Samsø Energy Vision 2030

Converting Samsø to 100% Renewable Energy

Mathiesen, Brian Vad; Hansen, Kenneth; Ridjan, Iva; Lund, Henrik; Nielsen, Steffen

Publication date:
2015

Document Version
Accepted author manuscript, peer reviewed version

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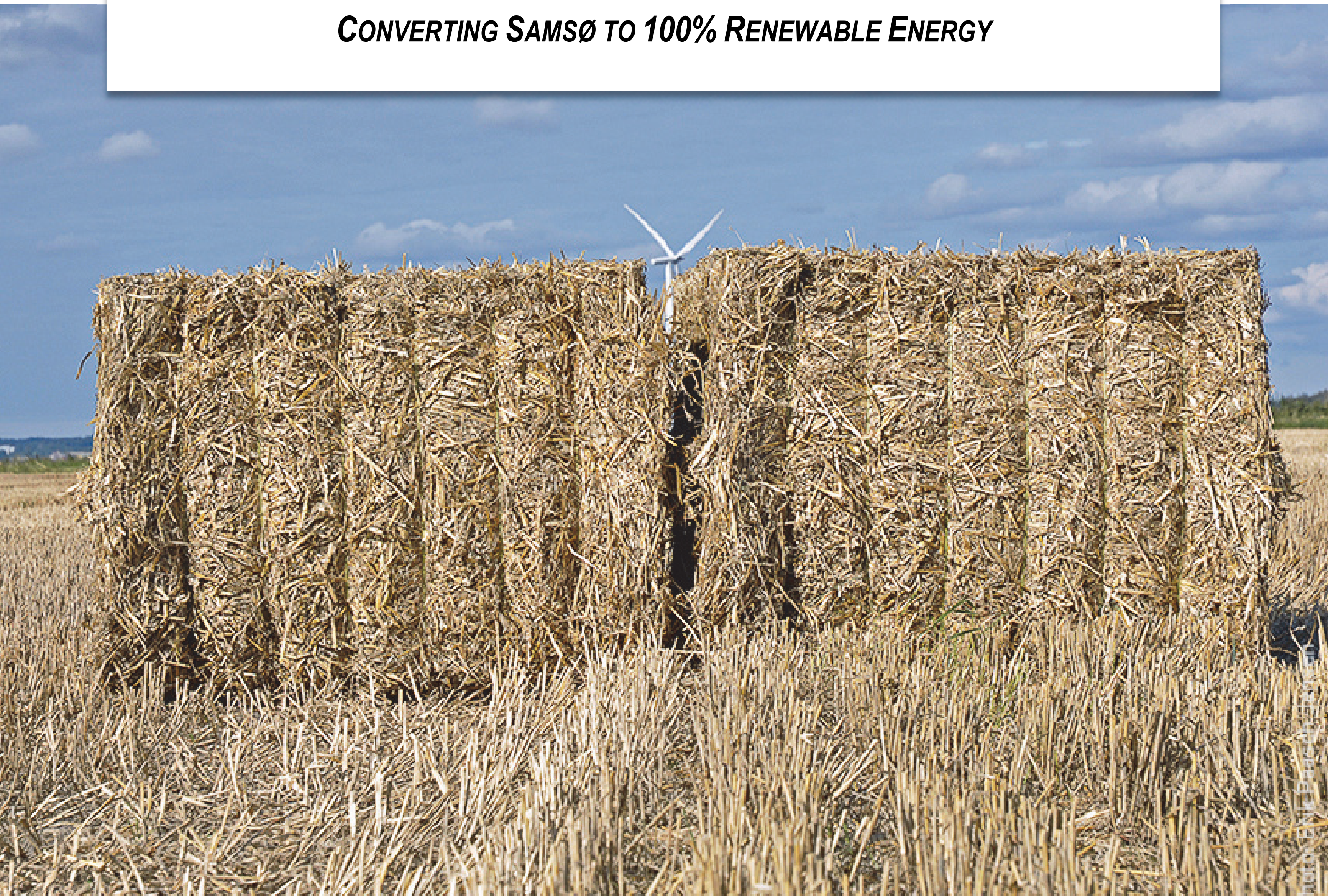

Samsø Energy Vision 2030 -

Converting Samsø to 100% Renewable Energy

September, 2015

Aalborg University, Department of Development and Planning

Brian Vad Mathiesen

Kenneth Hansen

Iva Ridjan

Henrik Lund

Steffen Nielsen

Aalborg University
Department of Development and Planning

Publisher:

Department of Development and Planning
Aalborg University
Vestre Havnepromenade 5
9000 Aalborg
Denmark

ISBN: 978-87-91404-74-0

Cover page: Photos adapted from Samsø Energy Academy and Erik Paasch Jensen

Abstract

The purpose of this report is to investigate potential scenarios for converting Samsø into 100% renewable energy supply in 2030 with focus on local electricity and biomass resources.

Firstly, a 2013 reference scenario is established to investigate whether Samsø is 100% renewable today. Next, scenarios are developed reducing the heating demand, expanding and installing large heat pumps in the district heating network followed by an implementation of individual heat pumps in the buildings outside of district heating areas. Subsequently, a number of transport scenarios are created utilizing the local electricity resources and converting biomass consumption from the heating sector to the transport sector.

The scenarios show that it is possible to create an energy system in 2030 on Samsø only supplied from renewable energy sources and only using local biomass resources. The results indicate that the socio-economic costs will stay similar to today and in addition, the scenarios can potentially contribute to local job creation and at the same time enhance security of supply.

Some of the risks in these developments are related to the technological developments, the capital intensive investments required as well as the implementation of the suggested measures.

Contents

Abbreviations

Abbreviation	**Meaning**
ICE	Internal combustion engine
EV	Electric vehicles
HP	Heat pumps
DH	District heating
PP	Power plants
CHP	Combined heat and power plant
SOEC	Solide Oxide Electrolyer cells
HDV	Heavy Duty Vehicles
DME	Dimethyl ether
O&M	Operation and Maintenance
CGB	Compressed biogas
LGB	Liquified biogas

1. Introduction

Samsø has been focusing on renewable energy supply for a number of years since 1997 where the island was awarded as a VE-Ø (renewable energy island) by Svend Auken. The beginning of the renewable development on Samsø started in the late 1990s with the development of 11 wind turbines that were primarily owned by local inhabitants. Later in the early 2000s district heating was built for integrating biomass in the heating sector while building renovations where carried out to reduce the heating demands. In this period offshore wind turbines were also built to compensate for the fossil fuels consumed in the transport sector. In 2006 Samsø Energy Academy opened and received visitors from 2007 to showcase the experiences and ideas developed on Samsø [1]. The case of Samsø is famous around the world for its continued focus on renewable energy. The Island has been showcased in numerous international newspapers and has had visits from governments and organizations from all over the world.

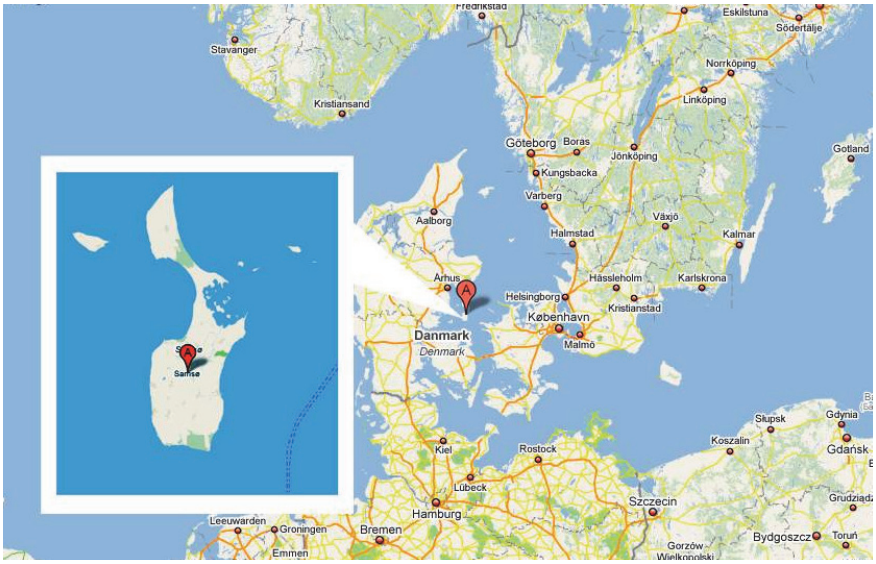

Figure 1: The Island of Samsø, Denmark

Samsø is now ready to enter the next phase: going from a net renewable energy island where some sectors are offset by the large wind power production to a 100% renewable energy island only supplied by renewable energy in all sectors of the energy system.

The purpose of the report is to develop scenarios for supporting this conversion of Samsø into a 100% renewable energy system by 2030. The focus is on the integration of local renewable resources and whether the local potentials are sufficient to meet the demands.

These scenarios are inspired of the smart energy systems approach which has previously been applied in a national scale in the CEESA project [2].

The impacts from this conversion will be quantified in terms of technical consequences (biomass and fuel demand) as well as economic consequences (socio-economic costs). In addition, reflections about the required energy exchange, the technical and implementation related risks, the security of supply, job creation and local impacts and the role of Samsø in the context of the national system will be carried out.

The scenarios can support the decision making regarding converting Samsø into 100% renewable energy and highlights the impacts of different choices, primarily in the heating and transport sectors.

This report is the outcome of Work Package (WP) 4 in the project EUDP 14-I: Biogas til transport.

In total the project entails five different WPs where the other WPs deal with different associated issues:

- WP 1: Feasibility study Biogasproduktion
- WP 2: Feasibility study: Produktion af LNG/CNG
- WP 3: Feasibility study Biogas til transport
- WP 5: Samsø som 2050 Modelsamfund

This report (WP 4) includes data and findings from other WPs such as the biomass potentials identified for Samsø in WP 1 under different circumstances.

The report is structured in a number of chapters starting with an outline of the methodology for the analysis followed by a chapter describing the background for the analysis. This chapter describes the 2013 Samsø energy system as well as the expected efficiency improvements towards 2030. Next, a presentation of how the various scenarios are developed can be found followed by the results chapter describing the findings of the analysis. In the chapter called Evaluation and discussion of scenarios the results and scenarios are discussed in the light of the local renewable resources as well as the possible risks for the scenarios.

Finally, the conclusions are drawn along with a number of recommendations for future energy system developments on Samsø. ***Our conclusions and recommendations can be found from page 68.***

2. Methodology

The methodology chapter presents the methods and modelling approach that have been applied in the development and evaluation of the scenarios for Samsø to achieve a 100% renewable energy system including all sectors in 2030.

In the existing energy system on Samsø fossil fuels are still used in the heating, industrial and particularly the transport sector and the challenge is therefore how to convert these to renewable energy sources. One option is to replace the fossil fuel demands with energy sources based on biomass as this would require only smaller changes in the energy system as many of the existing technologies are already suited for this. However, biomass is a scarce resource, also on Samsø (see section 3.4.1), and these resources should therefore be utilized for the purposes where the alternatives to biomass based fuels are non-existing such as for heavy duty vehicles (HDV) in the transport sector. The methodology applied in the analysis therefore pursues an energy system where the biomass resources are prioritized for other sectors than today where the majority is consumed in the heating sector for district heating and individual biomass boilers. Three different approaches are used to improve the system towards 100% renewable energy and CO_2-neutrality:

- Reduction of demands
- Improving the efficiency of the system
- Conversion to renewable fuels

These three approaches are ordered so that reductions in demand should be carried out first followed by improvements in the energy system to reduce fuel consumption to meet the demands and finally, the last option is to replace non-renewable fuels with renewable options. These approaches also apply to different sectors as the analysis in this report only includes demand reductions in the heating sector while improving the efficiency and the fuels in the system are applied to both the heating and transport sectors.

2.1. General methodology

The general methodology applied is firstly to understand the existing energy system as of 2013 and what the available renewable resources are, and secondly to create a model of what a business-as-usual system in 2030 might look like with smaller changes in key technologies. Based on this scenario the biomass demand was reduced in the heating sector as this is where the majority of the biomass is consumed and then finally to use the available biomass in the transport sector in order to ensure a 100% renewable energy system in all sectors, see Figure 2.

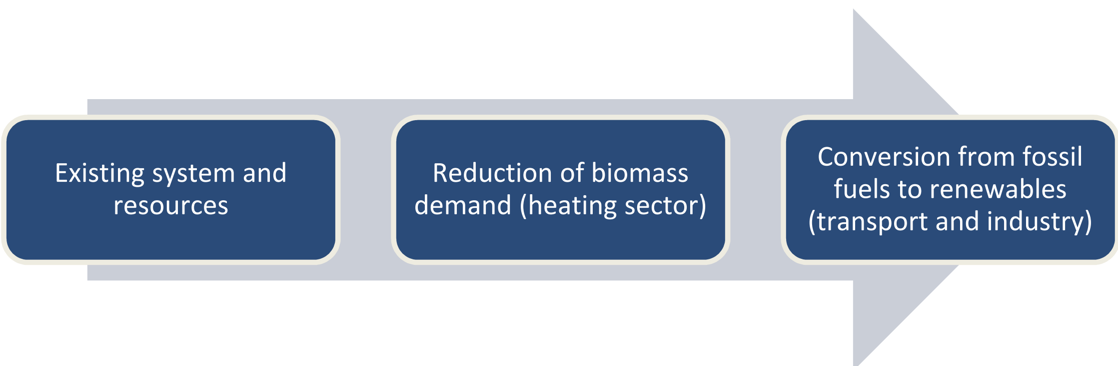

Figure 2: General approach for the analysis of converting Samsø into 100% renewable energy

This is also reflected by the scenarios that have been developed. The scenarios are also divided into these three groups; first reference scenarios, then heating focused scenarios and finally within transportation. The developed scenario categories can be found in Figure 3.

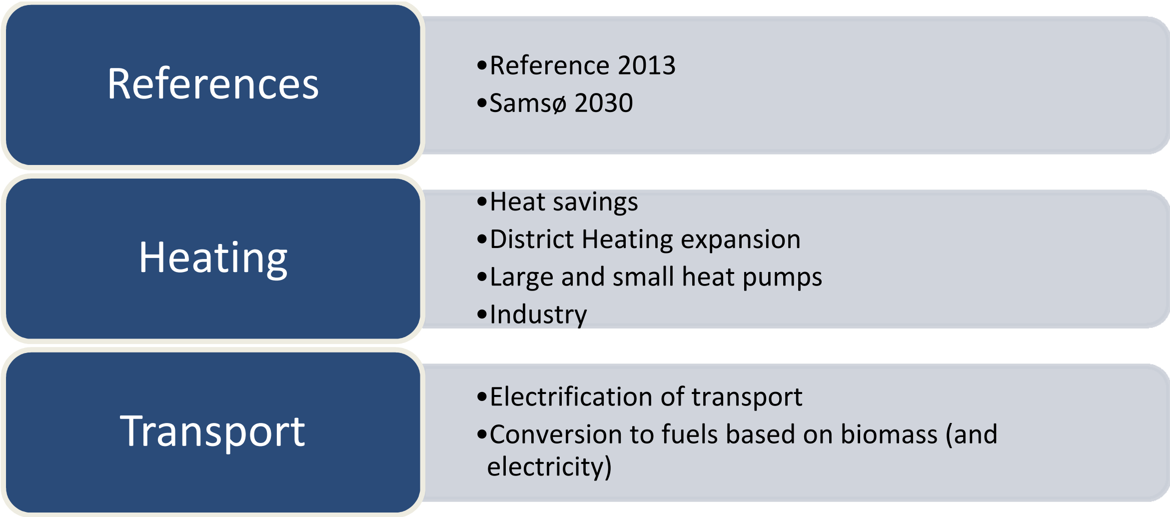

Figure 3: Scenario categories developed for Samsø

The scenarios are constructed so that they build on top of each other meaning that firstly e.g. heat savings are carried out and after this district heating expansions are analysed. Hence, the final scenario includes all the previous measures that were deemed feasible to implement in a future Samsø energy system. The consequence of this approach makes it difficult to compare the individual measures directly as e.g. district heating might look better or worse without carrying the heat savings that are implemented. However, this approach on the other hand enables the development of a full energy system combining measures within all sectors and thereby creates a complete energy system and makes it possible to investigate the synergies and dynamics between the different measures and sectors.

2.2. Modelling approach

In this chapter is a presentation of the energy system approach and the energy system analysis tool applied in the analysis.

2.2.1. Smart energy systems

As today's energy system is based on fossil fuels, the supply side of the energy system is very flexible and reliable. Large amounts of energy can be stored on the supply side in liquid, gas, and solid form via fossil fuels. This means that energy can be provided 'on demand', as long as there is a suitable fossil fuel storage nearby, such as:

- A diesel tank in a car
- A gas tank for a boiler
- A coal storage for a power plant

Fossil fuels have provided society with large amounts of energy storage and so the energy system has been designed around this key attribute.

Considering this dynamic, the key to achieving an affordable low-carbon energy system in the future is identifying new forms of cheap 'flexibility' that will enable us to accommodate the intermittency from wind and solar power. Flexibility can be created using various forms of energy storage, such as electricity, thermal, gaseous, and liquid. Each of these forms has very different characteristics, with Figure 4 presenting a typical cost and efficiency for each one. The important result to note here is that on a unit basis (i.e. €/MWh), electricity storage is ~100 times more expensive than thermal storage, while thermal storage is ~100 times more expensive than gas and liquid storage. Therefore, where possible, it is important to connect wind and solar to these cheaper forms of storage energy (i.e. thermal, gas, and liquid) rather than the much more expensive electricity storage. It is possible to connect these by integrating the various sectors of the energy system with one another much more in the future.

