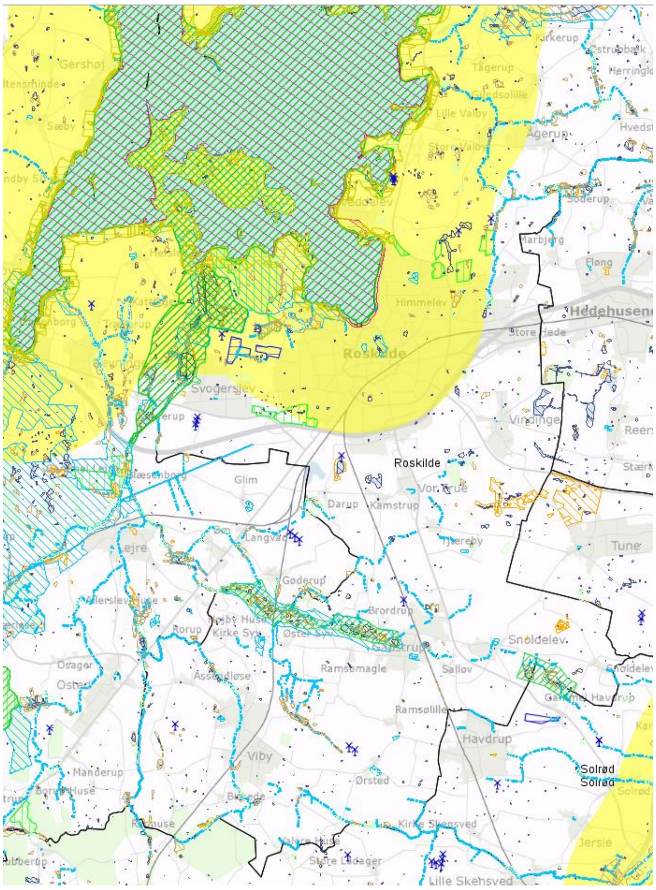

Figure 3-10 GIS map of protected areas in Roskilde municipality.
By a GIS map different protected areas can be explored, this is used for a fast overview of the municipality, where it can be seen, in the north there are large protected areas.
Yellow: Coast protection. Green: Bird protection. Light blue lines: Protected watercourse. Black line: Municipality border. Orange: Protected land area. Dark blue dots: Existing wind turbines.
From (GIS Map 2015)

From the figure it can be seen, there are several protected areas in Roskilde, hence the siting of wind turbines is limited.

Further, the wind turbines should also include the distance to the churches. The impact of the distance to the churches will be described further in section 4.

Before a wind project is being accepted a full EIA report must be accepted by the local council. The time for making an EIA report is around one year, to include all investigations (Volelen 2015). The developer, before any binding contract with the municipality, pays for the EIA preparation and analysis. This is a high risk for the developer and a potential large benefit for the municipality.
The different level of risks and benefits, can give some pressure on the municipality for accepting the project after the EIA report has been done. When the EIA report has been done, the developer has invested time and money, which can give some pressure on the local municipality.
In the next section the role of one stakeholder is analyzed to highlight the importance of

understanding public acceptance and the planning process, in addition to energy modeling requirements.

4. Wind Turbines and Churches

In this section, the relation between wind turbine siting and planning and the role of Danish churches are being analyzed as a way to broaden the analysis beyond energy modelling. First the ecclesiastical sector in Denmark being described, then the organization of Green Churches, and finally a media study is discussed. Churches were selected as a new area of investigation to show their potential role in wind turbine siting decisions and public acceptance.
In Denmark, there are 2350 churches, some from the eleventh century and other are new modern buildings (Aalborg Diocese 2013). These buildings are located, both in the cities and in the country.
The ecclesiastical sector in Denmark, is divided into different levels, this is being illustrated on Figure 4-1.

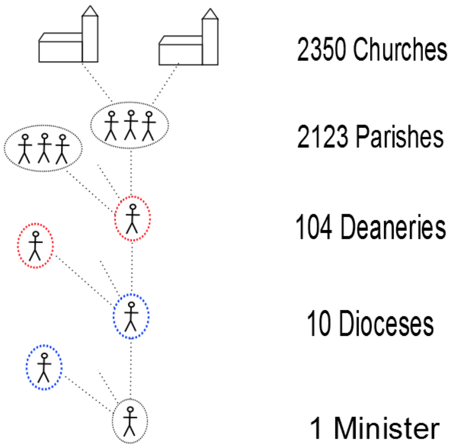

Figure 4-1 The ecclesiastical sector in Denmark
The different levels in the ecclesiastical sector in Denmark are illustrated. There are in Denmark 2350 churches, to control these 2123 groups of voluntary people are connected in parishes. There are 104 Deaneries, there have the direct contact with pastors and parishes. There are 10 bishops they have direct contact to the deans and the minister.
Data from (KM 2015).

Traditionally the churches were built on the top of hills, to show the new believe in Denmark (Lausten 1987). By siting the new churches on the top of the hills, it is shown that the Christian God is the strongest of them all. Present the churches still have a high impact on the environment, especially in the winter, where light is used on the churches (Fischer-Møller 2015).

In the planning process for wind turbines, the churches have a significant role, as they are a part of the Danish cultural history (The Nature Agency 2015) and related to the laws regarding buildings in Denmark. In the nature protection law it is declared that buildings, with a height over 8.5m, are not allowed in a radius of 300m, from a church, unless in cities (law 951 § 19). Regarding wind turbines, the plan must be accepted by every church in a radius of 28 times the total height of the turbine (The Nature Agency 2011 A). This indicates that the visual impact of the wind turbine can have a large impact on the churches placement in the local environment.

Because the churches are a part of the cultural history in Denmark, they have the right to veto, any plan proposal with impact on the church done by the municipality (Law 587 § 29). The churches should be kept as clear visual marks in the local environment, and high buildings or wind turbines can change this. The impact of the wind turbines should be shown, both as behind and side by side with the church, together with a description of the plan, for the local church council to decide (Aalborg 2015).
The municipalities do not have requirement for visualization in the local plan (Aalborg Diocese 2013). This makes the job for the churches hard to assess, whether or not the wind turbines will have a negative impact.
In general the visualization is a part of the EIA, which is done by the developer. Hence, this is done later in the process, where the planning process already is in full motion. This can also indicate more complications, as money already have been spend.
In (Aalborg Diocese 2013) it is being proposed to have visualizations in the local plan, so any objections can be done early by the churches. This could decrease the risk during the EIA- if the churches already have accepted, or being in dialogue with the developer and municipality.
The path for an onshore wind project in the ecclesiastical sector has been illustrated in Figure 4-2.

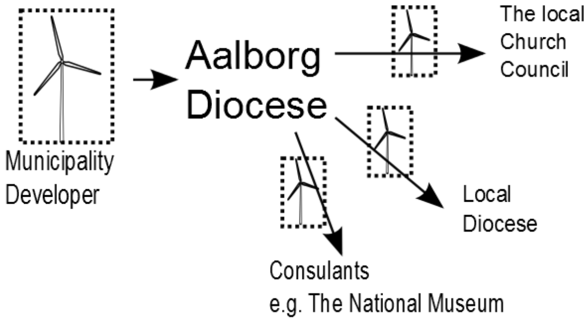

Figure 4-2 The path of the wind plan in the ecclesiastical sector in Denmark
Each plan is send by the municipality or developer to Aalborg Diocese, there has the first screening process. Aalborg is sending the plan to the local church council, the local diocese and to different consultants, e.g. the national museum, for help with impact on the buildings.
Data from (Aalborg 2015).

To increase the knowledge in the ecclesiastical sector all local plans from all over Denmark are send to Aalborg Diocese, for the first screening (Fischer-Møller 2015). In the screening the effected churches are being located and contacted (Aalborg 2015). In the screening process for wind turbines Aalborg diocese sends the plan directly to the affected dioceses and churches (Aalborg 2015).
The screening is done by office workers, based on parameters, which have been agreed by the 10 dioceses in Denmark. To do the screening Aalborg Diocese uses a public GIS map[26]. Thereby it can be investigated, if any churches will have an impact on the project. However, this cannot be seen as a result, but as a guideline.

[26] www.kirkeplan.dk

As there are over 2000 churches in Denmark, the deciding process has been divided into different parishes. A group of 5-15 voluntary people have the authority of the churches, together with the pastors, in the parish (The Danish Church 2015).
These groups, the local church councils, are local citizens, which present have an average age of 60.5 years (The Local Church Council 2014). The high average age and the local engagement can indicate that this specific group of people has a well-established contact to the local citizens. This could be used in the planning process of wind turbines, by increasing the communication to the local church council. However, the local church council is careful not to be frontrunner, in case of a bad project, as experienced with a district heating project in Roskilde (Fischer-Møller 2015).

The local church council is aware of the responsibility of keeping the church as the natural holding point in the country side regarding to the law (Fischer-Møller 2015, Law regarding Churches). The local church council can sometimes over protect the church (Fischer-Møller 2015). An example of over protection is a local church council using the veto against wind turbines several kilometers from the church even though a highway was located 300m from the church (Andersen 2015). This could also indicate that some local citizens can exploit the church's right to veto in projects which is not wanted by the locals even though it does not have a high effect on the church. This has also been experienced by the Bishop in Roskilde, where the diocese stopped a local church council's whish for veto (Fischer-Møller 2015). It was not the church, but local citizens who were against the project. How often this is used is not known, however, it is known that local citizens have contacted the local church council and ask for use of veto (Andersen 2015).

As indicated the wind turbine plan needs to be approved by several different levels in the ecclesiastical sector. The clearing process has been illustrated in Figure 4-3.

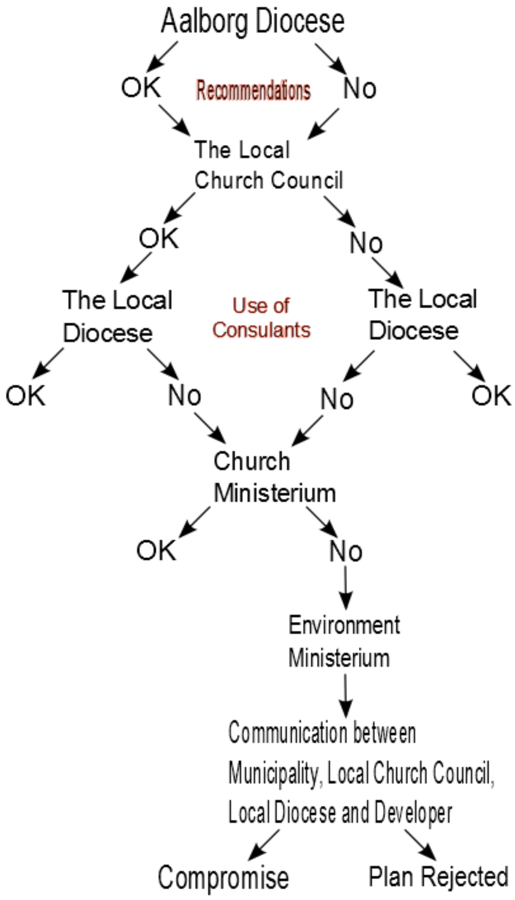

Figure 4-3 The clearing process for an onshore wind project in the ecclesiastical sector.
A plan for an onshore wind project needs to be accepted by several levels, when a plan is not accepted, there are higher levels in the ecclesiastical sector there can neglect this decision, and accept the wind project. Thereby a plan can take long time before being accepted. Where the communication is only implemented in the last level of the clearing path.
The red text is comments of the deciding process
Data from (Aalborg 2015).

Hereby, it is seen, that the plan can be neglected and approved several times, during a clearing process. This can increase the time, even though each level uses short amount of time, e.g. Aalborg uses 8 days (Aalborg 2015). With a use of veto the municipality, the developer, the diocese and the local church council should communicate to find a compromise.
In the screening process from Aalborg diocese, the national energy plan is not included however, in Roskilde diocese the national plan is included, in the recommendations from the energy council (Aalborg 2015, Fischer-Møller 2015). The churches cannot by law invest in wind turbines, as it is not a part of the normal operation (Fischer-Møller 2015). However, the churches are allowed to invest in solar PV, (this is however, not feasible because of changed support schemes). Therefore it could be discussed, if the churches in Denmark should be allowed to buy parts in an onshore wind project at the same level, as the normal electricity demand.
This indicates the importance for understanding the local concerns for each project, and should be included in the planning process. The general advantage for living close to onshore wind

turbines is financial, but for churches there are no financial advantages. Another motivation could be the theological; As God created the earth, the earth has a value of its own and not just as a resource for men (Fischer-Møller 2015). This theological understanding is used as base for the group “Green Churches”.

4.1 Green Churches

In this section the organization Green Churches is being introduced, with a focus on the relationship to renewable energy.
In Denmark there is a group of 148 churches which have agreed, on working towards a more “green” future: “The Green Churches”[27] (Green Church 2015 A).
The Green Churches are working on six different categories, as can be seen in Table 4-1.

Table 4-1 The different categories for a Green Church.
Green Churches in Denmark have to increase the focus in each of the six different categories, there are being described.
Data from (Green Church 2015 D).

The Different categories	Definition
The life/operation of the Church	The church has a specific language to tell the story of God’s creation of life, and say thanks. It is important to motivate the responsibility for taking care of the earth, both as a gift and challenge.
Information about the environment	Make the green church visible, both for the parish and the local environment, in hope to inspire others to have a more “green” lifestyle.
The purchases	The church is purchasing goods with a low CO_2 footprint, this includes all from food and paint to electronic newspapers.
The energy demand	To make an energy analysis in order to find areas where the energy demand can be decreased, especially in the heat sector. Increase the knowledge about the use of electronic devises.
The Transport and outdoor area of the church	Decrease the use of cars, trucks, airplanes when other transport opportunities are available. Plant trees and bushes at the outdoor area of the church, or use the area for bees etc.
The Waste	Reuse the waste, e.g. by activities in the church, or by using the recycle stations in the municipality.

In these six categories, there are 48 initiatives each church can get inspired by. To become a green church, it is necessary to do at least 25 of these initiatives and 2 in each category, see Appendix T for the list of the initiatives.
By these categories it is clear, that the churches are being active in the debate about the climate. From a theological point of view, it has always been obvious, to take extra care for the poor, the widow, and the stranger (Fischer-Møller 2015). The change in the climate is mostly striking the third world countries, aka the poor. Therefore, there is a theological responsibility for doing something against the changing of the climate, not only from the national point of view, but also for the poor and strangers in the third world (Fischer-Møller 2015).
Hereby, it is also seen that the Green churches have a specific theological point of view, which cannot be agreed upon by all churches in Denmark. This can be seen at Figure 4-4.

[27] http://www.gronkirke.dk/

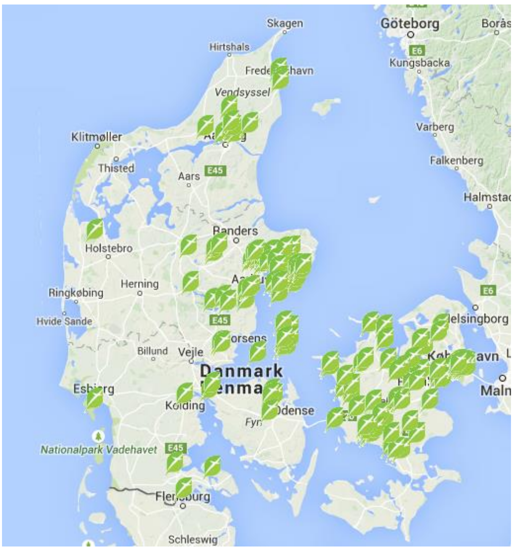

Figure 4-4 The location of all the Green Churches in Denmark.
In west Denmark the number of Green Churches are very low, where the level is high in the large cities in Denmark, and especially on Zealand.
(Green church 2015 C)

As seen, there are few green churches in west Denmark. This can be connected to the general theological point of view in that area: Tidehverv. Originally Tidehverv was based on protest against the theological point of view in Denmark (which was more populistic), and thought religion and politics should not be connected. However through the years Tidehverv and the party Dansk Folkeparti have been more and more connected (Kristeligt Dagblad 2007). By investigating Dansk Folkeparti it can be seen, that the environment is not prioritized. For the environmental politics, it is the finance behind the renewable technologies which is in focus, and the support should be decreased to a minimum (DF 2015 B, 2010 A). Further it is mentioned that all onshore wind turbines should be decommissioned and future turbines should be offshore, or not at all.
This can be connected to the missing Green churches in the west Denmark. When the political point of view is to decrease the priority of renewable energy, the point of view in the local church councils will be the same- for the same people (Fischer-Møller 2015).

There are three Green Dioceses; Aalborg, Århus and Roskilde[28] (Fischer-Møller 2015). This can also be seen on Figure 4-4, where all three dioceses are represented with several Green churches.
As seen the location of the green churches are mostly in the large cities, where the siting of wind turbines is minimum. The location of Green Churches should be investigated for new sites, as these can be a strong stakeholder for a wind turbine project.

As written before the churches have the right to veto against wind turbine projects, if the wind turbine is taking focus from the church buildings. The specific number of vetoes is not known, however it have at least happened 10 times in the last five years (Kommunen 2015 A). The

[28]In Roskilde diocese there are 339 churches and 40 of them are noted as green (Green Church 2015 C, Roskilde Diocese 2015).

local church councils are active in the municipalities, and could be a good contact to the citizens for the developer, if they are included in the communication early in the planning process. Even though the wind plan is sent to Aalborg diocese, and sent directly to the specific local church council, they can have heard about the project before through the media (Fischer-Møller 2015).

4.2 Media Investigation of Wind Turbines and Churches

In this section, a study of what the media in Denmark the last two years have written about wind turbines and churches. This is done by using Infomedia[29].
To analyze the media, articles with the “words” wind turbines and churches in the range of 5 words, have been investigated[30]. It is known, that the narrow number of “words” between church and wind turbine, can exclude some relevant articles, however, 491 articles was found. This was accepted to be used, as base for the media research in this thesis.
Several articles have “The churches against wind turbines” as headline (Politiken 2006, Jydskevestkysten 2011, Kristeligt Dagblad 2015 A). This indicates, that the process between church, developer and municipality, is described as a fight with winners and losers. The right to veto is used several times from the dioceses in Denmark. 6 out of 10 dioceses have used the right in the last three years (Kristeligt Dagblad 2014 A). The admin director of The Danish Wind Industry Association[31], Jan Serup Hylleberg, means that it is important, that the dioceses do not create an automatic veto, against all wind projects in the neighborhood of a church (Kristeligt Dagblad 2014 A). It is important to be aware of, as is Jan Serup Hylleberg’s experience that the number of vetoes have increased in the last years (Kristeligt Dagblad 2014 A).
The most vetoes are against the visual impact of the wind turbines, as the local church council has the responsibility to preserve the churches’ visual location in the local environment (Aalborg Diocese 2013). To explore the visual change, the visualizations are needed to be done, before the churches can make a decision (Jydskevestkysten 2013). This can give an uneven planning process, as communication between diocese and municipality starts late in the process. For the municipality, it can be irritating to use resources on a project, that the church vetoes (Jydskevestkysten 2013).
The developers are using money for making the EIA, and the visualization, hence a veto from the churches is not wanted (Dagbladet Ringkjøbing-Skjern 2014). When a veto right is used, a negotiation between diocese, developer and municipality is started, to find a project, all can agree on (Dagbladet Ringkjøbing-Skjern 2014). If a project is being closed down, the money already spend will have no effect, and this can give further reasons to go to courts, to get rid of the veto (Flensborg Avis 2013).

The direct distance between the church and the coming wind turbines, is not the most important impact, as the environment is very different over the country. It is the visual impact to the church, and from the church, which has an impact. The managing director in the Danish Wind Turbine Owners’ Association[32], Asbjørn Bjerre, means that when churches can use veto against projects 4 km from the church, it is difficult to site wind turbines in Denmark (Århus Stiftstidende 2012).

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[29] http://infomedia.dk/, that have 2377 different medias including local, national and web based medias (Infomedia 2015).

[30] It is written in danish as ”Vindmølle NEAR5 Kirke”

[31] http://www.windpower.org/en/

[32] http://www.dkvind.dk/html/eng/eng.html

Often the ages of the churches in Denmark are used as an argument against wind turbines. Asbjørn Bjerre comments on the age of churches, as they are over 800 years and wind turbines are taken down after 20-30 years (Århus Stiftstidende 2012). Hence, the time the church is affected is relative short. In Denmark, there are often less than 8 km between two churches, therefore, the sites for wind turbines are difficult to find, says Asbjøn Bjerre (Dagbladet Køge etc. 2012).

In some articles, Christian arguments are used (Lolland-Falsters Folketidende 2015, Kristeligt Dagblad 2015 B). An example pro the wind turbines is: it is Christian charity to accept wind turbines, as it will help the countries in the third world against climate change (Lollands-Falsters Folketidende 2015). A Christian argument against the turbines is: One of the seven deadly sins is, greediness. And it is only the turbine owner, who earns money on the turbines (Kristeligt Dagblad 2015 B).

In a wind project, there are often several complaints from the neighbors, about the coming wind turbines. For some projects, the neighbors' complaints do not have a large impact on the project, whereas a complaint from the church, gives the right to veto (Kristeligt Dagblad 2014 B). Erik Toft, a neighbor, writes that if it were not for the church, the complaints from the neighbors would not have any impact (Kristeligt Dagblad 2014 B). Further, he writes that the churches in Denmark have a higher weight than human neighbors, for the project developers (Kristeligt Dagblad 2014 B). Maja Frandsen agrees with Erik Toft's point of view, as the neighbors' complaints do not change a project, but a church can (Dagbladet Holstebro 2014). The fight between the local citizens and the municipalities is being compared, to the story about "David and Goliath" (Sønderborg Ugeavis 2013). As the citizens is the small and weak part, they need to use smart tricks, to win over the large and strong municipality.

By this media investigation it is seen that the visual impact on the environment in Denmark can have an important impact on the wind turbine siting. The churches in Denmark have been noticed on the landscape for several hundred years. The new wind turbines are often higher than a church tower, and the view of the church can seem smaller (Kristeligt Dagblad 2012). The view of Denmark has been characterized by the country churches in a quiet environment. This has however changed, as the view of the countryside today also has wind turbines.
It is seen that both local and national papers are writing about the churches and wind turbines. In Sweden a diocese has started a cooperation with the developer Vattenfall, to create a wind park on a field owned by the church (Kristeligt Dagblad 2009). Diocese director Christer Petré tells, that the church can earn money from the wind turbines, and further it is helping to reduce the climate change (Kristeligt Dagblad 2009). Thereby the discussion about wind turbines and old historic churches, is not only located in Denmark, and should be included in the planning process.
The ecclesiastical sector in Denmark can be included in the planning process as a stakeholder, as one of the important local citizens with decision making power.

4.3 Stakeholder Analysis

In this section a stakeholder analysis is being described, before making a stakeholder analysis for an onshore wind project in Denmark, with a focus on the ecclesiastical sector.
For any project, there are several different people, with impact and interest in the project. To manage them all, a tool such as the stakeholder analysis, can be used.

A stakeholder is a person, a group or an organization, that is involved or interested in the project (Corporate Education Group 2015). The different stakeholders can both be positive for the project and have a negative effect. Hence, it is important to have a close contact with the stakeholders, as they are the most important people for the project (Project Smart 2015).
To make an overview over the different stakeholders, an analysis is carried out, where both the level of interest and influence are noted for each stakeholder (MindTools 2015). Afterwards the communication with each stakeholder should be categorized.
The different communication should be chosen based on interviews. By definition, an interview is a formal conversation by using questions, the interviewer will learn about the person/organization (Dictionary 2015 A). To have a clear agenda for the interview, both parties should know what is wanted, and what is possible by this conversation.
To decrease the resources used on a stakeholder analysis, stakeholders with a low interest and influence could be excluded for interviews. The interviews are used to understand the stakeholders, and the wishes for future communication (MindTools 2015).
A stakeholder analysis can be used to manage different expectations for the stakeholders, and minimize any surprises for the developer (Corporate Education Group 2015). By using the stakeholder analysis, the process with the project can be smoother, because the communication has been started early, and is clear for all the different stakeholders.
A stakeholder analysis is carried out in different phases, described in Table 4-2.

Table 4-2 The phases in a stakeholder analysis.
The four phases in a general stakeholder analysis is being described.
Data from (MindTools 2015)

The level	**Description**
The first phase **The identification.**	The identification of all the different stakeholders for the project. This can be done by a brainstorm. All who have an influence on the project, or have an interest in the project, should be mentioned. During the brainstorm, both individual people, group of people and organizations can be included. However it is important to localize the most important person in each group and organization, for the specific project.
The second phase **The prioritize**	In this phase the different stakeholders from phase one should be divided into four different categories based on level of interest and influence.
The third phase **The understanding**	This is done by conversation, based on questions, with each stakeholder. The questions should both be about information method and level, the motivation for the stakeholder and who the stakeholder will have influence on and who have influence on the specific stakeholder. This interview should be used as base for the communication plan for each stakeholder. It is important to make it clear, before the interview, that the wishes from each stakeholder may not be possible for the project. However, the interview will increase the wanted communication, to each stakeholder.

The fourth phase **The communication plan**	To make a communication plan for each stakeholder during the project. It is important to keep the communication and relationship between the project and the stakeholders, during the entire project.

A small stakeholder analysis is done in this thesis, based on the first three phases as seen in Table 4-2.

4.3.1 A Stakeholder Analysis for an Onshore Wind Project

In this section, a stakeholder analysis, for an onshore wind project, will be done for Roskilde Municipality.
The first step will be a general brainstorm. The subsequent phases will be focusing on the ecclesiastical sector. During a stakeholder analysis, the level of wanted communication between the local church council, the diocese and the developer will be explored.

1. The first phase:
   A brainstorm over all the stakeholders, related to a wind project in Denmark. The brainstorm can be seen in Figure 4-5.

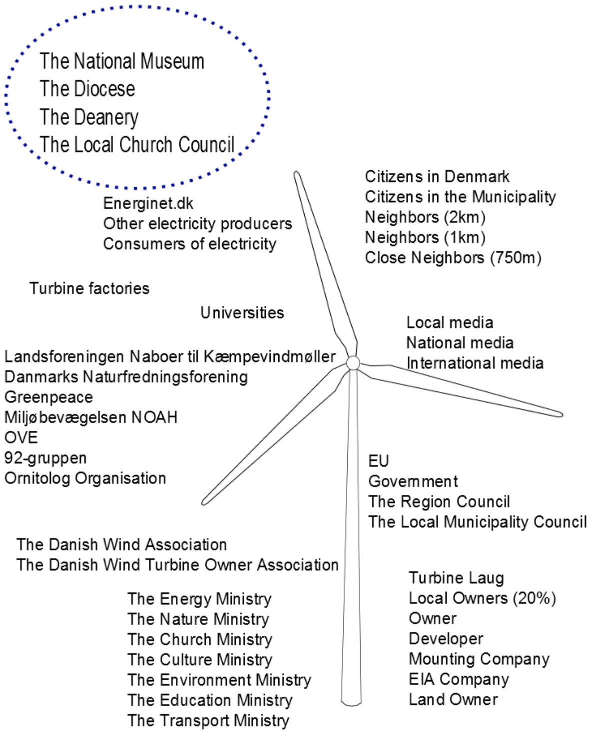

Figure 4-5 Brainstorm over stakeholders for an onshore wind project in Denmark.
The circle area indicates the ecclesiastical sector in Denmark regarding onshore wind projects.

As seen, there are many different stakeholders for an onshore wind project. To decrease the investigation the ecclesiastical sector (see circle at the figure), has been chosen as an example for investigation.

2. The second phase:

In this phase, the sector will be analyzed, by using the method of four categorizes of interest and influence. The priority can be seen in Figure 4-6.

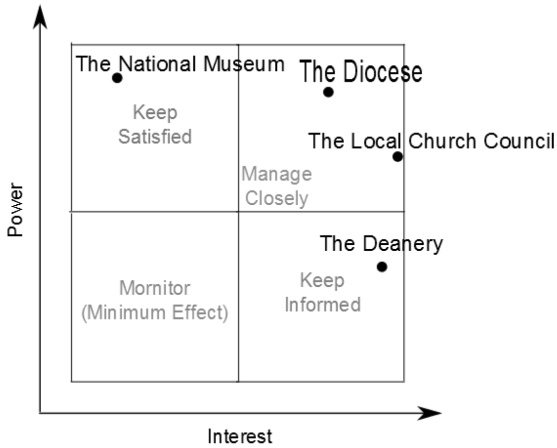

Figure 4-6 The priority of the different ecclesiastical stakeholders for a wind project in Denmark. The Local church council have the highest interest in the project, and have a relative high power, as this is the first level for rejecting a wind project. The Deanery also have a high interest, but not high power, as it is not including in the clearing path for a wind project. The Diocese have both a high interest and power, as this is the second level in the clearing path. To simplify the analysis only the National Museum are including as the rest of the levels in the clearing path. The National Museum have a high power but not interest, as the specific wind project is one out of many for this level.

It is seen that the highest power is the diocese and the national museum, whereas both the local church council and the deanery have a high interest, but a lower influence. The Deanery has no direct influence on an onshore wind project, but often it is used as a sparring partner for the local church council.

3. The third phase:
   To understand the different stakeholders, interviews are being conducted, with different stakeholders from the ecclesiastical sector. The bishop in Roskilde Peter Fischer-Møller and Aalborg Diocese who has the responsible for all first screenings in Denmark, were selected because they are the first actors regarding wind projects in Roskilde municipality. The interviews can be seen in Appendix U (In Danish).
   The research of the ecclesiastical sector can be seen in Table 4-3.

Table 4-3 The Communication parts with the ecclesiastical sector Based on the interviews (Aalborg 2015, Fischer-Møller 2015) a description for different communication parts have been written. This is based on two interviews, and therefore, this is not a final results, but a beginning for communication between developer and the ecclesiastical sector.

Parts for communication	**Description**
Information method	The most important information, for the ecclesiastical sector, is the visualization of the wind turbines' impact on the environment around the church. It is wanted, to keep the churches as a holding point for the countryside.