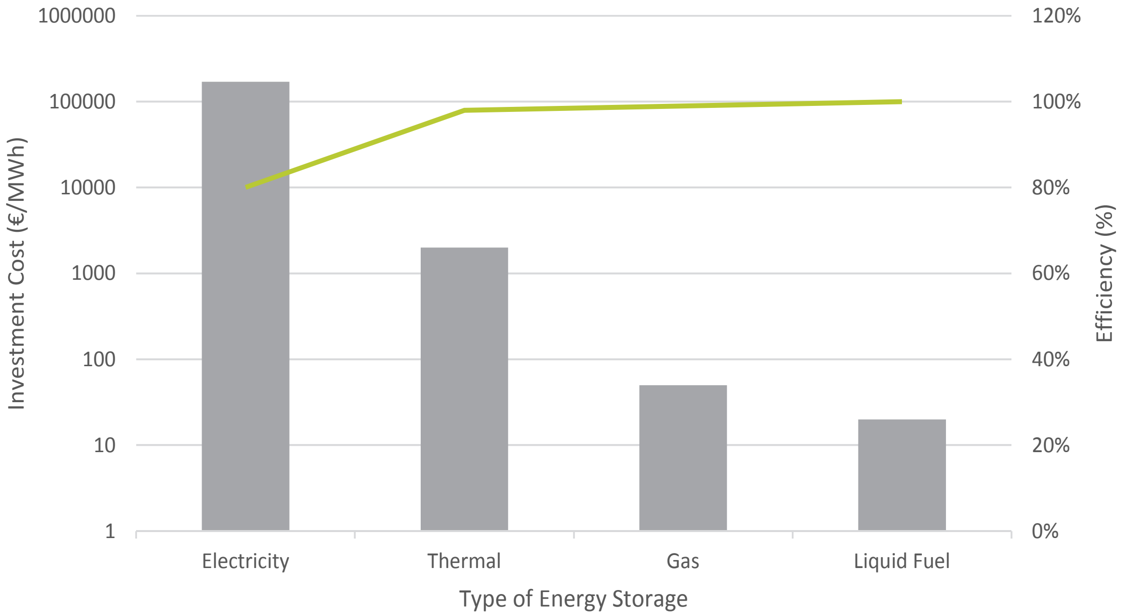

Figure 4: Comparison of the unit cost and efficiency for various forms of energy storage [3–6].

By connecting the electricity, thermal, and transport sectors to one another, it is possible for the electricity sector (i.e. wind and solar) to utilize these cheap forms of energy storage. This has been demonstrated in a concept call the Smart Energy System (www.SmartEnergySystem.eu) [7–10].

A smart energy system consists of new technologies and infrastructures that create new forms of flexibility, primarily in the 'conversion' stage of the energy system. This is achieved by transforming from a simple linear approach in today's energy system, to a more interconnected approach. As presented in Figure 5, the Smart Energy System combines the electricity, heat, and transport sectors so that the flexibility across these different areas can compensate for the lack of flexibility from renewable resources, such as wind and solar. The smart energy system uses technologies such as:

- **Smart Electricity Grids** to connect flexible electricity demands such as heat pumps and electric vehicles to the intermittent renewable resources such as wind and solar power.
- **Smart Thermal Grids** (District Heating and Cooling) to connect the electricity and heating sectors. This enables thermal storage to be utilised for creating additional flexibility and heat losses in the energy system to be recycled.

- **Smart Gas Grids** to connect the electricity, heating, and transport sectors. This enables gas storage to be utilised for creating additional flexibility. If the gas is refined to a liquid fuel, then liquid fuel storages can also be utilised.

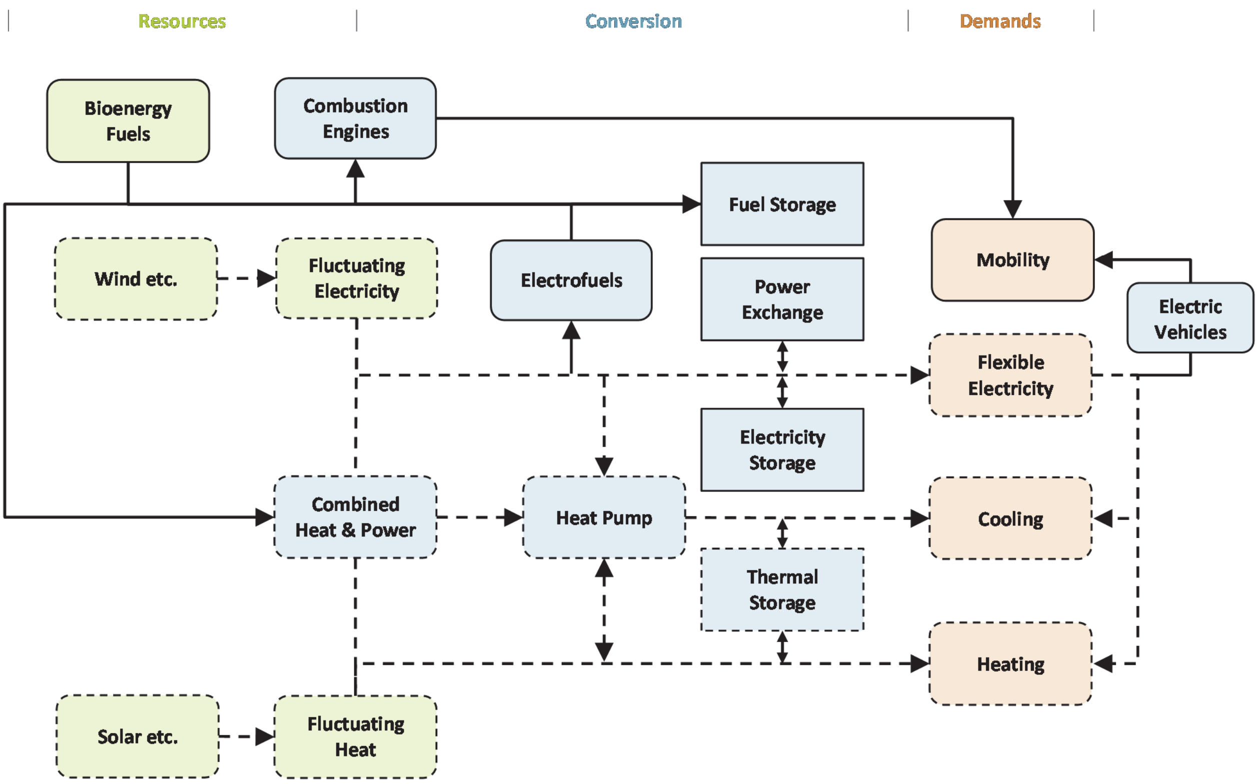

Figure 5: Interaction between sectors and technologies in a renewable energy system [11]**.**

Previous analysis applying the smart energy systems approach indicate that it will be necessary to produce and utilize new types of transport fuels such as e.g. methane, methanol/DME in order to stay within domestic biomass potentials [2,8,12].

To capture the benefits of integrating the different sectors a holistic energy planning tool called EnergyPLAN was used.

2.2.2. Modelling tool: EnergyPLAN

EnergyPLAN simulates the electricity, heating, cooling, industry, and transport sectors of an energy system. It simulates each sector on an hourly basis over a one-year time horizon and can be used on various levels of energy systems. EnergyPLAN is typically referred to as a simulation tool since it optimises how a mix of pre-defined technologies operate over its one-year time horizon [13]. The EnergyPLAN user can define a wide range of inputs before the simulation begins, such as technology capacities, efficiencies, and costs, which EnergyPLAN then uses to identify how this energy system will perform under either a technical or economic simulation. A technical simulation strategy is utilised here for all models so the energy system is operated as efficiently as possible during each hour in the EnergyPLAN tool.

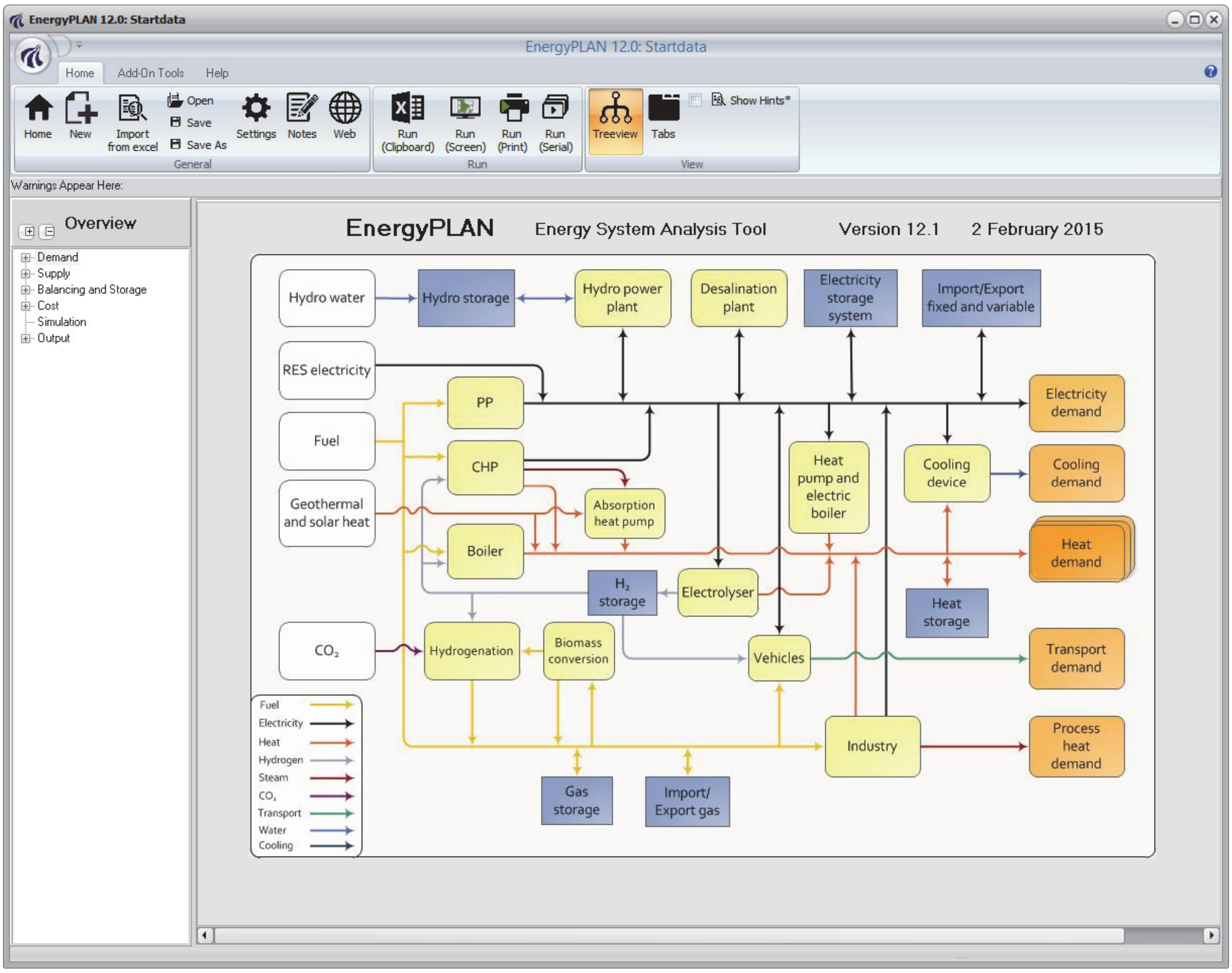

Figure 6: Screenshot of Version 12.1 of the EnergyPLAN tool (www.EnergyPLAN.eu).

EnergyPLAN is purposely designed to be able to identify and utilise synergies across the sectors in the energy system, especially when accommodating large penetrations of intermittent renewable energy such as wind and solar. It has been developed for approximately 15 years at Aalborg University based on the Smart Energy System concept. Therefore, as illustrated in the flow diagram from the model in Figure 6, it considers a variety of new technologies that are necessary in the Smart Energy System concept. EnergyPLAN is unique in this way, since very few existing models can simulate this type of radical technological change on an hourly basis.

Due to the wide variety of technologies available in EnergyPLAN, it is now possible to use the model to analyse many different potential changes to the energy system. Energy modelling can identify some key trends that are not intuitively evident in the energy sector. For example, the cost of district heating is usually very visible since it requires the construction of new infrastructure in the public space. However, energy modelling in the past has indicated that district heating is cheaper than natural gas in urban areas, since the fuel for district heating is often relatively cheap excess heat from the electricity sector [14]. Energy modelling is often required to see this due to the synergies being exploited when district heating uses excess heat from the electricity sector. By simulating different alternatives in an energy modelling tool such as EnergyPLAN, it is possible to quantify the impact of different choices for the energy system [7]. The procedure outlined in Figure 7 is repeated for numerous different choices so that impact of different choices can be compared with one another.

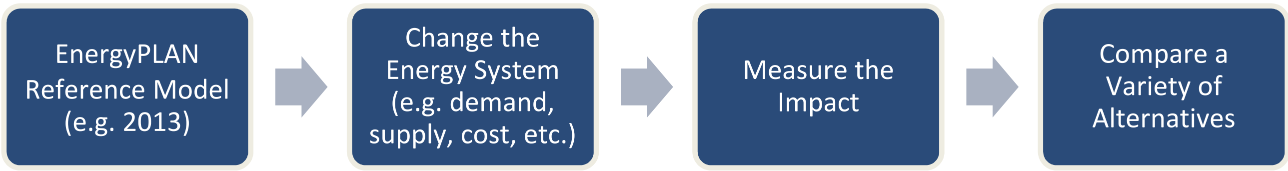

Figure 7: Procedure undertaken by an EnergyPLAN user during an analysis.

The impacts can be quantified in many ways. In this study the impact of each scenario simulated in EnergyPLAN is measured in terms of energy, environment, and economy. The impact from an energy perspective is identified by measuring the primary energy supply for each scenario. The impact on the environment is presented by measuring the carbon dioxide emissions for each scenario. This is presented as a total and in some cases on a per capita basis. Finally, the impact on the economy is obtained by calculating the total annual socio-economic costs of the energy system. The costs include investments, fuels, operation & maintenance (O&M), and carbon dioxide costs. All of the investments are annualised based on the lifetime of the technology and an interest rate of 3%. The costs include all centralised electricity and heating plants, all energy grids and storage facilities (i.e. electricity, thermal, gas, and oil), all individual heating units (i.e. boilers, heat pumps, substations), and all vehicles for transport. It is therefore assumed that the implementation of the suggested changes will occur over a number of years when appropriate rather than carrying out all the changes simultaneously.

In addition, a number of metrics will be discussed qualitatively, which are; potential risks for different scenarios and technologies, local job creation and local impacts, security of supply and a discussion regarding whether Samsø can be used as a model case for the rest of Denmark regarding how to achieve a 100% renewable energy system. These metrics are discussed in section 6.4.

Energy, economy, and environment are all measured since they reflect some of the key trade-offs associated with decisions in the energy sector. For example, implementing a new solution may reduce energy consumption, but if the costs are much higher, then it is unlikely that it can be implemented in reality. Similarly, reducing carbon dioxide emissions may be possible by using low-carbon fuels such as wind power and biomass, but if these carbon reductions are achieved using biomass or wind power that is not available, then it is again unlikely to be implemented in reality. Therefore, a balance across all three metrics is required when prioritising the most sustainable solutions for the Samsø energy system in the future.

3. Background for analysis

Some of the data for the 2013 reference and the 2030 system are described below, including the primary energy supply, electricity production and electricity exchange, heating production and the different demands. These results present the current state of the Samsø energy system and contribute to highlighting future challenges towards a 100% renewable energy system.

3.1. Description of 2013 and 2030 system characteristics

This section presents the system characteristics of the 2013 and 2030 energy systems. The 2013 energy account for Samsø can be found in Appendix B. Energy account for 2013.

3.1.1. Primary Energy supply

The primary energy demand for Samsø in 2013 and 2030 is shown in Table 1.

Table 1: The primary energy supply on Samsø for the 2013 reference and 2030

Primary energy supply / GWh/year	Reference 2013	2030
Fossil fuels	**90.4**	**87.8**
Coal	0.0	0.0
Oil	90.4	87.8
Natural Gas	0.0	0.0
Renewable sources	**165.4**	**193.1**
Biomass (excl. waste)	56.3	49.3
Waste	0.09	0.09
Hydro	0.0	0.0
Wind	104.64	139.04
Solar elec.	1.08	1.36
Geothermal elec.	0.0	0.0
Solar heat	3.29	3.29
Geothermal heat	0.0	0.0
Wave and tidal	0.0	0.0
Electricity Import(+)/Export(-)	-76	-109
Total	**179.3**	**171.4**

The primary energy in Samsø is to a large degree based on wind power from both onshore and offshore production. A large share of this electricity production is exported as it currently cannot be utilized on the island. Around 90 GWh/year of oil is consumed primarily in the transport sector, but also in households and industry. The difference between the 2013 reference and the 2030 model is primarily related to the increase in renewable electricity production from wind power due to the assumption regarding improved capacity factors for the wind turbines. This is line with the necessity of replacing the existing turbines with new ones before 2030. The specific changes applied can be found in section "changes for 2030".

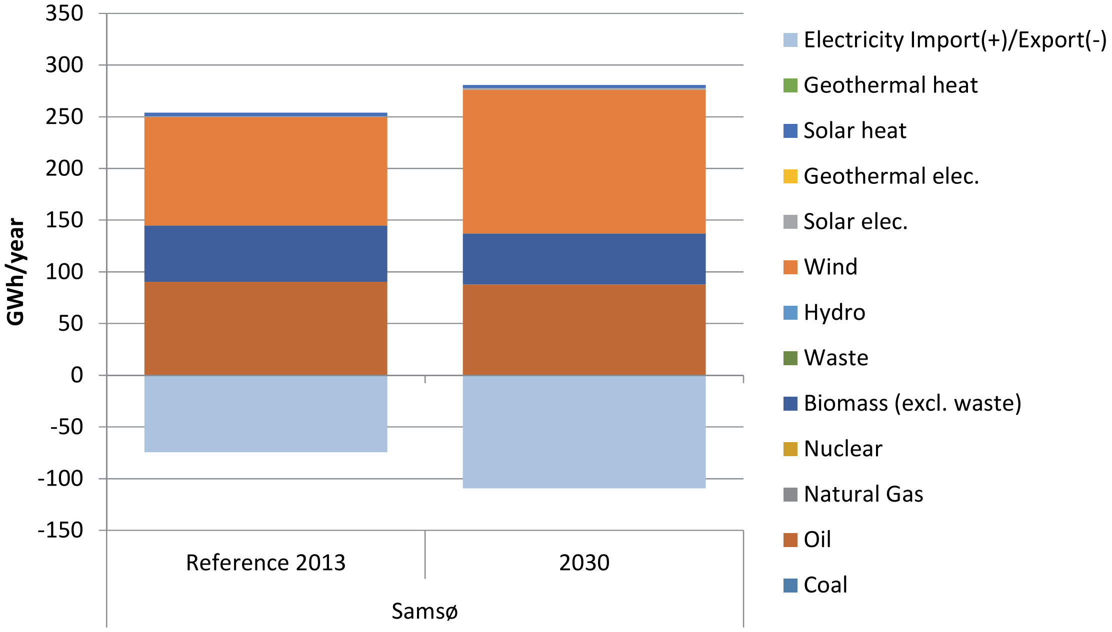

Figure 8: Primary energy supply for the 2013 reference Samsø energy system and 2030

3.1.2. Electricity production and electricity exchange

The electricity production on Samsø consists only of production from wind power and solar power. Samsø export around 70% of the electricity that is produced in the system in 2013 and around 80% in 2030. This shows that currently only a rather low share of the wind power is integrated in the local system.

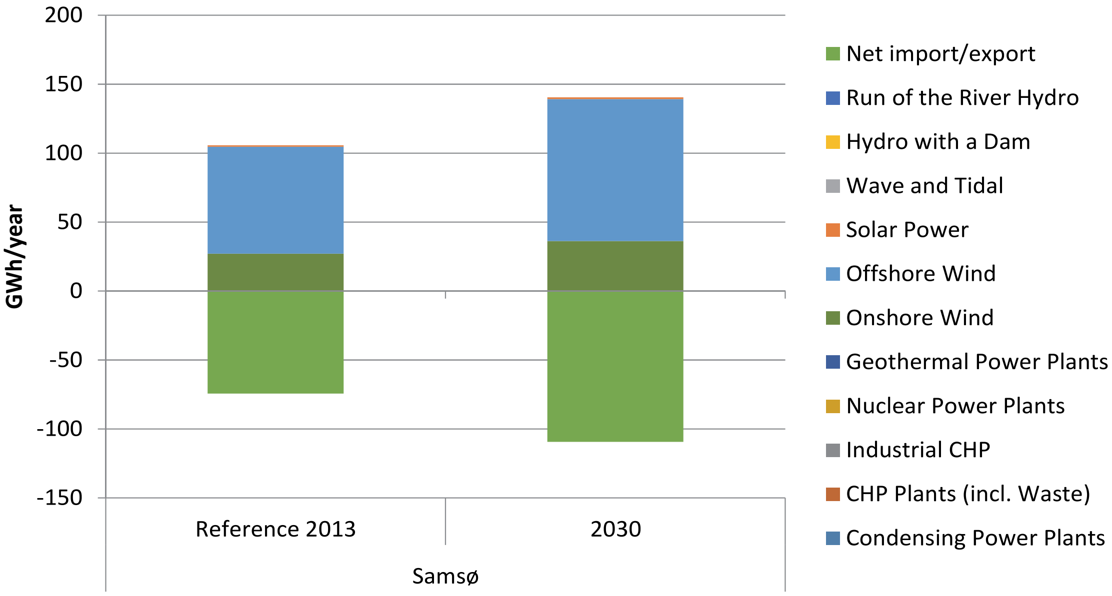

Figure 9: Electricity production and exchange in the 2013 Samsø reference and 2030. The electricity production is only from renewable sources.

3.1.3. Heat production

The heating production in Samsø is based on district heating as well as individual heating solutions. District heating is responsible for around 37% of the heat production in 2013 while it increases slightly to around 40% in 2030. The remaining heat production is mainly from individual oil and biomass boilers as well as small shares of electric heating, heat pumps and solar thermal. Overall, the heating production decreases between the 2013 reference and 2030 as it is assumed that the boiler efficiencies will improve towards 2030.

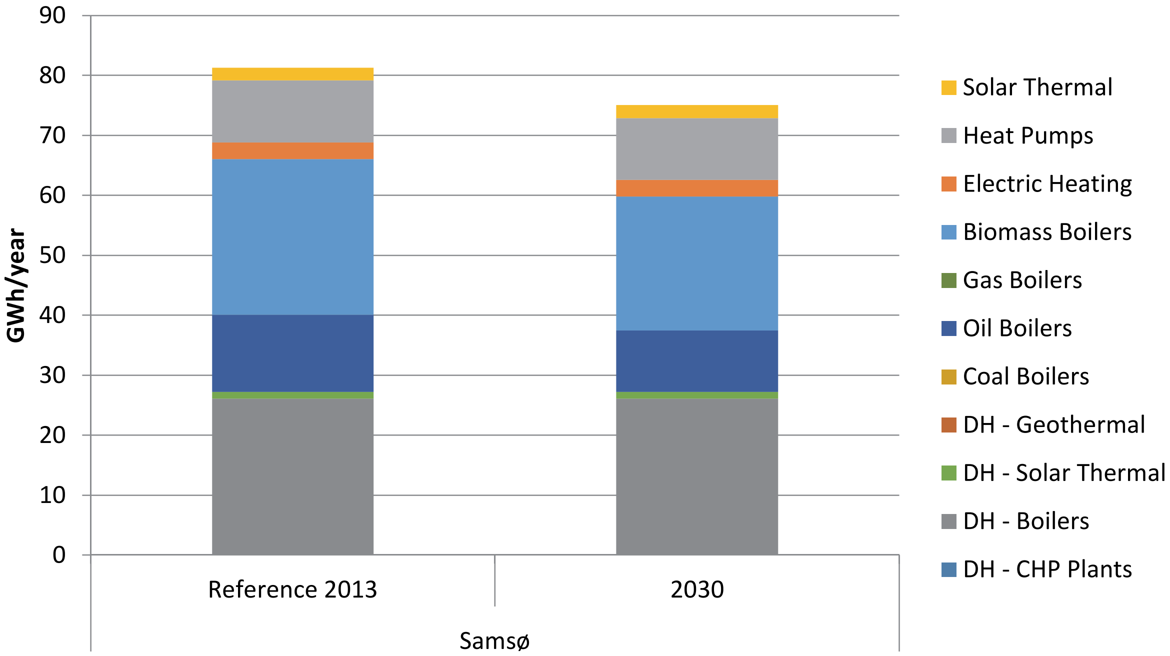

Figure 10: Heat production in the 2013 Samsø reference and 2030 by heat technologies and types (individual/collective)

3.1.4. Sector Demands

The demands on Samsø have been split into four different types; electricity, heat, transport and industrial demand and stay constant between reference 2013 and 2030 as no demand projections have been included. The largest demands on Samsø are within the transport sector followed by heating and electricity.

This proves that the largest demands are within transport despite the fact that this sector currently almost solely use fossil fuels and shows that there is a challenge when aiming at 100% renewable energy in all sectors in 2030.

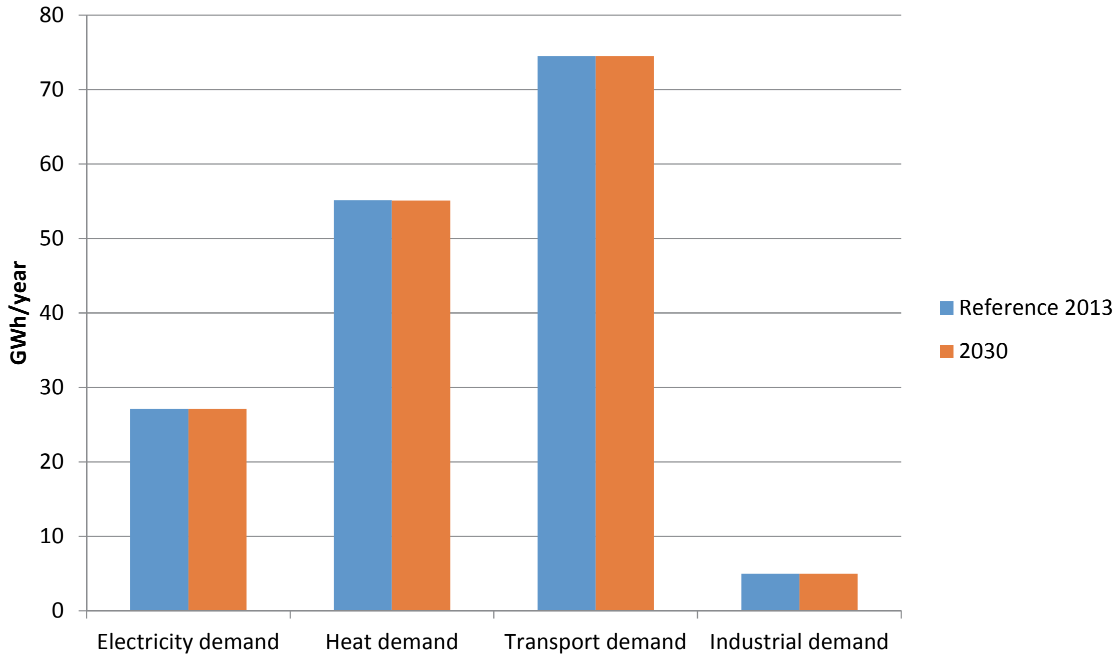

Figure 11: Demands for electricity, heat, transport and industry. The demands remain unchanged in 2030. *Industrial demands exclude industrial heating and electricity demand. Electric heating and heat pumps are included as heat demands.

3.1.5. CO_2-emissions

The CO_2-emissions can in general be analysed in two different perspectives: the emissions related to the energy consumption on Samsø and the CO_2 that can be offset somewhere else due to the electricity export. Figure 12 shows the CO_2-emission from the energy consumed on Samsø.

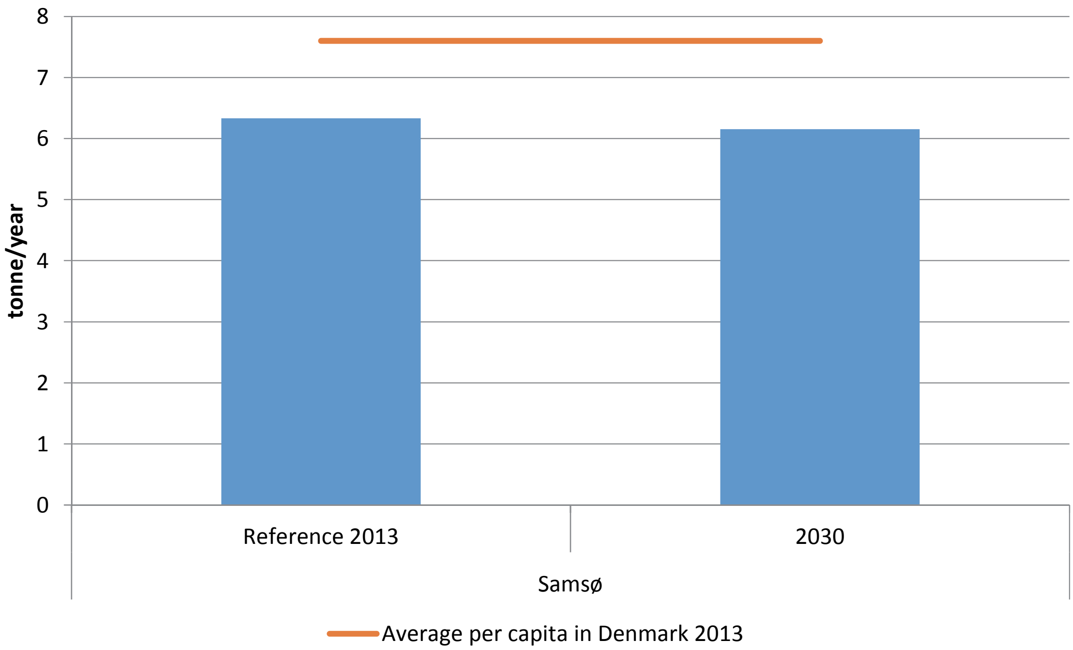

Figure 12: CO_2-emissions from the energy consumed on Samsø without emissions offsetting due to electricity export.

These emissions are only from the oil consumption for transport, households and industry and is around 6-7 tonne/year/capita. Even without offsetting some of this through electricity exports the Samsø average emission per capita is below the national average per capita [15].

When the electricity export is assumed to replace some fuel consumption somewhere else that would lead to CO_2 emissions Samsø can gain great benefits in the 2013 reference. In the 2013 reference system it is assumed that the electricity export will replace electricity that otherwise would have been produced by power plants consuming 50% coal and biomass. This share is an assumption as it is not possible to replicate the exact production mix in the energy system analysis tool applied as this mix would consist of many technologies such as power plants, CHP plants, wind, solar as well as import of electricity.

In the 2013 reference this means that the electricity export replaces more CO_2 than is emitted on Samsø making the island net CO_2-neutral. The power plant fuel distribution is however very important regarding this conclusion and is discussed further in a later section. In 2030 no emissions can be offset as it is assumed that the electricity export from Samsø will only replace electricity that is produced from power plants using only biomass and other renewable sources. This is assumed due to the Danish Government's targets of achieving no coal in power plants by 2030 and 100% renewable energy for electricity and heating in 2035 [16]. Hence, Samsø is no longer CO_2-neutral in 2030. This finding only applies assuming that the Danish energy system is seen as a closed system as there might still be fossil fuels in the imported energy from other countries.

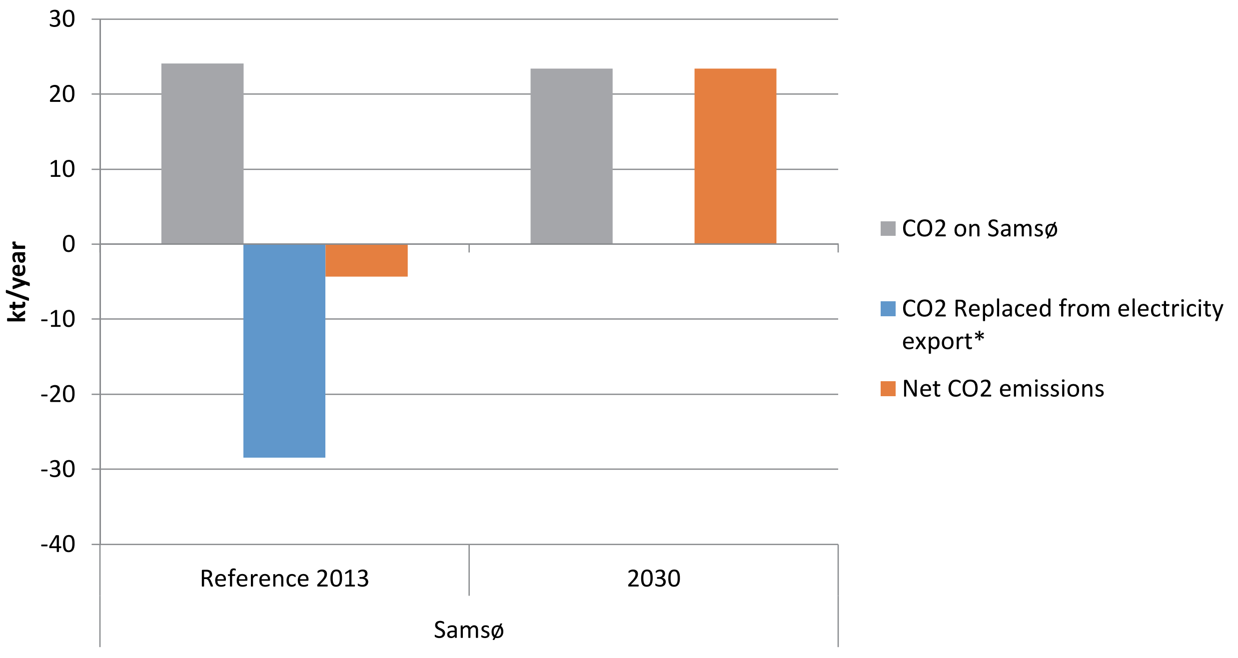

Figure 13: The net CO2-emissions in the 2013 reference and 2030. * It is assumed that in 2013 the electricity export from Samsø replaces electricity that otherwise would have been produced by power plants consuming 50% biomass and 50% coal. In 2030 it is assumed that export replaces 100% biomass power plants according to national targets.

3.1.6. Socio-economic costs

The socio-economic costs for the energy system of Samsø have also been calculated. Included in these socio-economic cost calculations are investments and O&M for all energy technologies and vehicles, fuel costs and

CO_2 costs. No taxes are included as it is seen from a societal perspective. The sources for the cost data can be found in Chapter 0.

The majority of the costs are for investments and O&M followed by fuel costs and CO_2 costs. Vehicles are responsible for around 50% of the total investments and O&M costs. The electricity exchange costs are based on an average cost of 40 €/MWh and follows the price distribution of Western Denmark for 2013.

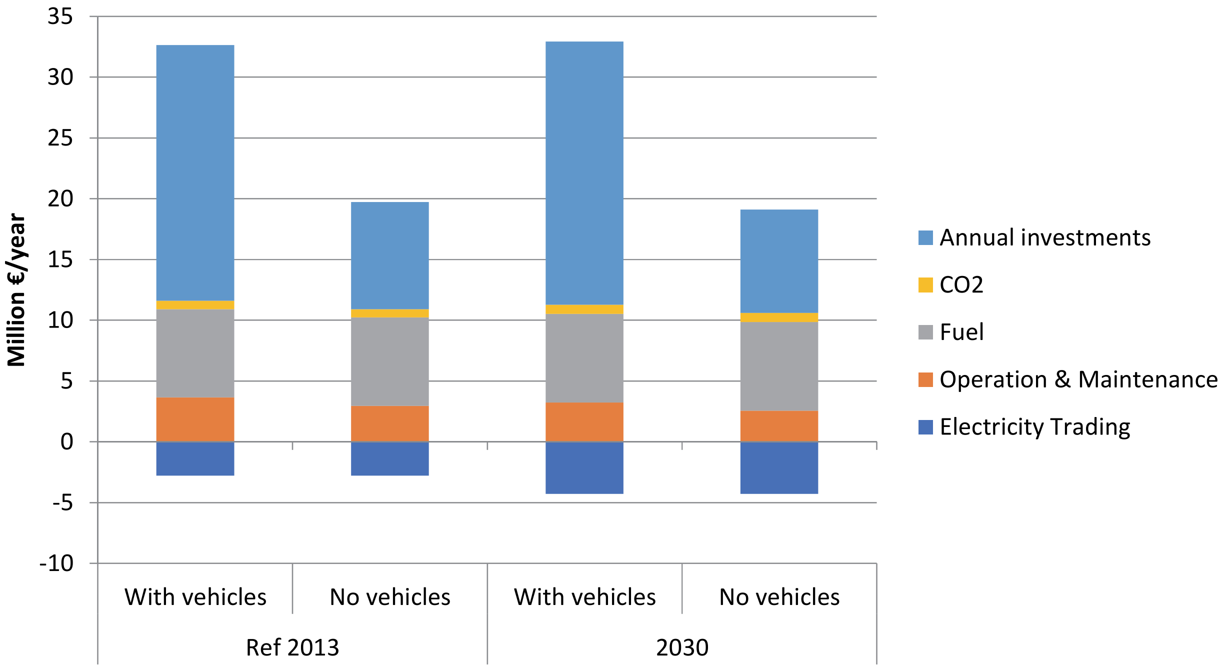

Figure 14: Socio-economic costs for Samsø reference 2013 and 2030 with and without vehicle investment and O&M costs. Transport fuel costs are still included.