	As Aalborg diocese has the first screening, all plans should be sent there. However, it could be wanted to increase the direct information to the local church council and diocese. It is wished to have the first information from the developer and municipality and not from the media. Therefore, it is wanted to be included in the early phases of the planning process. This can increase the communication between local church council, local diocese, municipality and developer- which can therefore decrease the use of vetoes.
Information level	The visual impact of the wind turbines is most important, and therefore is wanted to be analyzed from different spots. The visualization should, as a minimum, be made with wind turbines behind the church and side by side. However, as the churches are holding points for villages in the countryside, visualization from the approaches to the village are also wanted. As the church is located for silence and pray both the level and time for flicker and noise are wanted. The time plan for the project is also important for the churches, as the time for construction can have higher impact than the wind turbines.
Motivation	The churches in Denmark are not allowed to buy any shares of a wind project; therefore, there are no financial motivation- as the green externalities are not including the buildings of the church, e.g. the value loss arrangement. The motivation for the general church in Denmark is to keep the visible siting of the churches without disturbing objects, such as wind turbines close to the churches. There is a higher motivation for Green Churches for including wind turbines and renewable energy in general. This is based on the theological point of view: that humans do not control the nature, but have a responsibility towards it. However, it is important, for the developer to understand the differences in the Danish Lutheran Church and therefore understand the specific church at each project.
Stakeholders Influence	The ecclesiastical sector has many different stakeholders, on Figure 4-3 in Section 4 the acceptance path for a wind project can be seen.
Influence on the Stakeholder	The local citizens have some influence on the local church Council. This has been documented both by interviews and by media investigation. Therefore, it is important to start the communication as early in the process as possible. As seen on the acceptance path, there are many different stakeholders to accept the project. To decrease the local resistance, it is important to start with the local church council.

As seen from the table, there is no financial motivation which otherwise is highly used by wind projects. This indicates the need for new communication method. There is a need for respectful communication to the churches with an understanding of the theological motivation.
Often the used vetoes are not directly connected to the final wind turbines, but to the planning process (Kommunen 2015 A). The arguments against the process are that it is not including the historic culture, such as the churches (Kommunen 2015 B).

During the “normal” planning process, the direct communication between the developer, municipality and local church council is not present. It is recommended to start this, as the ecclesiastical sector has a close connection to the local citizens and has the right to veto.
In (Kommunen 2015 A) politicians argue to change the right to veto against wind projects. This is a short term conclusion. As the local environment is feeling like small David (From David and Goliath), it is not a result to take more rights away from them. Instead, the communication should be increased, with understanding and respect for the different motivations.

4. The fourth phase:
   In this phase, the communication plan should be documented. It is important to have different communication plans for each project. Therefore, this is not included in this thesis.

In general all large public projects, such as roads, bridges and wind turbines have some similarities. All have some impact on the nearest neighbors, which are needed to be included in the planning process. How and in what phase in the planning process the neighbors should be included can be found by a stakeholder analysis.
For project managers there are in general three parameters in large projects: time, economy and quality (Ingeniøren 2015 C). There is a need to expand the parameters with an extra reputation. It is important to prioritize the communication for each project, to tell the “great story” of the project. When the communication is one of the parameters, it is more realistic to keep the plan for time, economic and quality.
In Appendix R more about the planning process can be seen, where also a description of the “Good Process” from the national wind task force can be seen. In Appendix S the general complaints from neighbors towards wind projects has been analyzed and discussed.

5. The Present Wind Turbines in Roskilde

In this section the location of the present wind turbines in Roskilde municipality are being documented, together with the Annually Energy Production (AEP) from each turbine.
In Roskilde there are 15 older versions of wind turbines, this is included in the map in WAsP see Appendix P.
The 15 wind turbines can be seen in Table 5-1.

Table 5-1 The present turbines in Roskilde
List over the present wind turbines in Roskilde municipality, with specific turbine, capacity, hub height, location and time the turbine was connected to the grid.
Data from (The Danish Energy Agency 2015 I)

No.	Wind turbine	Capacity [kW]	Hub height [m]	Location	Time for grid connection
1	Bonus	300	30	689297 (E), 6168922 (N) Svogerslev	17-07-1994 (21 years)
2	Bonus	300	30	689270 (E), 6168825 (N) Svogerslev	14-07-1994 (21 years)

3	Bonus	300	30	689243 (E), 6168728 (N) Svogerslev	14-07-1994 (21 years)
4	Nordtank	550	33	694942 (E), 6163921 (N) Brordrup	18-06-1996 (19 years)
5	Wind World	750	45	688686 (E), 6160521 (N) Assendsløse	10-05-1999 (16 years)
6	Danwin	180	30	689965 (E), 6171195 (N) Kongemarken	05-09-1988 (27 years)
7	Nordtank	500	36	694665 (E), 6175505 (N) Veddelev, Risø	01-09-1992 (23 years)
8	GAIA Wind	11	18	694648 (E), 6175441 (N) Veddelev, Risø	-
9	Vestas	225	31.5	697337 (E), 6174352 (N) Veddelev, Risø	13-07-2004 (11 years)
10	Vestas	850	44m	697337 (E), 6174352 (N) Veddelev, Risø	2015 (1 year)
11	Aircon	10	18m	697337 (E), 6174352 (N) Veddelev, Risø	-
12	Vestas	600	44	693240.8 (E), 6167869 (N) Darup	01-06-1996 (19 years)
13	Norwin	599	45	693446.4 (E), 6159930 (N) Ørsted	16-12-1998 (16 years)
14	Norwin	599	45	693606.4 (E), 6159826 (N) Ørsted	16-12-1998 (16 years)
15	Unknown	11	18	696448 (E), 6174021 (N) Veddelev by, Himmerlev	24-08-2011 (4 years)

The average age of the wind turbines is 14.3 years (without the two small ones at Risø which do not have any date). The technical lifetime for a wind turbine is 20 years. This indicates that there are several old turbines in the municipality which could be repowered with a high improvement. The average capacity of the wind turbines is 385.7kW, where the average capacity for new onshore turbines is 3MW (The Danish Energy Agency 2009 A). The present total capacity of the 15 wind turbines are 5.7MW.
The average age and capacity of the present wind turbines indicates the possibility of repowering projects. Whether or not the different sites of the wind turbines, can be used for repowering is depending on the environmental impact. Especially the distance to the nearest neighbors is important.

By including the specific power curves for each wind turbine the annual energy production can be found for each wind direction and in total. The annual energy production (AEP) is calculated, by using the wind data from the met mast, and the different power curves for each turbine. The different AEP’ can be seen in Table 5-2.

Table 5-2 The present Annual Energy Production (AEP) List of the AEP for each turbine in Roskilde municipality. Data from (WAsP)

No.	Wind turbine	AEP [MWh]
1	Bonus 300	440.6
2	Bonus 300	443.2
3	Bonus 300	444.1
4	Nordtank 550	683.9
5	Wind World 750	1374
6	Danwin 180	231.1
7	Nordtank 500	826.2
8	GAIA Wind 11	31.9
9	Vestas 225	403.3
10	Vestas 850	1669
11	Aircon 10	15.0
12	Vestas 600	918.5
13	Norwin 599	1107
14	Norwin 599	1119
15	Unknown 11	28.3

In total the AEP in Roskilde municipality is 8.59 GWh.

6. New Wind Turbines

In this chapter Roskilde municipality will be explored for new wind turbines. This analysis will be based on documentation from (Rambøll 2014), together with a GIS research over the geographical area.

6.1 Siting

In this section the siting of new wind turbines will be explored.
By the analysis from Rambøll 2014, five wind turbines can be upgraded to higher capacity. As one of them has already been upgraded, this is not included in this thesis. The sites of the four wind turbines can be seen on Figure 6-1.

Figure 6-1 Sites for the possible upgrades
The marks are wind turbines that can be upgraded to higher capacity, according to the distance to the nearest neighbor.
Data from (Rambøll 2014) and map from (Google Earth).

As seen on the figure two of the four wind turbines are stand alone.
The limitation for distance to neighbors is not kept by the present wind turbine in Darup (Rambøll 2014). This is used as arguments that it can be repowered with a new larger wind turbine. However, the increased wind turbine height will also increase the impact on the neighbors, e.g. the noise. Based on this, the repowering for the Darup site is not included in the further study.
The upgrade opportunities can be seen in Table 6-1.

Table 6-1 Data for possible upgrades.
Data for the possible wind turbines, which can be upgraded in Roskilde municipality is listed, with age, capacity, upgraded capacity (from Rambøll 2014) and distance to nearest neighbor measured in (Google Earth).

Wind turbine	Site	Age for grid connection	Present capacity	Upgraded capacity	Nearest neighbor
Wind world	Assendløse	16 years	750kW	850kW	370m
Norwin	Ørsted	16 years	599kW	850kW	440m
Norwin	Ørsted	16 years	599kW	3000kW	600m

The measurements done in (Google Earth) are not comparable with the measurements in Rambøll 2014 report for one site at Ørsted. This indicates that the wanted increase to 3MW is not possible, due to the measured distance to neighbors. Further, it is not wanted to have two different wind turbines in one Wind Park. Therefore two scenarios are being studied, one with two 850kW wind turbines, and one with one 3MW wind turbine (the location of this is changed, to meet the distance requirement to neighbors).
Assendløse site can be upgraded to 850kW.

The sites in Roskilde have an extreme wind speed at 30m/s and the mean turbulence is 0.12[33], hence the wind turbines for these sites need to be at least in the class III C. Higher classes can be chosen, as the calculated wind has the least loads on a construction.

By research of different wind turbines, it can be seen that the number of different wind turbines are limited. Vestas has phased out the two V52 and V60 both at 850kW (DGAP 2012). Therefore a Gamesa[34] G58- 850kW can be used for the sites (Gamesa 2007). The wind turbine can operate with different heights. The tower height has been researched for the specific sites, as can be seen in Table 6-2. Where the wind turbine at 3MW also has been implemented both Vestas and Siemens turbines are included in the analysis.

Table 6-2 Height research for each interested site.
The height specifications for the different sites and wind turbines, explored in Roskilde municipality. There are two options for Ørsted, two medium sized wind turbines or one large. Both options are included in the list, together with different turbine specifications. It is seen all wind turbines can handle higher level of turbulence, and the 3.0MW can also handle higher 50 year extreme wind.
Data from (Gamesa 2007, Vestas 2014 A and Siemens 2015 A).

Site	Turbine	IEC standard	Tower height	Total height	Min. distance to neighbor	Nearest neighbor/ Building
Assenløse	Gamesa (58-850 kW)	IIIB	55m (3 sections)	83.3m	333.2m	370m
Ørsted	Gamesa (58-850 kW)	IIIB	71m (3 sections)	99.3m	397.2m	440
Ørsted	Gamesa (58-850 kW)	IIIB	71m (3 sections)	99.3m	397.2m	600m
Ørsted (one wind turbine)	Vestas V90-3MW (Vestas 2014 A)	IA/IIA	105m	150m	600m	613m
Ørsted (one wind turbine)	Siemens SWT 3.0 (Siemens 2015 A)	IIA	83.5m	138.5m	554m	613m
Ørsted (one wind turbine)	Siemens SWT 3.0 (Siemens 2015 A)	IIA	117.5m	172.5m	690m	613m

[33] Both the extreme wind speed and the turbulence have been calculated in WAsP Engineering. See Appendix L
[34] http://www.gamesacorp.com/en/

The location of the new 3MW wind turbine can be seen on Figure 6-2. The distance to nearest neighbor is distance to the nearest building, it is in a farmland, and therefore some buildings are not for living. The nearest building is estimated as non-residential, and the new location is possible for all 3MW wind turbines.

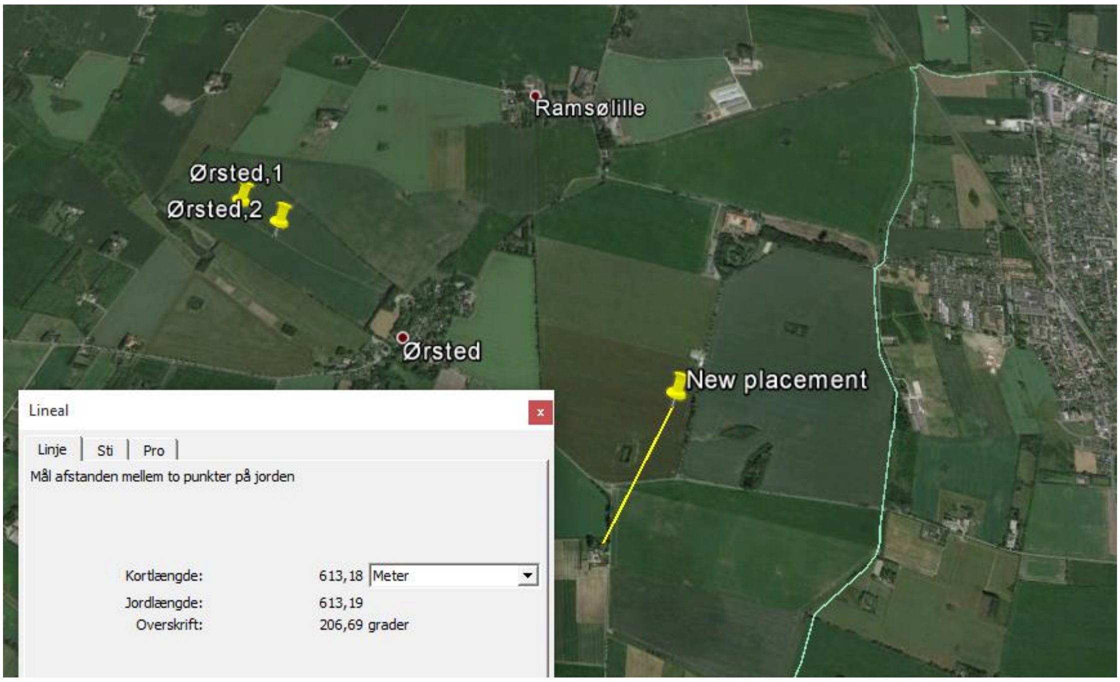

Figure 6-2 Location of the large 3MW wind turbine.
The new location for a wind turbine near Ørsted is located at the opposite site of the city, close to the border of the municipality. The distance to the nearest building is 613.18m. .
Figure from Google Earth.

It is seen on the figure, that the wind turbine is located on the east side of the village Ørsted. As seen, the wind turbine will be located close to the municipality border, hence Solrød municipality has to accept this new site. Therefore, a clear communication should be started with both Solrød municipality and Havdrup village (the closets village in the neighbor municipality).

6.1.1 Environmental Impact Assessment

In this section a short introduction to an EIA study for the location of the new 3.0MW wind turbine near Ørsted village.

Neighbor impact

By the analysis of distance to neighbors, it can be seen, that there is opportunity for a 3MW wind turbine at the new location. However, there is a building close to the wanted location, as can be seen on Figure 6-3.

Figure 6-3 The closest building to the new location.
It can be seen there is a building close by the new wanted site for a 3MW wind turbine. The building is circular and standing alone, hence it is estimated, it is a slurry tank, which does not change the location of the 3.0MW turbine.
Figure from Google Earth.

The use of the building, shown at the figure, should be explored. As seen from the picture, the building is standing alone and is circular. Therefore it is estimated, to be a slurry tank that does not have any effect on or by a wind turbine. The construction of a slurry tank is direct into the ground, and has a connection to the barn. The barn to the slurry tank is on the opposite site to the wind turbine. Therefore the slurry tank does not have any impact on the location. An average height of a slurry tank is 4m (Ministry of Environment). Therefore the slurry tank is not an obstacle for the 3MW wind turbine.
Clear communication to all neighbors should be started as early as possible. This includes the owner of the land. Both the flicker, visualization and the noise should be calculated for the site. The location is between two villages, Ørsted and Havdrup. Ørsted has for the time being two small wind turbines east of the city, and these should be taking down before erecting the new 3.0MW. Havdrup is located in Solrød municipality, thus cooperation across the municipalities is required. Both municipalities are parts of region Zealand, therefore the cooperation has already started with the Energy Cluster Zealand.

Birds and bats
A fast investigation of the area's birds and bats, can be done by mapping protected birds areas, this can be seen in Figure 6-4.

Figure 6-4 Protected birds areas.

The red circle is located at the site for the 3.0MW wind turbine, there are acceptable distances to both protected bird areas.

Figure from (GIS Map 2015)

For an EIA a site visit with calculation of the different birds and bats should be done. It is important to include several surveys, as the entire year has to be documented.

It is being expected, the impact on birds and bats do not change drastic over Ørsted. Therefore, it is concluded, there is no high impact on the bird and bats.

Flora and fauna

For the research of the environmental impact a GIS map is studied for the new site, this can be seen on Figure 6-5.

Figure 6-5 GIS map over the wanted new site.

The wanted location of the 3.0MW (the purple circle) is in the red area, with a distance over 600m from residents buildings. In the thesis the difference between non-residential and residential buildings cannot be seen, therefore only one wind turbine is included in the analysis. Both church buildings, protected areas and a municipality border are close to the wanted location. This indicates the difficulties with finding new areas for wind turbines.

<u>The green area:</u> Forrest building line, <u>Yellow lines:</u> Protected earth and stone dikes,

<u>Light blue lines:</u> Protected watercourse, <u>Light blue area:</u> Protected area,

Black and brawn area: protected habitats, Large black line: Rail ride, Small black line: Municipality border, Red circle: Church buildings and red area: area with buildings over 600m away.
Figure from (GIS Map 2015)

The wanted location is close to both protected areas, the municipality border and churches. There are 6 churches in the range of 28 times the total height, therefore it is important to include these in the planning process. See Figure 6-6 for location of the nearest churches.

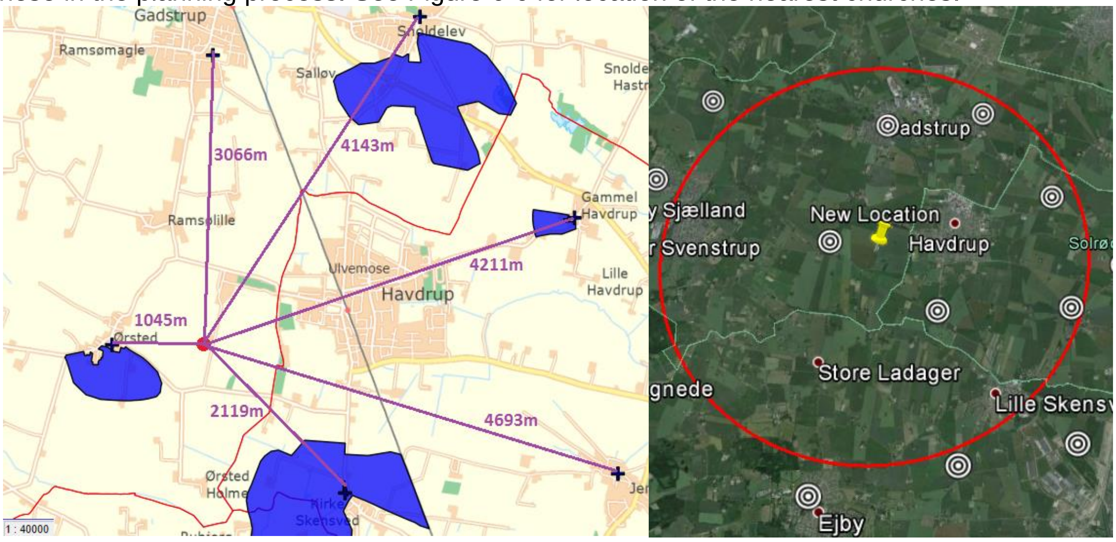

Figure 6-6 The distance to the closest churches.
There are six churches within 28 times the total height (here 4.8km), these should be included in the planning process for the new location.
Left figure: The red circle: The location of the 3MW wind turbine. The black crosses: Churches. The blue areas: areas of the churches. The red line: municipality border.
The purple lines: The direct line between the wind turbine and churches.
Right figure: Circle with a radius at 28 times the total height. The white and black circles: churches.
Figure from (Kirkeplan, google earth).

Even though the citizens in Ørsted have been neighbors to two medium wind turbines in 16 years, the communication should still be clear and early in the process. This should both be done in Roskilde and Solrød municipality.

By the EIA there has not been found any impact against the location of the wanted 3.0MW wind turbine.

6.2 The Grid in Roskilde

In this section the grid in Roskilde is being explored.
For wind turbines it is the capacity of the grid which is most important. As written the onshore wind turbines can be connected to the local grid, however a transformer station is needed. There are four transformer stations in the local grid in Roskilde. There are also a large transformer station west off the municipality border and another large station south off the municipality (Energinet 2014 A).
When there both are local grid transformer stations with a capacity at 150/60 kV or 132/50 kV, and two national grid transformer stations with a capacity at 400/220-150-132 kV, the area has grid connection capacity to site several onshore wind turbines.

6.3 Annual Energy Production

In this section the possible annual energy production is being analyzed.
The three different projects have been researched for the AEP. This can be seen in Table 6-3.

Table 6-3 Annual Energy Production for the new wind turbines.
The different wind projects have been calculated to find the AEP for each of the new wind turbines in Roskilde.
Data from (WAsP

Capacity	Wind turbines	AEP [MWh]
Present Capacity (1.95MW)	Wind World 750kW Norwin 599kW Norwin 599kW	(1374) (1107) (1119) Total: 3,600
Future Capacity (2.55MW)	Gamesa 850kW Gamesa 850kW Gamesa 850kW	(1,863) (2,189) (2,203) Total: 6,255
Future Capacity (3.85MW)	Gamesa 850kW Siemens 3MW (hub height 83.5m)	(1,863) (7,810) Total: 9,053
Future Capacity (3.85MW)	Gamesa 850kW Vestas 3MW (hub height 105m)	(1,863) (6,927) Total: 8790
Future Capacity (3.85MW)	Gamesa 850kW Siemens 3MW (hub height 117.5m)	(1,863) (9,769) Total: 11632

As it can be seen, the repowering project for Assendsløse (Wind World 750kW), does not radically increase the AEP, with a new wind turbine. Therefore, it is concluded, that a repowering project for Assendsløse cannot be recommended. This is based on the low increase of AEP, and the age of the present wind turbine (16 years). Thereby the wind turbine can be hold at least four more years, until the technical age is reached. Afterwards, a new slightly larger wind turbine can be erected at the same site.
The two wind turbines at Ørsted can be increased with a total extra production of 2.2 GWh. However, with one 3MW turbine the production can be increased with 7.5GWh. Therefore, it is recommended to take down the two old (16 years) wind turbines. To make area for a new and large wind turbine at the new site (opposite side of the village). This new wind turbine can be a 3MW wind turbine. It can be seen that the largest AEP is with a Siemens 3MW wind turbine with a hub height at 127.5m.
By a fast search of the map, the wind turbine has a limited height, because of the distance to the neighbors. However, the area is farmland, thereby some of the buildings are not residential and a higher wind turbine (127.5m hub height) is possible for the area.
Based on these conclusions, the new total AEP for Roskilde municipality will be: 16.13 GWh, giving an increase with 7.5 GWh, by repowering one site. Further it can be seen that the AEP from the 15 present wind turbines in the municipality can be relocated (and increased) by only one new wind turbine.

6.4 Feasibility

As seen a repowering project for a new 3 MW wind turbine located at Ørsted can increase the AEP. In this section the feasibility analysis of this project will be done, for all calculations see Appendix Q.

The support for onshore wind turbines in Denmark is feed-in premium at 25 øre/kWh. By calculations of the possible support the 3MW Siemens wind turbine can receive support for 9.5 years (see Section 44 for equations). The real price for wind produced electricity is calculated based on data from the last year, according to the production (Nordpool 2015), and found to be 179 DKK/MWh. See Table 6-4 for inputs in the feasibility calculations.

Table 6-4 Feasibility input

The input used for the feasibility calculation for a 3MW wind turbine in Roskilde. For unknown data different rules of thumps have been used.

Data from (Concito 2011, WAsP, General rule of thumps, Danish Statistic 2014)

Input	
Wind farm Capacity	3MW
AEP	9769 MWh
CAPEX (Capital Expenditure)	22.5 mill. DKK (1Mill Euro/MW)
OPEX (Operational Expenditure)	-87.6 DKK/MWh
Support	0.25 DKK/kWh, in 7.7years
Price	179 DKK/MWh[35]
Lifetime	20 years
Discount rate	6% p.a.
Socio Discount rate	4% p.a.
Inflation	2%
Tax	25%

In the private economy the discount rate, inflation and tax are included. Further there are included a straight-line depreciation.

The 3MW wind turbines gives an NPV at 2.1 mill DKK, therefore the project is feasible. By investigation of the IRR the project is feasible until the discount rate reaches 7.6%. The discount rate for wind projects is mostly between 5-10% (EWEA 2009), thereby the maximum rate for a feasible project is in the middle of a general wind project.

Thereby it is shown the project is feasible from a private point of view. For renewable energy projects the socio economics are also important. Therefore this is being explored.

In the socio economics the support schemes are not included, this has a high impact, as the income decreases drastically. The NPV = -10.4 mill DKK, and the project is not feasible from the socio economic point of view. In the socio study there are some externalities there can increase the feasibility.

[35] The price is based on the last year's price based on the wind production.

The project with one 3MW wind turbine in Roskilde is found feasible for the developer, with an AEP 9769 MWh, as calculated in WAsP for the high Siemens wind turbine.
A study for the low Siemens wind turbine with an AEP 7810 MWh, has also been done, see the results in Table 6-5.

Table 6-5 Feasibility for 3MW wind turbine (hub height 83.5m)
Results for feasibility calculations for Siemens 3MW with a total height of 138.5m.

Results for 3MW Siemens low wind turbine, with an AEP at 7810 MWh.	
NPV (private)	-0.14 mill DKK
IRR (Private)	6 %
NPV (Social)	-12.8 mill DKK
Discount rate (Social)	-4 %

Hereby it is shown that the project with the "low" 3MW wind turbine is not feasible for both the private and the social point of views, and is rejected for further study.

From a social point of view, the cost of CO_2 emission can be calculated. The amount of CO_2 which is avoided from the wind project is 35168 GJ/year, in the total lifetime of the wind turbine this results in 703368 GJ.
The cost for a ton CO_2 is dependent on the level of renewable energy in the system, as it is market based. In 2035 the cost for a ton CO_2 is estimated to be in range of 200DKK to 486DKK, this includes all scenarios. For further calculations the mid case has been chosen: 321DKK/ton CO_2 (Synapse Energy Economics 2015). The cost of the CO_2 reduction, from the wind project, has been calculated by two methods.
- If the replaced electricity is from a coal CHP plant the cost is 70 DKK/ton CO_2, which is low compared to the market base cost.
- If the replaced electricity is from marginal electricity the cost is 351 DKK/ton CO_2, which is higher than the average market cost, however it is lower than the highest cost estimate in 2035.
Based on this the project have been found feasible for the socio economics.

The wind project with the wind turbine with a hub height of 127.5m is recommended for further research. To explore the project further a sensitivity analysis has been done.

6.4.1 Sensitivity Analysis

To research the different inputs for the final NPV, a sensitivity analysis has been carried out. For the analysis, the feasibility calculations, for the Siemens wind turbine with a hub height of 127.5 m has been done. The calculations can be seen in Appendix Q
The five factors in the analysis are: The AEP, the CAPEX, the price for electricity, the level of support and the OPEX. The sensitivity analysis can be seen in Figure 6-7.

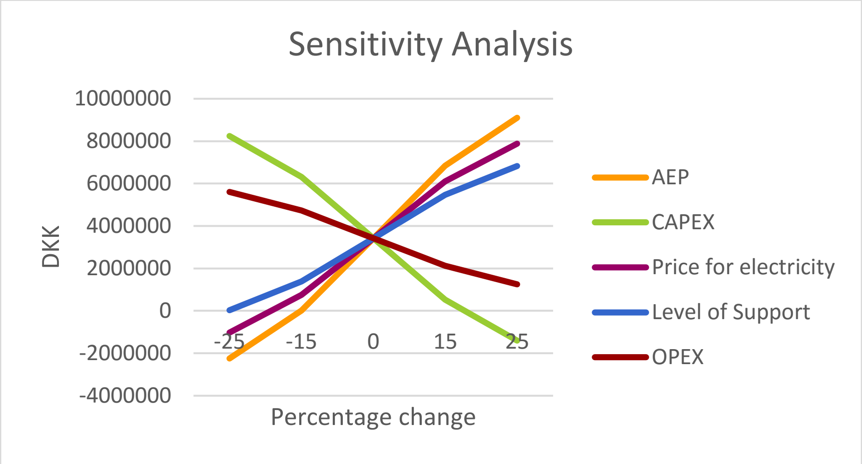

Figure 6-7 Sensitivity Analysis of the 3.0MW wind turbine
Feasibility calculations for a Siemens wind turbine with a hub height of 127.5m, where the different variables are AEP, level of CAPEX and OPEX, price for the electricity and support.

As seen on the figure, the AEP, CAPEX and the price for the electricity have the highest impact on the NPV. The level of the OPEX has the least impact. The level of support has a shown impact on the feasibility. With a 25% decrease of the support the NPV decreases to 20,000 DKK. Even though the support has a high impact, it can be seen that it can be decreased by approx. 10-15%, and the project will still be feasible. The 10-15 % of the support level can be changed from be given to the developer to the local environment.
It can be expected to have a higher CAPEX, as the decommission of the two old turbines is needed before erection of the new one. By the sensitivity analysis it can be seen with an increase of 15 % CAPEX the NPV results in 0.5 mill. DKK, which still is a feasible project. The age of the two present wind turbines are 16 years, the high age is an argument for repowering the area.

The highest risk for the project is the social part. The acceptance from the local citizens is important. As the new siting is close to two villages, Ørsted and Havdrup in Solrød municipality and can have an impact on three churches. Therefore, the communication plan should be clear. It should be a high priority for the project to have local contact, and include citizens, churches and Solrød municipality in the planning process.

6.5 New Areas in Roskilde

In this section a GIS research will be discussed for other possible areas for wind turbines in Roskilde municipality.
There are 8 areas where the distance to the nearest residential building is over 600m. These can be seen on Figure 6-8 for North part of the municipality, which has 7 possible areas, and Figure 6-9 for south part with 1 possible area for wind turbines.