It is assumed that vans have the same costs as conventional cars and tractors are half the investments of trucks. No specific data for these types of costs could be obtained.

3.2. Is Samsø 100% renewable and CO2-neutral in 2013?

In this chapter is a discussion of the methods and factors that influence whether Samsø can be considered as a 100% renewable energy island and CO_2-neutral in 2013.

The first discussion is regarding the renewable energy versus the fossil fuel consumption. The main assumption is whether the electricity export should offset some electricity production elsewhere and how this alternative electricity will be produced. In EnergyPLAN analyses have been conducted changing the fuel distribution in the power plants that are assumed to be replaced by the electricity export from Samsø. In Figure 15 is an illustration of the oil consumption, the wind export and the fuels that are replaced by the wind export. When comparing the oil consumption with the electricity export from Samsø and assuming that these different energy carriers have the same value Samsø is not 100% renewable as the oil consumption is higher. However, it can be argued that electricity has a higher value than oil as electricity production often includes energy losses in the production process. Hence, different types of power plants (PP) have been assumed to be replaced by the wind export from Samsø, including: 100% coal PPs, 100% natural gas PPs, 100% biomass PPs and 50% coal and biomass PPs (this last mix is assumed in the 2013 reference). When assuming that the electricity export replaces coal and natural gas PPs then Samsø can claim to be 100% renewable as the fossil fuels replaced elsewhere offset the fossil fuels used on the island. However, when replacing biomass PPs the island is no longer 100% renewable and when assuming 50% coal and biomass the fuel consumption on Samsø is still slightly higher than what is replaced elsewhere. Hence, the question of whether Samsø is 100% renewable all depends on the assumption about what type of electricity production is replaced. Other types of electricity might also be replaced such as CHP plants that replace a large share of the electricity in Denmark.

In the reference 2013 model it is assumed that the fuel replaces is based on 50% coal and biomass PPs and the island is therefore not 100% renewable (only 91%) applying this assumption.

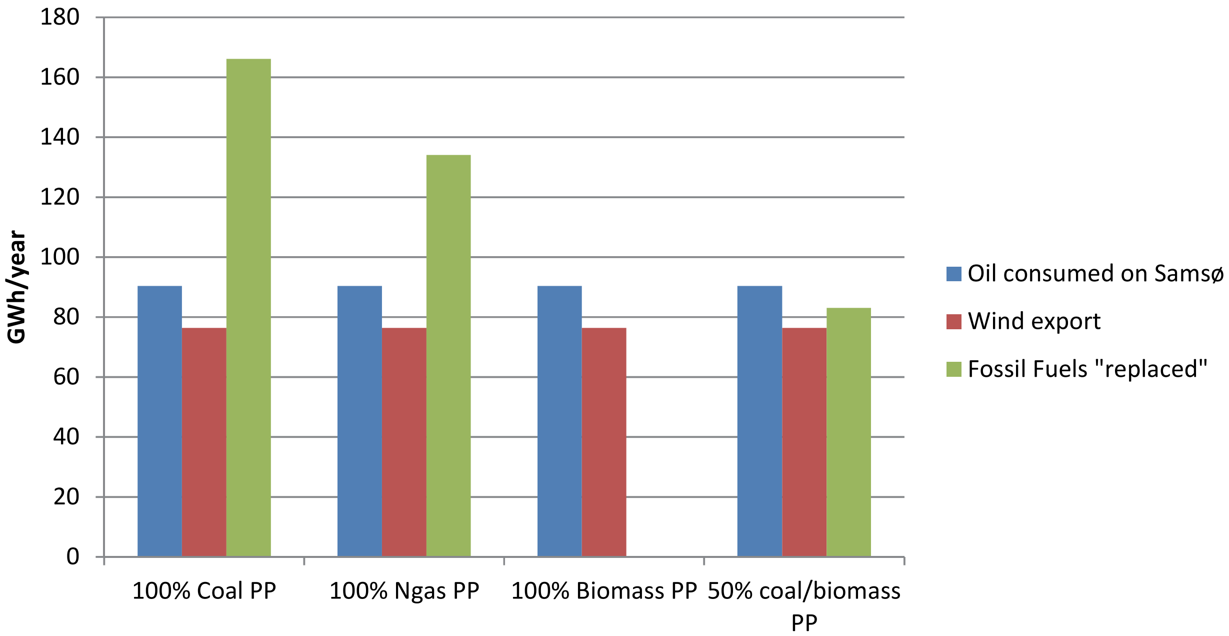

Figure 15: Oil consumed on Samsø, wind export and the fuels that are replaced by the wind export applying different fuel distributions for the power plants´

3.3. CO_2 emissions when applying different production and emission factors

The next question evolves the CO_2-neutrality of Samsø that also changes according to the assumptions applied. The first method is rather similar to the one used above investigating the renewable share on Samsø, but only measuring CO_2-emissions instead. Samsø can claim to be CO_2-neutral if the electricity export replaces electricity based on 100% coal, 100% natural gas and 50% coal and biomass PPs. Here the replaced fuel consumption would have led to emissions that are higher than the oil consumed on Samsø. However, if the electricity export replaces biomass electricity production the island is no longer CO_2-neutral.

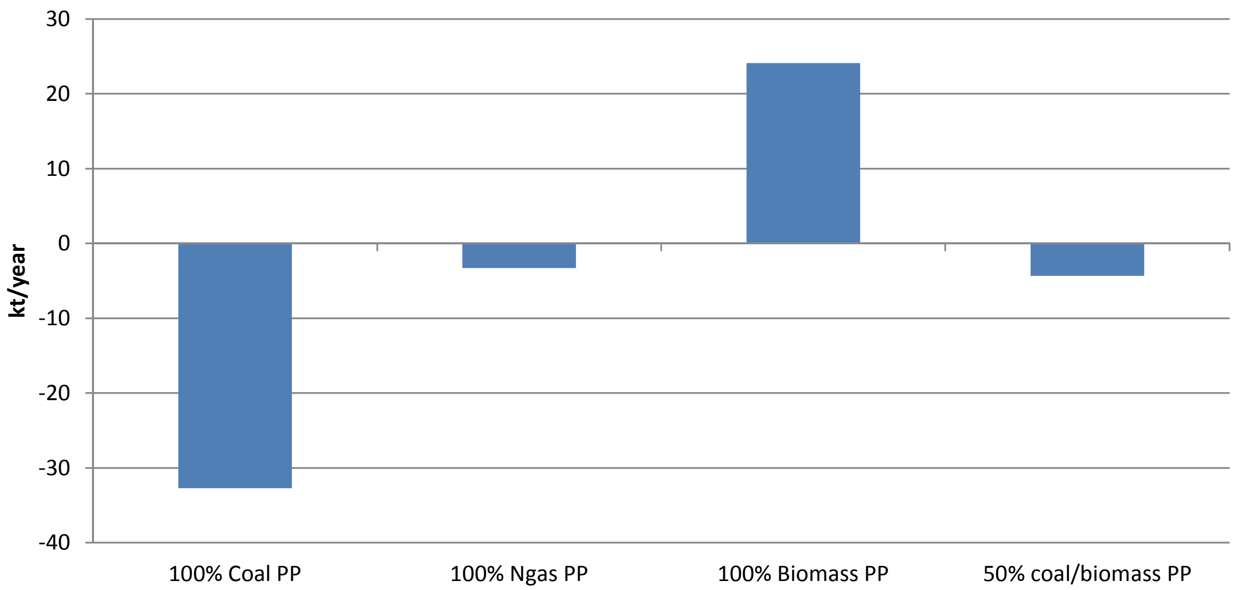

Figure 16: Net CO_2-emissions applying different electricity production mixes for the fuel that is replaced by the electricity export

A different approach to analyzing whether Samsø is CO_2-neutral is by applying emission factors connected to the electricity that is replaced by the electricity export from Samsø. Table 2 shows a variety of emission factors using different methodologies with emission factors between 281-433 kg/MWh [17,18].

Table 2: CO_2-emission factors with different methodologies

Emission factor	Method	Emission factor
Unit		kg/MWh
Danish Energy Agency	50% coal/offshore	430
Energinet.dk average electricity emission factors	125% method	377
	200% method	422
	Energy quality	433
	Energy content	281

When applying these emission factors Samsø is CO_2-neutral using all emission factors except the energy content methodology from Energinet.dk.

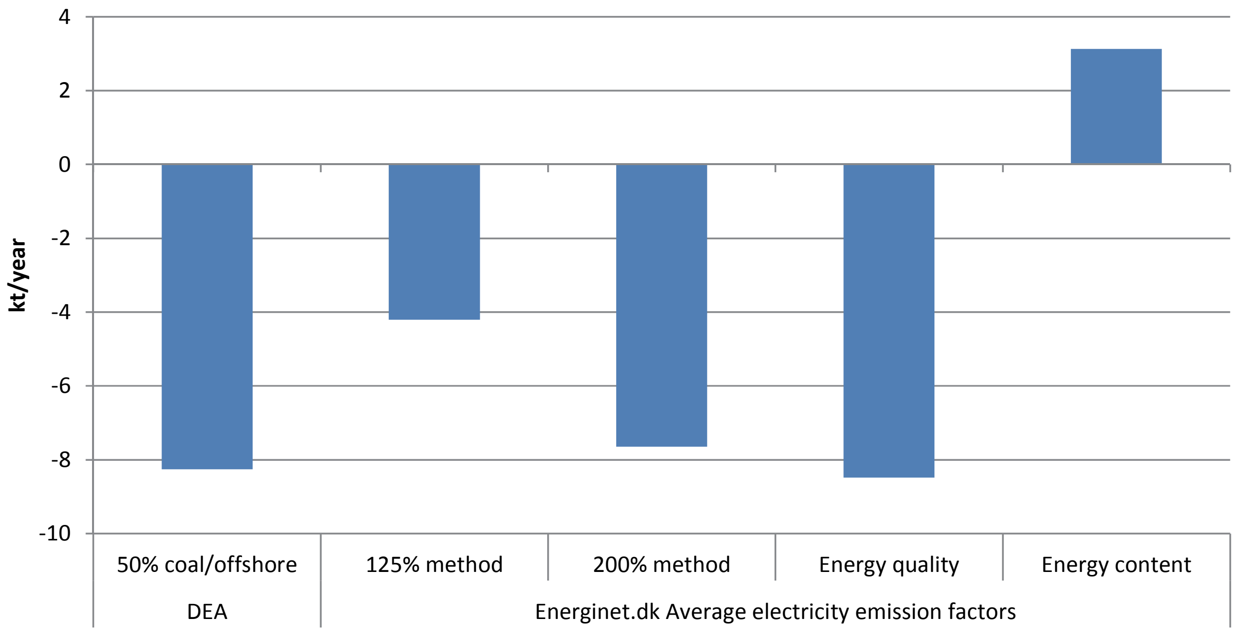

Figure 17: Net CO_2-emissions applying different emission factors from the Danish Energy Agency and Energinet.dk

This means that it is safe to claim that Samsø is CO_2-neutral and depending on the assumptions could also be 100% renewable when offsetting the electricity export from wind from the island.

3.4. Renewable energy potentials for the future Samsø system

The renewable energy potentials on Samsø are important if all the sectors are to be converted to a future fossil free system. Hence, the potentials for firstly biomass and secondly other resources have been analysed.

3.4.1. Bioenergy potentials

Bioenergy will play a vital role in the future as it is flexible in terms of storage and can be used for multiple purposes such as transport, heating and industry. The key is therefore to identify the areas where the bioenergy will provide the greatest benefits for the system.

Table 3 shows the relation between biomass resources, biomass for biogas and current biomass consumption.

The biomass potentials are divided into four different biomass pathways:

A. Biomass potentials – current,

B. Biomass potentials with conversion to energy crops,

C. Biomass potentials with biogas using energy crops

D. Biomass potentials with biogas using straw.

These different pathways represent different options in terms of 1) conversion to energy crops and 2) the use of biogas. Pathway A represents the existing biomass potentials dominated by straw and wood and where wet biomass such as manure and wastewater cannot be utilized and is therefore shown in brackets. Pathway B is similar to the current potentials with the exception that 15% of the grain area is converted to energy crops thereby increasing the total biomass potentials. However, the wet types of biomass can still not be utilized in this pathway. The energy crops replace an area today that supplies grain for animal production. In pathway C a biogas plant is installed at the same time as energy crops are produced. The biogas technology means that it is now possible to utilize some of the wet biomass available for the production of biogas. In pathway C the majority of the biomass for biogas production is from energy crops. Pathway D also produces biogas, but as no conversion to energy crops has taken place in this pathway straw is used for biogas production. When looking at the current biomass demand it is already higher than the potentials in Biomass path A. even with import of wood pellets.

Table 3: Biomass potentials under different assumptions compared to the current biomass demand. Manure and waste and waste water potentials can currently not be used and is therefore shown in brackets in addition to the total biomass potentials.

	Biomass potentials (GWh/year)				Biomass Demand
Category	A. Biomass potentials - current	B. Biomass potentials with conversion to energy crops	C. Biomass potentials with biogas using energy crops	D. Biomass potentials with biogas using straw*	Current 2013 demand
Manure	(8)	(8)	(1)	(1)	0
Energy crops (and biofuels)	0	28	7	0	2
Straw	27	24	23	5	25
Firewood and wood chips	26	26	26	26	24
Waste and waste water	(6)	(6)	(1)	(1)	0
Biogas	0	0	*34*	34	0
Import: Wood pellets and wood waste	0	0	*0*	0	7
Total	53 (+14)	78 (+14)	*90 (+2)*	65 (+2)	58
Conversion from grain to energy crops	0%	15%	*15%*	0%	-
Biomass Self-sufficiency					No

** The biogas technology using a large amount of straw requires a different technology than what is currently available on the market. The purpose is rather to illustrate the consequences of converting to biogas without energy crops production.*

The current biomass potential amounts to around 67 GWh while the demand is 58 GWh/year. In the current demand is however also 7 GWh of wood pellets that are not part of the potential as they are imported to Samsø. Hence, if the island has to be self-sufficient these 7 GWh of wood pellets has to be replaced by other types of biomass that are not imported. However, the only biomass potentials that are not utilized in the current system are manure and waste and waste water that amounts to 14 GWh. These types of biomass potentials cannot replace the import of wood pellets. Therefore, Samsø is currently not self-sufficient in terms of biomass production and demand.

When investigating the biomass potentials for biogas production more energy crops can be produced. These energy crops replace straw production, but the overall biomass potential increase by 25 GWh/year to 92 GWh/year. Some of these 92 GWh will be used for biogas production, primarily energy crops, waste and waste water and manure – all resources that either do not exist or are not fit for use in the current energy system. In order to establish a biogas plant it is therefore possible to convert 15% of the current area for grain to energy crops as otherwise there is not enough biomass potential on the island and further import would be necessary. An alternative solution for biogas production could however also be to increase the share of straw in the biogas production on behalf of the energy crops.

The biomass resources that could be used for biogas production is outlined in Table 4 below using energy crops as suggested in [19].

Table 4: Biomass resources for biogas production on Samsø with the biogas potentials in terms of 1000 m^3 and GWh [19]**.**

Suggested Biomass for biogas plant		**Biogas potential**	**Biogas potential**
	Tonne per year	**1000 m^3 (65 % methane)**	**GWh**
Cattle manure (Kvæggylle)	10,000	234	1.5
Pig manure (Svinegylle)	33,000	581	3.8
Waste water Trolleborg	35,000	319	2.1
Liquid total	***78,000***	***1,134***	**7.4**
Deep litter (Dybstrøelse)	3,000	207	1.3
Surplus straw (Overskudshalm)	700	217	1.4
Cover crops (Efterafgrøder)	2,000	236	1.5
Meadow grass (Enggræs)	2,000	226	1.5
Energy crops (Energiafgrøder)	17,500	2,748	17.9
Vegetable waste Trolleborg (Grøntsagsaffald)	1,400	115	0.7
Horticultural waste (Gartneriaffald)	3,245	276	1.8
Organic household waste (Organisk husholdningsaffald)	580	108	0.7
Solid total	***30,425***	***4,133***	**26.9**
Total	***108,425***	***5,265***	**34.2**

The main biomass resources for biogas production are energy crops that will deliver around half of the biomass while other important sources are manure and waste products. The total potential for biogas production is calculated to be around 34 GWh/year.

The importance of energy crops and manure for biogas production is clear from the following quote: "*The large resources are manure and especially energy crops, without which it would not be realistic to establish an economical sustainable plant of a certain size*" (own translation) [19].

However, the biomass mix for biogas production can be altered so that a lower degree of energy crops are used and more straw or cover crops are harvested for biogas production instead. This will however affect the current biogas plant design and probably enhance the technical complexity of the plant and thereby the investment costs. At current, the regulations specify the amount of energy crops that can be used in biogas plants to increase the production. This amount is currently 25% of the amount and in the future this has to be halved. The reason is that biogas production is not allowed to compete with the production of food for humans [20]. In comparison, the energy crops in Table 4 above are around 16%.

It is noteworthy that the energy crops suggested for biogas production do not exist currently on Samsø, but is a resource that can be created in the future if 15% of the current area for grain (530 ha) (korn til modenhed) and 32 ha of "udtagne arealer på højbund" is converted to energy crops. This means that the dry matter production would be around 10 t/ha, but can increase slightly depending on the types of crops. To realise this, the grain production from Samsø would have to be decreased at the expense of energy crop production.