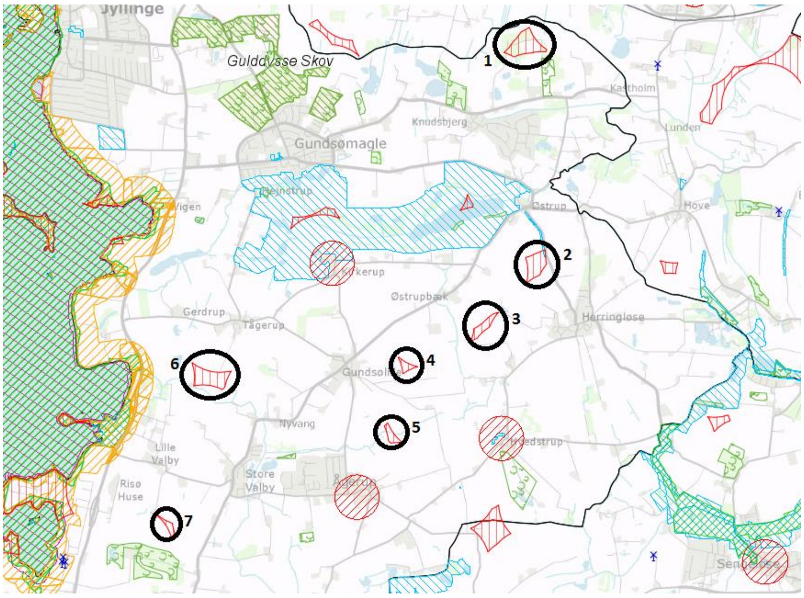

Figure 6-8 Possible areas in Roskilde North

In the north of Roskilde municipality there are 7 possible areas for erecting wind turbines (Black circles).

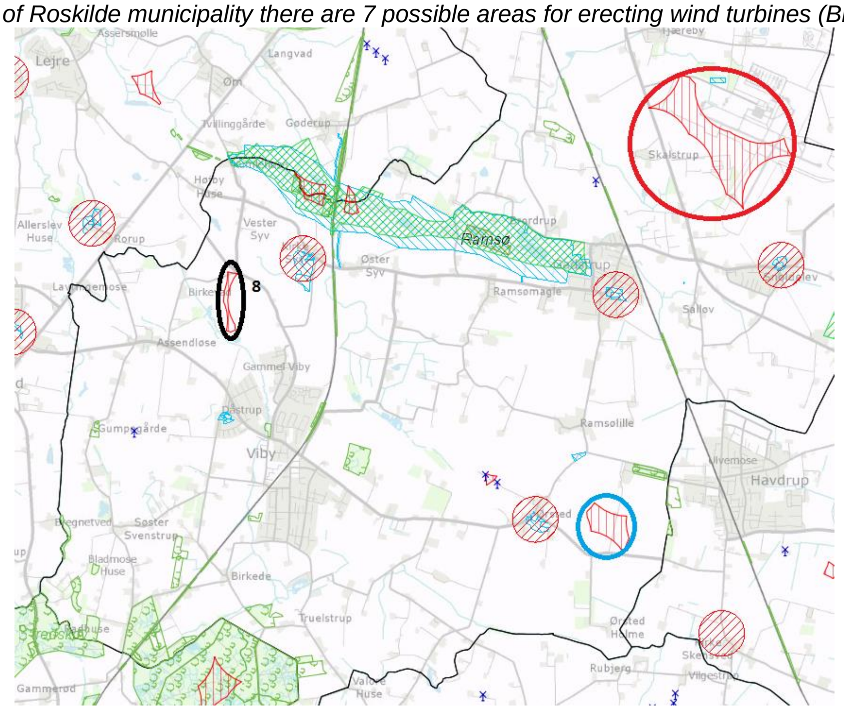

Figure 6-9 Possible area for wind turbines in Roskilde south

In the south part of Roskilde municipality there are two possible areas for wind turbines (including the Ørsted area- blue circle). The red circle is Roskilde airport.

From this fast research it is shown there are other possible areas in Roskilde. Thereby it is possible for the municipality to increase the wind energy capacity drastic. This can be explored in further projects regarding onshore wind turbines in Roskilde municipality.

7. Upscaling Roskilde Model

In this section the STREAM model is being used to upscale the political point of view in Roskilde to a national level. The BAU for Denmark is used as base, where the 7 projects from Roskilde municipality are implemented. This is used for analyzing the effect of the energy politics in the local council in Roskilde on a national level

The research will be based on different upscaling methods of Roskilde municipality; the geographical area, the number of citizens and the energy demand. Description of this can be seen in Table 7-1.

Table 7-1 The upscale methods

The different measurements effects used for upscaling the local politics in Roskilde to a national level. Data from (Danish Statistic 2015, Rambøll 2014)

The investigation of the different upscaling methods	Description and calculation
The geographical area	The geographical area of Roskilde municipality (212km^2) compared to the geographical area of Denmark (42924km^2). (Thus Roskilde is about 0.5% of Denmark). The up scaled scenario has been done by energy production per km^2.
The number of citizens	In Roskilde municipality there are 85516 citizens, in Denmark there are 5678348 citizens (thus Roskilde is about 1.5% of Danish citizens). The up scaled scenario has been done by energy production per citizen.
The Energy Demand	The electricity and heat demand in Roskilde municipality (in 2012) was 79 TJ. The same demand in Denmark was 311388 TJ (Thus Roskilde's demand is about 0.03% of Denmark's demand). The up scaled scenario has been done by energy production in Roskilde, divided by the energy demand in Roskilde.

The politics in Roskilde have been up scaled by three different methods, which are used to analyze the politics in Roskilde. For both the geographical area and number of citizens, the total future capacity has been divided into capacity/km^2 or citizen, and up scaled afterwards to find the different shares of production.

For the energy demand, the different shares have been found based on the electricity and heat demand in Roskilde.

Roskilde had 7 projects researched, however, only 5 was included with capacity increase, therefore, five projects have been included in this analysis, as can be seen in Table 7-2.

Table 7-2 Upscale Roskilde energy production to national level.

The 5 projects in Roskilde municipality that are studied, the calculated shares are based on the upscaling methods from Table 7-1.

Project	Present capacity in Roskilde	Increase capacity in Roskilde	Upscaling by heat and electricity	Upscaling by geogra-phical area by percent	Upscaling by number of citizens by percent	The business as usual scenario from the Danish Energy Agency.

			demand in Roskilde. (Percent of total production)	of national area. (Percent of total production)	of national resident. (Percent of total production)	(Percent of total production)
PV project	412kW	400kW	1.4%	3.8%	1.2%	7%
wind turbine	5.78MW	3.2MW	15.0%	40.1%	13.5%	20%
"oil cities"	9.73MW	-2.6MW	7.9%	10.2%	8.0%	5% (residential) 6% (tertiary) 2% (Industry)
District heating	47.94MW	5.2MW	58.5%	76.2%	59.7%	51% (residential) 70% (tertiary) 10% (industry)
Busses	2790000 km	720000 km	25.8%	25.8%	25.8%	0%

As seen the level of solar PV is lower for Roskilde than the level at national scale in the BAU scenario for all upscaling methods, this indicates that an increase is possible.
The level of oil heated residents (oil villages) is on the other hand higher in Roskilde for all three upscaling methods. This indicates the need for a change in the heating source outside the district heating grid.
The district heating share is also higher for all methods, for the residential sector. District heating has been a focus area, for the municipality several years, therefore, this was expected. This indicates the municipality has a large district heating grid. The heating focus for the coming years could therefore be villages outside the district heating grid.
In Roskilde city a new waste CHP plant was built in 2014, and it is assumed the CO_2 emission to be zero for the waste CHP plant (Energitårnet 2013). Waste has a CO_2 emission level, however, this level is low, compared to coal and oil. The specific emission depends on the mix of waste, therefore the emission is an estimate. In this thesis it is set to the recommended value 32.5 kg/GJ (The Danish Energy Agency 2012 B). The emission of renewables is set to 0.

In Roskilde the CHP plant with waste has a high share of the electricity and heat production. Scaled up to national level this will result in an unrealistic amount of waste, therefore some (16%) of this production has been changed to biomass fuel in the CHP plants, working in backpressure mode. The share of waste (2%) is equal to the BAU.

The wind project results in high differences between the different methods. As seen in both the energy demand and number of citizens the share of wind power is lower than the BAU. For the geographical area the share is however double the amount in BAU. This indicates that the geographical area of Roskilde municipality has a high level of wind.
The different upscaling methods have been included in STREAM, the results can be seen in the level of CO_2 emission.

In any scenario there are some assumptions done, in this it is assumed the offshore wind capacity to be equal to the BAU scenario at 28% of the production. As the local target for Roskilde is to be 100% fossil free in heat and electricity in 2035, all electricity productions with fossil fuels have been set to 0%. This has increased the needed imported electricity, with the emissions set to the marginal electricity in 2030 at 150g /kWh. Both the tertiary sector and the industry sector have been maintained as in the BAU scenario, as this is not included in the plans for Roskilde.

The result from the upscaling can be seen in Figure 7-1 for all scenarios.

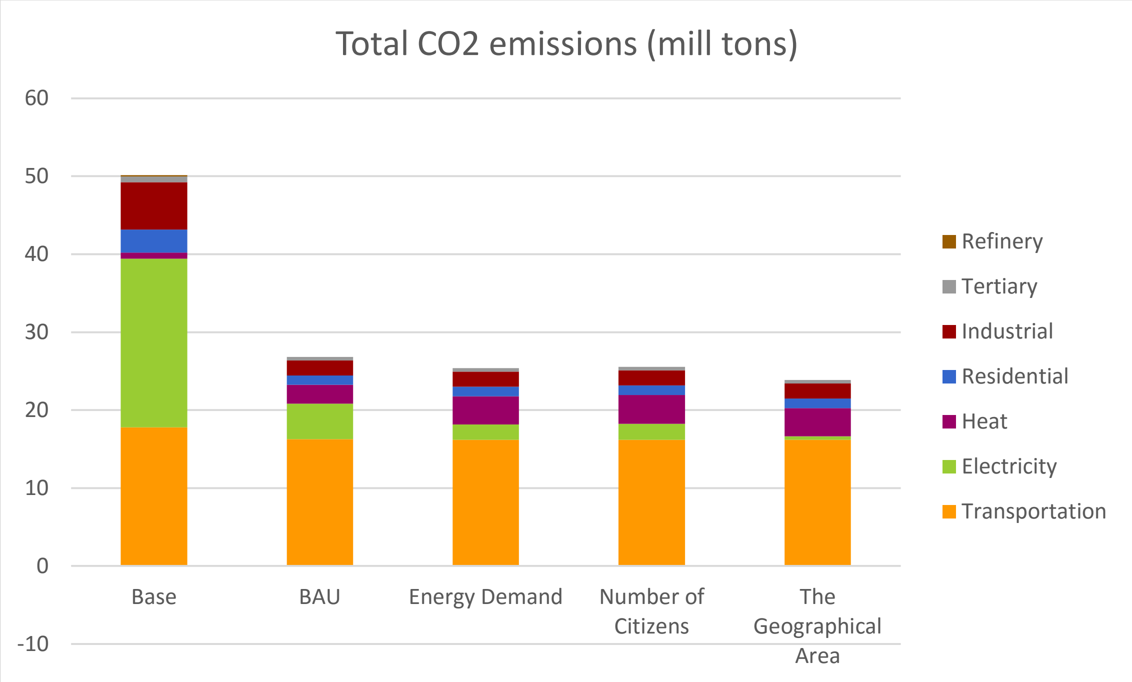

Figure 7-1 The CO_2 emissions for the different scenarios in 2035
The different CO_2 emission for the base (the present emission level), the BAU, and the three up-scaled scenarios. The transport sector has not changed dramatically. It is seen the emissions from the electrical sector is changing for the geographical area. The heat sector is increasing the level of emissions for the three up-scaled scenarios, as the district heating is drastically increased, and the fuels for this is not changed, as this is in cooperation with other municipalities.
Data from (STREAM)

From the figure it can be seen that all three scenarios have an almost constant CO_2 emissions compared to the BAU. As seen the current planned projects in Roskilde do not reach the target with 100% fossil free, with any of the three sectors; electricity, heat and residential.
The similarity between energy demand and the number of citizens is high, which indicates the people in Roskilde have an average energy demand, similar to the average Dane.

It can be seen that the high increase of the district heating grid increases the CO_2 emission when no change in the fuels is applied.
The target for district heating in Copenhagen region has been included in the analysis. Two different scenarios (biomass and wind) in district heating grid in Copenhagen have been studied (Energi På Tværs 2015). In 2035 both scenarios have biomass as the primary fuel. In this thesis

the wind scenario has been chosen, to increase the demand for electricity. This has been changed in the up scaled scenarios from Roskilde. In region Copenhagen the share of waste is 18%, for a national level this will indicate large import of waste, therefore, this has been changed to extra biomass (16%) in the up-scaled Roskilde scenarios, the total share of biomass is 76% and waste to 2% (as the BAU scenario). The share of solar heat is increased to 12% and geothermal to 6%. The result can be seen in Figure 7-2.

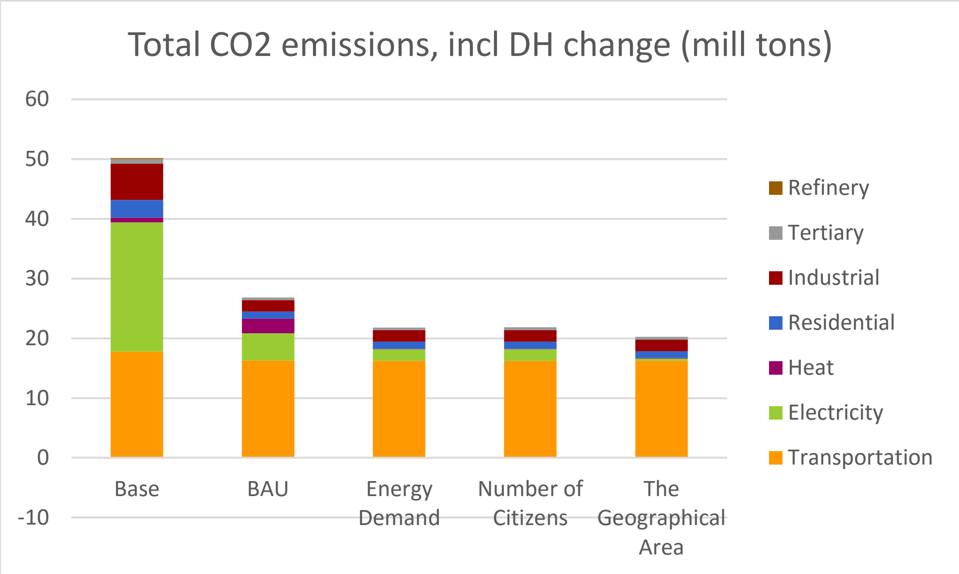

Figure 7-2 The CO_2 emission for different scenarios incl. change of district heating fuel, in 2035. By including the change in fuels for the district heating, the heating sector does not have a large CO_2 emission. However the residential still has an impact, because of e.g. the oil villages. The transport sector has a stable level of emissions, as only the city busses should change towards biofuels. The change in wind turbine share can be seen by the electricity emission.

When including the change in fuels for district heating, the heat sector does not have a large CO_2 emissions, as seen on Figure 7-2. However, the emission from oil villages can be seen in the residential sector. This indicates the need for change of fuels in this sector, e.g. with heat pumps, biomass etc.

It is seen that the transport sector is stable for all scenarios as the target for change in this sector is set to after 2035.

The target for 2035 is to be 100% free for fossil fuels for electricity and heat. By the results in this section it can be seen this is not reached by the 5 projects for Roskilde. Roskilde is depending on other municipalities to have an overproduction from renewable energies for reaching the 2035 target for the municipality.

The national council sets the targets for onshore wind turbine capacity. It is the 98 municipalities in Denmark which have the responsibility for increasing the capacity. The distribution between the municipalities can be discussed, as seen by the up-scaled methods for Roskilde. Onshore wind turbines are depending on both the wind resources and availability of nonresidential area, thereby it can be argued the most reasonable distribution is based on the geographical area. However, it should be noted, the difference in the municipalities. The AEP from the wind turbines is based on the wind resources, thereby; they should be erected in highly windy areas. This should be done without thoughts on the distribution. Municipalities with low wind or low nonresidential area could increase the cost for import of electricity, in order to give higher compensation to the municipalities with high level of wind capacity or by implementing other renewable energy technologies e.g. heat pumps for extra flexibility in the electricity sector. As can be seen on Figure 7-3, the electricity production does not follows the electricity demand. On a national level it is wanted to increase the wind capacity, which will give some periods with high production, on a windy day. On Figure 7-3 the modelled electricity production and demand in week 43 in 2035 can be seen.

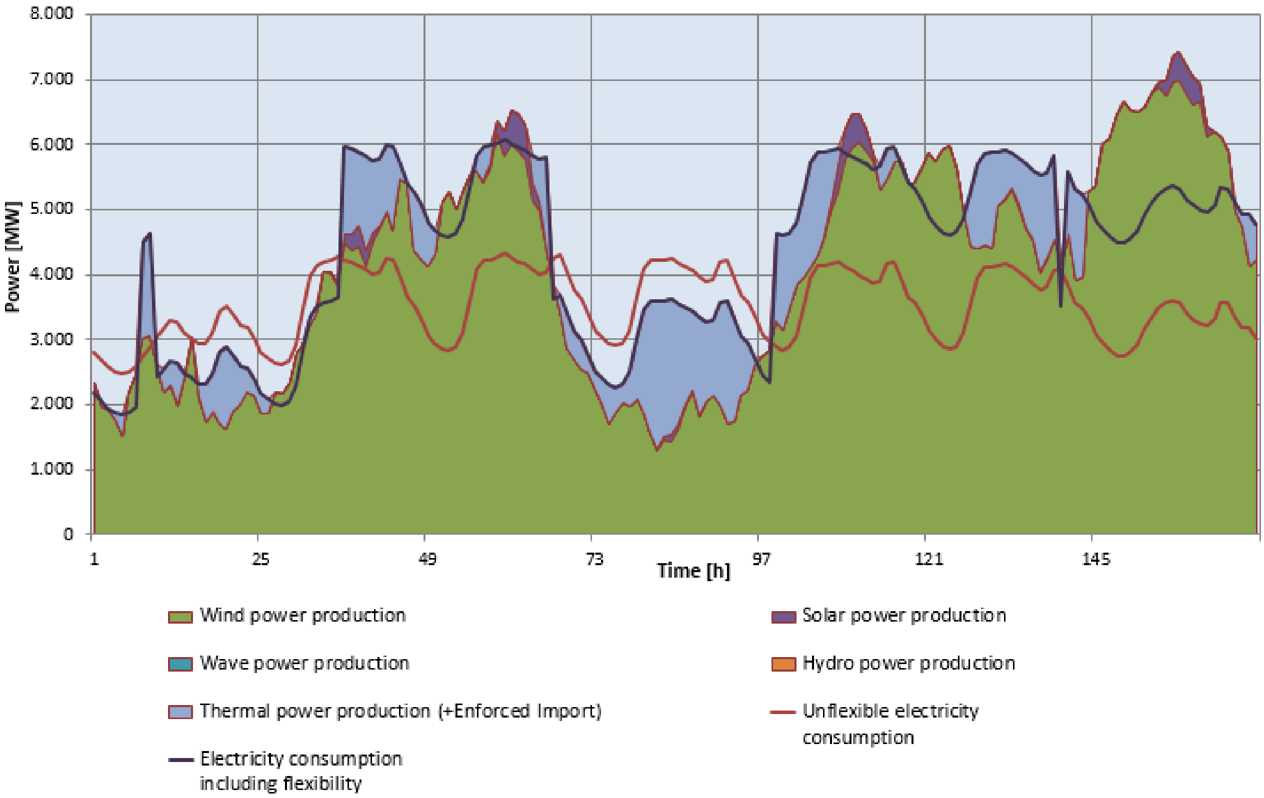

Figure 7-3 Week 43 in 2035 modelled of the electricity sector.

The estimation of the electricity demand and production in week 43 (October). The wind production does not follow the demand, which give a pressure on the flexibility in the system, the orange curve shows the inflexible demand, by increasing the flexibility the demand changes (the black curve)..

Figure from (Duration Curve, STREAM)

As seen there are periods with a high overproduction of electricity (above the orange line). If electricity is not used in Denmark, it is sold to the neighbor countries, often at low prices. By increasing the flexibility in the system the level of this sold electricity could be decreased (the black curve). Roskilde is a part of a large district heating grid, which could be used with flexibility by large heat pumps. Heat pumps could also be used in the villages outside the district heating sector. This would decrease the CO_2 emission level in this sector, and increase the flexibility in the system.

From the analysis it can be seen, that by upscaling the politics in Roskilde according to geographical method both the electricity and heat sector (almost[36]) reaches the target of being 100% fossil free. From that perspective it can be said that Roskilde municipality contributes with

[36] The electricity sector have an emission level at: 0.14 tonnes and heat at 0.04 tonnes.

a fair share to achieve the national targets. However, there is a need for focus on the residential sector, to change the heating fuels in villages outside the district heating grid.

7.1 How to Plan the Future

In this section the effects of the SEP will be discussed.
Roskilde municipality has in 2015 made a SEP for the geographical area of the municipality. Therefore, the effect of implementation of this SEP cannot be measured during this thesis.
The explored SEPs have shown a diversity for the plans in the different municipalities. Most of the municipalities have been focusing on mapping the present energy system, and the cooperation (non-specific where and how) between the municipalities (ENS 2015 Dyhr-Mikkelsen). The Danish Energy Agency is satisfied with the different SEPs, all municipalities in the project have started with a discussion and focus for renewable energy in the municipalities. The mapping of the present energy system is important; however, if all resources are used for this, there is no time for developing the plans and analyze how to reach the political set targets (ENS 2015 Wied). The missing specific plans can be seen in both Roskilde and Høje Taastrup municipalities. The SEPs includes many plans for when to start new research projects, thereby a need for further economic support to implement the projects of the SEP in the energy system is also indicated.

During the final conference for the SEP cooperation in Denmark a compulsory SEP for all municipalities was discussed. It was argued; even though all municipalities make a SEP, this does not equal all municipalities increasing the renewable energy.
It costs a lot to change the energy system (in the short term), however in a long term the CAPEX can be low, for the decrease of CO_2 emissions when externalities are included.
When plans do not have founding for implementing the projects in the energy system, it does not change the energy system. As in Høje Taastrup municipality, where each project for implementing a change, requires founding from outside the municipality (ENS 2015 Lemgart). This can decrease the implementation of the projects in the SEP.

In Roskilde municipality the present renewable electricity production is 3% (Rambøll 2014). Even without any new projects the CO_2 emission is decreasing in the municipality. This is based on the assumed change in the marginal electricity emission. As the offshore wind capacity increases the emission for the marginal electricity decreases, which can be seen in each municipality. This can be seen in the calculations for CoM for Roskilde, which have increased the target to 35% reduction- otherwise there would be no requirements for new projects.

The change in marginal electricity can thereby be used in municipalities instead of implementing new renewable technologies. This can decrease the incentive for investing in new local renewable energy production, but may increase the willingness for electrification of the energy system, e.g. with heat pumps and electric vehicles.

In Denmark, the taxes for electricity are high. Some of the taxes are used for support mechanisms for e.g. onshore wind turbines. At the final conference for the SEP project, the different support mechanisms were discussed. The price for electrification of the heat area has a too high OPEX, as no taxes for electricity are neglected. Biomass as heat fuel is not taxed, which can give a difference in the used fuel. This should be researched further, as e.g. heat pumps can use the peaks produced from wind turbines for windy hours.

The different renewable technologies can decrease the level of export of electricity. The flexibility from the different technologies can be seen by using energy models, which have different sectors included. The models cannot be used alone for a SEP, but can illustrate the impact different projects have. Models can also show if all parts of the energy system have been included in the research, to find the lowest hanging fruits.

During process for energy plans, the local engagement is very important to implement in the plans for the municipality. For wind turbine siting, it is important to engage the locals, as early in the process as possible. A social EIA could be done in the municipality, to increase the connection and communication between residents and the municipality's energy planners. It is important to have arguments for energy changes on a local level, to increase the interest.

7.1.1 National to Local

In this section, the difference between national and local energy plans will be discussed.
On a national level different scenarios are being explored, based on this the government decides the political targets. The parliament has the responsibility to increase the offshore wind capacity. The onshore wind and solar PV targets are set by the parliament. However, the distribution of the targets is not decided by the parliament.
Each municipality is required to point out possible areas for onshore wind turbines, where developers can start the planning process. This indicates that the approach for renewable energy is a top-down process. The renewable energy projects affects the local citizens, therefore a bottom-up approach is preferable, to ensure local accept of the project.

The parliament helps the municipalities financially, for a wind project, both with the support mechanisms for feasibility and by externalities to the local environment. The parliament can also decrease the help, e.g. with the large national health investigation, which started in 2014 (Ingeniøren 2014 A). The health effect of wind turbines is not yet documented in Denmark, therefore municipalities have paused some wind projects until this research is done. This indicates the importance for stable national political will towards wind energy, and renewable energy in general. A planning process for a large wind project lasts several years: therefore a stable parliament is needed, regardless of the different governments.

When the distribution of the capacity is not divided, the municipalities can choose not to be included in the change of fuels. This can both be for political or financial reasons.
The parliament does currently not have any opportunities to force the municipalities into this change. The change is based on a voluntary level.
For starting the change the parliament has helped financially e.g. with starting the SEP process. Every half year the contributing municipalities meet for a conference. This gave motivation for each municipality, to show a progress for each conference (ENS 2015 Dyhr-Mikkelsen).
Through the SEP project, the municipalities made the energy system a conversation topic for the local councils, and thereby, hopefully, started the change in the municipalities' energy systems. It can be discussed if the SEP project has started a top-down pressure from the parliament to the municipalities for increasing the share of renewable energy, or if the municipalities wait for the offshore wind capacity to increase and decrease the marginal electricity emission.

A result from the SEP process in Roskilde can be seen through a new project for the Energy Cluster Zealand. The new project, “Wind as a catalyst for local development”, is document and challenge the local opinion towards wind turbines in the region, to reach a goal for 3-6 new wind projects.

8. Discussion

The motivation for this thesis is to shown the needed cooperation between the energy planning and wind turbine siting. In the energy models, the local resources are included, however, for wind turbine the wind map is not the only impact of the resource use. There are many social impacts in siting of the onshore turbines, and these need to be included. This indicates a need for change in the planning of the energy system, which presently do not include social impacts.

The change of owners of the wind turbines from locals to companies can be an important parameter shaping the local attitude against wind turbines. 5% of the vocal locals can stop a wind project. This shows the requirement for implementing the local environment into the planning, as an active part. For the local society the immediate result of a wind project is not better environment, less CO_2 emissions, lower electricity price etc. The immediate result is a large noisy construction in the backyard.
All communication about wind projects is on international and national level, nothing on a local level (ENS 2015 Hermansen). Furthermore, the arguments used are financial (Petersen 2015): however, the largest earning from a wind project is to the developer.
It is recommended to change the communication towards the local level, as it is essential to give some local advantages for the neighbors.
The local advantages could be a change in the support system. Onshore wind projects are as shown feasible. Therefore, a part of the current given support, could be given to the local environment, to give local advantages, e.g. sports facilities, upgraded buildings etc. However, it is needed to ensure that the locals do not feel “bought”. This should not be instead of the present externalities, but to give the local environment a part of the profit.

In the present planning process for wind projects the ecclesiastical sector has not been included until late in the process for accept. The highest impact for rejecting a project has been found to be the visualization of the wind turbines. It is recommended to make visualization of the wind turbines in the beginning of a project, and begin direct communication to the local church council and diocese. This can decrease the time for acceptance of the plan, and decrease the use of veto based on the local attitude and not the impact on the church.

The present prioritization of renewable energy technologies can also be discussed. Are onshore wind turbines the best electricity production in Denmark?
The change with increasing the renewable energy could be by increasing solar PV or offshore wind turbines. Offshore wind parks have shown, a large increase in the recent years. This increase can give location difficulties. The difficulties with location of onshore wind turbines and cost of offshore, have started a new type of location: near-shore. These projects are controlled on a national level: therefore, the local councils have no power, even though the future wind turbines are near the coast. This has caused large complaints e.g. with the near-shore project Jammerland Bugt in Kalundborg (Sjællandske 2015).

It has been shown in this thesis that the electricity production from the present 15 wind turbines in Roskilde municipality, can be relocated by one 3MW wind turbine. This can be used as motivation for Roskilde. 5 of the 15 wind turbines are located on Risø, and are used for research, however there are 10 turbines which can be decommissioned for erection of one.
The political will to implement wind energy in Roskilde is low. Therefore it can be recommended to argue for other projects in the energy system. This could be by increasing the flexibility by implementing large heat pumps. Roskilde municipality has a large district heating grid, therefore heat pumps can be used in Roskilde and give flexibility in the energy system. However, for large heat pumps to be preferred a change of support is required. All electricity has an extra tax, whereas biomass is excluded from taxes. This has been an argument to increase the use of biomass as heating fuel, instead of electric heat pumps (Ingeniøren 2015 K).

In the thesis different methods have been used. For the siting of wind turbines in Roskilde municipality, the program WAsP has been used. The calculations in WAsP are basis for other siting programs there are used in the industry (Windpro). The location of the 3MW wind turbine is near present wind turbine locations. In Roskilde there are 8 other areas, there can locate a 3MW wind turbine, therefore the location could be researched to find the optimal location both according to the wind resources and the distance to neighbors and churches.

To explore the ecclesiastical sector semi structured interviews of Aalborg and Roskilde dioceses have been used, this could be followed by interviews with developers, neighbors and the local church councils. By including this more point of views would be implemented in the stakeholder analysis. In this thesis one stakeholder has been chosen to be analyzed, this is based on the stakeholders influence, together with the spread location of churches in Denmark, and the increased use of veto in the recent years.
The externalities are used to increase the will to erect wind turbines by the locals- another important stakeholder. These externalities have not been included in the financial method, cash flow, in this thesis. The externalities are different for each project, e.g. the value loss for residential buildings, therefore the feasibility will decrease as the cost for the wind project will increase. The level of cost to neighbors, according to the externalities, is set after the erection of the wind turbines. This increases the risk for a wind project, and can decrease the will for erect wind turbines in some areas.

To explore the politics in Roskilde on a national level, the program STREAM has been used. All models are simplification of the reality, this is needed to be able for analyze the entire energy system. Some of the simplifications in STREAM is the district heating grid. It is assumed Denmark has one grid, to connect all users. When there is one grid, the location of the production do not have an impact in the modelling. Another simplification is the electricity production of the wind turbines. There is one AEP from the onshore wind turbines and one for offshore. It is known wind turbines does not produce the same, this will have an impact of the cost calculations in the model.
By upscaling Roskilde three different methods have been used, energy demand, number of citizens and the geographical area. The best method can be discussed, if it is wanted to decrease the import/export of electricity the energy demand should be used, to ensure same level of production and demand within the geographical area.