In the figure below is an illustration of the biomass potentials under different circumstances and the current biomass and oil demand. As already explained, the biomass potential increase from 67 to 92 when converting to energy crops and a share of this can be used for biogas production. The interesting comparison is however when the biomass potentials are compared with the current consumption of biomass and oil. The combined demands for biomass and oil are significantly higher than the bioenergy that can be produced even after conversion to energy crops.

This shows that the conversion to energy crops and production of biogas will not be the only solutions to ensure a conversion to 100% renewable energy in all sectors.

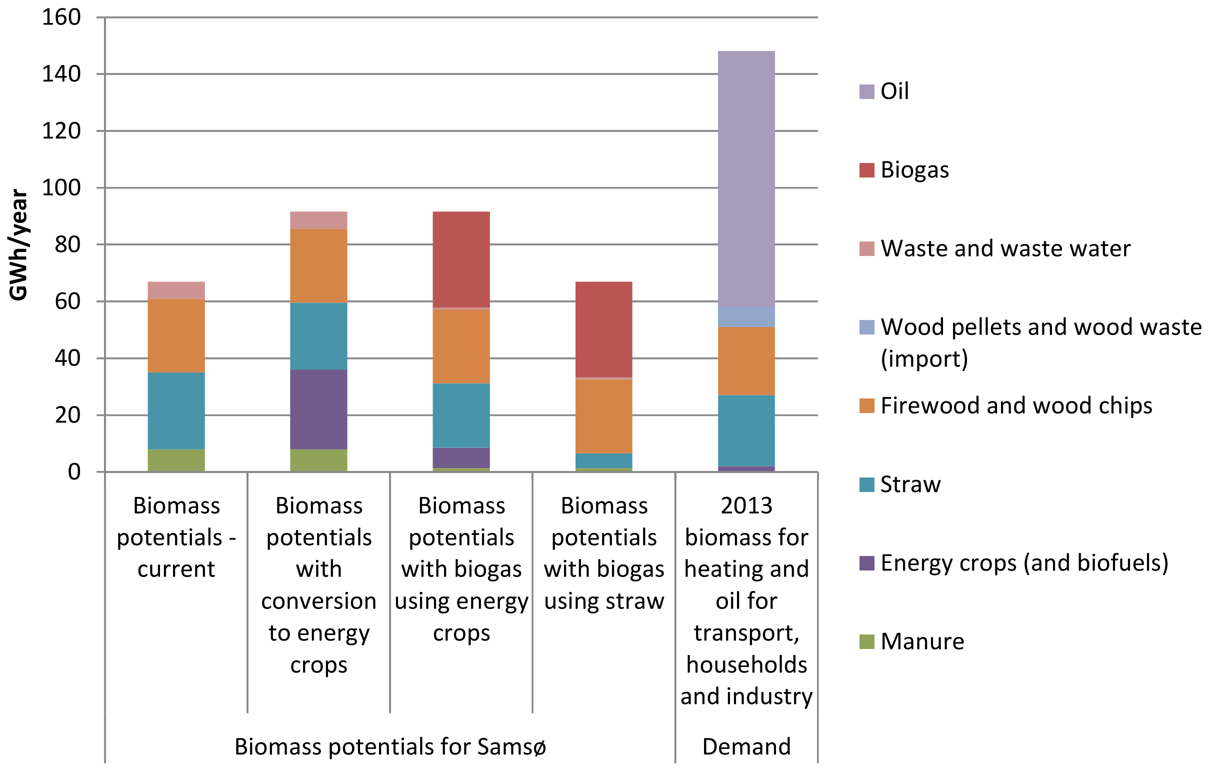

Figure 18: Biomass potentials in different situations and the demand for biomass for heating and oil for transport, households and industry

3.4.2. Wind and PV resources

Apart from biomass potentials other resources might be necessary to integrate into the future energy systems. Already today Samsø has a significant wind power production where around 70% of the wind production is exported and therefore not used in the system. It has been assumed that the wind power potential in 2030 is twice as much as the 2013 production both due to technological improvements and the favorable location of Samsø. The 2030 wind potential is therefore assumed to be around 210 GWh/year which with an expected 2030 capacity factor equals around 15 MW onshore wind and 35 MW offshore wind.

To supplement the wind production PV is a resource that could be feasible to harvest on Samsø. The PV potentials on Samsø have been analysed using a "solar atlas" based on the Danish elevation model which is a raster dataset with a resolution of 1.6 x 1.6 meters [21]. Using a GIS model the annual PV potential on rooftops is calculated for each raster. An example of the solar atlas can be found in Figure 19.

Figure 19: Example of the solar atlas where all roof tops are included

If all rooftops on Samsø are included the potential is 87.3 GWh/year which is more than three times the current electricity demand. The potential by different categories can be seen in Figure 20 below.

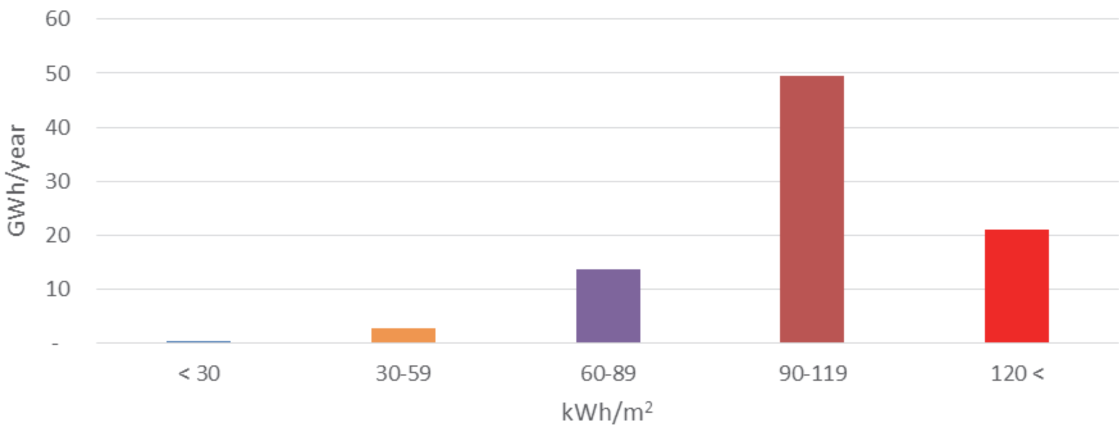

Figure 20: Total PV potential by categories when all rooftops are included

However, not all potentials are economical feasible due to low production and partly because the level of detail in the solar atlas is too low. If only rooftops with a production higher than 90 kWh/m^2 and only the raster cells within the roof areas are selected the potentials can be seen in Figure 21.

Figure 21: Example of the PV potential with only high production rooftops

In Figure 22 below is the production potentials indicated when selecting the same rooftops with a production of more than 90 kWh/m². The highest yielding rooftops are used first and the potentials are listed from left to right.

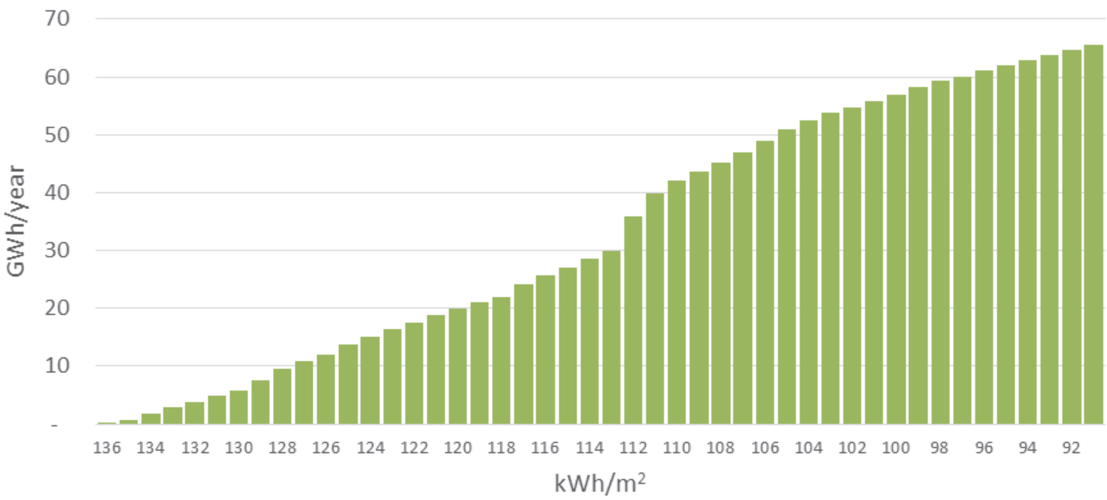

Figure 22: Accumulated potentials when using the best roof areas first

With this assumption regarding only rooftops with a production of more than 90 kWh/m² the accumulated potential for Samsø is still above 60 GWh, almost similar to the current wind production. The renewable electricity resources therefore seem to be plentiful for Samsø compared to the demands also taking into consideration that the future efficiencies of these technologies are expected to improve.

4. Scenario development

This chapter describes the individual scenarios and the assumptions that have been used to create them.

4.1. General considerations for all scenarios

Some of the assumptions in the analysis apply for all the scenarios and are important to bear in mind when considering the results and recommendations from the analysis.

Samsø energy system currently has a large wind production compared to its demand where around 70% of the wind production is exported to systems outside of Samsø. The logic behind this is that Samsø can generate revenue from the electricity export, offset the fossil fuel consumption on the island with the electricity export, assuming that it replaces non-renewable sources elsewhere and the fact that Samsø is a wind-rich municipality in Denmark and therefore has to produce more than the local demand in order for other municipalities in Denmark with less wind resources to increase their renewable shares as well. Hence, in the future scenarios for Samsø, electricity export is also a part of the scenarios due to the latter point about the local wind resources in the Municipality.

The primary measures in the analysis are connected to the heating and transport sectors as these are the sectors with the highest biomass demand and the sectors with the highest fossil fuel demands in 2013. The electricity sector (in terms of demand and production) and the industrial sector only experience changes to conversion of fuels, but no measures regarding savings or improving the efficiency have been implemented. Furthermore, the cooling demands are kept constant assuming that they are met by a share of the electricity demand.

Regarding the transport demand in Samsø it has been decided that no aviation demand is included as this does not take place inside of the municipality. To investigate the impact of this assumption a sensitivity analysis including a larger share of transport demand for aviation has been carried out, see section 5.5.4. On the other hand all the transport and fuel demand for the ferries to and from Samsø are included as transport demand for Samsø with the argument that the ferries would not be operating if there was no Samsø.

It is assumed that the boiler capacity for district heating production is equal to 120% of the district heating peak demand. The district heating losses are assumed to be 29% in the existing system based on data from the 2013 reference system.

The implementation of electric vehicles and heat pumps will lead to a higher electricity demand and the electricity grid should therefore be reinforced in these cases. However, it has not been possible to quantify these reinforcements and the associated costs in this project. Cost assumptions for all the scenarios can be found in Appendix C. Cost database. Sunk costs are not included, i.e. the 2013 costs are a calculation of the annualized costs of reinvestments in the existing technologies.

The overview of all the scenarios including the scenarios that are not carried on to the next step are shown in Figure 23.

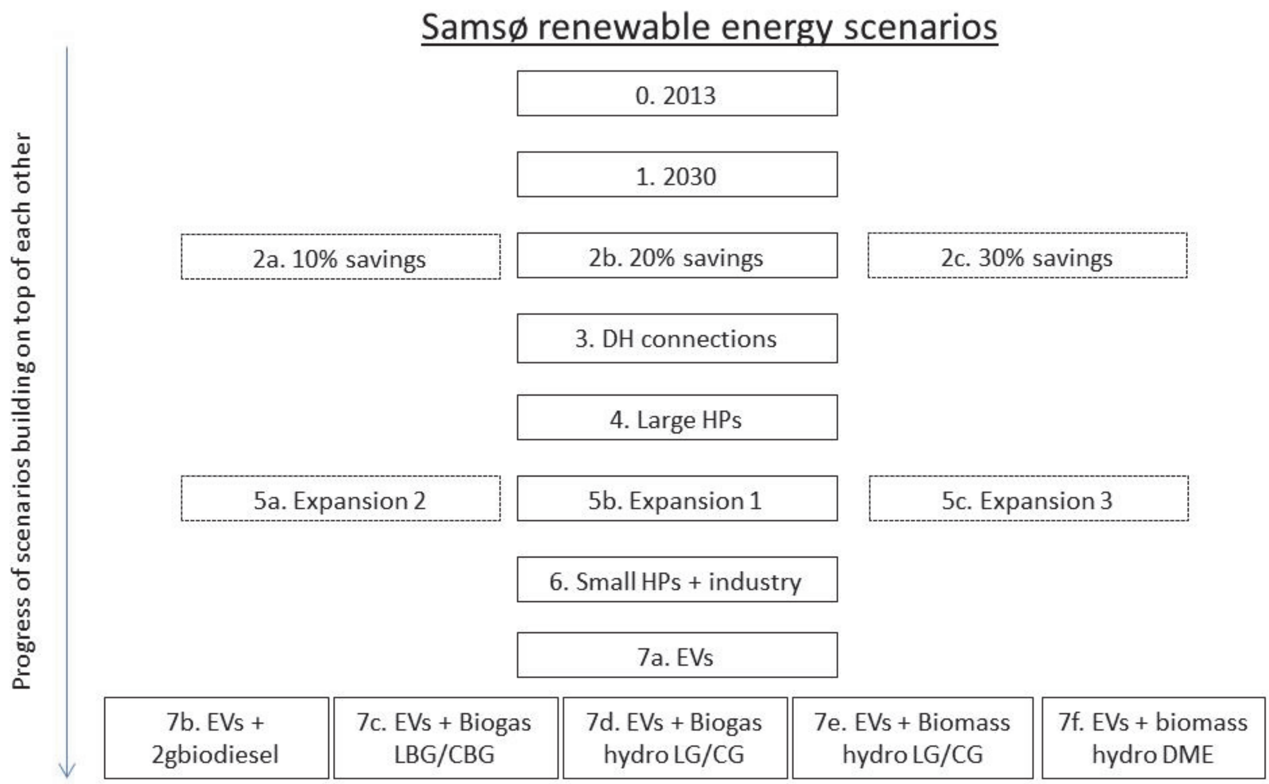

Figure 23: Overview of the different scenarios for the Samsø renewable energy transition

4.2. Step 0 - Reference 2013

The first scenario developed is the 2013 reference of Samsø representing a model of what the system looked like this year. This model is developed based on a mixture of measured and assumed data, and the data collection methods are described further in chapter 0. Some of the key assumptions and methods are explained below.

4.3. Step 1 - Samsø 2030

The Samsø 2030 reference is in large details similar to the 2013 Samsø reference model. Changes have been carried out for some key technologies and costs in the electricity and heating sectors. Efficiency improvements have been updated for onshore and offshore wind power, photo voltaic (PV), district heating boilers, individual boilers and thermal power plants.

All the technology data are based on [22,23] and indicates lower heating values.

For renewable electricity technologies the capacity factors have been improved for onshore, offshore and PV. This results in an overall increase in production of electricity of around 30% despite no increases in capacities.

Table 5: Changes in renewable electricity production technologies between 2013 and 2030 related to capacity factors and costs

Technologies	Unit	Onshore wind	Offshore wind	PV	Total
Capacity 2013 and 2030	MW	11.36	23	1.25	35.61
Capacity factor/efficiency 2013	%	27.3	38.5	9.9	-
Capacity factor/ efficiency 2030	%	36.5	51	12	-
Production 2013	GWh	27.05	77.59	1.08	105.72
Production 2030	GWh	36.25	102.79	1.36	140.4
Investments 2013	k€/kW	1.32	2.4	1.3	-
Investments 2030	k€/kW	1.29	2.3	1.1	-
Lifetime 2013	years	20	30	20	-
Lifetime 2030	years	25	30	25	-
O&M 2013	% of investment	2.97	2.09	0.6	-
O&M 2030	% of investment	3.06	1.38	1	-

Also in the heating sector technologies have improved efficiencies in 2030 compared to 2013 as well as slightly moderated costs.

Table 6: Changes in heat production technologies between 2013 and 2030 related to efficiencies and costs

Technologies	Unit	DH boiler	Individual oil boiler	Individual biomass boiler	Individual heat pumps
Efficiency 2013	%	95	80	68	250
Efficiency 2030	%	108*	100	79	370
Investments 2013	k€/unit	0.1	6.1		11.5
Investments 2030	k€/kW	0.08	6.1		11.5
Lifetime 2013	Years	35	21		20
Lifetime 2030	years	27	21		20
O&M 2013	% of investment	3.7	1.8		1
O&M 2030	% of investment	3.2	1.8		1

** Efficiencies might exceed 100% when employing flue gas condensations*

Power plants have also been improved slightly in terms of their production efficiencies going from a total fuel consumption of 169.8 GWh/year to 213.6 GWh/year. The explanation for the increasing fuel consumption is that the electricity export increases in 2030 thereby replacing more electricity elsewhere.

Table 7: Improvements in power plant efficiencies towards 2030

Technology	Efficiency 2013	Efficiency 2030	Ref 2013 Fuel Replaced		2030 Fuel Replaced	
			Coal	Biomass	Coal	Biomass
	%	%	GWh		GWh	
Power plants	46	52	84.9	84.9	0	213.62

Overall, the efficiency and cost changes for the technologies means that the 2030 scenario has lower costs than the 2013 scenario, see section 3.1.6.

Due to the increasing electricity production from wind and solar power the electricity export increases in 2030 while the import similarly to the situation in 2013 is almost negligible.

Table 8: Changes in electricity exchange between reference 2013 and 2030

Electricity exchange	Import Ref 2013	Export Ref 2013	Import 2030	Export 2030
	GWh	GWh	GWh	GWh
Electricity	0.52	74.99	0.21	109.68

In the Samsø 2030 scenario the transport fuel mix also changes as the ferry transport demand of 30 GWh is converted from diesel to LNG. This is done as the ferry after 2013 (the reference year) was converted to a duel-fuel ferry using LNG and to be able to compare the different transport scenarios with the actual situation this conversion is carried out. The conversion in fuel in the ferry meant higher costs transport because of higher investments costs and it is assumed that the LNG price is the natural gas price of 2030 (10.2 €/GJ) along with the LNG upgrade costs (5.6 €/GJ) [24]. This conversion also applies to the subsequent scenarios until other transport fuels are investigated in the transport scenarios.