The division of the national political set target could be by number of citizens, by municipality (each municipality should produce with the same) or by geographical area. As each municipality is different, the resources are also different, therefore a specific division of the national target is difficult to set. However, it should be possible to demand all municipalities to assist to the national change in the energy system. This could be by a compulsory SEP, which should include practical financed plans, to ensure the change in the energy system.

Roskilde municipality is part of the Energy Cluster, and has done a SEP in cooperation. The direct effect of the SEP in the municipalities in Denmark cannot yet be measured. However, the SEP project has increased the cooperation between the municipalities, and there can increase the cooperated projects in the future. In Energy Cluster Zealand a new project has been an effect of the SEP process. In 2015 the location for 3-6 wind projects in the region will be identified. Thereby location of wind parks close to municipality borders can be increased. In this project the 8 other areas in Roskilde could be analyzed.

8.1 Further Projects

In this section area which could be interesting for further research is described.
During this thesis the ecclesiastical sector's impact on a wind project has been documented. The general planning process for a wind project has not included the ecclesiastical sector. In Denmark the number of churches is 2350 and the use of veto has increased (Kommunen 2015 A), therefore, a project with further analysis of this is recommended. The project could include analysis of the Green Churches, the difference in the 10 diocese, interviews with different local church councils etc.

Research analysis of the different SEP's could also be interesting. This could be used to analyze the difference in the plans, and the effect of these. Furthermore mapping of the subsequent projects from the SEP process could be done, to document the impacts. This documentation could be used in discussion of financial support to other planning projects on a national and local level.

9. Conclusion

In this interdisciplinary thesis the energy changes on a municipality level have been researched, together with energy planning, modeling and siting of onshore wind turbines in Roskilde municipality. In particular the importance of one stakeholder, the ecclesiastical sector, was explored for the future planning process for onshore wind turbines as this surprisingly has not been investigated previously despite the influence they have on the planning process. A single church has the power to veto a wind turbine project. And in fact this right is often used as 6 out of 10 diocese has used this right in the years 2011-2014.

In 2015 the national project for implementing strategic energy plans in municipalities was completed. Roskilde was included in the regional Energy Cluster Zealand. From analyses, it has been shown that the municipalities have made the plans differently. In Roskilde the focus was on increasing the district heating. From a report in 2014, this was shown to have the highest impact on CO_2 reduction at 6486 tons/year (Rambøll 2014).
A political target in Roskilde and national is 100% free of fossil fuels in 2035 in the heating and

electricity sector (Roskilde Municipality 2015 A). This indicates a necessary change in the electricity sector as well as heating. The change in the electricity sector can be realized with the use of onshore wind turbines. In this thesis, it has been documented that one 3MW wind turbine has an annual energy production at 9.8GWh, where the 15 present wind turbines in the municipality have a total annual energy production at 8.6GWh. Thereby one wind turbine can increase the production from wind turbines in Roskilde by 14%.
The strategic energy plans have increased the collaboration between the municipalities. The increased collaboration may result in more projects across borders, e.g. wind projects. This can be seen in the new project from the Energy Cluster Zealand with planning and siting of 3-6 wind turbine projects in the region.

It is shown that Roskilde can have a feasible wind project, seen both from the private (Net present value at 2.1 mill DKK) and social economics (by including the cost of CO_2 in the range of 70-351 DKK/ton CO_2). By taking down two old wind turbines west of Ørsted, it will be possible to erect a new 3MW wind turbine east of the village.
Previous wind projects have proven, that local concerns may have a large impact on the feasibility of a project. Therefore, it is important to consider the different stakeholders in the planning of both the energy system and the onshore wind turbines.

One of the important stakeholders is the ecclesiastical sector. In this thesis, the importance of including the local church council and diocese, early in the planning process has been pointed out. Especially in relation to the visualization of the wind turbines and the churches has a large influence on the acceptance from the ecclesiastical sector.
In some projects the local church councils have considered and acted upon the local resistance in the decision (Fischer-Møller 2015). By early communication between developers, local church councils and dioceses the motivation for the veto can be identified, and the late use of veto can be decreased. Further research in this area is recommended.

By upscaling the energy politics in Roskilde to a national level, it is shown that Roskilde is in front on the district heating sector compared to the national BAU scenario. However, Roskilde is dependent on importing of energy (4.4% of the electricity production). At the up-scaled scenario, it is required to further decrease 1.84 mill tons CO_2 emissions to reach the 2035 target. Especially in the heating sector, outside the district heating grid requires a new project with a decrease at 1.16 mill. Tons CO_2.

In this thesis it has been shown that planning and siting of wind turbines are important to include in the planning of the energy system, as it is not only the wind resources that make a good project, but the planning process with consideration of the different stakeholders, the EIA process, the grid, and economic feasibility should be included.

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Appendix A The National Energy System

National Energy

Resources in Denmark:

In 1970', there was a large oil crisis, which resulted in an increased political focus on safety in the energy supply (Gyldendal 2015 A). The supply safety gave an increase in the use of natural gas, and decrease the oil use- Denmark increase the search for oil in the North Sea (Gyldendal 2015 A), which also increase the safety of supply. The energy system was based on fossil fuels; oil, natural gas and coal, where there still is a large part of the coal and oil in the present energy system.
Later the political objectives were not only the safety of energy supply for Denmark, but also the environmental changes, as increased global temperature. To decrease the temperature rise, the renewable energy in Denmark have been investigated.
On Figure A-9-1 the change in the different energy fuels can be seen from 1972-2012, it is clear to see the decrease in use of oil, and increase of natural gas and renewable energy (The Danish Energy Agency 2015 A).

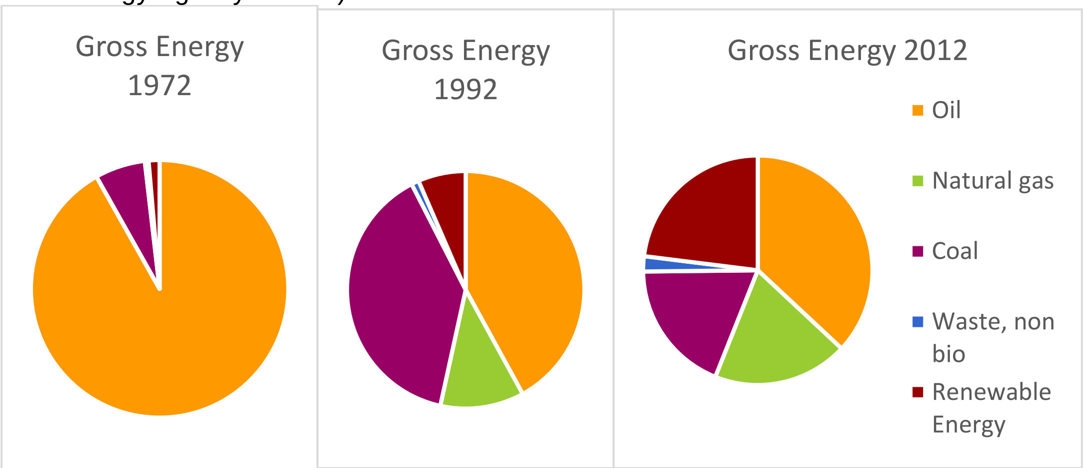

Figure A-9-1 Energy fuel from 1972-2012
Data from (Ens.dk)

The gross energy includes both the heating, electric and transport sector. Each of these sectors are important for the total energy system, and are needed to be included in a future strategic energy plan.

The present energy system

In this section the present energy system in Denmark will be describe, to have a clear understanding of the system, it is divided into the three sectors; heat, electricity and transport.

The heating sources

60% of the households in Denmark are using district heating (The Danish Energy Agency 2015 B). The rest have individual heating sources, such as oil or gas burner, heat pumps or wood burner.
The district heating has been increased since the crisis in 1970' to decrease the use of individual oil burners. The district heating is using the excess heat from the electricity production the Combined Heat and power plants (CHP plants) and the fuels used for the district heating can be seen in Figure A-9-2.

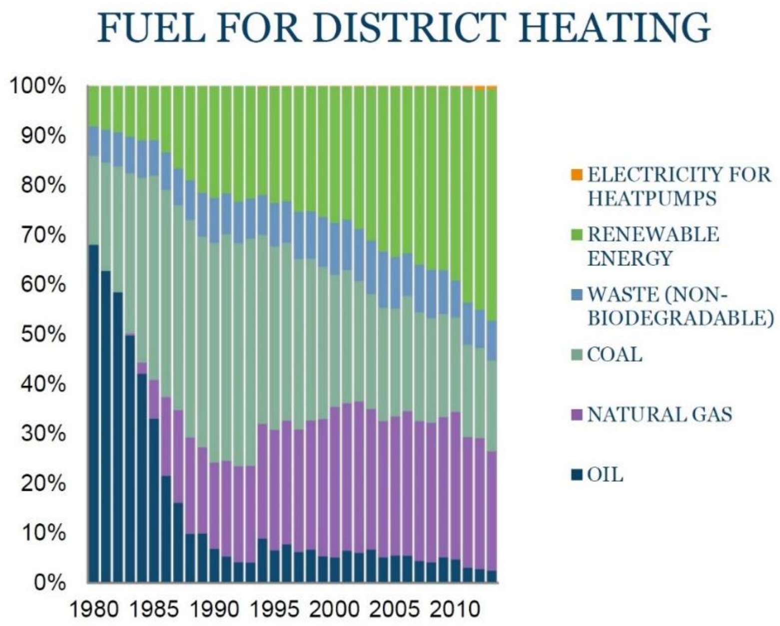

Figure A-9-2 Fuel for district heating in Denmark.
(The Danish Energy Model 2014)

It can be seen that the waste have been almost constant in the period 1980-2014, whereas the renewable energy and natural gas have a high increase.

The electric sources

In the electric sector the renewable energy, has also a high increase and the use of fossil fuels has decreased in the same period. The change in fuels for electricity production can be seen on Figure A-9-3.

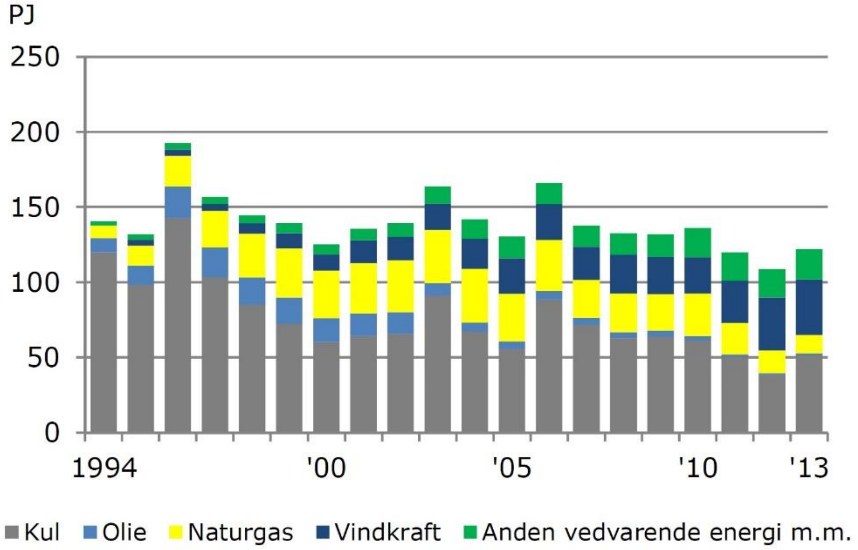

Figure A-9-3 Fuels for electricity production in Denmark. The color code: grey: coal, Light blue: oil, Yellow: natural gas, Dark blue: wind, Green: other RE.
From (Energy statistic 2013)

As seen the renewable energy have a significant impact on the electricity production, whereas wind has the highest impact, both onshore and offshore are included.

By expanding the onshore wind park instead of the offshore wind park, the Danish society can save 30% (Ingeniøren 2015 A). Which areas will have the highest output of the onshore wind turbines can be seen on Figure A-9-4.

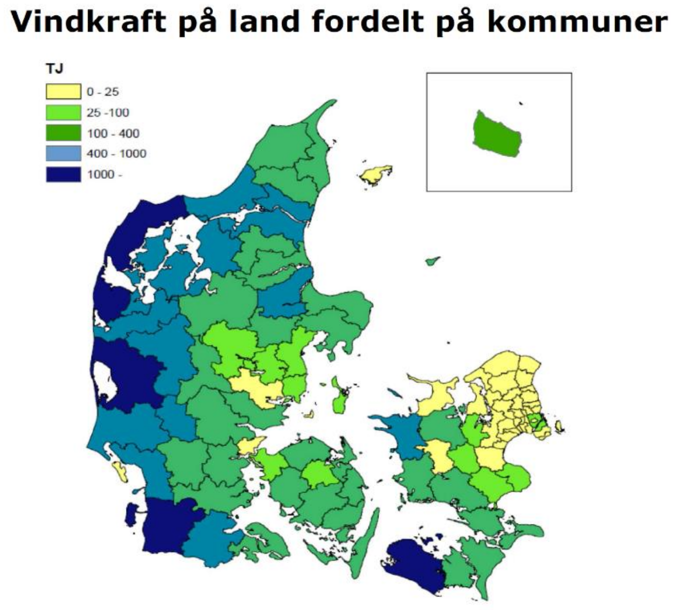

Figure A-9-4 The wind capacity in Denmark.
The wind capacity in Denmark, divided into the different municipalities,
From (Energy statistic 2013)

It is clear to see the highest capacity of wind is in the west part of Denmark. Roskilde municipality has a wind capacity between 25-100 TJ, which indicates there are some opportunities for increased wind in the municipality.

Onshore wind gives a high economic advantages, the visual impact for the public will be high, which can give some conflicts between the economic consultants and the locals.

The transport sources

In Denmark the highest transport is the personal transport in 2013 the personal transport (counted on the energy used) was 74.3%, where the transport of goods was 24.8% and the rest was the transport of the military (Energy statistic 2013).

In the personal transport, the cars and air transport have the highest impact (Energy statistic 2013). The personal cars have the highest impact of the energy use in the transport sector, the fuel used for cars is mostly oil based, 70% have gasoline as fuel, 29% have diesel as fuel and only 1% is electric (Electric car facts 2013).

This indicates the resource for transport in Denmark is mostly based on oil, both diesel and gasoline.

An overview of the energy system in Denmark can be seen in Table A-9-1:

Table A-9-1 Analysis of the present energy system

Sector	Description (The Danish Energy Agency 2012 B)

Heating	40% of the energy demand is used for heating of buildings and water. The different production methods should be investigated to reach the demand.
Electricity	20% of the energy demand is used for electricity. The different production methods should be investigated to reach the demand. The demand should be divided into different ending users.
Cooling	13% of the energy demand is used for cooling. The production methods should be investigated. Further it should be investigated if the electricity use for cooling is included in the electricity sector.
Process	Process energy is used for the industry. The level of process energy should be included, together with the different production methods used to reach the demand.
Transport	This sector could be analyzed by two different methods, before the investigation it should be discussed which is most relevant for the specific municipality. The municipality can be analyzed as a geographical area, however this is not to prefer for a municipality with a large level of commute through transport. However it should be documented the level of going through transport. The second method for analyze is to investigate the transport level of the residents in the municipality.
The buildings of the municipality	The energy use, both electricity, heating and cooling should be included in this. It should be clear if it is included in the previous sectors.
The present electricity and district heating production	The level of production of electricity and district heating in the municipality should be investigated, e.g. the capacity of onshore wind turbines. This is done to include all minor production, especially the renewable energy production.

Appendix B National Energy Policies

In this section the politics in Denmark regarding the energy sector will be described. There will only be used plans there have already been agreed in the parliament, to decrease any political points of view in this thesis.
In Denmark, there has been planned energy transformation until the year 2020. Because Denmark is a part of the EU, it is also a part of the European energy plan, where the CO_2 emission should be decreased with 20% in 2020 compared to the 1990 level. Further the Danish government have set the goal at 40% reduction of CO_2 emission in 2020 compared to the level in 1990 (Energy and Climate Projection 2014).
In 2015, the national election changed the political government. The previous government had increased the target for the emission reduction to 40% (Ingeniøren 2015 B). In August 2015, the new government set the proposal, to decrease the ambition to 37% (as in the agreement from 2012) (Politiken 2015 A). As the thesis is written, this is being discussed in the parliament. Therefore in this thesis an energy level of 37% is assumed.

The agreed energy targets for Denmark can be seen in Figure B-1.

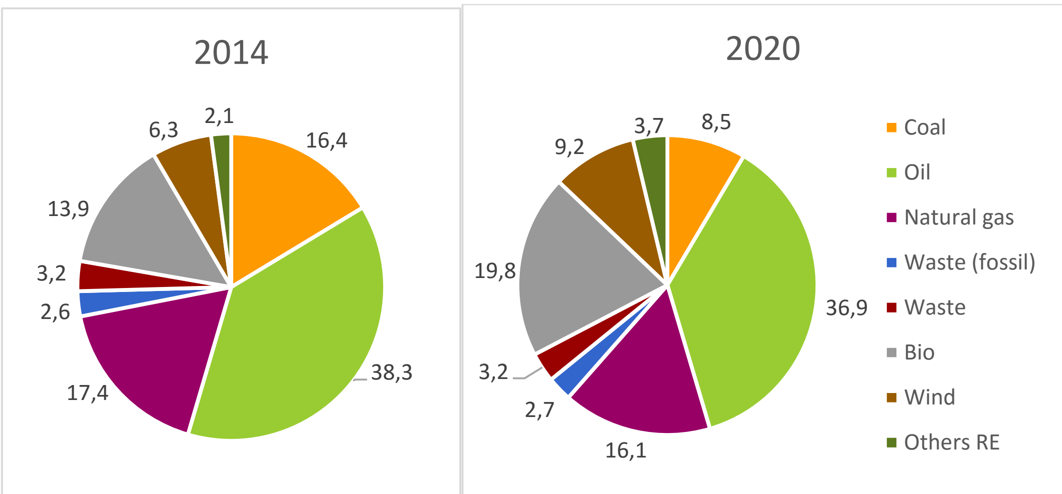

Figure B-1 The political set targets for the energy sector of Denmark.
The difference between the energy resources in 2014 and the wanted resources in 2020. It is seen the fossil resources are decreasing, however, oil are increasing- there is mostly used for transport. Both wind and bio are increasing in the time period.
Data from (The Danish Energy Agency 2015 D)

As seen, the consumption of oil, there mostly are used for traffic, does not change radically. However, both the use of natural gas and coal, are decreasing in the ten years shown. Whereas, both the use of biomass, wind and other renewables are increasing.
To be able for reaching the goal at 37%, several sectors needs to contribute, the level of renewable energy has to increase dramatically, as it is expected to have an increase in the final energy use from 616PJ-623PJ for 2012-2020 (Energy and Climate Projection 2014).
The transport sector stands for a third part of the final energy use in Denmark, hence this sector has a high part of the fuel use. As written the transport sector use mostly fossil fuels, as an European energy plan 10% of the fuel for transport should be renewable in 2020 (Energy and Climate Projection 2014).

For an increase in renewable energy, there is a need to be focused on the available energy resources in Denmark. There is as known a high resource in wind, which also can be seen in the energy plan for Denmark in 2020 where the wind is set to produce 51% of the electricity, 20% of the electricity is from other renewable energy beside wind, this is mainly bioenergy, waste and solar.

The wind share will be increased by increasing in the number of offshore wind parks, e.g. the Krieger's flak with a counted capacity at 600MW, this wind park is in tender at the moment and will be built before 2020 (The Danish Energy Agency 2015 C).

As written a national target, is to implement large capacity of wind energy. Wind energy is fluctuating, as the production is based on the wind. The fluctuating production of electricity, can be implemented, in the national energy system as, e.g. the large Combined Heat and Power plant (CHP plant) can increase and decrease the electricity production, as long as the level of fluctuating production is low.

When the capacity of the wind increases, the level of fluctuation electricity can be too large for the CHP plants to handle'. Therefore, the export of electricity, to the neighbor countries is required for the national system. At Figure B-2 the export (negative values) and import (positive values), can be seen for Denmark.

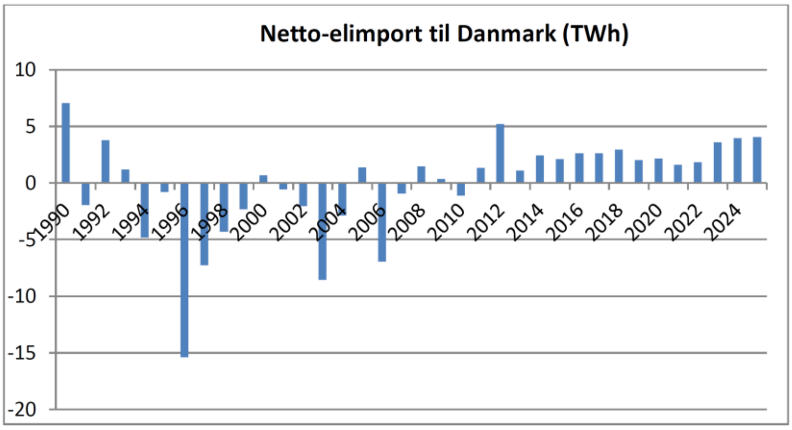

Figure B-2 Electric import and export for Denmark (TWh) in the period 1990-2016. Before 2008 Denmark exported mostly electricity. Present Denmark is importing electricity, and it is expected this import will increase in the future. From (Energy and Climate Projection 2014)

As seen, the import has increased the last five years, and it is estimated that this will increase further in the future (Energy and Climate Projection 2014). The Danish electricity system relies on the electricity systems of the neighbor countries; hence, the electrical connections also have a high impact on the energy system (Energy and Climate Projection 2014). On Figure B-3 the international connections can be seen, which are used for import/export of the electricity.

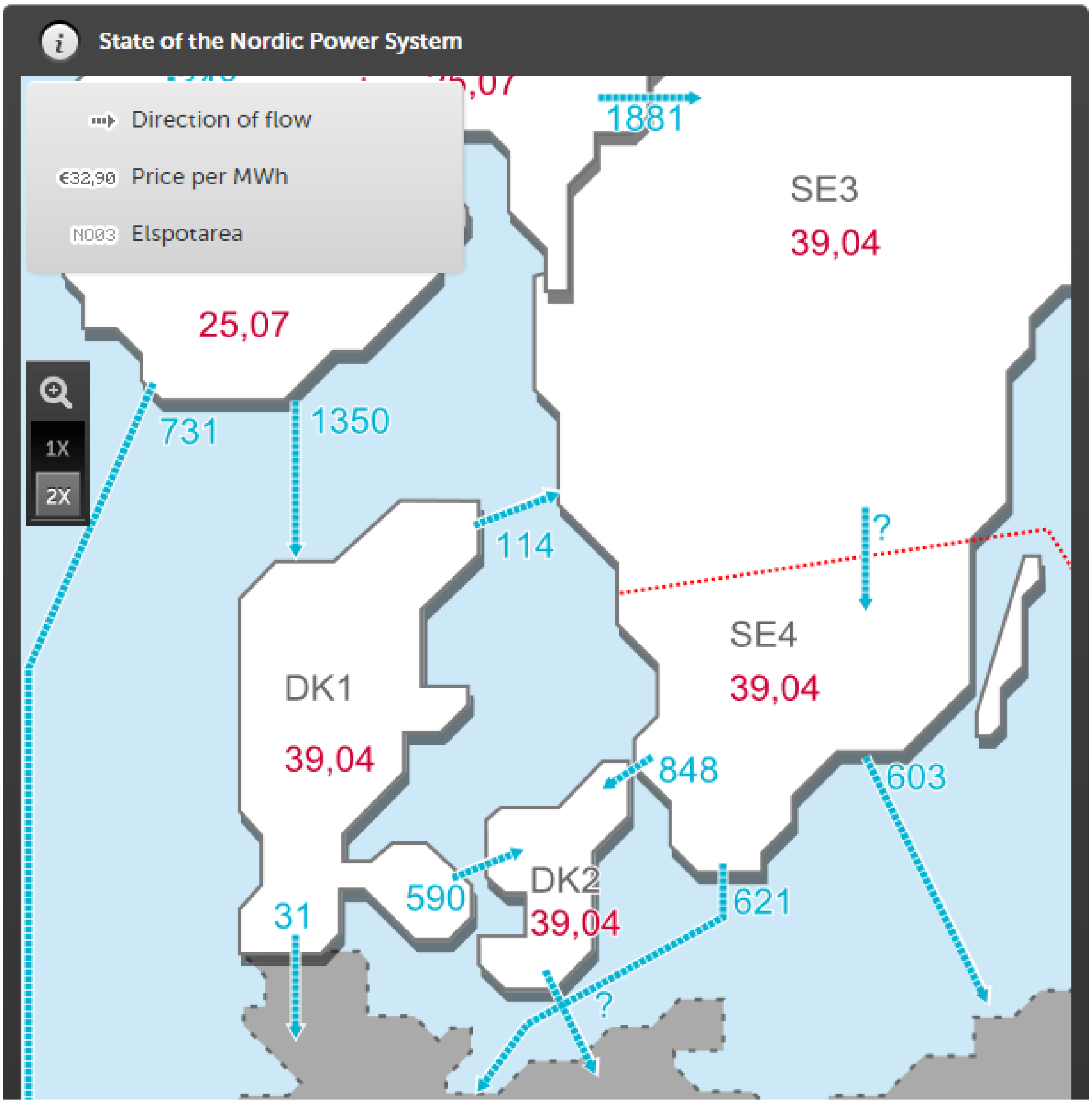

Figure B-3The Nordic Electric System.

The Nordic electricity connections, across the national borders. The level figure is from October 13, 2015, 09.40. The level of electricity transfer and cost can be seen at each electricity system.

Figure from (Energinet 2015 A).

To increase the renewable energy in the heating sector, the CHP plants is changing from coal as primer fuel to biomass, this will decrease the fossil fuel in the district heating from 50% in 2012 to 28% in 2020. Further the electric heating should be used, in times where there are a high production based on wind.

In Figure B-4 the change in the energy sources can be seen. In 2020 oil is still the highest impact on the energy sector, this indicates that the change in the transport sector is low until 2020. It is seen that coal decreases 7.9 percentage points in the 6 years, where bio, there includes solid biomass, biofuels and biogas, increases with 5.9 percentage points.

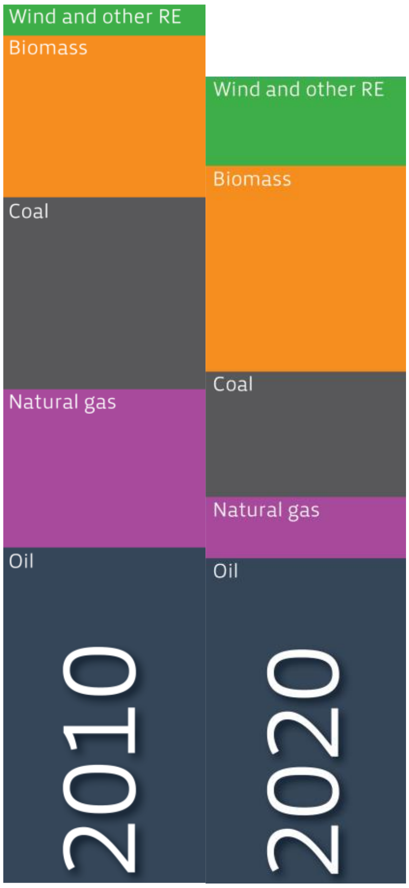

Figure B-4 The political target for fossil fuels in Denmark
Figure from (The Danish Energy Agreement 2015)

As the years goes by, new energy plans are needed for Denmark to ensure the renewable path, this can be done by introducing different energy scenarios for 2050. The Danish energy agency did five[37] different scenarios to show the effects of each, both energy wise and economical (Energy Scenario 2014). These scenarios will be used in the new political debates for the future of energy in Denmark.

[37] The Wind scenario, the biomass scenario, the bio+ scenario, the hydrogen scenario and the fossil fuel scenario.

Appendix C Skjoldungelandet

The 21th of March 2015 a part of Roskilde municipality became a national park, Skjoldungernes Land (Skjoldungelandet 2015). The area of the national park can be seen in Figure C-1.

Figure C-1 The national park: Skjoldungelandet.
Part of the location of the national park is in Roskilde Municipality.
Figure from Danish National Parks

The change to the national park will give some economic advantages for the area, to increase the nature, it is based on voluntary obligations by the population, the firms in the area and the guests to the national park (Danish National Parks).
The national park will not change the restrictions for the firms and populations (Danish National Parks) this will therefore not change the restrictions for energy production in the area.

Appendix D Roskilde Energy Sector and politics

Due to the increase focus on the climate Roskilde municipality has made a report of the projects in the municipality which will decrease the CO_2, this is done by the consult firm Rambøll in August 2014 (Rambøll 2014).
The highest CO_2 emission is mainly from three energy areas; Heating, Electricity and Transport, hence these three areas will be the introduced in this section.

Heating sources

In Roskilde municipality there are 18 villages there have oil, electric heating or gas as the main heating sources (Rambøll 2014), these are call fossil villages in the further discussion. In the city Roskilde the main heating source is district heating, which is also expanding further to e.g. Risø and Himmelev (Rambøll 2014). This share can be seen in Figure D-1.
KARA/Novoren CHP plant in Roskilde city is using waste as fuel and is exploring 98% of the energy. There is treated waste from 7 municipalities and imported waste from the Great Britain to cover the demand for electricity and district heating in Roskilde. The import will end after 2025, hence the calculated level of waste from the municipalities will then cover the demand (Roskilde Municipality 2014 A).