4.4. Step 2 – Heat savings

The first step in the scenarios after developing the 2030 model is renovations and improvements of the building stock in order to reduce the heat demand. In the current heating sector district heating supplies around 30% of the heat demand based on biomass while the remainder is met by individual solutions such as oil boilers, biomass boilers, electric heating and heat pumps. Hence, the heating sector is the sector with the largest biomass use in 2013. As the aim is to free some of these biomass resources for other purposes, heat savings are essential in this regard. However, Samsø already has carried out significant heat savings and building renovations and the remaining potentials are therefore limited. For this reason, the heat savings are analysed on three different levels – 10%, 20% and 30% savings of the total net heat demand. The heat savings are implemented across all buildings meaning that the heat demand is equally distributed across production technologies, i.e. the technology shares remain the same, but the demands changes.

The investments for heat savings are assumed to be DKK 13.8 per kWh (1.85 €/kWh) of heat saved based on the Danish Heat Atlas. The investment cost is the average cost of implementing savings in Samsø building stock, excluding vacation homes, which means that the cost takes into account the type and age of buildings on Samsø. The investment in building improvements are further annualised with a lifetime of 50 years and O&M costs of 1% of the investment.

The heat savings and the associated costs are presented in Table 9 below.

Table 9: Heat savings in the different scenarios and the associated annualised costs

Heat savings	Heat demand reduction	Annualised costs
	GWh net heat demand	k€/year
10% heat savings	1.93	567
20% heat savings	3.86	1134
30% heat savings	5.79	1696

One of the benefits from investing in heat savings is that the fuel demand is reduced and this will offset some of the renovation investments required. Another benefit that is included in the heat savings calculations is that the heat demand is reduced in all buildings meaning that the heat unit capacity similarly can be lower. Therefore, it is assumed that the heating units are decreased in the same way as the heat demand, i.e. if the heat savings are 20% then the heat unit capacity (the capacity of the boiler in kW) is also reduced by 20% which in turn leads to lower investments in heating units.

The heat savings only include space heating and it is therefore assumed that the hot water demand will remain constant for all the scenarios.

4.5. Step 3 – District heating interconnections

This step entails an integration of the three individual district heating networks in the southern part of the island in order to harvest operational benefits from a greater network. These benefits can relate to sharing the production capacity across the existing networks and a larger heat storage. It is also assumed that the interconnections will benefit the following steps where large heat pumps are installed to supply the district heating and when district heating expansions are analysed.

The investment costs for building interconnections are calculated to be 3.8 M€ or 212 k€/year based on the distance between the networks and the size of pipes required to transmit heat between the areas. As an example, this means that the size of the pipe between Transbjerg and Onsbjerg is based on the heat demand in Onsbjerg. The specific numbers for the interconnections are shown in Table 10 in Step 5.

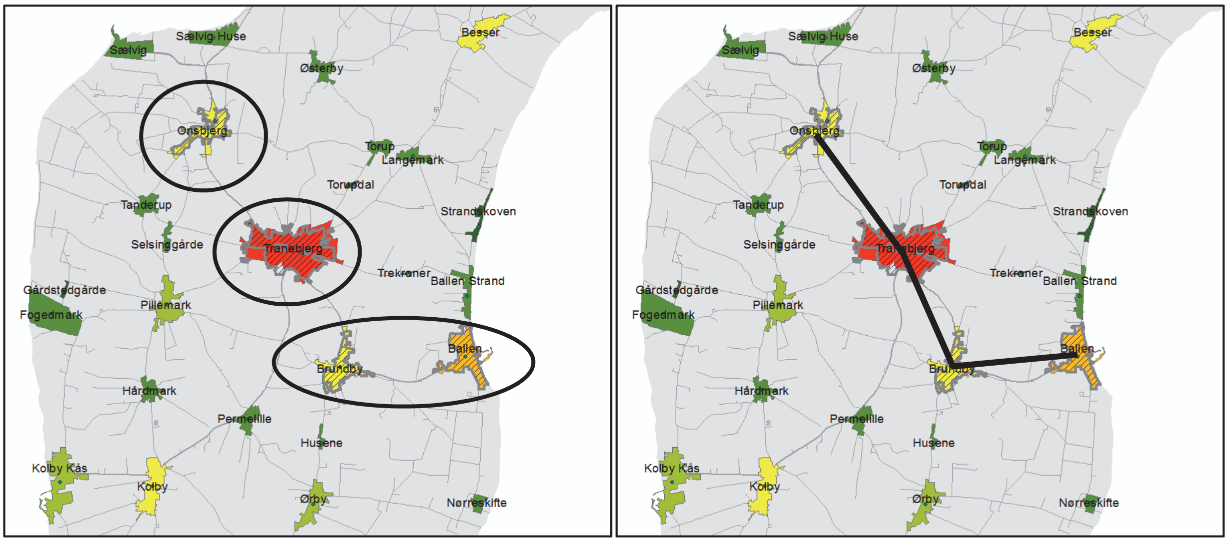

Figure 24: The existing district heating networks of Onsbjerg, Tranebjerg and Ballen-Brundby and how they might be interconnected.

4.6. Step 4 – Large heat pumps

In order to reduce the biomass consumption and improve the efficiency of the district heating network a large heat pump is installed and replaces the majority of the district heating production from the existing biomass boilers.

The capacity of the large heat pump installed is 1 MW with an assumed COP of 3 (assuming that the heat source is ambient temperature) and investment costs of 3.4 M€ [4]. The heat pump supplies the majority of the heat demand, but the same district heating boiler capacity remains installed to cover the heat demand in the hours where the electricity is expensive due to lower wind production or in hours where the large heat pumps are down for maintenance. The district heating boilers still cover 14% of the district heating demand while the remainder is met primarily by the heat pump and by solar heating. Currently, there is not much knowledge about the optimal balance between large heat pumps and boilers and the ratio applied here is therefore a best estimate.

Other benefits from the large heat pump that make them suitable for Samsø is the large export of electricity that instead could be integrated into the local system and thereby replace other fuels. Furthermore, storing this electricity is cumbersome and expensive, but by connecting the electricity and heating sectors relatively cheap thermal storage becomes available.

It is assumed that the same district heating boiler capacity as in the previous scenario is needed. Hence, the boilers can meet the entire maximum heat demand in any hour during the year if there is no wind for the large HPs.

It is furthermore assumed that it is required to install sufficient heat pump capacity to produce the same as the boilers did. The max production from boilers in any hour in the 20% savings scenario is 7538 kWh and the HP capacity is therefore 7800 kW heat out or 2600 kW electric capacity.

Instead of installing heat pumps to cover the entire district heating demand it could also be an option to integrate a higher share of solar thermal. This was not investigated in this report as the electricity resources are so significant that almost no other sources are required for heating purposes.

4.7. Step 5 – District heating expansions

After installing the large heat pumps in the district heating network three different options for expansions of the network are analysed. The purpose of the expansions is to improve the efficiency and replace individual heating with more efficient large heat pumps. The three different expansion options are 1) an expansion to Pillemark, Hårdmark, Kolby og Kolby Kås and 2) an expansion to Permelille, Kolby and Kolby Kås and 3) an expansion to Husene and Ørby, see Figure 25. Other expansions might be possible, but these three were deemed as the most likely ones for Samsø. It is assumed that the district heating coverage share is 80% in the new areas, which is slightly lower than the current coverage rate between 80-90% [25].

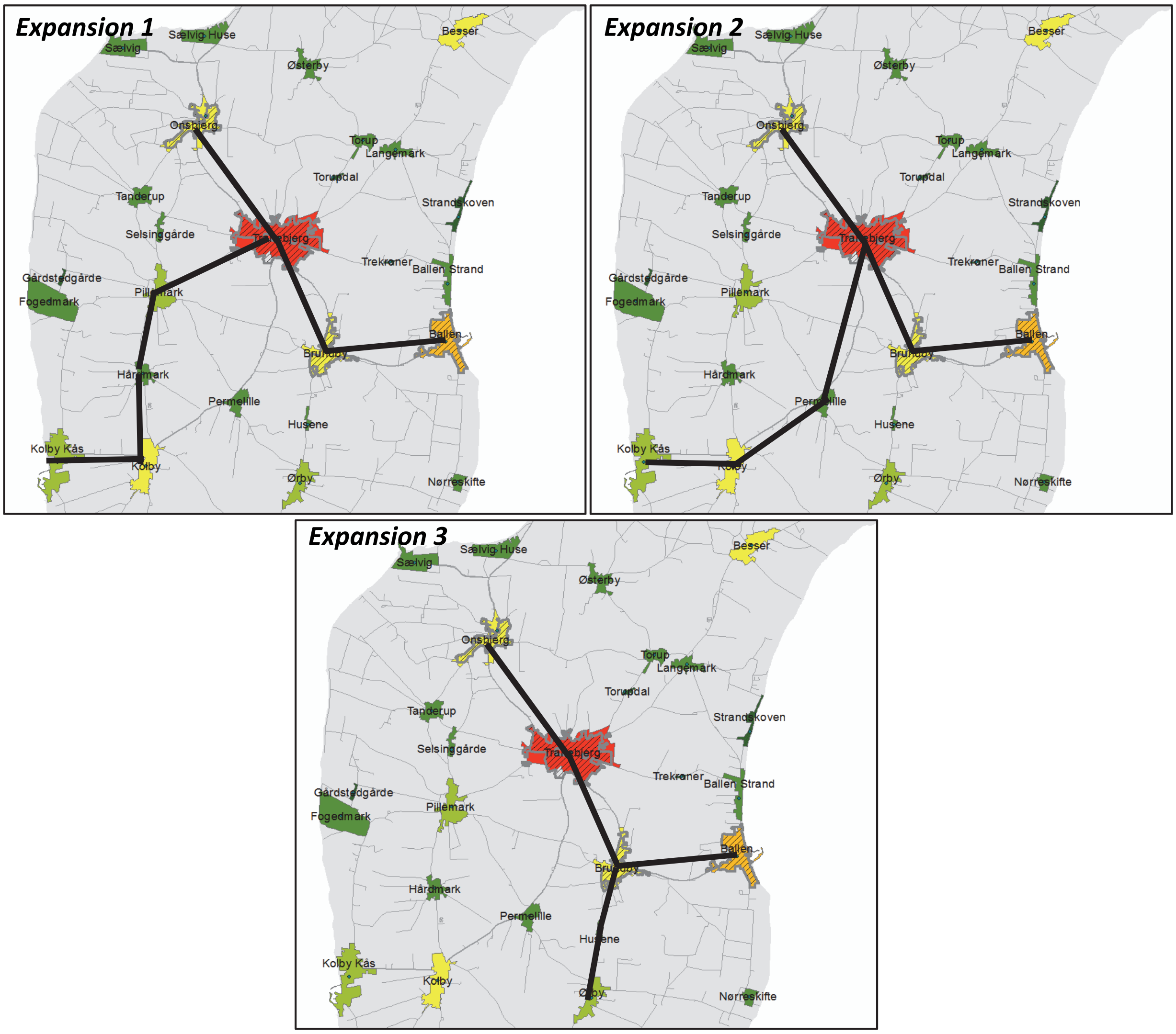

Figure 25a-c: Options for district heating expansions on Samsø. The options expand to Pillemark, Hårdmark, Kolby, Kolby Kås, Permelille, Husene and Ørby in different combinations.

The expansions lead to higher investments in the form of transmission pipes, distribution pipes and heat exchangers in the connected buildings. In Table 10 below is an overview of the costs for the different expansion options divided into transmission, distribution and installation costs. The transmission costs are based on the the distrance between towns as well as the required pipe size based on the heat demand in each town. The distribution pipe investment is based on a cost of 2.3 € per m^2 of town area and the installation cost is based on 5441 € per building.

Table 10: District heating expansions and the associated investment costs for the different options

District heating expansions	Unit	Interconnections	Expansion 1	Expansion 2	Expansion 3
New DH areas		-	Pillemark, Hårdmark, Kolby, Kolby Kås	Permelille, Kolby, Kolby Kås	Husene, Ørby
District heating demand	GWh/year	15.45	19.49	18.31	16.46
District heating share	% of total heat demand	31	39	37	33
Interconnection investments	M€	3.8			
Transmission pipes	M€	-	5.8	5.1	1.5
Distribution pipes	M€	-	2.0	1.6	0.4
Installations	M€	-	2.7	1.9	0.7
Total costs	M€	3.8	14.4	12.3	6.4

It is assumed that the district heating expansions replace an average mix of individual heating production as no data for the heating units were available with a geographical context. After further analysis of the results expansion 1 was selected as the preferable option (see also section 5.1.2).

4.8. Step 6 – Small heat pumps

All individual heating is replaced by small heat pumps with the exception of a small share of individual biomass boilers representing 10% of the heat demand outside of the district heating areas. The biomass consumption in these boilers is around 3 GWh/year. This share of biomass boilers is included as there always will be cases where heat consumers are located in proximity of biomass resources and that a complete transition to small heat pumps will not be realistic. The COP of the small heat pumps are assumed to be 3.7 with half of the heat pumps being respectively ground-source technologies and the other half air-based (these are more common in summerhouses of which there are many on Samsø).

After step 6 the biomass demand in the heating sector is reduced as much as possible and it is therefore appropriate to optimize the only fossil fuel consuming sector left in the scenarios – the transport sector.

4.9. Step 7 – Transport solutions

Six different transport scenarios are developed and analysed as possible options for a future 100% renewable system.

The first scenario implements electric vehicles (EVs) instead of all cars and vans and 50% of the bus fuel demand. The other five scenarios are then additions to this EV conversion and different ways of achieving a 100% renewable transport sector and thereby a full renewable energy system in Samsø.

The six transport scenarios are called:

- *7a* EVs
- *7b* EVs + 2g biodiesel
- *7c* EVs + Biogas LBG/CBG
- *7d* EVs + Biogas hydro LG/CG
- *7e* EVs + Biomass hydro LG/CG
- *7f* EVs + Biomass hydro DME

These options differ in the mix of technologies and the end fuel products produced. The six transport pathways and the methodology and assumptions applied are described below.

The transport pathways are selected to meet the highest share of the transport demand, e.g. was biopetrol not selected as an option as this type of fuel is only suitable for a rather small share of the transport demand.

The costs for biofuel plants are listed in Table 11 and are used in the transport scenarios.

Table 11: Investments, O&M and lifetimes applied for biofuel technologies

Technology	Investment (1000€/GWh)	O&M (% of investment)	Lifetime (years)
Biogas plant*	212		
Biogas upgrade*	34		
Gas pipeline*	27	7	20
LNG**	20		
CNG**	31		

* [4], ** [24]

For the scenarios where electrolysers are installed the technology applied is SOEC (Solid Oxide Electrolyser Cells) and an additional buffer of 30% capacity is added which means that the electrolyser to a larger degree can produce according to the wind production rather than as a constant production. This buffer can be debated as it leads to additional investments, but in general a slightly higher capacity than baseload can be recommended [26]. In addition a hydrogen storage equal to around 3 days of production is included.

Recent developments discuss the possibilities of capturing carbon from the air as an external source for hydrogenation, but this has not been included in these analyses. If this becomes an option in the future it should be considered in connection with the transport scenarios using hydrogenation.

4.9.1. *7a* - EVs

In the EVs path all cars and vans are converted to electricity along with 50% of the bus demand. The reasons for doing this are that Samsø has abundance of wind power resources, EVs have a better efficiency and the electricity can be produced from renewable sources. The efficiencies that are assumed for the different technologies are a demand of 1.63 MJ/km for diesel cars, 2.11 MJ/km for petrol cars while the electric cars consume 0.41 MJ/km [24]. Hence, the EVs are between 400-500% more efficient than the petrol and diesel cars when comparing their drive-to-wheel efficiency. For the busses it is assumed that the energy demands are 14.12 MJ/km for diesel busses and 3.41 MJ/km for electric busses. In this manner 27.8 GWh of transport fossil fuel demand is converted to a demand of 5.9 GWh of electricity.

This scenario is not comparable to the other transport pathways as this system is not 100% renewable, but is rather created with the purpose of illustrating the impact of EVs in the system.

4.9.2. *7b* – EVs + 2gbiodiesel

In this scenario, the HDV transport (ferries, trucks, busses, tractors) demand is converted to 2nd generation biodiesel. Diesel in this pathway is produced by using BTL technology (biomass to liquid) using straw, wood or energy crops. The biomass is firstly gasified and the produced gas is then cleaned, reformed and converted to long chained alkanes by using Fischer-Tropsch synthesis and further the alkanes go through thermal cracking to produce the desired fuel. The efficiency of the process, defined as a diesel fuel output divided by biomass input is 39%.

The most critical technology for the 2nd generation biodiesel production is biomass gasification. While gasification of wood is already a commercialized technology, the gasification of straw still needs to be further developed and demonstrated [27]. However, there are many gasifiers that have proven that operation is possible even with different types of biomass used for the same gasifier [28]. The other parts of the production cycle are already used for other xTL technologies and they are accounted as fully developed and commercialized.

4.9.3. *7c* – EVs + Biogas LBG/CBG

Biogas is here modelled according to [4]. Biogas is produced by an anaerobic process treating the animal manure and organic waste to produce biogas. The daily input of the manure is 1000 tonnes per day. The share of wet and dry biomass used for the process is based on today's potentials of 22% wet and 78% of dry biomass. The biogas produced is composed of 65% methane and 35% CO_2. The biogas is upgraded in order to clean the gas from the carbon dioxide part and other contaminants. The produced biomethane is further compressed and/or liquefied for transport purposes with additional 5% losses. Both options are added as some transport modes such as road vehicles are more suitable for using compressed biogas (CBG), while others such as a ferry is more suitable for using liquefied biogas (LBG).

In order to meet the same transport demand for HDV using compressed or liquefied biogas the fuel demand is adjusted according to 20% lower conversion efficiency of the vehicles running on gas.

4.9.4. *7d* – EVs + Biogas hydro LG/CG

Biogas hydrogenation process includes two steps. Firstly, biomass is converted to biogas by anaerobic process and the produced biogas is further treated by hydrogenation of the CO_2 fraction of the gas. The produced biogas can have between 30-45% of CO_2 depending on the technology and resources used. This fraction can be methanated in order to get high quality biogas. This is done by hydrogenating the produced CO_2 by hydrogen from steam electrolysis with SOEC technology to produce methane. The methanation of CO_2 to methane is a commercialized technology, however no turnkey solution that include hydrogen production from high temperature electrolysis is available currently.