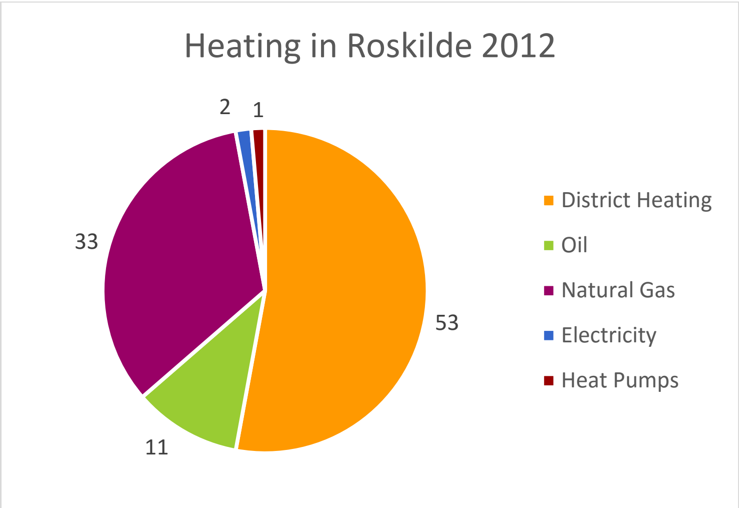

Figure D-1 The heating methods in 2012
Data from (Magnussen 2015 A)

Electricity sector:

In the last four years, the increase of solar in the municipality is 1% of the total electricity used in Roskilde (Roskilde Municipality 2015 A). Present there are 15 wind turbines in Roskilde, and because of the last try with new sites for wind turbines, there showed a large local resistance, there are no new sites for wind turbines present (Roskilde Municipality 2014 A, Magnussen 2015 A).
The municipality is buying electricity from the neighbor municipalities, the trade in electricity can be seen on Figure D-2.

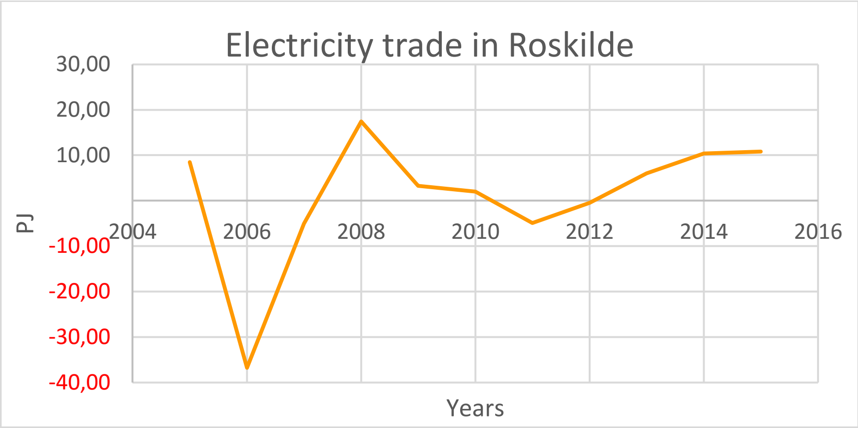

Figure D-2 The electricity trade for Roskilde municipality as a geographical area. In 2006 the export was high, however, the import have increased overall from 2007 until present. Data from (Magnussen 2015 A and Roskilde Municipality 2014)

Transport sector:

The public transport is big in Roskilde, hence the train station is on the main rail road between Copenhagen and Jutland. Further there is a big network of busses, both city busses but also busses across the borders of the municipality and one regional bus (Rambøll 2014). Both the busses and the trains are using gas as energy source.

From down town Roskilde there are around 200,000 car trips between the distances 0 to 5 km, from these 60,000 is in the city center. Because 5 km is analyzed to be an acceptable distance to bike, the bike roads will be increased from 2015-2018 (Roskilde Municipality 2014 B).

To decrease the environmental change the CO_2 emissions has been analyzed to point out the areas where the largest reduction can be made in the future. 3% of the municipality as a geographic area' CO_2 emission is from the municipality, the rest is from transport, citizens, agriculture etc. (Roskilde Municipality 2015 A). 51% of the municipality as a geographic area' CO_2 emissions is from the buildings in both heating and electricity (Roskilde Municipality 2015 A).

Energy politics in Roskilde:

In "Energiaftalen 2012" the wind energy is a big part of the foundation of the future energy system. Hence onshore wind turbines gives the highest output of decreased CO_2 emissions. However it is decided by the politicians to wait with the wind energy plans, until the national report about low frequency is written. It is the administration in the municipality' estimate that onshore wind turbines will only be realistic in Roskilde if the demand is coming from the public. To do this, it is needed to have a long term plan for both communication and planning of the wind turbines in each site (Roskilde Municipality 2014 B). It is recommended from Rambøll to repower the 14 old wind turbines there is in the municipality, this will however also need a public support (Rambøll 2014).

Appendix E Recommended CO_2 Emission Levels

Fuel	GJ/ton fuel	Kg CO_2/GJ
Gas-/Diesel oil	42.7	74
Fuel oil	40.65	78
Natural Gas (GJ/1000 Nm^3)	39.46	56.74
Coal for CHP plants	24.44	95
Waste	10.50	32.5

All renewable energies: 0 CO_2 emission.
Data from (The Danish Energy Agency 2012 B)

Marginal Electricity

The development of the marginal electricity from 2015 to 2035

Year	Marginal CO_2-emissionsfactor	Share of RE
	kg/MWh	-
2015	430	45%
2016	444	44%
2017	441	42%
2018	407	47%
2019	331	58%
2020	275	65%
2021	266	67%
2022	256	68%
2023	247	69%
2024	238	70%
2025	229	71%
2026	220	72%
2027	211	73%
2028	202	75%
2029	192	76%
2030	183	77%
2031	174	78%
2032	165	79%
2033	156	80%
2034	147	82%
2035	137	83%

Appendix F Strategic Energy Plan

The SEP process in the municipality can be seen in Figure F-1.

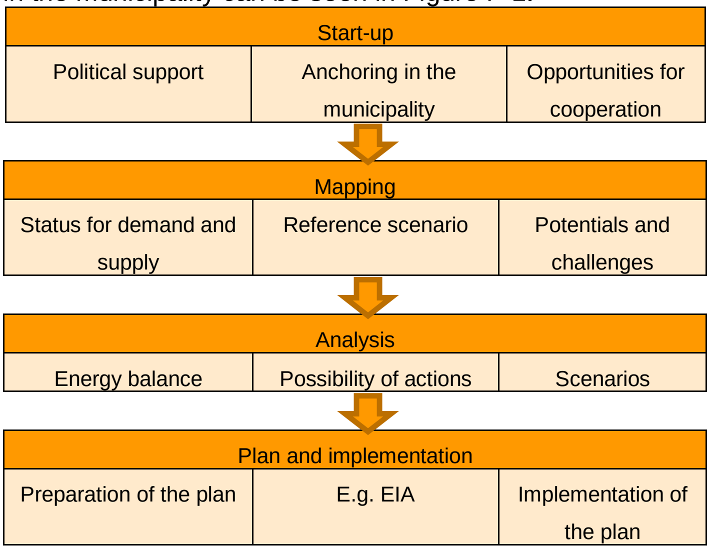

Figure F-1 SEP process in the municipalities

Graphic from (The Danish Energy Agency 2015 G) own translation from Danish

As seen, the first step is to have the broad political agreement, as the SEP plan will be anchored, in all the political parties.
The second step is to get an overview of the present energy system. As written, it is important to know the present status, to find a realistic target for the plan.
The third step is to investigate the different scenarios there are possible in the municipality. It is important, to have cooperation with the neighbor municipalities, to find the optimal scenario for the whole area/region, instead of only focusing on the individual municipalities.
To investigate different scenarios, computer models can be used. There are many different models, hence, it is important to know, which to use for each project.
The last and fourth step is to make an environment assessment and start, for the different projects (Connolly et al 2009).

Strategic Energy Plan, Roskilde

The SEP planes from Roskilde, divided into two groups: a plan for new research and a group with the plans there can be implemented in the energy system without new research. The two groups is also divided into small groups based on the division in the SEP. See Figure F-2.

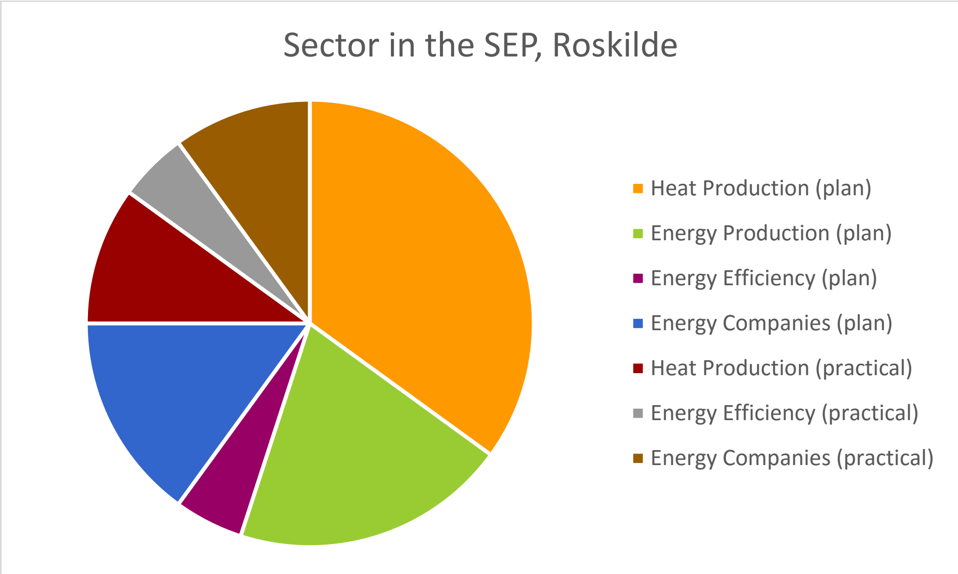

Figure F-2 The SEP plans divided as the SEP report from Roskilde
Data from (Roskilde Municipality 2015 A)

Location of Høje Taastrup municipality

The location of Høje Taastrup municipality can be seen in Figure F-3, as seen Høje Taastrup is a neighbor municipality to Roskilde.

Figure F-3 Location of Høje Taastrup Municipality.
Høje Taastrup municipality is a neighbor municipality to Roskilde, and is connected by both roads and trains.

Strategic Energy Plan, Høje Taastrup

The SEP planes from Høje Taastrup, divided into two groups: a plan for new research and a group with the plans there can be implemented in the energy system without new research. The two groups is also divided into small groups based on the division in the SEP. See Figure F-4.

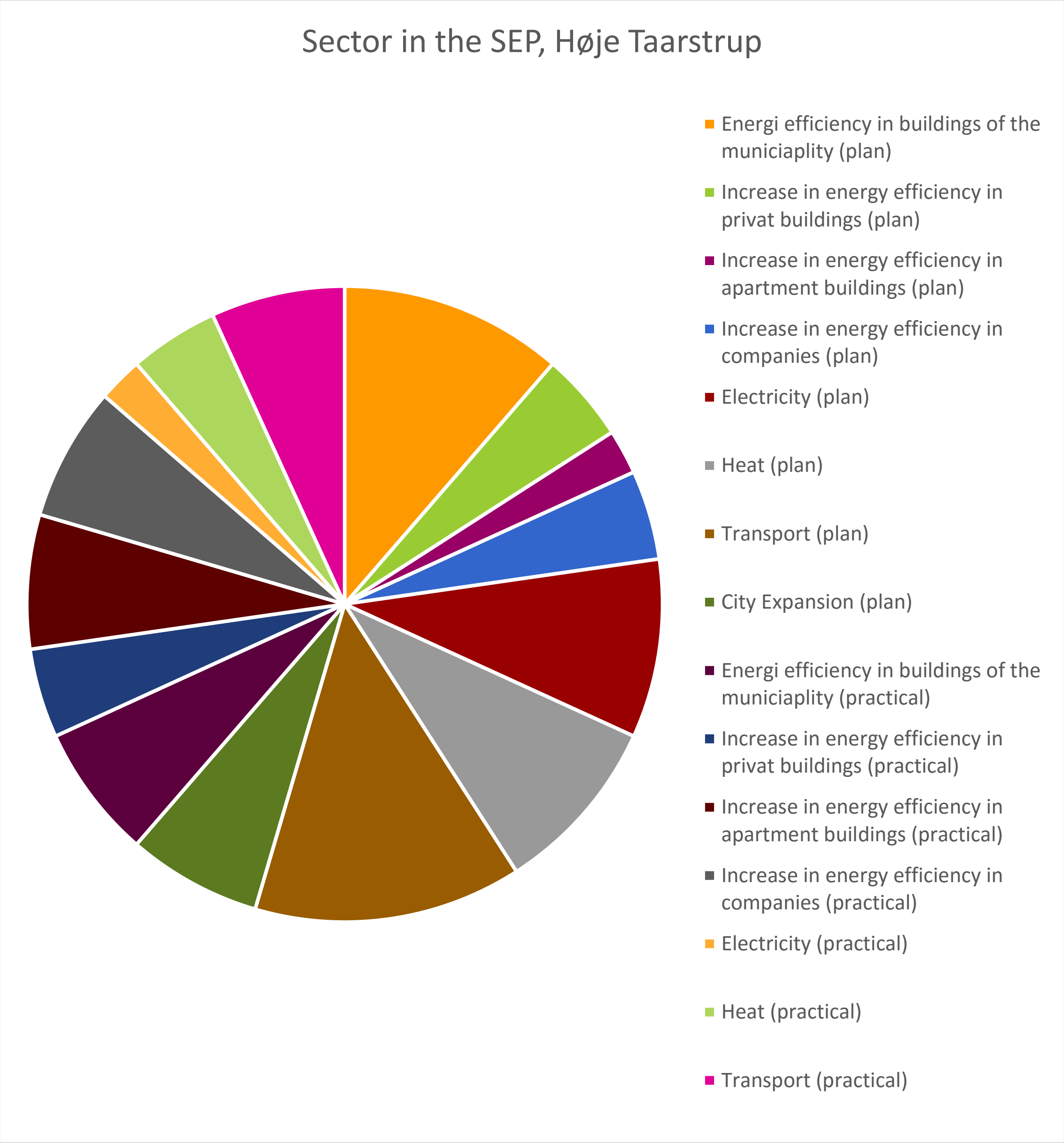

Figure 9-5 SEP plans for Høje Taastrup, divided as the report.
Data from (Høje Taastrup Municipality 2015).

Appendix G Comparison of the models

Table G-1 Comparison of two energy models.
The two models are the Balmorel and the STREAM model.
(Connolly et al 2009).

Analyzed area	**Definition**	**STREAM**	**Balmorel**
Time to learn	How long time does it take, to learn the specific energy model tool.	A few hours	One week
Simulation	Simulation tool simulates the operation of the energy system, in specific time steps.	Yes	Yes
Scenario	The scenario tool combines several years of data, into scenarios of typically 20-50 years.	-	Yes
Equilibrium	Equilibrium tool is used for explanation of the behavior or demand, supply and prices in a whole economy.	-	Partial
Top-down	Top-down is a macroeconomic tool, used for identify of the growth in energy prices and demand.	Partly	-
Bottom-up	The bottom-up tool is the technical identification, to identify the investment options and alternatives.	Yes	Yes
Operation Optimization	Operation optimization tool is used to optimize the energy system.	-	Yes
Investment Optimization	Tool is optimization of the investment.	-	Yes
Geographical area	Where can the model be used?	National/State/Region	International
Scenario timeframe	The timeframe where the model can include data.	1 year	Max 50 years
Time-step	The time-steps are the timeframe for the division of the energy system, both demand and supply.	Hourly	Hourly

Electric sector	The electric sector in the energy system.	Yes	Yes
Heat sector	The heat sector in the energy system.	Yes	Partly (Only district heating is included)
Transport sector	The transport sector in the energy system.	Partly	-
Storage	Is it possible to include an energy storage in the model, and how?	Pumped hydroelectric energy storage and electric vehicles- not used as storage, but can have impact on the flexible electricity demand.	Short term heat storage and electricity storage by hydrogen storage/pumped hydroelectric.
Used for:	Examples of projects used by each model	Scenarios in Denmark regarding GHG and reduction of fossil fuel.	Evaluation of international markets for green certificates and emission trading and environmental policy.
Model language	The model language behind the models, and which licenses are needed to run the models.	Excel	GAMS

It can be seen from Table G-1, that the two models have several similar parts. These will not be discussed in this thesis.

Appendix H BAU CO_2 Emissions

The BAU scenario present a short conclusion for Roskilde municipality, as can be seen in Table H-1.

Table H-1 Conclusion for the BAU scenario (Rambøll 2014).

BAU, years	% CO_2 emission reductions	Tons CO_2
2008-2012	-16	103,696
2008-2020	-28	185,020
2008-2030	-30	199,662

As Roskilde municipality, Høje Taastrup municipality is a climate municipality, but not included in the CoM (CoM 2015 C). As a climate municipality Høje Taastrup have agreed for a CO_2 emission reduction of 2%/year until 2017 (Climate Municipality 2015). Høje Taastrup have included the municipality as a geographical area (Climate Municipality 2015). In Table H-2 the CO_2 emission reduction can be seen:

Table H-2 The CO_2 emission reduction compared to 2008 for Høje Taastrup municipality. (Climate Municipality 2015)

Year:	2009	2010	2011	2012	2013	2014
CO_2 reduction [%]	+ 7.9	-9.9	-15.4	-7.9	-2.8	-9.4

As seen the first year (2009) there was an increase in the CO_2 emission, by investigation of the data it can be seen the increased sectors was the electricity and district heating (Høje Taastrup Municipality 2012). The reduction can be seen to base on reduction in the landfill, electricity and change in fossil heating (Høje Taastrup Municipality 2012). The emission of the district heating has not change drastic during the investigated years.

Both the agreement with the Danish Society for Nature Conversation and the marked as a pioneer municipality can give motivation for the local council for prioritizing of energy plans. The energy plan there are needed of a climate municipality is the SEP for Høje Taastrup municipality (Climate Municipality 2015).

Appendix I WAsP Limitations

The WAsP program was introduced in 1987 by the wind department at Risø (DTU wind energy) (WAsP 2015 A). The program have been updated, and e.g. both WAsP engineering and WAsP CFD have been added to the original program.
The WAsP program can set the specific map for the different sites, the most significant obstacles can be included.

Since the program is used all over the world, it is necessary to investigate the errors in complex terrain, where e.g. steep terrain promotes separation on the lee side (Bowen and Mortensen 1996). The steepness of the hill is important for the separation to happen (Wood 1995). General the separation will appear when the steepness is higher than 40%. The roughness of the area does however have some impact on the wind flow as can be seen in where slopes down to 32% have separation, because of a high roughness.

The development of the program is used to decrease this limitation. WAsP is based on linear numerical models, why it is expected, to over predict the flow speeds, some error calculations are needed in the calculations (Bowen and Mortensen 1996).

In "Exploring the limits of WAsP" it can be seen the effects of the errors given in WAsP, based on the distance between different met mast for a complexed terrain (Bowen and Mortensen 1996).

Appendix J Roughness and Elevation

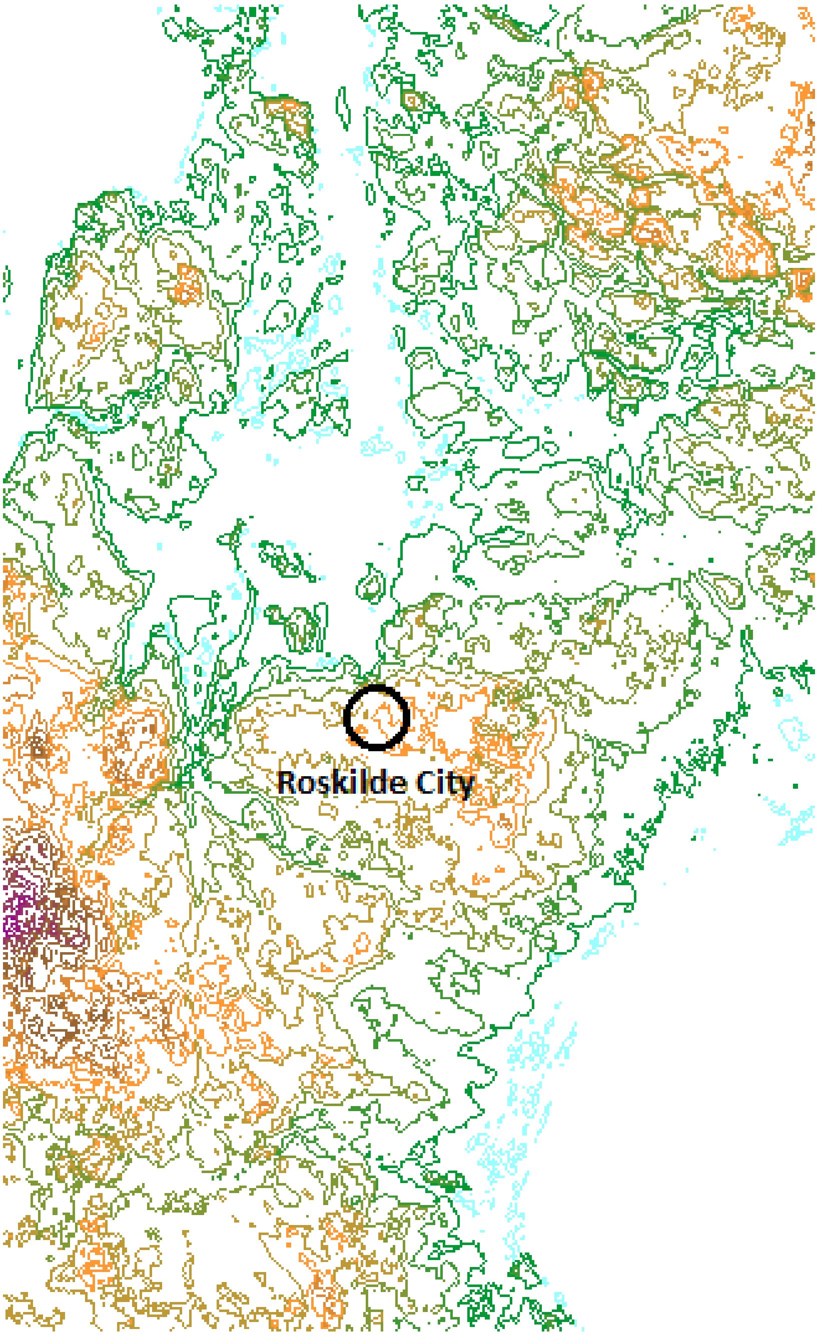

Figure J-1 Elevation map of the analyzed area.
The different colors indicates the different elevation levels in Roskilde. It is seen these changes are not drastic, hence the elevation in the area does not change drastically. Roskilde City is marked to give an understanding of the map.

Roughness impact on the wind profile

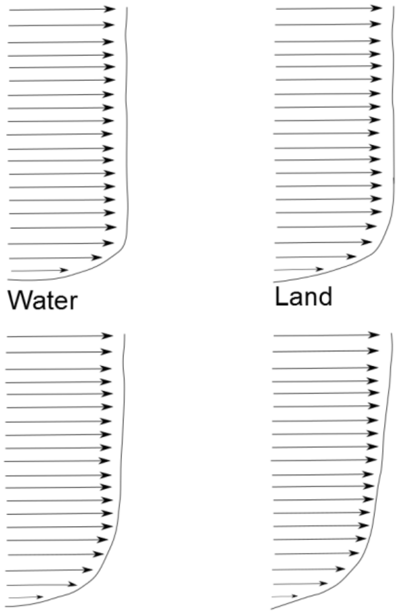

Figure J-2 Roughness Impact on the Wind Profile.
Drawing of the roughness impact on the wind profile for four different roughness classes. The changes can be seen in the boundary layer, there are increasing as the roughness increases as well.

The wind speed is shown with the general two dimensional wind profile. The velocity at the ground is zero, and increasing during the boundary layer (Fox et al. 2010).

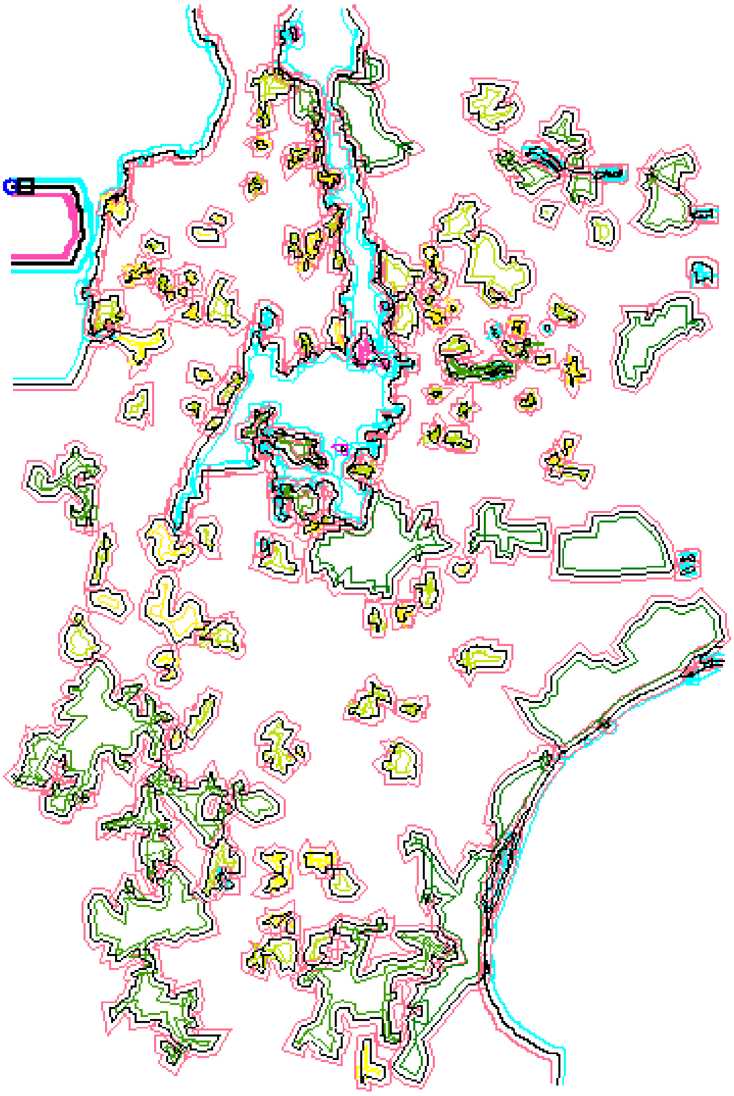

Figure J-3 Roughness map of Roskilde municipality from Map Editor 11

Appendix K Calculations of Wind Data in WAsP

Collection of wind data

The data used in this project is collected directly from the Risø met mast, however this is not always possible. For the European countries the European Wind Atlas[38] can be used, to find data. There are databases like the European one for several parts of the world e.g. Russian wind atlas, wind atlas for Egypt (WAsP 2015 C). In the resent years DTU is started to connect the difference wind atlases to one, covering the entire world (Mortensen 2015).
The wind data can also be found at Winddata.dk[39], where there are 17 measuring sites in Denmark (Winddata 2014) whereas Risø is one.
The low topographical inputs makes it's not necessary to include other measurements to calculate the wind in the municipality (Mortensen 2015).
The calculated wind atlas in WAsP Climate Analyst is included in the map of the municipality, this is needed for calculation of the wind turbines.

First WAsP Climate Analyst is applying the speed the multiplier and the known speed offset is added, this is used for measured data there is not converted into [m/s]. For the used data the unit is given in [m/s], as the multiplier is set to one and the offset to zero. There is also used a multiplier and offset for the wind direction, to convert the measured data into a direction between 0 and 359 degrees. As for the wind speed, the used data have direction in the used unit [°], hence the direction multiplier is set to one and the offset is set to zero.

The Mean Wind Speed

The average mean wind speed is calculating the overall average wind speed and direction for the area of interest. The wind direction will be shown in a wind rose and the wind speed as a Weibull distribution for each direction, this can be seen in Figure K-1.

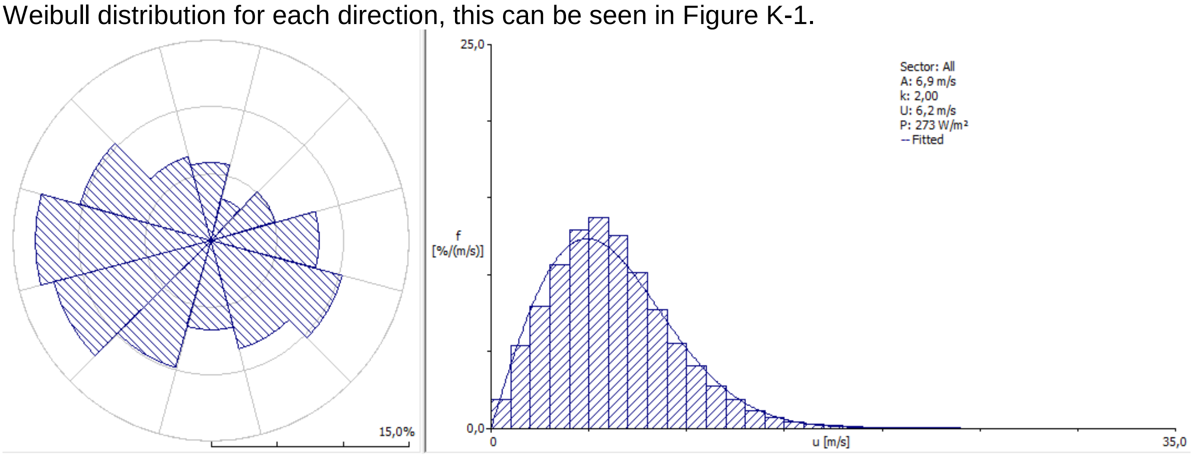

Figure K-1 Imported wind data, height 44m a.g.l. both the direction and the mean wind speed can be seen.

From the figure it is seen, that the mean wind speed is 6.2m/s. By the wind rose at Figure K-1, it can be seen that most of the wind is from the west, as it is generally in Denmark.

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[38] http://www.wasp.dk/Wind-Atlas
[39] http://www.winddata.com/

The mean wind speed is used to investigate the possible wind energy available for the site. When the average wind climate is calculated, the different turbine generators can be added, to find the average electricity produced at that site.
Another analyses of the measured data is to calculate the extreme wind speed.

The Extreme Wind Speed
The extreme wind speed is calculating the magnitude of the strongest wind speed at the area. It is the highest wind speed, there are given the highest loads on the wind turbines. The high loads are important to investigate the technical lifetime for each project. The extreme wind speed is used, to calculate the maximum wind speed in 50 years, to show the maximum load for the specific site. The extreme wind speed is used for categorizing the area for a specific wind turbine.

Appendix L Analysis of Wind Data

The acceptance level of the measured data can be seen in Table L-1.

Table L-1 The wind data from Risø met mast. Both data from 44m a.g.l. and 125m a.g.l. will be used in the investigation of the wind data.

Year	Height a.g.l. [m]	Comment	Entirely value recordings accepted (%)
1995	44	The data is only for the two last months.	99.93
1996	44	Nothing to comment	99.99
1997	44	Nothing to comment	99.98
1998	44	Nothing to comment	99.99
1999	44	Nothing to comment	99.98
2000	44	Nothing to comment	99.79
2001	44	There are missing data from end March to beginning August. – Not acceptable, so not incl. further on.	64.3
2002	44	Included data from 01.01.02-31.10.02[40].	100.0
1995	125	The data is only for the two last months	99.93
1996	125	Nothing to comment	99.99
1997	125	Nothing to comment	99.95
1998	125	Nothing to comment	98.9
1999	125	Nothing to comment	99.96
2000	125	There is missing data from end January to mid-June. Not acceptable, so not incl. further on.	67.72
2001	125	Nothing to comment	100
2002	125	Missing data from end October. The impact of this will be investigated further.	82.29
2003	125	There was a mistake in the timestamp, hence this could not be included in the program.	-
2004	125	In mid-June there is an estimate of the wind climate, the impact of this will be investigated. Data 01.01.04-31.10.04 is included[18].	97.83

The mean wind speed (U) is being investigated, both with the source and the fitted wind speed, as the power (P) for the wind is compared between the source and the fitted data.
To investigate the quality of a wind data set the statistical parameters, A (scale parameter) and k (shape parameter) from a Weibull distribution[41] are also included (MathWorks 2015).

[40] To have only full years, there is only included data from the first 10 month.

[41] The Weibull distribution pdf: $f_X(x) = k\frac{x^{k-1}}{A^k}e^{\left(-\left(\frac{x}{A}\right)^k\right)}$.

The difference between the observed wind (the source) and the fitted (and emergent) wind speed should be lower than a few percent (DTU Course Note 2014). The difference for the power between the source and the fitted data should be less than one percent (DTU Course Note 2014). This is needed to be investigated to ensure the value of the fitted data, there is used further in the calculations. See Table L-2 for the results of the investigation.

Table L-2 Analysis of the wind data.
Results from analyze of the wind data from the Risø met mast. Both analysis with different years are being done, and a cross-prediction between the two measured heights, from both 44m a.g.l. and 125m a.g.l.

Data sets	U [m/s] Source	U [m/s] Fitted	Diff. U [%]	P [W/m^2] Source	P [W/m^2] Fitted	Diff. P [%]	A-Weibull	k-Weibull
Excl. 03 Incl. 95-02 +04 h=125m a.g.l.	7.77	7.85	1.093	480	481	0.313	8.9	2.41
Excl. 00+03 Incl. 95-99 + 01-02 +04(Oct) h=125m a.g.l.	7.77	7.85	1.042	482	483	0.295	8.9	2.39
Excl.00+02-03 Incl. 95-99 +01+04(Oct) h=125m a.g.l.	7.75	7.83	1.023	479	480	0.307	8.8	2.39
Excl.00+03-04 Incl. 95-99 +01-02(Oct) h=125m a.g.l.	7.78	7.85	1.013	487	488	0.306	8.9	2.36
Excl. 03-04 Incl. 95-02 (Oct) h=44m a.g.l.	6.18	6.14	-0.548	272	273	0.552	6.9	1.99
Excl. 01 + 03-04 incl. 95-00 +02 (Oct.) h=44m a.g.l.	6.18	6.15	-0.334	272	273	0.497	6.9	2.00

Appendix M EIA

Visualization

There are two sides for the public, one is the wish for renewable energy, and the other the environmental impact from siting of wind turbines (Molnarova et al. 2011). Environments with high aesthetic quality, can provoke stronger negative reactions, regarding wind turbines (Molnarova et al. 2011). It is the emotions, there are controlling the reactions from the residents (Voltelen). By analyzing the area, all-important points should be visualized, included local observations points (Molnarova et al. 2011). However, this can be difficult to handle, as the person doing the visualization is not necessary local. It is often after the visualization is done, the public starts to react- even though there has been asked for any special points needed to be included in the analysis (Voltelen).

Flicker

Flicker can in some cases course epilepsy, this is documented with helicopter blades (Cushman and Floccare 2015). It is investigated whether turbine blades can give epilepsy (PropertyMetrics 2013 A, Smedley et al. 2010). Most modern wind turbines operate slower and at different speed as they are variable speed, this give a flicker rate below the rate of epilepsy (Harding et al. 2008). Smaller variable speed turbines can, have a rotation speed, in the range 30-300rpm, which gives a different flicker rate (Harding et al. 2008). Epilepsy can result in different illnesses, e.g. mild discomfort and headache (Cushman and Floccare 2015). These illnesses have been some of the complaints regarding wind projects.

For flicker to have an impact on the environment, several factors need to be included: the hub height, the rotor diameter, the height of the sun, the wind direction and the direction to the observer (Harding et al. 2008). This indicates that the level of flicker impact is decreased to specific times per year.

Noise

There are both mechanical and the aerodynamic noise from a wind turbine.

The mechanical noise is mainly from the gearbox and generator in the nacelle (Pedersen and Waye 2004). The noise from the mechanical parts are in the frequency of 1000Hz (Pedersen and Waye 2004). The mechanical noise is decreased during the last ten years (Pedersen and Waye 2004, Pedersen 2003). Because of the reduction of mechanic noise, it is the aerodynamic noise there has the highest impact on the noise level.

The aerodynamic noise is mainly from the wind flow around the blades (Pedersen 2003). The aerodynamic noise can be divided into the airfoil self-noise and the turbulence inflow noise (Leloudas et al. 2007). The airfoil self-noise is the interaction of the boundary layer on the blade, with the trailing edge (Leloudas et al. 2007). The turbulence inflow noise, is the existing turbulence in the wind interacts with the blades (Leloudas et al. 2007). Both should be included in the calculations for the total noise level. The boundary layer at the blades, have a high impact on the noise level, this should be accurate in the modeling (Zhu et al. 2005).

As the turbines are increasing, a discussion whether the level of low frequency noise is increasing as well (Bolin et al. 2011). The dominant source for the low frequency noise, is the turbulence inflow noise. Low frequency noise is in the range of 20-200Hz (Bolin et al. 2011).

There have been several investigations, about the annoyance the noise from wind turbines, has on the neighbors (Pedersen and Waye 2004, Bolin et al. 2011, Pedersen 2003). From these, it can be concluded, that there are a connection between the level of noise, and the annoyance by the neighbors (Bakker et al. 2011). Further, it is concluded, that the annoyance increase with the visualization of the wind turbines. The level of economic advantages also have an impact of the level of annoyance. As the neighbors with an economic advantages are less annoyed by the turbines.
Wind turbines are often sited in rural environments with low background noise (Leloudas et al. 2007). Citizens are often moving to these areas for the quietness, and then any sound, will have a negative impact, no matter the level (Pedersen 2003).
There have been several cases, with neighbors getting sick from the wind turbines (National Organization for Neighbors 2014 C). By the science world, it has not been possible to conclude the direct link, between being a neighbor to a wind turbine and the health effects there have happened (Bolin et al. 2011). However, it has been concluded that there is a higher health risk for being a neighbor to traffic noise[42] (The Nature Agency), it can be discussed how different wind turbine noise is.

Electromagnetic Interference

Electromagnetic interference (EMI) is, when the wind turbine has an impact on the radio signals. The impact can be coursed by three different locations (Krug and Lewke 2009):

- Near field: When the generator and switching components in the nacelle are given an electromagnetic field, courses change in the signals.
- Diffraction: When the turbine reflects or absorb some of the signal, by obstructing the path of the radio signal.
- Reflection/scattering: When the turbine interact with the signal between the transmitter and the receiver. The receiver will receive two signals, there can be out of phase.

To decrease the EMI both the distance between the wind turbines, the receiver and the transmitter are needed to be scheduled. The wind turbines should be held out of the direct path between the transmitter and the receiver (Krug and Lewke 2009
The EMI have not been a large problem in Denmark in the past. Therefore the EMI should be included in the EIA, but in Denmark it does not have a large impact on the siting of wind turbines.

Birds and Bats

The impact on birds and bats have been researched with different focuses, first the impact of the birds was prioritized. As investigations were done, several bats carcasses were discovered, this started the investigation for the bats (Kuvelsky et al. 2007).

As the different areas for wind farms, have different level of birds, the level of killed birds, are also different. There has been measured in the range of 0.01-23 birds/turbine/year (Drewitt and Langston 2006). As the area has an impact, it has been investigated, if the increased height of turbines also has increased the collision rate (Krijgsveld et al. 2009). As the turbines has

[42] The health impact have been: Sleep disorder, sleepiness, headache, hypertension, stress etc. (The Nature Agency).

increased to larger capacity, both the height and the rotor area have increased as well. This has not had any impact of the collision (Krijgsveld et al. 2009, Barclay et al. 2007).
For bat on the other hand does the tower height has a large impact, when the tower height is above 65m (Barclay et al. 2007).
For the birds, it is the collision with the wind turbines, there is dangerous. Whereas, for bats the change in pressure, also has a large negative impact (Baerwald et al. 2008 A, Grodsky et al. 2011). It is 90% of the killed bats there has internal hemorrhaging, there is consisting with the pressure change.
For the bat collision rate there has also been measured in a large range from 0.07-47.53 bat/turbine/year (Kuvelsky et al. 2007).
To decrease the collision rate, an investigation, of the impact from the wind speed, has been done (Baerwald et al. 2008 B, Arnett et al. 2007). It is seen, the highest rate happens, before and after storms, and during nights with low wind speeds (Arnett et al. 2007). To decrease the collision rate, the cut in wind was set to 4.5m/s (Baerwald et al. 2008 B). This decreased the collision, but also decreased the production from the wind turbine (Baerwald et al. 2008 B).

Appendix N The Grid in DK

The grid is dimensioned by the N-1 principle, where it is able to handle a down of one component; this could be either a producing plant or a specific grid line (Energinet 2008). When there is, a component down the grid will be overloaded on other lines. The overloading is possible as long as it is not temporary. If it is over a longer period, the grid lines will be exposed to damages (Energinet 2008).

It is needed to update the grid as the change in production is changing, in 1985 the production was centralized as can be seen in Figure N-1, where the connection to the neighboring countries also is clear.

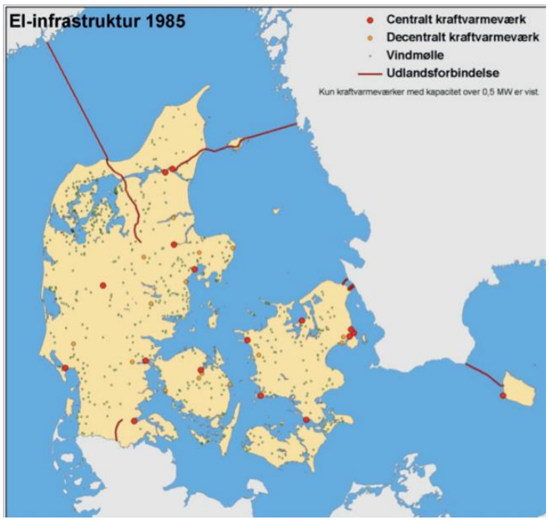

Figure N-1 The grid system in Denmark in 1985

A few large centralized power plants producing electricity in Denmark.

From (The Danish Energy Agency 2014 B)

The first oil crisis did have an impact on the Danish grid. The production fuel change from oil to coal for most of the CHP plants, as several countries have coal (The Danish Energy Agency 2014 B). In the years from 1973-1979 the share of coal changed from 10% to 90% in the production of electricity (The Danish Energy Agency 2014 B).

Because of the oil crisis the fuel for heating changed as well. It went from individual oil heating to district heating, for decreasing the prices (The Danish Energy Agency 2014 B). As the district heating increased the need for local heat production facilities were increased. By increasing the number of CHP plants the fuels was exploit to the maximum.

The number of wind turbines did also increase, first by local enthusiast and later by the national support for renewable energy (The Danish Energy Agency 2014 B). Both the increase in wind turbines and small CHP plants etc. the production went from centralized to decentralize as can be seen in Figure N-2 from 2013 as the increase in national and international connections.

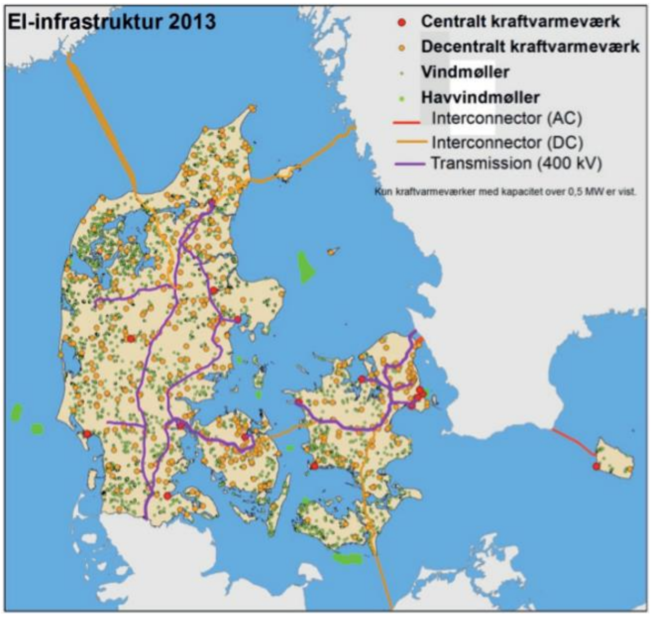

Figure N-9-6 The grid system in Denmark 2013
Many small decentralize power plants producing electricity and heat in Denmark.
From (The Danish Energy Agency 2014 B)

Therefore the grid needed to be updated from a few big production locates to smaller and several production locates.
The Danish gird is divided into two areas, the Scandinavian on the east side of the Great Belt, and the European on the west side. Both grids are 50Hz, but they are asynchronous so the connection between the west and the east Denmark were first done in 2010 (The Danish Energy Agency 2014 B). Both the grids are AC as this is easy to transform between the different grids (400kV, 150kV-132kV and 60-10kV) (Energinet 2008). The transformation is needed to decrease the losses during transport. To connect two asynchronous AC grids the electric needs to be transformed to DC, connected, and transformed to synchronous AC again (Energinet 2008). The same connection strategic is used for the international connections (The Danish Energy Agency 2014 B).

Appendix O Figures for Support Mechanisms

Figure O-1 Support by Feed-in Premium

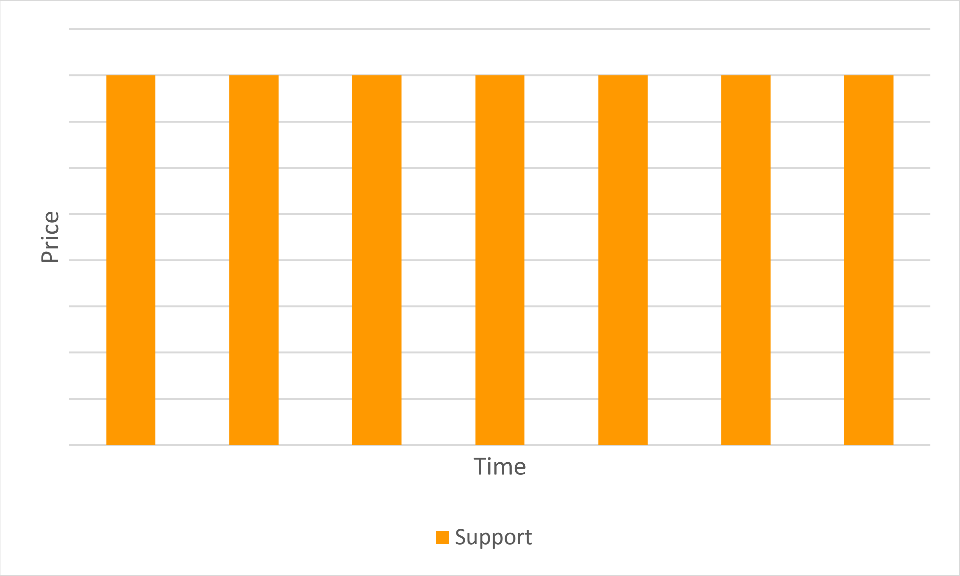

Figure O-2 Support Feed-in Tariff

Figure O-3 Support by Green Certificates

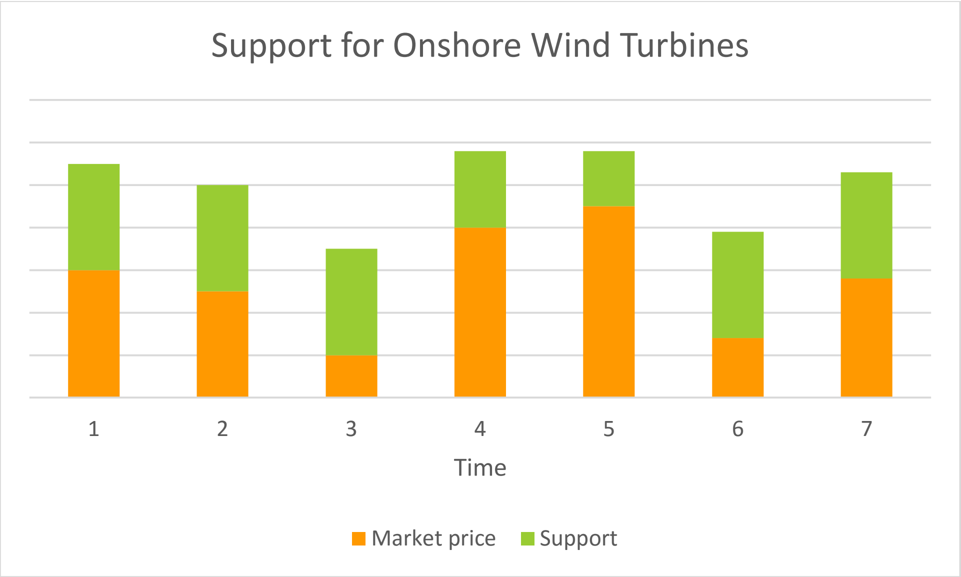

Figure O-4 The support mechanism in Denmark for onshore wind turbines.
The level of support is 25 øre/kWh, however if the market price increases to more than 33 øre/kWh, the support decreases to a total of max 58 øre/kWh (see "time" 4 and 5 on the visualization).

Appendix P Map with the Present Wind Turbines

In Roskilde municipality there are 15 wind turbines installed, where the average age for the wind turbines is 14.3 years, and the average capacity is around 385.7 kW (Rambøll 2014). The locations for these 15 existing wind turbines can be seen in Figure P-1.

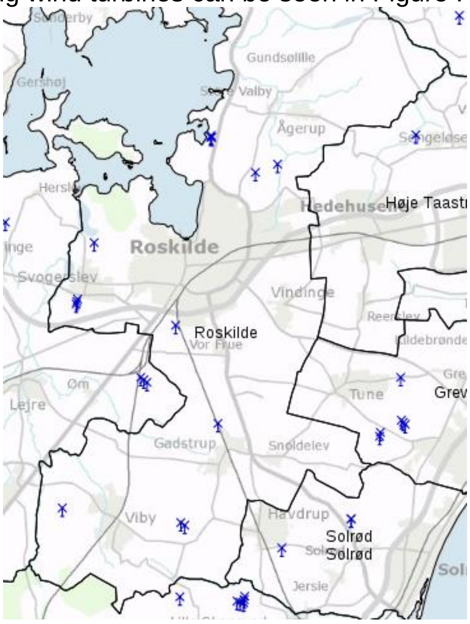

Figure P-1 Location of the present wind turbines.

The location of the 15 present wind turbines in Roskilde, with an average age at 14.3 year and average capacity at 385.7 kW.

From (GIS map 2015)

It can be seen that all the wind turbines are located in the south of the municipality, and all the neighbor municipalities does also have wind turbines. Based on the age and capacity for the turbines the municipality could use re-powering project, to increase the share of renewable energy in the system, and to update the old wind turbines. However re-powering project needs a new analysis of the area, and the process for acceptance is almost the same as for new locates. Rambøll 2014 did an investigation for the opportunity for re-powering the old wind turbines[43]. It is concluded that 5 of the existing wind turbines can be upgraded to a larger wind turbine, without exceed new distance requirements (Rambøll 2014).

In 2013 there were several areas in Roskilde municipality pointed out for wind turbines, however, the public responses were negative, and there were over 1000 herring responses (Municipality Plan Consultation 2013). The herring was before the local election. The timing of the siting of wind turbines was therefore connected to the political election, which can indicate the fast stop for the project after the first herring (Magnussen 2015 A).

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[43] In the investigation, it was only the distance between buildings and existing wind turbines there was investigated.

Appendix Q Feasibility and Sensitivity Calculations for a 3MW Wind Turbine

In this appendix a small screen picture has been included, as an addition to the thesis an Excel sheet has been uploaded, which includes all financial calculations.

Inputs					
Wind farm total	3	MW			
AEP	9769	MWh		Production with support	
investment cost	22,5	mill dkr		75968,3	MWh
O&M	-87,6	DKK/MWh		Years with support	
Support	0,25	DKK/kWh		7,77646	
lifetime	20	years			
discount rate	0,0608	% p.a.	((1+RR)*(1+r)-1)		
Price	179	dkk/MWh	321,5	Øst Dk = DK2	

Electricity plan

		Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Inflation				2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Inflation index			1,00	1,02	1,04	1,06	1,08	1,10	1,13	1,15	1,17	1,20	1,22	1,24	1,27	1,29	1,32	1,35	1,37	1,40	1,43	1,46	1,49
Coorperate Tax				25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Depreciation (straight line)	20	years																					

Calculations		Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Revenue																							
Power price	DKK/MWh, real			429	429	429	429	429	429	429	429	179	179	179	179	179	179	179	179	179	179	179	179
Power price	DKK/MWh, nominal			438	446	455	464	474	483	493	503	214	218	223	227	232	236	241	246	251	256	261	266
Power Production	MWh			9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769
Power Revenue	**DKK**			**4.274.719**	######	#######	#######	######	#######	######	######	######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
Operational Cost																							
O&M cost	DKK/MWh, real			-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88	-88
O&M cost	DKK/MWh, nominal			-89	-91	-93	-95	-97	-99	-101	-103	-105	-107	-109	-111	-113	-116	-118	-120	-123	-125	-128	-130
Power Production	MWh			9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769	9.769
OPEX	**DKK**			**-872.880**	######	#######	#######	######	**-963.730**	######	######	######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######	#######
EBITDA Earnings before Interests, Taxes, Depreciation and Amortisation (EBITDA)																							
Revenue	**DKK**			4.274.719	4.360.213	4.447.418	4.536.366	4.627.093	4.719.635	#######	4.910.308	#######	2.131.596	2.174.228	2.217.712	2.262.067	2.307.308	2.353.454	2.400.523	2.448.534	2.497.504	2.547.454	2.598.403
Operational Cost (OPEX)	**DKK**			-872.880	-890.337	-908.144	-926.307	-944.833	-963.730	#######	#######	#######	-1.043.172	########	-1.085.316	-1.107.023	-1.129.163	-1.151.746	-1.174.781	-1.198.277	########	########	-1.271.621
Investment Cost (CAPEX)	**DKK**		-22.500.000																				
Net Cashflows	**DKK**		**-22.500.000**	**3.401.839**	######	#######	#######	######	#######	######	######	######	#######	**1.110.192**	#######	#######	#######	#######	#######	#######	#######	#######	#######
	Tax calculation (payable tax)																						
	EBITDA			3.401.839	#######	3.539.274	3.610.059	3.682.260	3.755.906	#######	#######	#######	1.088.424	1.110.192	1.132.396	1.155.044	1.178.145	1.201.708	1.225.742	1.250.257	1.275.262	1.300.767	1.326.783
	Corporate Tax rate	%		25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
	Payable tax (before depreciation)			-850.460	-867.469	-884.818	-902.515	-920.565	-938.976	#######	-976.911	-266.771	-272.106	-277.548	-283.099	-288.761	-294.536	-300.427	-306.435	-312.564	-318.815	-325.192	-331.696
Tax shield from depreciation																							
	Investment Cost (CAPEX)	DKK	-22.500.000																				
	Straight line depreciation	%		5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
	Depreciation	DKK		1.125.000	1.125.000	1.125.000	1.125.000	1.125.000	1.125.000	#######	1.125.000	1.125.000	1.125.000	1.125.000	1.125.000	1.125.000	1.125.000	1.125.000	1.125.000	1.125.000	1.125.000	1.125.000	1.125.000
	Corporate Tax rate	%		25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
	Tax shield from depreciation	DKK		281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250	281.250

Figure Q-1 Screen short of the feasibility calculations for the private developer.

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Sensitivity map

Large Siemens WT
Privat feasibility

Things to change	-25	-15	0	15	25
AEP	-2254804,23	**17212,68578**	**3425238,063**	6833263,44	**9105280,358**
CAPEX	8248970,843	6319477,731	**3425238,063**	530998,3952	-1398494,717
Price	-1030650,27	751705,0658	**3425238,063**	6098771,06	7881126,392
Support	20437,07069	1382357,468	**3425238,063**	5468118,658	6830039,055
OPEX	5605885,089	4733626,278	**3425238,063**	2116849,848	1244591,037

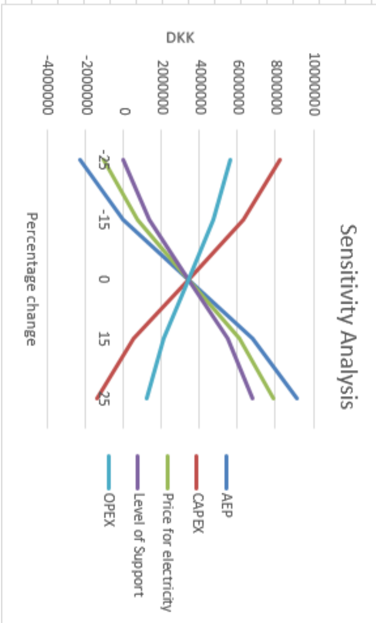

Figure Q-2 Screen short of sensitivity analysis for the private developer.

Appendix R Planning Process

In this section, the general definition of a planning process will be described. The use of a planning process will be investigated, and how it is used for wind projects.
It is important to know the central stakeholders, who have the largest impact on the project and who have the largest interest in it (Ingeniøren 2015 C).
When the central stakeholders are known, together with an open and professional communication the “great story” will be told by others than the project managers, because more want to be a part of the project (Ingeniøren 2015 C). Carsten Sandgaard says that all projects have a “great story” to tell, even though it can be had to find (Ingeniøren 2015 C).

In Denmark the wind turbines have been a part of the electric grid since 1973 (The Danish Energy Agency 2009 A). In the beginning of the Danish wind history, the wind turbines where owned and erected by local groups.
In the 1990s the change from local ownership to private/company owned (The Danish Energy Agency 2009 A). The first series production of wind turbines was in 1970s, with a capacity at 22kW, the latest onshore wind turbines have a capacity around 3MW (The Danish Energy Agency 2009 A). There was a market for increasing the size of the wind turbines, to increase the electricity production per turbine. When the wind turbines increases so does the price for each wind turbines.
The more expensive wind turbines make it harder for the locals to pay for a local turbine. The number of local owned turbines have decreased, and the number of large companies or private (outside the local community) have increased. This change in ownership of the wind turbines also decreases the local connection to the wind turbines.
The change of ownership and planning process have required to map the planning process, to decrease the disagreement between locals, politicians and owners of the wind turbines. The siting of wind turbines is no longer a local wish for renewable energy it is decided by politicians, and the ownership is by companies or private who have no connection to the area.
To help with the planning process the Danish government has a helping task force for wind turbines planning called The Wind Turbine Task Force[44] (Vindmøllerejseholdet).

The Good Planning Process

In this section, the “good process” from the wind turbine task force is being investigated and discussed. It is known that there is not one single correct planning process for wind turbines. Every project is different, thus the planning process also needs to be different. However, there are some similarities that are needed for the planning process to be successful for all parties.

The 21th of April 2009 the wind turbine task force connected some of the key players in the planning of wind turbines in Denmark to find the key elements of a good planning (The Nature Agency 2009). The results from this day became a process, visualized by a simple board game, see Figure R-1.

[44] The wind turbine task force: http://naturstyrelsen.dk/81820

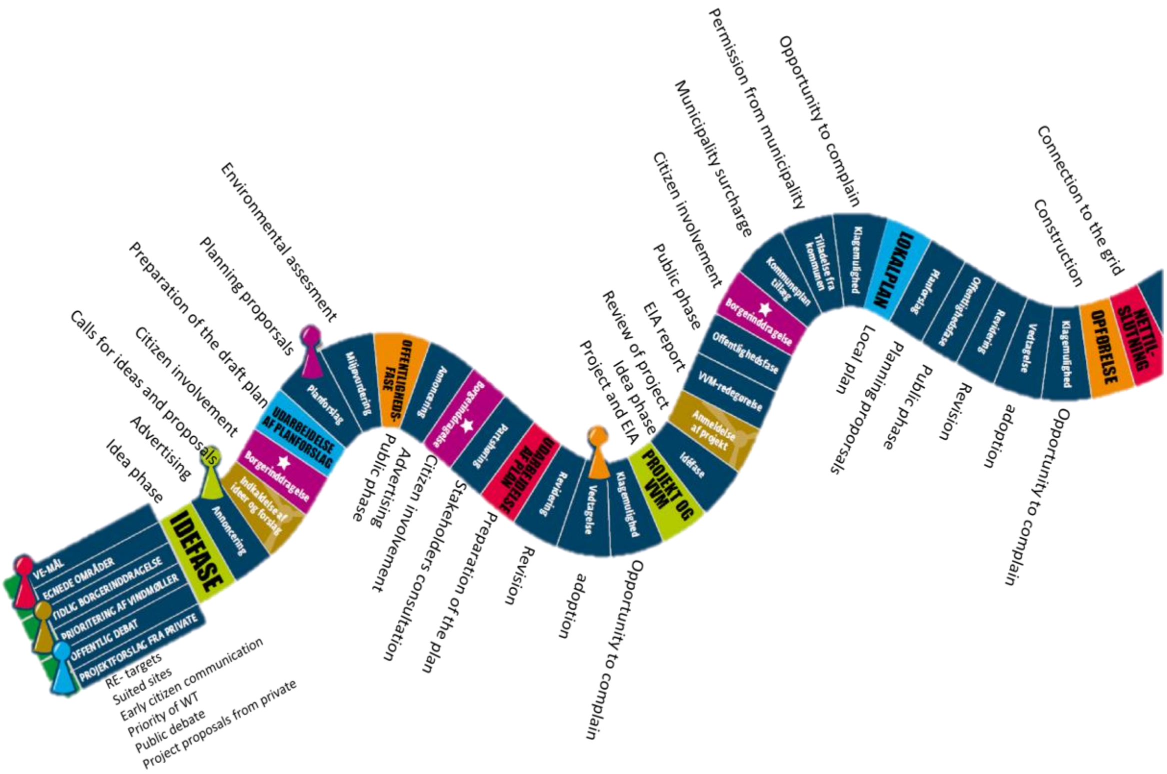

Figure R-1 The planning process for a wind project

The planning process for a wind project is long, and have many different phases, this is illustrated as a board game. The purple areas are involvement of the citizens. As seen this is early in the process and at least three times. Further there are public phases, time for public proposals and time for complaints, such as the local citizens increases the involvement in the different phases of a planning process. Figure from (The Nature Agency 2009).