The produced biomethane is further compressed and/or liquefied in order to be used for transport purposes with additional 5% of losses. The same assumption for fuel demand was applied as in previous pathway, by adjusting it to 20% lower efficiency of vehicles running on gas.

The electrolyser capacity installed in this scenario is 7 MW-e along with a hydrogen storage of 500 MWh.

4.9.5. *7e* – EVs + Biomass hydro LG/CG

Biomass hydrogenation pathway to methane can be divided into three steps. Firstly, biomass needs to be gasified in order to produce synthetic gas that can be treated further with hydrogen. Different biomass feedstocks can be used depending on the technology used and the pathway was modelled using wood, straw and energy crops as main inputs for the gasifier. Once the biomass is gasified, it is possible to do hydrogenation/methanation of the produced gas by adding hydrogen produced by steam electrolysis (SOECs). The produced methane is then further compressed and/or liquefied for transport purposes.

This way of producing methane is lowering the biomass input per fuel output as the added hydrogen is boosting the energy content of the produced fuel. The same assumption for fuel demand was applied as in previous pathway, by adjusting it to 20% lower efficiency of vehicles running on gas. The 5% of the excess heat produced in the process is redirected to district heating.

In this scenario a total of 6.6 MW-e electrolyser is installed and a hydrogen storage of 500 MWh.

4.9.6. *7f* – EVs + Biomass hydro DME

Biomass hydrogenation to dimethyl ether (DME) is the same production process as biomass hydrogenation to methane, apart from conversion of the upgraded gas to the desired fuel. The produced gas from biomass gasification is after its upgrade with hydrogen converted to liquid fuel by using DME synthesis process. DME synthesis is a commercialized technology and the produced fuel can be used in diesel engines with small alterations.

The fuel demand is the same as for the biodiesel pathway as the vehicle efficiency is identical for these two fuel types. The use of DME as transport fuel is demonstrated for HDV by Volvo [29–31] testing the truck performances fueled by DME. It is assumed that the total HDV demand on Samsø can be met by using DME as final fuel.

In *7f* 4 MW-e of electrolyser is installed and 450 MWh of hydrogen storage.

5. Scenario results

The results for all the scenarios are presented in this chapter allowing for comparison of the different options and their impacts on respectively energy, economy and environment. For further details about scenarios and results look into Appendix E. Printouts of EnergyPLAN models

5.1. Heat savings and district heating expansions

In this section are the results from some of the different alternatives when implementing heat savings and district heating expansions.

5.1.1. Heat savings

Three different heat saving shares were analysed; respectively 10%, 20%, and 30% savings of the total heat demand in the 2030 scenario. These savings might not seem significant, but Samsø has already carried out ambitious heat savings and it was therefore assessed that it can be difficult and costly to go further than these heat saving shares.

The two parameters used for deciding between the heat saving shares are biomass demand and socio-economic costs, see

Figure 26. The investments in heat saving measures (see section 4.4 for further details) leads to higher socio-economic costs. On the other hand the biomass demand decreases the higher heat saving shares and it was therefore necessary to take both these trends into consideration when choosing which heat saving share to use for the later analysis. It was decided to use 20% heat savings as this reduces the biomass demand without compromising the total costs too much. Furthermore, it was found after discussion with local stakeholders that it might be difficult to go higher due to the already carried out heat savings. If more heat savings are possible to implement these should be pursued to reduce the energy demands even further.

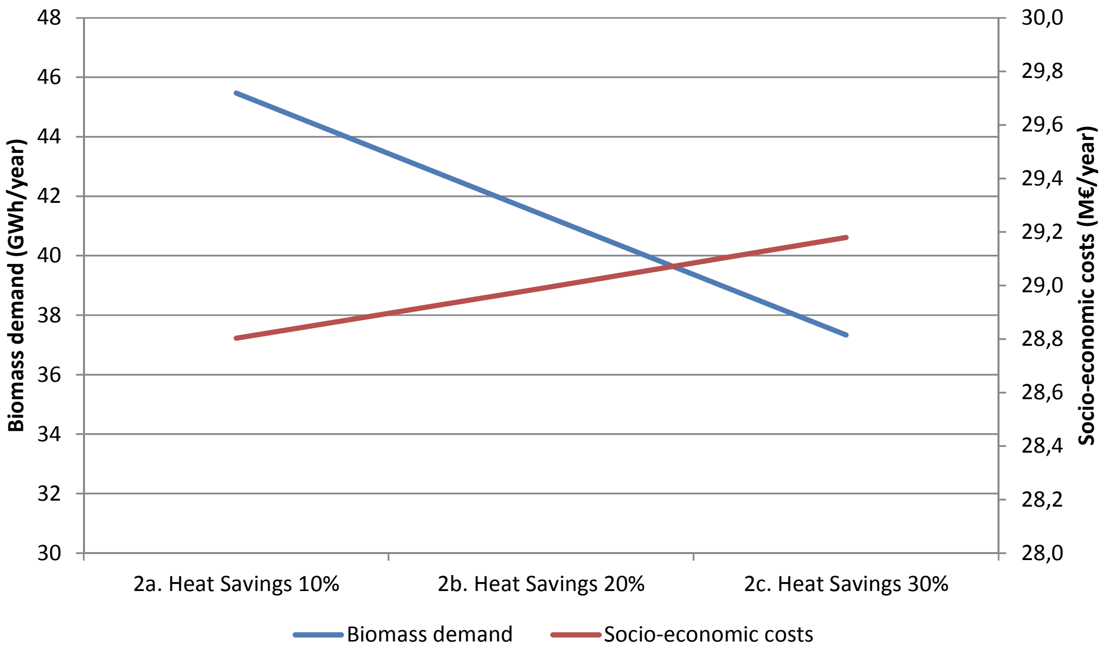

Figure 26: The biomass demand and socio-economic costs in the scenarios 2a-2c.

5.1.2. District heating expansions

After heat savings the district heating networks in the southern part of Samsø was interconnected in order to allow for installing large heat pumps. After this it was time to decide if the district heating network should be expanded again using the biomass demand and the socio-economic costs as the key parameters. The impacts are visible in Figure 27 comparing the scenario with the existing district heating demand and three different expansion options (see section 0 for more details). The district heating expansions lead to higher costs in all cases while the biomass demand decreases replacing less efficient boilers in the individual buildings and allowing for better use of heat storage.

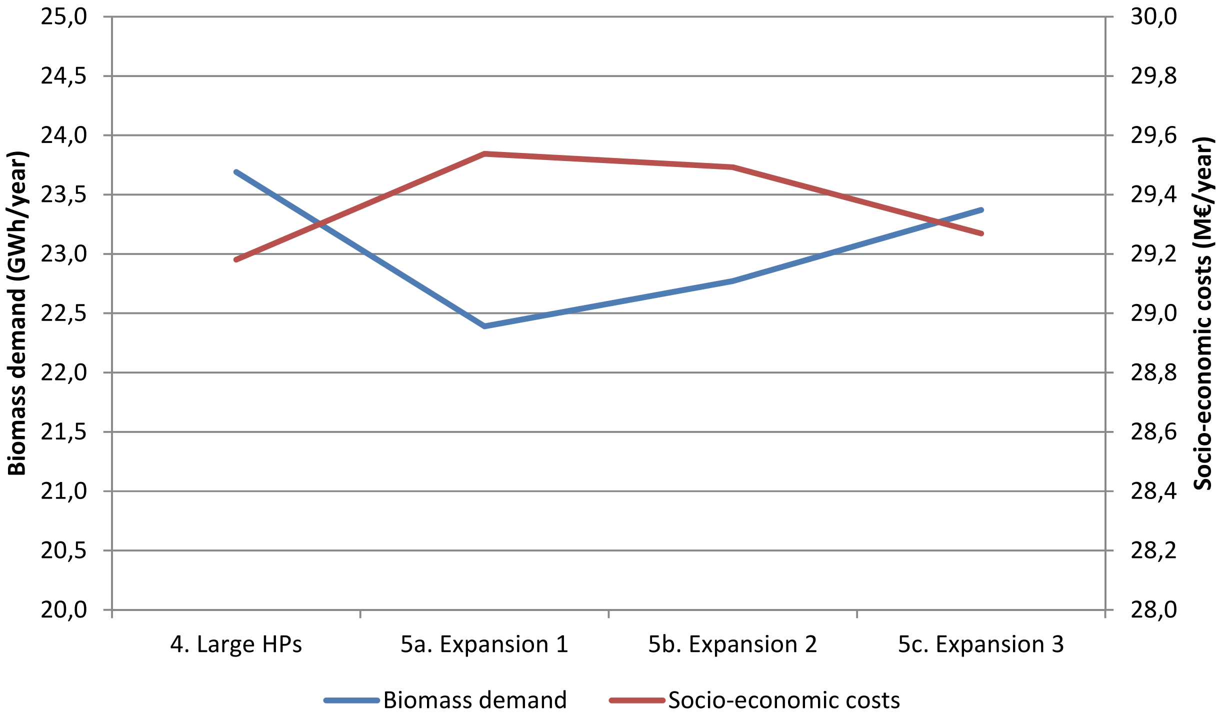

Figure 27: The biomass demand and socio-economic costs from different district heating expansion options

Expansion 1 was selected as it has the lowest biomass demand despite this scenario having the highest costs. It was however assessed that these cost differences are so minimal that they should not be the determining factor.

5.2.Scenario impacts on energy

The primary energy supply changes throughout the different scenarios as can be seen in Figure 28 below showing all the scenarios from the Reference 2013 to the various transport options.

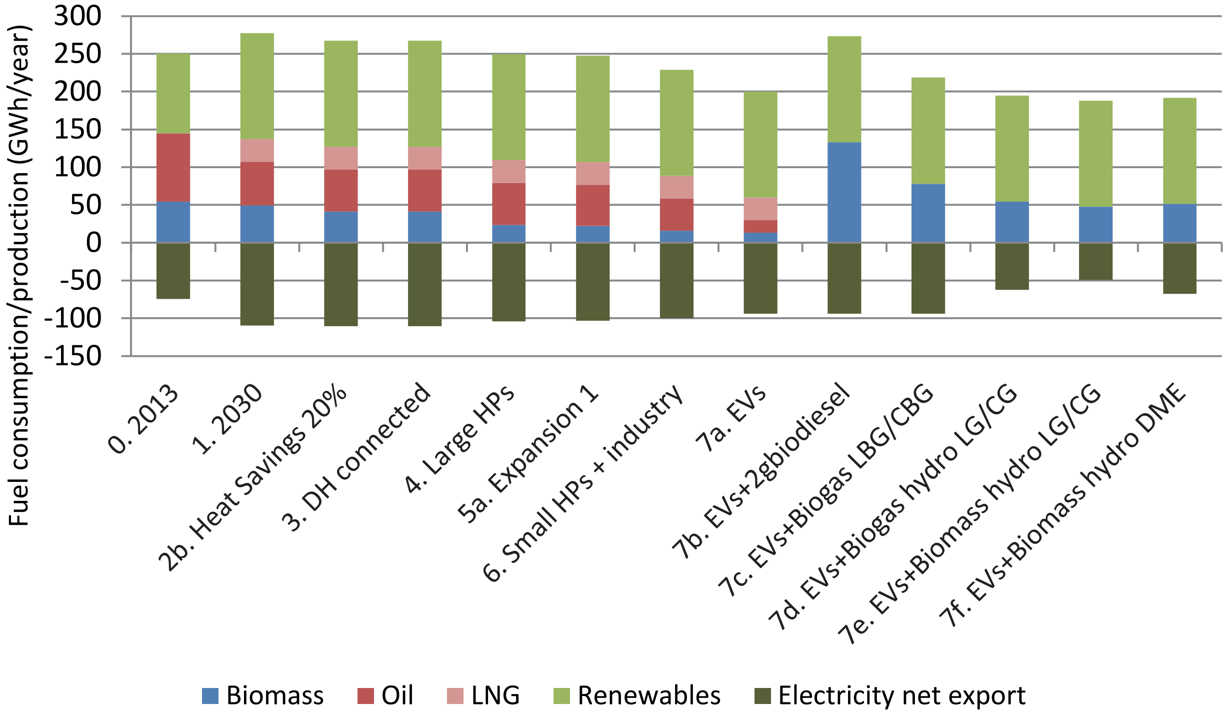

Figure 28: Primary energy supply for the different scenarios in terms of biomass, oil and LNG consumption, renewable electricity production and net export of electricity

As previously discussed the important resource on Samsø is biomass as this is scarce on might impact other areas such as agriculture. The biomass demand for each scenario is listed in Table 12 showing only the biomass that will be consumed on Samsø and does not include the biomass that could potentially be replaced elsewhere when a share of the renewable electricity is exported. On Samsø section 3.4.2 proved that there are plenty of renewable electricity resources and the aim has therefore been to reduce the biomass demand and replace this with a higher electricity demand. The net electricity export is an estimate of this as the electricity production remains constant after the 2030 scenario.

The results prove that the biomass demand is reducing when conducting changes in the heating sector in the steps 2-6 as the demand goes from 49 GWh/year to around 16 GWh/year. In addition, the conversion to EVs reduces the demand to 13.5 GWh/year as the small shares of biofuel in the transport sector are converted to electricity as well. In the steps *7a-7f* the biomass made available from the heating sector is put into the transport sector resulting in biomass demands between 50-130 GWh/year.

In many of the steps where the biomass demand is declining so is the electricity export indicating that more electricity is consumed in the system, e.g. when installing Large HPs, Small HPs, EVs and transport technologies consuming electricity in the process of creating either a liquid or gaseous transport fuel. The primary energy supply is also declining throughout the steps from around 250 GWh/year in 2013 to around 200 in some of the last steps. However, the primary energy should not be used as the sole measurement as there can be a large difference between the types of fuels that are consumed and the availability of these. The primary energy supply nonetheless provides a useful guideline for the efficiency of the system.

Table 12: Biomass demand and net electricity export for the Samsø scenarios

Scenario fuel consumption	Biomass demand	Electricity net export	Total Primary Energy Supply, excluding export
	GWh/year	GWh/year	GWh/year
0. 2013	54.5	74.5	254
1. 2030	49.4	109.5	281
2b. Heat Savings 20%	41.4	110.6	271
3. DH connected	41.4	110.6	281
4. Large HPs	23.7	104.2	253
5a. Expansion 2	22.4	103.0	251
6. Small HPs and industry	16.0	100.0	232
***7a* EVs**	13.5	94.1	203
***7b* EVs + 2gbiodiesel**	132.8	94.1	276
***7c* EVs + Biogas LBG/CBG**	78.2	94.1	222
***7d* EVs + Biogas hydro LG/LC**	54.2	62.1	198
***7e* EVs + Biomass hydro LG/CG**	47.6	49.0	191
***7f* EVs + Biomass hydro DME**	51.3	67.9	195

5.3. Scenario impact on economy

The socio-economic costs of the scenarios are impacted by a number of changes such as fuel costs, investments and O&M, CO2 costs and the amount of electricity that is sold from the system. The impacts are illustrated in Figure 29. In all the scenarios the investments are the largest cost share followed by fuel costs or fixed O&M. The total system costs in the reference 2013 are 29.7 M€/year decreasing to 28.6 M€ in 2030 due to more efficient technologies and this is the scenario that can be compared to the other scenarios. The total socio-economic costs increases when carrying out heat savings and district heating expansions as the growing investments exceeds the savings from improved efficiency and fuel savings. The large and small HPs do not increase the total costs despite the higher investment costs and the declining income from electricity export. When comparing the transport scenarios there is a relative large difference between some of the scenarios, but this is also caused by the increased electricity consumption which leads to less electricity being exported meaning less income to offset the cost.

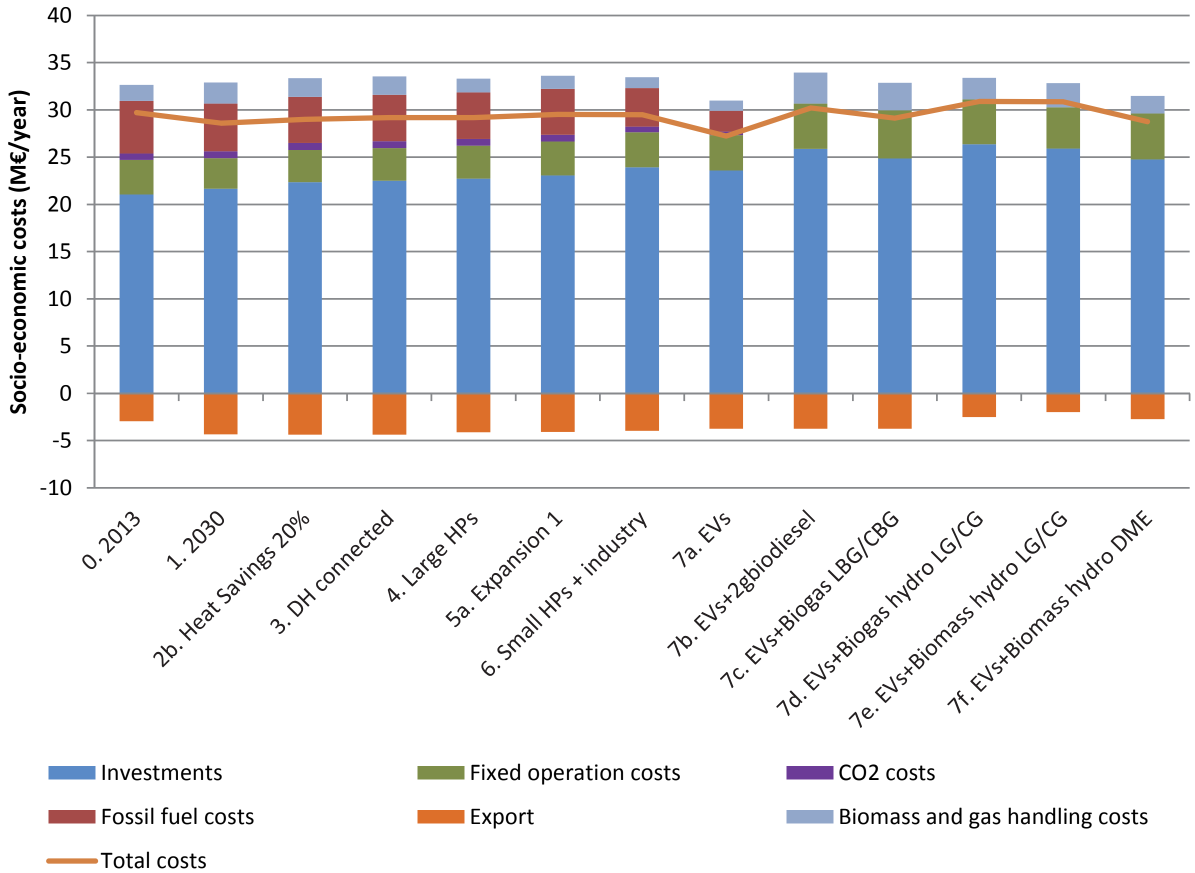

Figure 29: Socio-economic costs for the Samsø scenarios by different cost types

The costs in scenario *7a* decreases compared to the previous scenario as the EVs are more efficient than ICE vehicles and thereby reduces the fuel demand. In addition the saved fuel is expensive fossil fuels that are replaced by electricity and even though the electricity export decreases this is offset by the efficiency gains. Also, it is expected that EV investments are competitive with ICE engines in 2030 [24].