It is seen on the figure, that the citizens should be involved several times in the process. The experience with wind turbine planning shows, that early involvement of the local citizens increases the local support (The Nature Agency 2009).

The first involvement should be before the planning process, as a public debate. Here the municipality's priority of renewable energy should be discussed as the first screening for siting of wind turbines (The Nature Agency 2009). This can give the locals an opportunity, to discuss the pros and cons for all areas, and give a larger understanding between the different players. It is being concluded, that the open and equal discussion is the key for the process, together with the use of different experts (The Nature Agency 2009).

The time consuming is one of the large factors against early public involvement, as time is money. However, it can be shown, in the whole process that an open and equal discussion is a good investment, as it (most properly), will decrease the protest against the wind turbines.

In the planning process there are different players who have very different roles, needs and challenges.

In 2013, a pilot project was done with Kalundborg municipality as case (The Nature Agency 2014 A). The goal for the project is to analyze the theoretical process as described and to investigate if early involvement is possible. The project is based on anthropologic methods, to learn with and by people not only about them. The planning process have been driven by the network, there are based on dialog, understanding and contact between people. It is known that the knowledge and trust are built over time and the early engagement demands interest from all players to be functional.

The pilot project have analyzed three players in the process, and the three players were divided into six different profiles as can be seen in Table R-1.

Table R-1 The different players connected to a planning process for wind turbines in Denmark. Data from (The Nature Agency 2014 A)

The profiles	**The role**	**Needs**	**Challenges**
Officials (Government)	Needs to know and inform about the law. The lead in the involvement of the citizens.	Clear and stable political decisions. Money and time for the involvement.	Prioritize the time between different projects. To balance between the public and the different political leaders.
Politicians (Government)	Decide the renewable energy goals.	Clear and stable political decisions from the national parliament. Help from different experts.	To balance between local resources, money, laws and the public wishes. To explain and discuss the different aspects at the right time to avoid any distrust.
Developer/owner (Business)	Drives the wind project. Have the technical responsibility of the project.	To be able of expanding the business of wind projects. Clear and stable political decisions.	Compete with other developers for one project before payment. To explain complex technical questions, demands, process etc. Getting local accept, by both the citizens and the politicians.
Landowner (Business)	Sale or rent their land to the project, have an economic advantage of the wind turbines.	Expand the business from only farming to wind. To have a clear and open connection to the area.	To balance between the economic advantage and the social accept in the area. To find different ways of involving the citizens in the project, so they will have a positive view of the project.
Proactive citizens (public)	Local with interest in both the local and national politics. Involves early in the project. Often positive for wind projects.	Good time for debates in the planning process. To explain the ideological, visionary and economic advantages.	To find the time for debate in a normal planning process. That some resistance is a result of missing information and knowledge.

Reactive citizens (public)	Local, involves late in the process. Often positive for wind projects, but can be against specific projects.	To get a lot of information and involvement early in the process. To get accepted for the emotional arguments. Know where to contact.	The ads for the project is mostly done by local newspaper, or in the last minute. The hearing have a short time limit. Public meetings are more like information meetings than dialog.

A good citizen involvement is to involve all players early in the process, where it should be clear what is up for debate. Is it an information or debate meeting (The Nature Agency 2014 A)? The early and clear involvement, can improve the positive view of the project by the locals.
From the developer's point of view, it is very important, not only to focus on how, but also why for each activity (The Nature Agency 2014 A). By focus on the why, each activity will not only have a time schedule, but also a two-way communication.
A long planning process with time for debate, will give the citizens the time to get involved.
It is important to have a two-way communication, so all questions, uncertainties, and emotional arguments are being heard
It is important that the municipality does not think of the minimum demands, for time for hearings, number of public meetings etc. as standards (The Nature Agency 2014 A)

Appendix S Complaints about Wind Turbines

In this section, some of the most common complaints will be discussed- are the complaints about the wind turbines or about the process?

In general, the complaints- or the uncertainties, questions and frustration, during the process are mostly focused on the planning. In the wind planning process, there are several information ‘channels’, to the local community. Who is on the community’s side, in this process? This question can be difficult to answer, as any complaints should be written to, the local city council- the same council who have approved the siting (National Organization for Neighbors 2014). The national organizations for neighbors to giant wind turbines[45] writes, that it often is a waste of time to complaint over wind turbines.
In the media there are several tales about the effect for neighbors to large wind turbines[46], this indicates that there are several who have large negative impact of the wind turbines. In the last 30 years the Danish citizens have increase the number of complaints general in the society (Politikken 2013 A), this can have some of the effect on the number of complaints for wind turbines, but cannot be the only reason.

To investigate the complaints in a scientific/industry point of view several questionnaires have been made. This is to investigate the neighborhood with wind turbines in general. “Jysk analyse”[47] have made a questioners with participation of 1278 persons in a radius of 2km to the nearest turbine, this is corresponds to 19% of the households in the radius (VidenOmVind 2012 A).
From this analysis it is seen that 20% of the neighbors feel a negative impact of the wind turbines, as seen on Figure S-1.

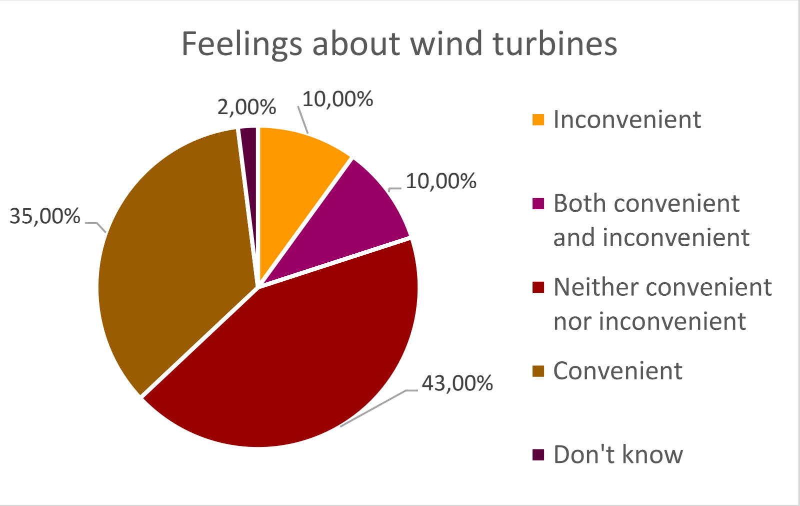

Figure S-1 Feelings from neighbors in a radius of 2km to a wind turbine.
Opinion poll conducted by Jysk Analyse (VidenOmVind 2012 A)

[45] Landsforeningen Naboer til Kæmpevindmøller, http://stilhed.eu/
[46] A search in Infomedia of ”Vindmølle klager” gave 4887 results in the last 10 years.
[47] http://www.jyskanalyse.dk/

It is also investigated if the near wind turbines have changed the citizens thought of them, 23% have become more positive and 12% more negative against wind turbines by being neighbors to wind turbines (VidenOmVind 2012 A). From this it can be seen that the majority (78%) of the neighbors in a radius of 2km does not have any negative effect from the wind turbines.

16% of the neighbors experience inconveniences from the wind turbines (VidenOmVind 2012 A). Out of these 14% of them has noise as the greatest inconvenience, 1% the shadow casting from the turbines and the last percent is most invent by the turbines effect on the natural view (VidenOmVind 2012 A). From this it can be concluded that the noise has the largest effect. The noise impact have been investigated further to find whether it is the low frequency noise that have the highest impact on the neighbors. The result can be seen on Figure S-2.

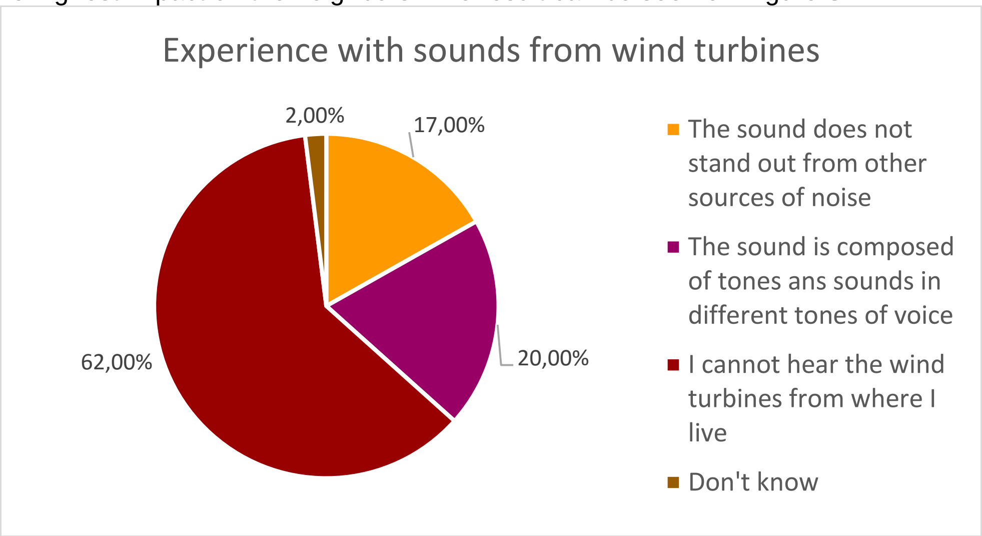

Figure S-2 Experiences with sound, from neighbors in a radius of 2km from a wind turbine. Opinion poll conducted by Jysk Analyse (VidenOmVind 2012 A)

Here it can be seen that 20% of the neighbors hear sounds in a different tones, and 18% hear buzzing sounds in a low tone of voice that are known as low frequency (VidenOmVind 2012 A). Most of these hears the sounds outside the houses (12%), where 5% also can hear it inside the house (VidenOmVind 2012 A). It is known that some neighbors have a change in the sleep. In the investigation done by Jysk Analyse 4% of the 1278 people asked, indicates that their sleep is affected by present of the wind turbines (VidenOmVind 2012 A).
The investigation done by Jysk Analyse has included neighbors in a radius of 2km, but as seen on Figure S-3, the distance to the wind turbines has a large impact on the experience (National Organization for Neighbors 2014).

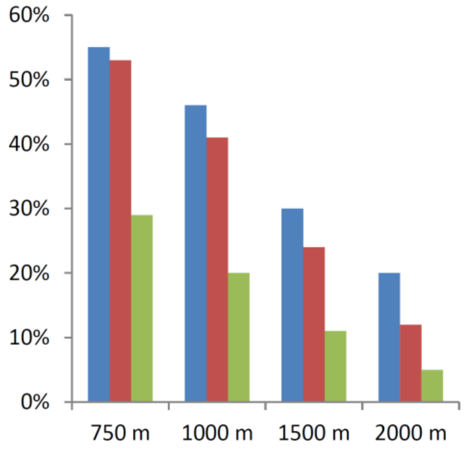

Figure S-3 The impact of the wind turbines on neighbors.
The level of impact from the wind turbines on the neighbors, have been investigated with the distance to the wind turbine as a variable. Three different impacts have been asked the citizens:
Blue: Can hear low frequency noise. Red: Is inconvenient by the turbines. Green: Disturbance in the sleep.
The distance to the wind turbines have a high impact on the neighbors, as the closest have highest level of impact on the everyday life, such as sleep.
Figure from (National organization for neighbors 2014 A).

Here it is seen, that the neighbors living close to the wind turbines have a larger negative effect of them. Which is why the national organization for neighbors to large wind turbines criticize the analysis from Jysk Analyse, as it could give a wrong impression (National Organization for Neighbors 2014).
To get an overview of the complaints Jysk Analyse have documented all complaints to 81 municipalities in 2011 and 2012.

The complaints are focusing on the health issue for being a neighbor to large wind turbines (National Organisation for Neighbors). All scientific analysis have shown that it does not have a physical impact to live close to a large wind turbine[48] (Delta 2011). It is being concluded, that there are low frequency sounds from the wind turbines, but the level is lower than the hearing limit, and should not be felt by the neighbors (Delta 2011).
There are several studies for health effects and noise pollutions from transport (National Organization for Neighbors 2014). This is being discussed in (National Organization for Neighbors 2014), why should the noise be different when it is from wind turbines?
The missing scientific documentation can increase the frustrations from the neighbors, as the experiences they have are not accepted, by the scientific world. To get acceptance and understanding the neighbors get together in groups, both locals (mostly done on Facebook), national (National Organization for neighbors 2014 B) and international (e.g. National Wind facts).

There are new diseases for neighbors to wind turbines, these are called the wind turbine syndrome and the Vibro acoustic disease (Delta 2011). These are used for neighbors there are complaining about the health impact from the turbines, which gives the impact, that it is the

[48] In 2011 Delta[48] made an investigation for "The Danish health and medicines authority" (Delta 2011).

people who are annoyed by the turbines that are the problem, and not the sounds from the turbines . This can be seen by an equation from (Delta 2011).

$$Annoyance = Noise + Context + Person$$

This can give the impression that it is the small neighbors against the large developers, who have money to increase the impact. Together with the feeling that the neighbors are trying to be bought with coffee and cake (National Organization for Neighbors 2014).
From investigation it is seen that the majority of the neighbors does not feel any impact, however this does not help the people who does. This is why any investigation is important, to increase the understanding and communication, even though the trust in the science world are not high for (National Organization for Neighbors 2014).

Appendix T The 48 areas for a Green Church

From (Green Church 2015 D)

KIRKENS LIV

At være Grøn Kirke præger hele kirkens liv og har også med det holdningsskabende arbejde at gøre. Kirker har et særligt sprog og en særlig tilgang til naturen og forvaltningen af skaberværket. Det handler ikke om at være moraliserende, men om at sætte ord på glæden og taknemligheden og at motivere til ansvar for jorden – som gave og opgave.

__ 1. Vi afholder mindst en årlig temagudstjeneste med skaberværket, klima, miljø, natur og retfærdighed som tema.

__ 2. Vi inkluderer skaberværket, klima, miljø, natur og retfærdighed i gudstjenestens liturgi gennem hele året, der hvor det er naturligt (f.eks. prædiken, salmer, bønner).

__ 3. Vi markerer Skabelsestiden hvert år – gerne sammen med andre.

__ 4. Vi integrerer klima, miljø, natur og retfærdighed i kirkens undervisning.

__ 5. Vi samler ind i kirken til støtte af kirkelige klima- og miljøprojekter i verdens fattige lande og/eller i truede områder.

__ 6. Vi arrangerer eller deltager i en temaaften, studiekreds, udflugt el.lign. om skaberværket, klima, miljø, natur og/eller retfærdighed.

__ 7. Vi arrangerer loppemarked, byttemarked, og/eller deltager i indsamlinger til fordel for klima- og miljøprojekter i verdens fattige lande og/eller i truede områder.

KIRKENS INFORMATION OG FORANKRING AF DET GRØNNE ARBEJDE

Det er vigtigt, at arbejdet med Grøn Kirke er synligt og forankres i kirkens daglige liv. Arbejdet med at være Grøn Kirke er ikke kun for de særligt interesserede, men både menighedsrådsmedlemmer, kirkens ansatte, menigheden og kirkens øvrige brugere bør optimalt set inkluderes i arbejdet. Det, som sker i kirken, må også gerne inspireres af eller inspirere i menigheden og lokalsamfundet.

__ 8. Vi formidler stof om skaberværket, klima, miljø og retfærdighed i kirkebladet, på kirkens hjemmeside, via sociale medier og/eller andre informationskanaler.

__ 9. Vi fortæller, at vi er en Grøn Kirke ved at hænge en Grøn Kirke-plakat op og ved at skrive om det i kirkebladet, på kirkens hjemmeside, på sociale medier og andre af kirkens informationskanaler.

__ 10. Vi har udarbejdet en handlingsplan for vores arbejde som Grøn Kirke og gennemgår den mindst en gang om året.

__ 11. Vi har Grøn Kirke på menighedsrådets dagsorden som fast punkt eller mindst 1-2 gange om året.

__ 12. Vi søger at samarbejde med lokale virksomheder, kommunale enheder, andre kirker og organisationer i vores klima- og miljøarbejde.

KIRKENS INDKØB

At være Grøn Kirke indebærer at være konkret og tage tiltag, som har betydning for kirkens grønne fodaftryk. Kirkens indkøb af varer og tjenester kan have stor klima- og miljøpåvirkning. Indkøb gælder alle de produkter og varer, kirken indkøber, herunder

mad, papir, blomster, computere, værktøj, maskiner, elektricitet, brændstof osv. Det er en god ide at gennemgå alle kirkens indkøb for hvert arbejdsområde og overveje, om de kan gøres mere klima- og miljøvenlige. Ved faste og/eller store leverancer er det altid en god ide at indhente tilbud fra flere leverandører, inden man beslutter sig for, hvad man vil købe. Efterspørg gerne produkter med lav klima- og miljøpåvirkning, også selvom firmaerne ikke umiddelbart udbyder dem. Det viser en interesse for sådanne varer, som kan forplante sig til forhandlere og producenter.

__ 13. Vi begrænser kirkens indkøb og køber evt. genbrug.

__ 14. Vi køber madvarer, som har mindst mulig klima- og miljøpåvirkning (økologiske, Fairtrade-mærkede, lokalt producerede og årstidens).

__ 15. Vi køber så vidt muligt miljømærkede produkter til rengøring, vedligeholdelse, kontor og udearealer.

__ 16. Vi bruger så vidt muligt miljøcertificerede, økologiske og/eller Fairtrade-leverandører af varer og tjenester.

__ 17. Ved større anskaffelser, renoveringer og byggeprojekter køber vi miljøcertificerede produkter og materialer.

__ 18. Vi begrænser brugen af kemikalier i f.eks. rengøring, vedligeholdelse og på udearealer.

__ 19. Vi anvender genopladelige batterier, hvor vi kan.

__ 20. Kirken overgår til mest muligt at informere elektronisk og til fortrinsvist at modtage aviser, tidsskrifter og publikationer elektronisk.

KIRKENS ENERGIFORBRUG

Kirkens energiforbrug – særligt af varme – er ofte en dyr post i budgettet. Her kan der ofte spares meget CO2 og mange penge. At spare på energien kan indebære eftersyn af produkter (varmekilder, vandhaner, vinduer osv.), men ofte er der meget at spare ved blot at blive bevidst om forbruget og ændre vaner i hverdagen. Det er altid godt at få professionel vejledning.

__ 21. Vi har fået foretaget en energiøkonomisk gennemgang af kirkens bygninger (kirke, sognegård, præstebolig osv.) og følger dens anvisninger, så godt vi kan.

__ 22. Vi aflæser vores målere for vand, el, varme og gas med passende intervaller, f.eks. 1 gang om måneden.

__ 23. Vi prioriterer lavt energiforbrug og god brændstoføkonomi ved indkøb af f.eks. fryser, vaske- og opvaskemaskine, pc og maskiner til kirkegården.

__ 24. Vi køber certificeret klimavenlig strøm.

__ 25. Vi bruger LED-pærer, hvor det er muligt.

__ 26. Vi slukker lyset i rum, som ikke er i brug og/eller har opsat (lys)sensorer og timere.

__ 27. Vi slukker for computere og andre kontormaskiner, når de ikke er i brug, f.eks. ved at bruge spareskinner.

__ 28. Vi opvarmer med varme, der produceres mest muligt miljø- og klimavenligt.

__ 29. Vi sænker temperaturen, når der ikke er folk i kirken, menighedshuset/sognegården og på kontoret.

__ 30. Vi begrænser brugen af vand.

__ 31. Vi fylder opvaskemaskinen, før den sættes i gang.

KIRKENS TRANSPORT OG UDEAREALER

Forbrug af brændstof i forbindelse med transport med personbiler, lastbiler og fly udgør et stort bidrag til de globale udledninger af CO2 i atmosfæren. Alle kan bidrage til at

mindske dette ved at vælge transportformer, der belaster klima og miljø mindre. Mange kirker har udearealer – både store og små – som kan bruges til grønne formål. Det kræver ikke meget plads at plante træer, bærbuske, sætte fuglekasser eller bistader op. Der er plads til megen fantasi.

__ 32. Vi sikrer cykelparkering ved kirken eller kirkegården.

__ 33. Vi bruger cykel, bus, tog og samkørsel mere og bil og fly mindre ifm. gudstjenester, menighedsudflugter, møder og tjenesterejser.

__ 34. Vi betaler CO2-kompensation ved f.eks. flyrejser.

__ 35. Vi har anskaffet en eller flere tjenestecykler, f.eks. ladcykler til lokal transport for kirkens ansatte og frivillige.

__ 36. Vi afholder nogle af vore møder og kurser som videokonferencer, telefonmøder, via Skype el.lign.

__ 37. Vi gennemfører miljøvenlige og økologiske aktiviteter og forbedringer på kirkens udearealer og kirkegård.

__ 38. Vi laver levesteder for vilde dyr og planter på kirkens udearealer.

__ 39. Vi sikrer økologisk drift af kirkens landbrugsjord og skov mest muligt.

KIRKENS AFFALD

Affald er ikke altid affald, men en ressource, der kan bruges et andet sted. Pap, papir, glas, mælkekartoner osv. kan anvendes i kirkens aktiviteter med børn. Papir, hvor der kun er printet på den ene side, kan laves til notesblokke. Det affald, man ikke selv kan genbruge, kan andre måske anvende. Kirken bør aktivt bakke op om kommunens affalds- og komposteringsordninger.

__ 40. Vi prøver at reparere vores ting og afleverer, hvad vi ikke kan bruge, til genbrug.

__ 41. Vi reducerer vores madspild.

__ 42. Vi bruger fortrinsvist rigtigt service frem for engangsservice. Køber vi engangsservice, er det så vidt muligt af nedbrydelige materialer.

__ 43. Vi printer og kopierer fortrinsvist på begge sider af arket. Vi anvender restpapir og sorterer det, vi ikke bruger.

__ 44. Vi komposterer affald forsvarligt, enten på egen jord eller ved godkendt kompostering.

__ 45. Vi leverer pap, papir, glas og metal til genbrug.

__ 46. Vi leverer elektrisk affald til godkendt modtagelse eller, hvor det er muligt, til en genbrugsordning.

__ 47. Vi leverer batterier, PVC-plast, kemikalierester, el-pærer, samt toner- og printerpatroner til godkendt modtagelse.

__48. Vi opfordrer til genbrug og indsamling af f.eks. tøj, lysestumper, mobiltelefoner, briller.

KIRKENS EGNE TILTAG

Der kan være mange grønne tiltag, som ikke er dækket ind under denne tjeklistes kategorier og punkter.

De tæller også med! Tilføj jeres egne ideer og tiltag her.

__ 49.

__ 50.

__ 51.

__ 52.

Appendix U Interviews

Interview med Biskop: **Peter Fisher-Møller** d. 2/9-15 kl. 11-12.

Kender du det nationale mål for DK.

- Ja

Bliver dette taget med i kirkernes vurdering

- Ja, Poul klenz Larsen der er energikonsulent for kirkerne er meget opmærksom på dette. I den generelle rådgivning til kirkerne er de nationale mål med. Beslutningskompetencen ligger hos menighedsrådene og dermed hos den enkelte kirke, og der er det ikke nødvendigvis samme billede, i forbindelse med priotering. Ved ændring af varmesystem er energikonsulent med.

  Nogle stifter og provstier arbejder meget, og der er også grønne kirke som er moralsk forpligtede til at tage del i dette. Nogle provstier har energipuljer, det er midler der er sat til side i forhold til grønne energi ændringer. Der taget tilbagebetalings tiden med i beslutningen efter hvilken ændring der laves først.

Har du nogle erfaringer med hvad holdningen er i stiftet? (General)

- Det er meget forskelligt. Det er menighedsrådende som skal vælge at priotere bidrag til nedbringelsen af CO2, og dermed er det meget forskelligt i stiftet. Det er menighedsråd som har ansvaret.
  Stiftet kan inspirere og være et grønt stift, fx ved at gøre opmærksom på klima ændringerne, og skrive i stift bladet. Provstiet kan sætte puljer af.

  Vedrørende vindmøller er der kun ved Flakkebjerg (fem år siden), hvor vindmøllen var langt fra kirken, hvor menighedsrådet søgte veto. I virkeligheden handlede det nok ikke så meget om kirken, det var andre i lokalområdet som ikke ville have reflekser og brummelyde. De lokale kom så til menighedsrådet og spurgte om de ikke var enige om at det var dårligt for kirken. Lokalt ønskede man at menighedsrådet bakkede op om den lokale holdning. Dog sagde stiftet nej, da det blev vurderet at man ikke ville kunne høre noget på den afstand og derudover var der blot gudstjeneste en gang om ugen i en time. Hvor meget betyder reflekser så i forhold til at forstyrrer gudstjenesten.

  Aalborg stift har screening af alle opgaver. De kan ikke gøre noget, men fortæller menighedsråd hvornår der er noget at være opmærksom på.
  Aalborg er ikke indsigelses berettet. Det er de enkelte stift der er indsigelses berettiget. Stiftet agere på baggrund af menighedsråd.

Er der lokale som har kontaktet dig direkte for brug af veto retten?

- Nej.

Er der nogle økonomiske interesser i forhold til vindmøller fra kirkernes synspunkt?

- Nej, ikke med vindmøller. Der har været i forbindelse med solfangere. Der arbejdes meget på varmeområdet, bl.a. ved varmepumpe, luft til luft og jordvarmeanlæg (ikke effektive ved periodisk opvarmning som kirker, dog god hvis der er min. 10grader i

kirken). Varmeovne kan varme luften i en kirke op og ikke muren (som er 1m tyk). Der er kuldebro mellem væggen og luften i kirken.
Kalkmalerier har bedst af ikke at blive varmet op. De er malet til det kolde rum.
Jakob Lidegaard, ændrede sol anlæg støtten. Anlæg ved jorden blev ikke længere støttet. Da kirken ikke kan have solfangere på tagene- grundet historisk og fredede bygninger, blev økonomien dårlig for kirkerne. Der var brevudveksling med ministrere, dog var det blevet for politisk så det ændrede ikke noget.

Er der noget imod at en kirke køber andele af en vindmølle?

- Det ved jeg ikke. Det er ikke et spørgsmål om teologi, men lovgivning. Der er en klar lovgivning om hvad menighedsråd må investere i. De må kun investere i kirkens drift i almindelighed, personale og kirkelige handlinger. De må ikke støtte noget, de må købe ydelser der er relateret til kirken. Man kan købe andele af vindmølle som svare til kirkens el forbrug, medmindre de forpligter sig til noget. Man er som andelshaver også ansvarlig i forhold til møllen. Det kan være en risiko fyldt investering hvis møllen falder ned.
  Men der bliver ikke opstillet landvindmøller så meget mere. Kirken kan nok ikke købe en andel af de store havvindmølle parker.

Hvad er motivationen i stiftet, hvad kan motivere i forhold til vindmølle projekter?

- Grøn kirke kan motivere, det er iværksat af danske kirkers råd, meget oppe under klima topmødet i Kbh. Der er flere punkter som har fokus på transport, bygninger etc. det er motiverende faktorer. Der er grønne provstier som har energipuljer.
  Der er fælles tiltag fx med det fælles krematorium i stiftet. Der reducere energiforbruget til krematorier med 50%.
  Stiftet motivere ved samarbejde med grøn kirke, hvor man har 200000 til samarbejde med grøn kirke, til vejledning, støtte og brede grøn kirke ud. Dette har resulteret i 40 grønne kirker i stiftet. Der er flest grønne kirker i Roskilde stift i dk.
  Stiftet kan ikke bestemme, men kan inspirere og stille ekspertise til rådighed og sætte grøn kirke på dagsordenen ved fx møder, stift bladet og hjemmeside.

Er det for sent for kirkerne at blive informeret via VVM redegørelsen gennem Aalborg stift eller om det kunne være ønskeligt at have en anden informations kilde?

- Det har jeg ingen fornemmelse af. Det er godt at kirken har etableret et fælles forum i Aalborg stift, og har dannet ekspertise inden for dette felt.

Kunne det være en ide at gøre menighedsråd mere aktivt.

- Ja det kunne man godt, særligt hvis menighedsrådet er en del af grøn kirke. Så kunne det sagtens være en mulighed. En ting er det økonomiske bag de grønne tiltag i grøn kirke, noget andet er at arbejde med hele baggrunden med en teologisk vision. Den handler om at når Gud har skabt verden og set at det var godt, så har naturen i sig selv en værdi og ikke kun som ressource for vores aktiviteter. Bibels historie er at vi er blevet udstyret med evner som gør os i stand til at leve op til et ansvar, vi er skabt i hans bilede, vi har følelser, fantasi, sprog. Og vi er blevet betroet forvalter ansvaret, hvad vil det siget at herske over verden. Tidligere har det været understreget at vi (mennesket) har en magt over for naturen, nu er det mere at vi har et ansvar over for naturen. Det er bibelsk tradition et kald på retfærdighed. Vær særlig opmærksom på

enken, den fattige og den fremmede, dem som ikke har så meget. "riv i marken let" det bliver også brugt i salmer, kaldet til at tage sig af de fattige. Det er også noget der bliver brugt i klima diskutionen, hvem er det klima ændringerne går mest ud over, det er dem som har for lidt i forvejen. Vi har et ansvar ikke kun for os og vores eget, men også for andre, for de fattige.
I teologien er der en håbs dimension, som bruges, til at give kræfter til at tage fat i dette område. Og ikke give op pga. opgavens uoverskuelighed.
Kirken har en opgave i klimadebatten, dog står der ikke noget direkte i biblen, det er et perspektiv som kirken kan bidrage med. Og være en del af civil samfundet.
Det at aktivere menighedsrådet som en del af civilsamfundet er fint, så der ikke bliver fokuseret på dårlig presse eller fordomme, men fokus på fakta. Samarbejdspartnere kunne også være idrætsforeninger fdf etc.

Menighedsråd har en høj gennemsnits alder, og respekteret i lokal samfundet- er det korrekt opfattelse?

- Ja, dog skal man være forsigtig som kirke.
  Der var en gang et varmeværk som kom til kirken. Der var ved dette projekt en god økonomi, og sikkert i forhold til risiko. De bad kirken går ind og bakke op om dette projekt. Energimæssigt gav det mening. Men de lange rørledninger gav stort varmetab. Der blev lokket fra projektets side med at det var gratis at melde sig med i dag, i morgen ville det koste 10.000 og når det var bygget ville det koste 40.000 at komme med. Så derfor var der mange som meldte sig med. Der var fællesøkonomi i projektet og mange meldte sig til. Da det var bygget viste økonomien sig at være dårlig, støtte fra staten blev tilbagetrukket. Energi, gas etc. priser udviklede sig anderledes end forventet. Det endte med at koste det dobbelte af tidligere, derfor var der nogle som ville købe sig ud af projektet. Dette kostede dog 100.000. Da var jeg glad for at kirken ikke havde været talsmand for projektet, da det ikke gik som ventet. Kirken havde økonomi til at betale, men folk havde ikke. Det har plaget flere landsbyer i 15 år. Varmekilden var fornuftig i forhold til CO2 dog ikke økonomisk.
  Derfor kan kirken være til tilbage trykket.

Hvad har den højeste indflydelse på beslutningen for veto?

- Det er forskelligt for menighedsrådende. Dog har det en vis indflydelse at kirkerne altid har været et vartegn for landskabet. Dette kan ses fx med lys på kirke om vinteren. Det tegner kulturen og naturen i Danmark. Mange vindmøller meget tæt på kirken, med høje tårne. Ligesom med forbrændingen i Roskilde (3km fra domkirken), der gik vi ind og spurgte til forhold med domkirken. Det viste sig at de havde lagt 8m til i højden fordi det var sjovt at være højere end domkirken, der indgik samtale om at slette de 8m. Det visuelle betyder noget. I forhold til lyd of reflekser betyder dette ikke noget for kirkerne, da folk sidder ned i kort tid, og risikoen for refleks under en begravelse er lille. Lyd og refleks er høj prioteret blandt lokal befolkningen, men ikke for kirkerne.

Beslutningen?

- Aalborg stift screener og ser om der er noget relevant. De laver ingen udtalelser og har ingen magt. Menighedsråd kan have hørt om det gennem lokalpressen først.
  Stiftet har ingen meninger før de har talt med menighedsråddet, som får VVM direkte fra Aalborg. Menighedsråd skal sige ok. Dog kan stiftet sige nej derefter. Der bruges

landskabsarkitekt og national museet som har specielle kompetencer. Provstier er intet at skulle have sagt.

Informationer der er vigtige i forhold til kirken?

- Det er VVM redegørelsen som er vigtig, og der er ikke brug for andre informationer. Hvis man ser på kirken som veto ret, men anderledes hvis man ønsker kirken som en medpartner.

Er visualisioner nok for kirken?

- Kirken er ikke den som siger mest nej. Den er ikke den væsentligste enhed.
  For lokalbefolkningen er det godt med tidligere visualiseringer. Få gødet jorden lokalt inden VVM er en god ting.
  Det var kunsten i gamle dage at det var lokale som opsatte møller, da var det et billede for fællesskab og penge til de lokale. Det var kun de lokale som kunne investere i det. Nu er det store firmaer, som sætter møller op. Derfor er det for lokalbefolkningen først of fremmest en hindring i min udsigt og nogle der er ude på at skjule noget- når de skal have et projekt igennem. Det er vigtigt hvem der sætter en mølle op. Er lokalbefolkningen nogle som bare skal overtales.

Teologisk kunne der være mulighed for samarbejde mellem mølle og kirke (særligt grøn kirke)?

- Det kunne der, jeg kender ikke mulighed for økonomisk samarbejde. Men der kunne være samarbejde, måske ved at kirken talte positivt om møllen. Rappelling kunne godt være en mulighed man gør det jo på kirketårne så hvorfor ikke mølle tårne.
  Der kunne også være friluftsgudstjenester ved en mølle, med særligt fokus på den grønne kirke. Hvis sikkerheden og ejerforhold er i orden.

Kan du se om et vindmølle projekt kan hjælpe et lokalsamfund?

- Jeg synes ikke at det kan hjælpe et lokalsamfund, da det ikke længere er de lokale som laver en andelsforening. Dengang havde man noget sammen og bakke op om. Men nu hvor der er store kommercielle sager der ikke tager del i lokalsamfundet, derfor er det ikke en fordel. Medmindre at det kan blive et kendetegn som fx tvind møllen, men der er så mange møller at det ikke længere kan være et vartegn. Møllen er ikke ressource på den måde, den skal være lokalt eget, så det er befolkningens mølle.

Grøn kirkes locatering?

- Der er næsten ikke nogen i Ribe stift, (Ribe stift er et af de stifter som har lavet flest indsigelser imod vindmøller – Dorte), ja. Det er en politisk sammenhæng, det er DF land i et vist omfang. Hvis man generelt er klima skepsis, vil man også være det i menighedsrådet. Der er sket en sammenkobling mellem tidehverv og DF. Tidehvervs inspireret teologi, tænker kirke for sig og politik for sig. Derfor argumentere man meget skarpt, og er kun politiker ved politik møder i kirken er det kun om syndernes forladelse. Og kirken skal ikke blande sig i politik. Og klima er politik.

Hvordan kommer grøn kirke ud til kirkerne?

- Der er tre grønne stifter (Aalborg, Åhus og Roskilde), som bruger stift bladet til at komme ud til kirkerne på. Og giver mulighed for at trække på ekspertise.
  Det handler også om biskoppen er pro grøn kirke, fordi det er nemmest at få det videre ud igennem stift møder, hjemmeside og stift blad etc.

Biskopperne i DK er af forskellige opfattelser om hvorvidt det er kirkens opgave at ændre klimaet. Alle er pro for de økonomiske tanker bag, dog ikke for den teologiske argumentation.

Der er en teologisk drejning i grøn kirke

- I høj grad.

Det er naturligt at tidehverv og andre konservative kirker ikke bliver grøn kirke. Birthe Rønn Hornbæk har udtalt til Peter om de skulle til at køre en særlig kirke klima politik, men Peter fortalte at det ikke handlede om det. Der er ikke nogle som presser grøn kirke ned over menighedsrådende men stiller ekspertise til rådighed, og det er menighedsrådende som tager alene beslutningen om at være grøn eller ej.

Mail correspondence 23/09-15 with **Marie Johansen from Aalborg Diocese**

1. Can you please explain the process from the ecclesiastical sector?
Når en kommune udarbejder et planforslag - enten i form af en lokalplan, kommuneplan el-ler kommuneplantillæg, skal dette offentliggøres på www.plansystem.dk. Da Aalborg Stift har opgaven som screeningsenhed for alle planforslag i Folkekirken (Plancenter Aalborg), modtager Aalborg Stift samtlige offentliggjorte planforslag. I forbindelse med screeningen af planforslagene, er Plancenter Aalborgs opgave at frasortere sager, der umiddelbart er uden interesse for folkekirken, hvorefter sager, der kan indebære negativ påvirkning af den visuelle og landskabelige oplevelse af kirkebygninger og samspillet med de umiddelbare omgivelser overgår til videre sagsbehandling i de enkelte stifter.

Dette er også fremgangsmåde med de planforslag som screenes af Plancenter Aalborg og så videresendes til sagsbehandling i Aalborg Stift.

Når et planforslag omhandler vindmøller, bliver planforslaget øjeblikligt fremsendt til det lokale stift, til videre sagsbehandling.

I denne videre sagsbehandling vurdere Aalborg Stift planforslaget og foretager en vurdering af, hvilke kirker, der eventuelt bliver berørt af de planlagte møller. Derefter sendes planfor-slaget til udtalelse hos stiftets konsulenter. Såfremt der er tale om en lokalplan fremsendes forslaget til udtalelse hos stiftets kirkegårdskonsulent. Er der tale om en kommuneplan eller et kommuneplantillæg sendes sagen til udtalelse hos Den kongelige Bygningsinspektør.

Når konsulentens udtalelse foreligger, indeholder den en indstilling til stiftet om, hvorvidt konsulenten vurdere, om der er behov for at stiftet fremsender en indsigelse. Derefter træffer stiftet beslutning om, hvorvidt der skal fremsendes en indsigelse imod planforslaget.

Såfremt der er tale om en lokalplan, kan stiftet i henhold til planlovens § 29, stk. 3 fremsætte indsigelser imod forslaget ud fra de særlige hensyn som myndigheden varetager.

De særlige hensyn som vores myndighed skal varetage, udspringer blandt andet af § 29 i be-kendtgørelse nr. 338 af 29/03/2014 om folkekirkens kirkebygninger og kirkegårde, hvoraf der fremgår følgende:

"Menighedsrådet skal søge at forhindre, at kirkens og kirkegårdens nærmeste omgivelser bebygges eller bruges på skæmmende måde.
Stk. 2. Det bør så vidt muligt undgås, at der foretages sådanne ændringer i bebyggelsen og beplantningen ved kirke og på kirkegården, at skønhedsværdiger, der er knyttet til samspillet mellem kirke, kirkegård og omgivelser, forringes."

Er der tale om en kommuneplan eller et kommuneplantillæg, skal indsigelsen fremsættes via Kirkeministeriet til Miljøministeriet, hvorefter Miljøministeriet fremsender en indsigelse. Dette følger ligeledes af § 29, stk. 1. Indsigelsen jævnfør denne bestemmelse tager sigte på kommuneplaner og kommuneplantillæg, der ikke er i overensstemmelse med de overordne-de interesser, herunder de statslige interesser.

Når en indsigelse er fremsendt i henhold til planlovens § 29 har denne opsættende virkning. Dette betyder at planforslaget ikke kan vedtages endeligt. Forslaget kan først vedtages, når der er opnået enighed mellem parterne om de nødvendige ændringer. Kan de involverede myndigheder ikke nå til enighed, kan spørgsmålet indbringes for erhvervsministeren (tidli-gere miljøministeren.)

Når en indsigelse fremsætter efter § 29 skal de være begrundede.

2. Is the national energy plan included in the screening process in Aalborg?

Nej.

3. Who are doing the screening? - What are the educations?

Den primære screening foretages af kontoruddannede på Aalborg Stift. Screeningen foreta-ges ud fra parametre, der er fastsat af ledelsen i de 10 stifter. Til brug for screeningen har Plancenter Aalborg (Aalborg Stift) udarbejdet et system, der blandt andet viser samspillet mellem kirke, planforslag fredninger. Systemet er et offentligt system, der kan ses på www.kirkeplan.dk.

Screeningen skal som udgangspunkt frasortere de sager, der umiddelbart er uden interesse for folkekirken, hvorefter sager, der kan indebære negativ påvirkning af den visuelle og landskabelige oplevelse af kirkebygninger og samspillet med de umiddelbare omgivelser overgår til sagsbehandling i de enkelte stifter.

Plancenter Aalborg screener lokalplaner, bevarende lokalplaner, kommuneplantillæg og VVM-husdyrgodkendelser.

Hvorimod kommuneplaner - herunder vindmølleplaner, miljøvurderinger - planer og pro-grammer, VVM - herunder scoping og anlægsprojekter samt landzonetilladelser sendes di-rekte til sagsbehandling i de enkelte stifter.

Screeningen foretages ud fra planområdets beliggenhed i forhold til kirkebygnin-ger/kirkegårde. Her frasorteres sager, hvor planområdet ligger helt eller delvist udenfor
a. Kirkebyggelinjen (300 meter fra kirker, der ligger mere eller mindre åbent i landska-bet) og/eller
b. Kirkebeskyttelseszonen (områder med særlige beskyttelse, fastlagt i kommuneplanen)
c. Kommuneplanen

Uden for disse zoner er formodningen for, at planforslaget ikke har betydning for folkekir-ken. MEN større anlæg, antenner, skorsten, master eller lignende kan - også over større afstande ende de fastlagte beskyttelseslinjer - indvirke på den landskabelige oplevelse af kirkerne som markante kendingsmærker i landskabet.
Det er derfor vigtigt at forslagets formål også indgår i screeningen.
Forslagets bygningsregulerende bestemmelser vurderes i forhold til nærliggende kirkebyg-ninger: stor max højde/volumen.

Screeningen foretages inden for 8 dage efter at planforslaget er modtaget i Plancenter Aal-borg.

Efter screening henlægges de sager der ingen betydning har i forhold til kirkerne og deres omgivelser. Resten overdrages til videre sagsbehandling i de enkelte stifter, samme med ovenstående der overdrages direkte.

4. Are there general current opinions for wind turbines in the dioceses in Denmark?
a. Experiences?
Nej

5. What emotional interest can a diocese have regarding wind projects?
Sagerne vurderes ud fra objektive kriterier og der er ingen følelsesmæssige interesser invol-veret i vurderingen af, hvorvidt et planforslag om vindmøller har negativ indflydelse på kir-ken og dens omgivelser eller ej.

6. What financial interest can a diocese have regarding wind projects?
Stifterne har ingen økonomiske interesser i vindmølleprojekterne.

7. What theological interest can a diocese have regarding wind projects?
Umiddelbart ingen.

8. Other interest?
Nej.

9. What motivates a diocese- regarding wind projects?
Alene hensynet til at kirken har en fremtrædende og markant position i landskabet og at oplevelsen af kirken ikke forringes af forstyrrende elementer.

10. What is most important for at diocese regarding wind projects?
Det er at sikre at bevarer den landskabelige oplevelse af kirkerne som markante kendingsmærker i landskabet. Dermed ikke sagt at stifterne er imod vindmøller, absolut ikke. Stifter-ne skal alene sikre at vindmøllerne locateres så de ikke får en negativ indflydelse på oplevel-sen af kirken.

11. What information is wanted from the projects to a diocese?
Til brug for sagsbehandlingen har stifterne oftest brug for visualiseringsbilleder, der viser samspillet mellem kirker og vindmøller. Det er her vigtigt at få belyst samspillet mellem kirken og vindmøllerne, både med møllerne som baggrund og ved siden af kirken. Ligeledes er der behov for en grundig beskrivelse af projektet.

12. How should the communication be?
De oplysninger som stifterne har brug for bør fremgå af det offentliggjorte planmateriale. Det er naturligvis altid muligt at indgå i en dialog med kommunerne. Såfremt der fremsen-des en skriftlig indsigelse imod planforslaget vil den videre kommunikation som oftest fore-gå i møder.
a. By mail?
b. Face to face?
c. Information?
d. Conversations?
e. Should the diocese be included in several meetings?
f. Other?

13. How often should the communication be?
a. What parts of a wind projects is interesting for a diocese?
Ingen bemærkninger.

14. In the ecclesiastical sector, who should be contacted first from a wind project?
Stifterne har opfordret kommunerne til, så tidligt som muligt at kontakte stifterne, også ger-ne inden planforslaget er udarbejdet, da de kan være med til at sikre en hurtigere proces, så-fremt der tidligt i processen kan inddrages de oplysninger som stifterne har brug for.
15. Who in a diocese should be contacted first (a talk person for the project)?
Det er vigtigt at kommunikationen går til bade menighedsrådet og stift.

16. At what time in the planning process should a diocese be included (ideally)?
Så tidligt som muligt. Dette er med til at sikre at de korrekte oplysninger er med i planfor-slaget, således at processen ikke bliver forsinket senere hen.

17. Who have a diocese influences on?
Ingen bemærkninger.

18. Who have influences on a diocese?
Ingen bemærkninger.

19. Who have the “power” for the decision?
a. The local church council?
Det lokale menighedsråd har altid mulighed for at fremsende bemærkninger til et planforslag. Menighedsrådet kan også anmode stiftet om at vurdere en sag og even-tuelt fremsende en indsigelse.

b. The deanery?
Det lokale provsti har også altid mulighed for at fremsende bemærkninger til et plan-forslag. Provstiet kan også anmode stiftet om at vurdere en sag og eventuelt frem-sende en indsigelse.

c. The diocese?
Stiftet har mulighed for at fremsende indsigelser imod lokalplaner, hvilket i givet fald vil have opsættende virkning for vedtagelse af planforslaget.

d. The national museum (The Royal Surveyor)
Ingen bemærkninger.

e. The ministry? - Which?
Såfremt der er tale om en kommuneplan skal indsigelsen fremsendes via Kirkemini-steriet til Erhvervsministeriet (tidligere miljøministeriet), der så kan fremsætte en indsigelse imod kommuneplanen eller kommuneplantillægget.

20. According to the history of the dioceses, what impact has had the highest influence on the decision for veto or not?
Ingen bemærkninger.

21. In wind turbine planning, what is most important - from your point of view?
Ingen bemærkninger.

22. In the ideal world - where should wind turbines be located? (Do not thing about the money in this question).
Ingen bemærkninger.

23. How can the church and the wind turbines be more connected (for this questions it is assumed that there are wind turbines near a church).
a. Should there be a connection?
b. How often should the connection be?
c. Could the church bye any shares in a wind projects?
d. Will the possible connection change your opinion for wind projects?
Ingen bemærkninger.

24. Can a wind project help a local community from your point of view? And if yes - how?
Ingen bemækrninger.

Meeting with Energiplan.dk 8/01-2015, **Benedicte Julie Volelen**

At Energiplan (In Copenhagen) there are not working on energy planning and siting of wind turbines. It is possible to contact Jørgen Linnegård Olsen (located in Jutland) for the energy planning.
In Copenhagen the work is about the EIA report. The timeline is min. one year for one report, and there is some waiting time because there is a need for different investigation, the writing of the report is only around 3 months.
It is the project manager there is taking contact to Energiplan, and is paying for all the investigations. This is done without any binding contract with the municipality, hence it is the project manager there is taking the risk. Energiplan is investigating the sites given by the project manager.
There is a contact person in the municipality, there can use other specialist in different parts of the municipality if there are any questions.
In the EIA report there is visualizations of the possible future wind turbines. There are taking pictures from all the nearest neighbors, public locates (roads, buildings etc.), from all historical/cultural locates (e.g. churches) and from all four corners of the world, in different length.
There is a highly need for local engagement to find all the small local locates, where the wind turbines can have an impact. The local engagement can be difficult to find, hence sometimes local locates have been missed by Energiplan.
There is used to program Vindpro to locate the wind turbines in the pictures by GPS coordinate, the wind turbines can change direction to give the correct visualization.
It is energiplan there is given the conclusion if the wind turbines has a large/medium or small change of the area, this is a subjective conclusion. (Are wind turbines pretty or ugly?)
In the hearings Energiplan is only talking about the EIA reports, and is receiving objections about this. It is being experience that it is one group of people there is coming to many hearings, and have many objections about all wind turbine projects, even though they does not live close to the project.
It is Energinet there handles both the flexibility in the energy system, and the purchase option at the hearings.
It is wanted to have good EIA reports, hence this will give the best arguments in a future discussion, hence the energiplan sometimes want to do more investigations than the project managers do.
It is the locale politicians there is taking the last decision if the project is going to be realized. Hence it is free for the municipality to do siting investigation for wind turbines.
Present there is a health investigation from the environment agency about being a neighbor to large wind turbines. This investigates have been expended several times, which results in projects setting on hold- the municipality are waiting for the result before setting large wind turbines up. The environment agency is urging the municipalities to keep planning the projects as before.

Telefon interview med **Søren Magnussen**, energiplanlægger i Roskilde kommune, fredag d. 30 jan 2015

- Hvad skete der med sidste plan?
    - Forvaltningen anbefalede at dele vindmølle planen og valget, men politikerne ville gerne have en grøn profil og derfor ville have vindmøllerne med i valgkampen. Det var kun SF og Enhedslisten som stod fast på at have vindmøller i kommunen. Efter valget blev der nedsat et politisk udvalg til energiplanlægningen.
    - Søren er strategisk energiplanlægger, han laver CO2 kortlægning, men bruger ikke modeller.
- Hvad er der i Roskilde kommune
    - Der er private og offentlige solceller
    - Sol og vind er 3% i Roskilde
    - Der er begrænsede muligheder, da der er givet et millionbeløb til et nyt kraftvarmeværk som har affald til energikilde.
    - Der arbejdes på at udvide fjernvarmen i Roskilde
    - Der skal laves en ændring fra olie, el, og naturgas landsbyer til mere grøn energi
    - Roskilde ønsker at styre energi selskaberne mere ved at opruste det administrative og politiske styring.
    - Der ønskes en ændring af solvarme og fjernvarme.
- Rambøl laver energiplanlægningen for kommunen, og der bruges derudover andre konsulent virksomheder.
- Det skal overvejes om det samfundsøkonomiske er ok, om det kan betale sig at ændre naturen?
    - Forskellige konsulent virksomheder diskutere dette og Søren hjælper til med at tage valget.
- Det excel sheet som er leveret af Søren er fra 2008-2012
    - Rambøl lavede beregningerne
    - Søren lavede rapporten og graferne, således at han har forståelsen for arket.
    - Der er sendt et lille udvalgt del af arket, hvis der er behov for yderligere oplysninger skal jeg skrive til Søren og spørge efter de mere specifikke tal.
- Dansk energi havde i August måned en ”sommerskole” for at forklare energi systemet hvor energi ministeriet havde fokus på det politiske og energinet har fokus på systemet. (Der var nogle gode diskussioner).
- Der er nogle dage med fokus på energien i Roskilde kommune d. 10-11 marts på RUC. Kontakt Lærke Møller Toftlund for at høre om det er muligt at komme med.
- Kontakt energiklynge Sjælland for at høre om deres rolle i kommunen.

Interview with the **Lia Kaufmann** the Wind turbine task force 20th of January

- The task force role in the Roskilde case:
    - The task force did not helping with the planning process.
    - The task force was called in, in the last moment to help with the public meeting.
- The project in Roskilde did only go to the overall plan, before it was stopped.
- The task force are working in Ringkøbing the geographical area is different from Roskilde.
- People involed in the process:
    - Politicians
    - Landowner
    - citizens
    - projectleader
    - See picture from work
- The task force have done a GIS analysis of Roskilde
- The flexibility is not taking into account on municipality level, it is the Energinet.
- When are the task force being involved in the process?
    - It is very different, most is for public hearings or public meetings.
    - For specific questions by mail/phone etc.
    - In Århus there are public engagement in the planning process.
    - The task force is being consultant on the process
- The communication with the public
    - The task force recommend more communication to the public, personal contact, letter, telephone face to face etc.
    - Most communication is more traditional from the municipality:
        - Ads in local newspaper
        - Webpages
        - Few letters to the closes neighbourghs.
    - The task force recommend to use coffee tables in public meetings, to increase the communication between the public and the decisions maker.
- There is no caseworker, it is the municipalities that takes the decisions.
- Look into vindinfo.dk
- The task force recommend:
    - Involve the public faster in the process
    - The municipality worker should reflect over the work there is done and his/her role, how to be "Peter" and not just the municipality worker.
    - Other areas (social areas) are further ahead in the communication, take this into account. Find good communication from these areas and put it into the energy area.
    - The communication is sender oriented, instead of receiver oriented. "I have already said that".
- The task force is not involved with the energyplanning and modeling.
- The task force can help with the purchase options if the Energinet it not at the hearing.

- When the old turbine has to be taking down and a new one is put up, the process is like with a new area for wind turbines.

Interview with **Thomas Budde Christensen**, RUC, 19/01-2015

He works at a project called STEPS.
The people working on Roskilde energyplan are Energiklynge Sjælland and Klimaråd Roskilde.

They have done heating planning and the bio ressources in Roskilde municipality.
Roskilde have assigned Bogmesterpagten (to reduce 20% CO_2)
Roskilde want to buy wind, last project had it down to 6-8 areas for onshore wind turbines
The wind should be bought from other municipalities in Zealand. This could become a problem with double counting of lost emissions from the wind turbines.

The municipalities does not take the flexibility into account, that is the Energinet. This is a part of the “armslængdeprincippet”.

Some of the input to the heating plan is to change the small villages to small cities, and change the heating of the houses. The emissions is counted up. And the biomass is being counted.

Look into the webpage: bioenergisjælland.dk (and look into Roskilde)

The strategic energyplan for Roskilde is meant to be done in June. Remember the time to make the changes.

Rambøll made a climaplan in November

RUC use a backcasting model.
The goal is decided by the politicians.
Heating use is calculated by the year of the building ,the area and the heating model.

Meeting with Energiklyngecenter Sjælland, with **Lærke Møller Toftlund**, Tuesday the 17th of February

- It is the municipalities at Zealand there is paying for the center, and the region is given the center projects, in the same range (economic) as the municipalities' membership.

- In STEPS there is no communication, there is communication plans in other projects, e.g. "Bioenergi Sjælland" and "Implemensering af Bioenergi Sjælland".

- It is suggested to let wind energy finance other projects, to lift other projects e.g. biogas. This is because the economic in wind is good now, and can help make other projects more feasible.

- STEPS: the goal is to have 16 strategic energy plans, this have been change to have inputs for 16 strategic energy plans during the project. Thyge Kjær (RUC) does all calculation regarding Roskilde municipality.
  It is the different municipalities there can decide which projects to work on- it is not the region- as other regions in Denmark.

- It is the municipalities responsible for the projects.

- The long-term goal is 100% renewable in electric and heating sector in 2035. The short term is 2020; hence, the projects need to begin now. The ideas for 2020 is concrete and are fluffier for the ideas for 2035.

- For the planning, it is expected that the municipalities have to be covered by local resources.

- Energiklynge center Sjælland makes plans for projects to cover the goals 1.5 times, so the politicians can choose between the different projects.

- The cooperation between the municipalities in the region is mostly about competence, method and development.
  The DH cooperation set the pipes across the municipalities' borders.
  The cooperation should decrease the double planning, when two municipalities are planning in the same area.
  Roskilde municipality is working about the water supply with Lejre municipality.

- There is a goal about the share of wind in the region.
  There is cooperation about the competence.
  Increase the communication over the borderlines.
  One year before the project STEPS there was a plane for making a regional wind park, offshore. This was not completed because Greve municipality was not pro the project.

- The security of supply is not good now because of the import of oil and gas. For the future, the local resources should be used first to increase the security.

- The flexibility is not being calculated, but there have been thoughts about it, e.g. by increasing the biomass in the region. At the present, it is the heating sector there are mostly concrete.

- The partners of Energiklyngecenter Sjælland have a deadline for the calculations at 1/7-15.

- It is experienced a change in the public, more citizens wants wind in the system, e.g. in Guldborgsund municipality.
  The public is ready for some change in the system, they are positive for more RE.

Interview med **Tyge Kjær** d. 10-06 2015.

Der skal ikke snakkes om lokal accept af vindmøller, men de lokale skal ville vindmøller i stedet for.
Planloven kan sætte en stopper for vindprojekter, der er nogle landområder som ikke må udvikles.

Vindmøllers locatering i Danmark er top-down model, indtjening er til andre end dem som har generne.
Det kan være svært at lave andelsselskaber som kan købe 3 vindmøller. Dette kan være en af grundende til et fald i disse.

RUC bruger programmet Vindpro, til at lave vindmølle locatering. Det som er positivt set fra RUC er at eksisterende møller er inkluderet, sammen med et kort og vind ressourcer.

El systemet er et sjællandsk system, det er et sammenhængende net. Varme er til gengæld et lokalt system.

Det største problem er manglende vind, og dermed manglende elektricitet.
Modeller tænker teknologi, og glemmer ”Fru Jensen”.

Energi systemet i Danmark.

1950: Mange små værker, kaotisk produktion
De blev mere centrale, 1972 store kraftvarmeværker
PT har vi et system der ikke kan ændre mængde, og derfor er der behov for tanker omkring lagring.

Negative elektricitets priser i kolde nætter, dette er grundet af kraftvarmeværkerne producere varme, og derfor også elektricitet. Når der er meget blæst vil der være en over produktion af elektricitet.
Det er tilskud som bestemmer hvilke vedvarende energi typer som opsættes i Danmark.

I modeller er der en pris antagelse, dette fungerer ikke, derfor skal man i stedet tænke over teknologi udvikling, og lade dette styre modellen.

Der er nogle som vil vind, derfor kommer det af sig selv til Roskilde.
Der kan sættes spørgsmålstegn til hvad afgifter i Danmark skal bruges til: progressiv planlægning vs back casting.

Alle projekter i Roskilde som bliver lavet nu skal have kurs mod 100% bæredygtig energi, dette er målet at komme i land med de politiske mål for 2035.
Mulighederne skal ikke hele tiden opdateres, der skal vælges ved kommunens ressourcer.

Ved en ekstra afgift på fx olie (fossile brændsler) er det udkants Danmark som betaler for dette, og dermed vil det være en skæv fordeling af afgifter og muligheden for ændring af dette.

Det er vigtigt at huske flexibilitet, fx mellem varme og elektricitet.

DTU Vindenergi er et institut under Danmarks Tekniske Universitet med en unik integration af forskning, uddannelse, innovation og offentlige/private konsulentopgaver inden for vindenergi. Vores aktiviteter bidrager til nye muligheder og teknologier inden for udnyttelse af vindenergi, både globalt og nationalt. Forskningen har fokus på specifikke tekniske og videnskabelige områder, der er centrale for udvikling, innovation og brug af vindenergi, og som danner grundlaget for højt kvalificerede uddannelser på universitetet.

Vi har mere end 240 ansatte og heraf er ca. 60 ph.d. studerende. Forskningen tager udgangspunkt i ni forskningsprogrammer, der er organiseret i tre hovedgrupper: vindenergisystemer, vindmølleteknologi og grundlag for vindenergi.

Danmarks Tekniske Universitet
DTU Vindenergi
Nils Koppels Allé
Bygning 403
2800 Kgs. Lyngby
Telefon 45 25 25 25

info@vindenergi.dtu.dk
www.vindenergi.dtu.dk