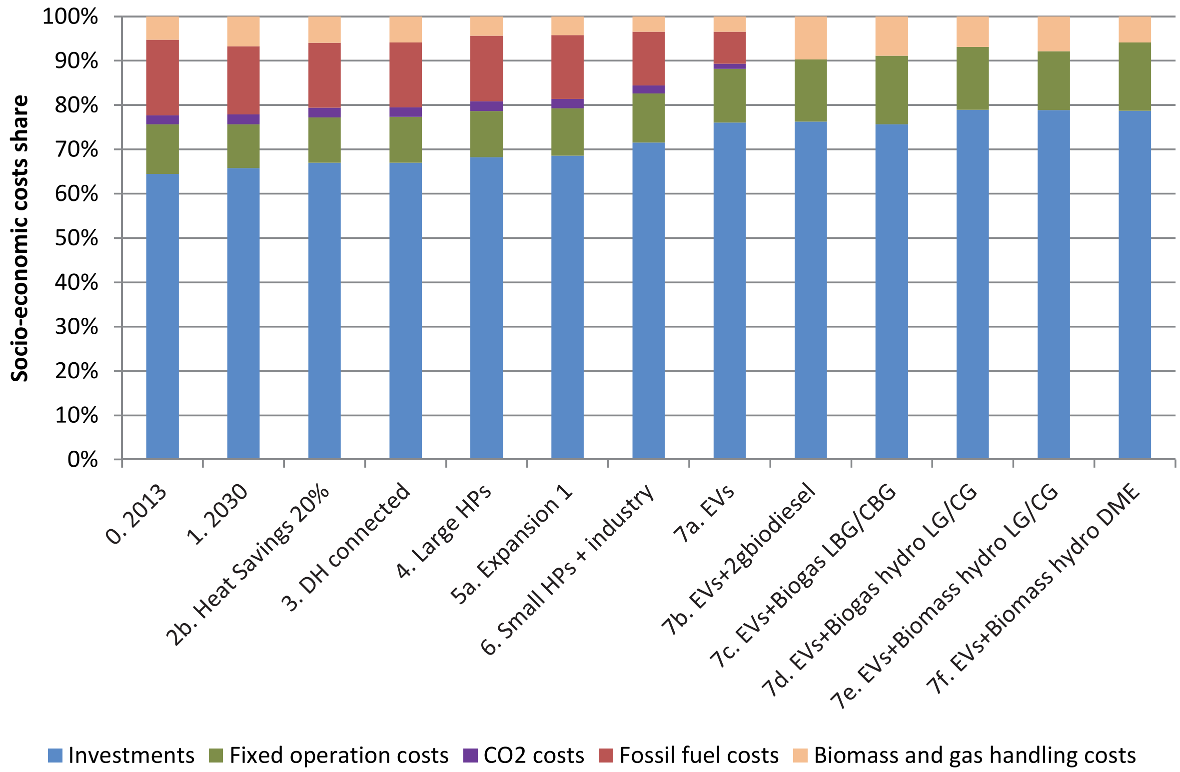

Figure 30: The cost types as a share of the total socio-economic costs for the different scenarios

Another important point is the increase in investment and O&M costs as these are more often benefitting to the local economy via jobs during installation, maintenance, etc., than import of fossil fuels that will not generate revenue in the local area. The combined investments and O&M share of the total costs (excl. export) is around 75% in the 2013 reference while it increases to above 90% in some of the transport scenarios.

5.4. Scenario impact on environment

The environmental impacts are measured in terms of CO_2-emissions emitted from the fuel consumption in Samsø. It is assumed that biomass do not have any emissions in line with what the Danish Energy Agency recommends. The transport scenarios *7b-7f* are all CO_2-neutral using only wind power, PV, solar thermal or biomass.

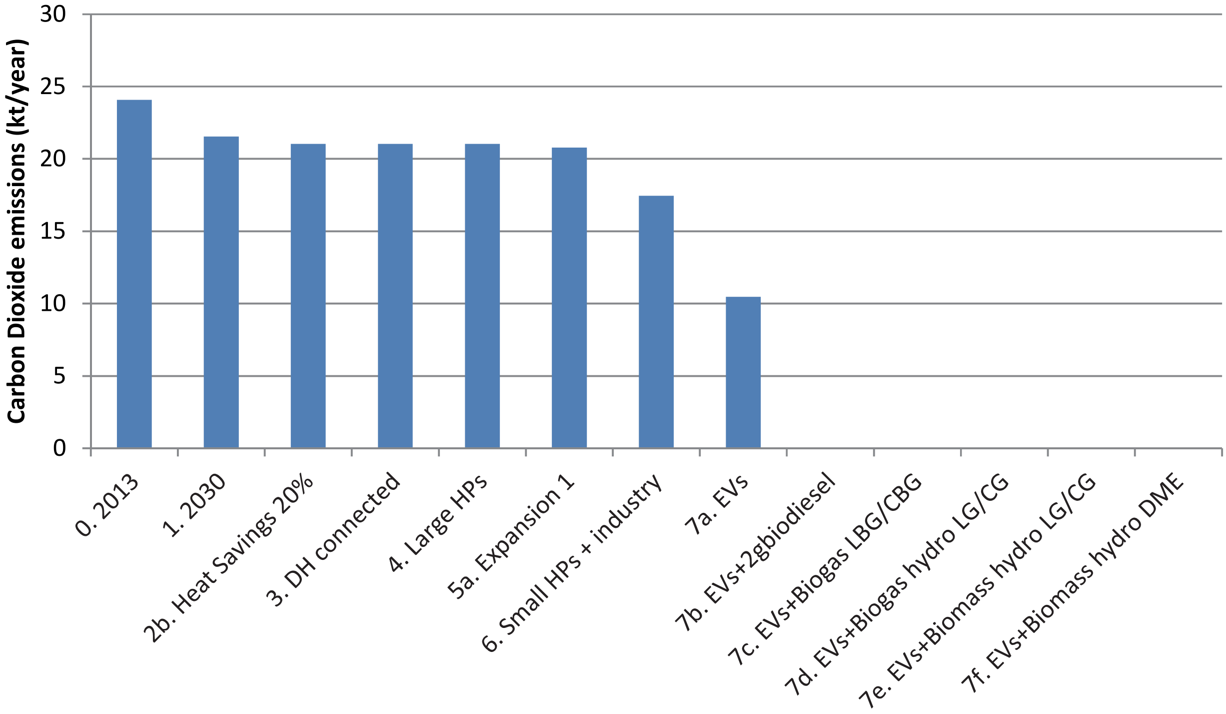

Figure 31: Carbon Dioxide Emissions in the scenarios measured as both the emissions in Samsø and including the fuels replaced elsewhere for electricity production

5.5. Sensitivity analysis

The results presented in the previous sections are all based on a number of decisions throughout the scenarios. This section contains analyses of changing some of these decisions or choosing a different path than the ones presented in the results. The changed assumptions in this section relate to the installed wind capacity, the vehicle efficiency in the gas paths, the implementation of individual heat pumps instead of district heating, an increased transport demand and the implementation of alkaline electrolysers instead of

5.5.1. Reduction of electricity export

An analysis is carried out where the electricity export is adjusted so the net electricity export from Samsø is 5% of the electricity demand thereby investigating the impact of the large wind production on Samsø. This situation represents a situation that is more comparable with what the situation might look like on a national scale. Figure 32 shows the electricity exchange in the scenarios without any changes and it is clear that there is a large net electricity export.

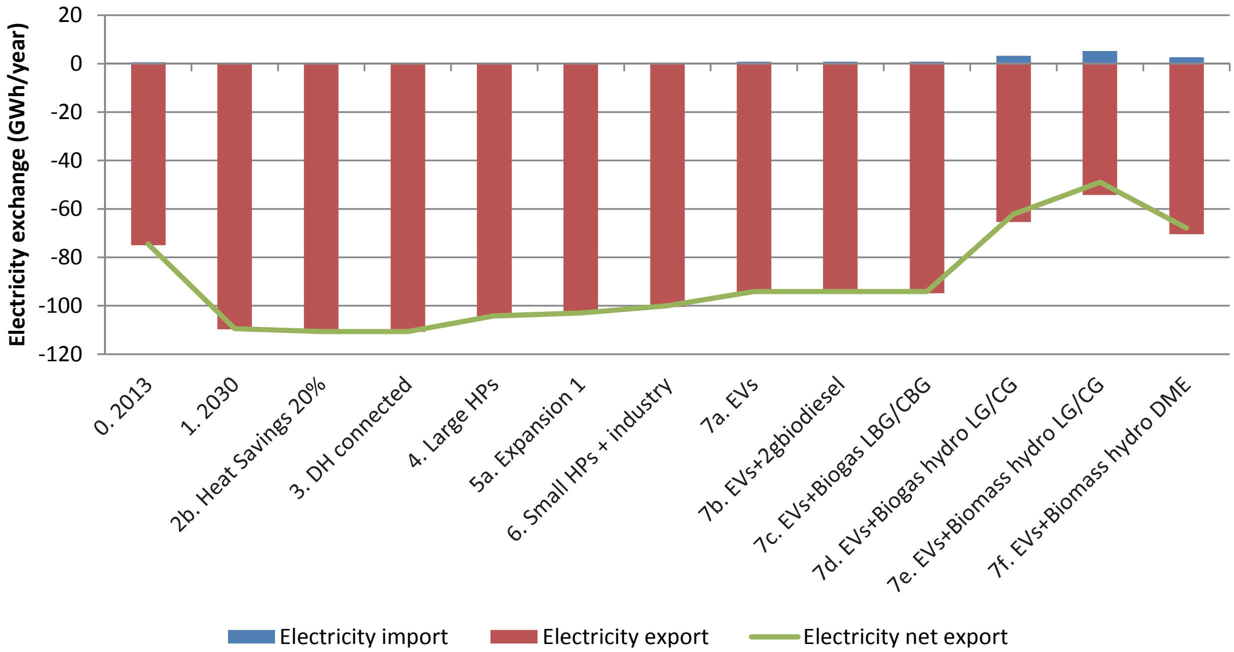

Figure 32: The electricity exchange in the Samsø scenarios

In Figure 33 has the wind capacities been altered so that the net electricity exchange is 5% and compared to Figure 32 the import increases while the export decreases significantly. This latter situation is more comparable to a Danish situation as it cannot be expected that Denmark will export a similar share of electricity production as Samsø.

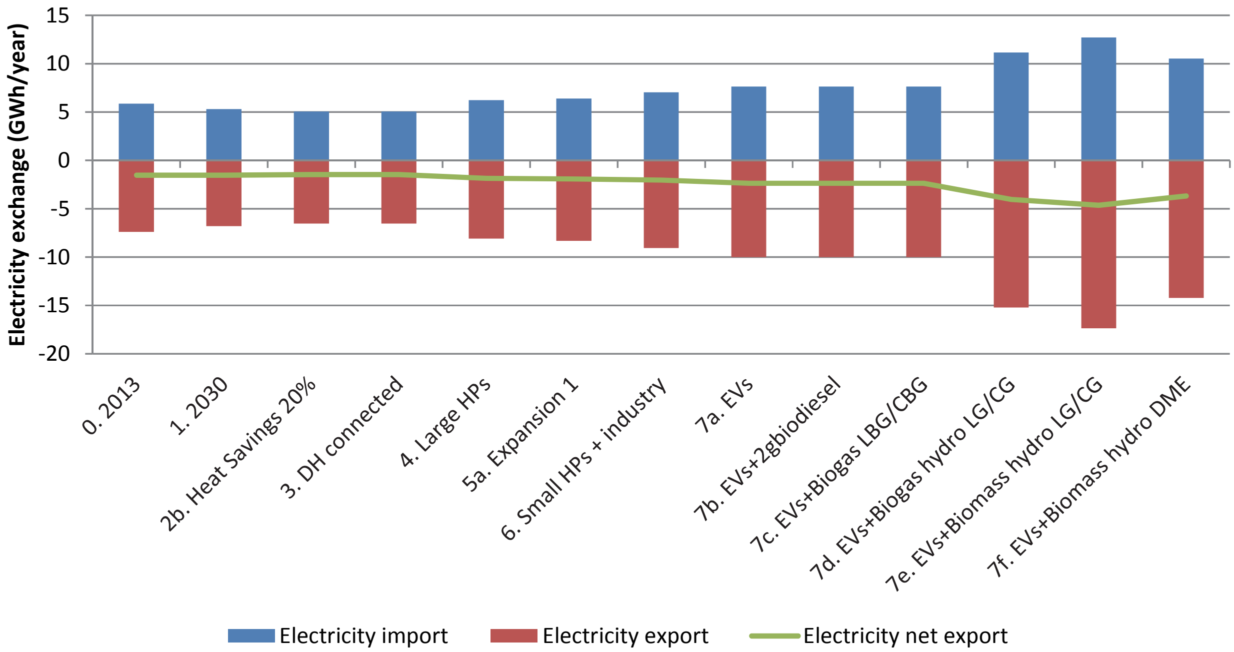

Figure 33: The electricity exchange when altering the wind capacity so the net export is 5%

The changed wind capacity also has a slight impact on the socio-economic costs of the scenarios as seen in Figure 34. The costs increase by between 1-2% when reducing the wind capacity as less income is generated from export of electricity and the difference between the two curves are of course highly dependent on the price expected for the electricity exported. In the 2013 reference the costs are lower due to lower earnings in that concrete year.

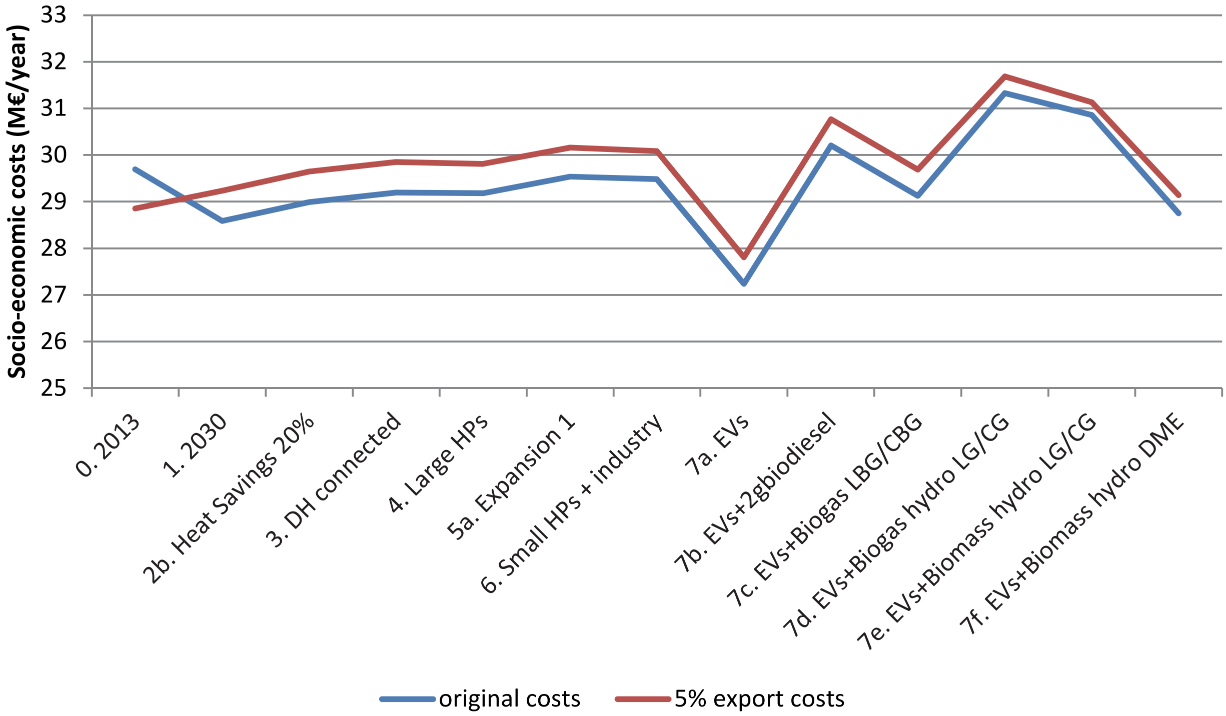

Figure 34: Socio-economic costs in the original Samsø scenarios and after altering the wind capacities so the net electricity export is 5%

The analysis shows that a large wind production might benefit Samsø also taking into consideration the electricity integration options provided in the transport and heating sectors.

5.5.2. Lower efficiency for gas vehicles

It is uncertain what the future efficiencies of different vehicle types will be and to illustrate that this sensitivity analysis changes the gas vehicle efficiencies. In the scenarios it is assumed that gas vehicles efficiencies are 20% lower than diesel vehicles while in this sensitivity analysis the efficiencies are reduced so that the gas vehicles have 30% lower efficiencies compared to diesel engines. This has been included in the scenarios *7c-7e* as these are the only scenarios with gas technologies in the transport sector.

The impacts of decreasing the efficiency of gas vehicles show that the primary energy demand and the socio-economic costs increase by around 1-3% while the biomass demand increases by 6-7% for the different scenarios.

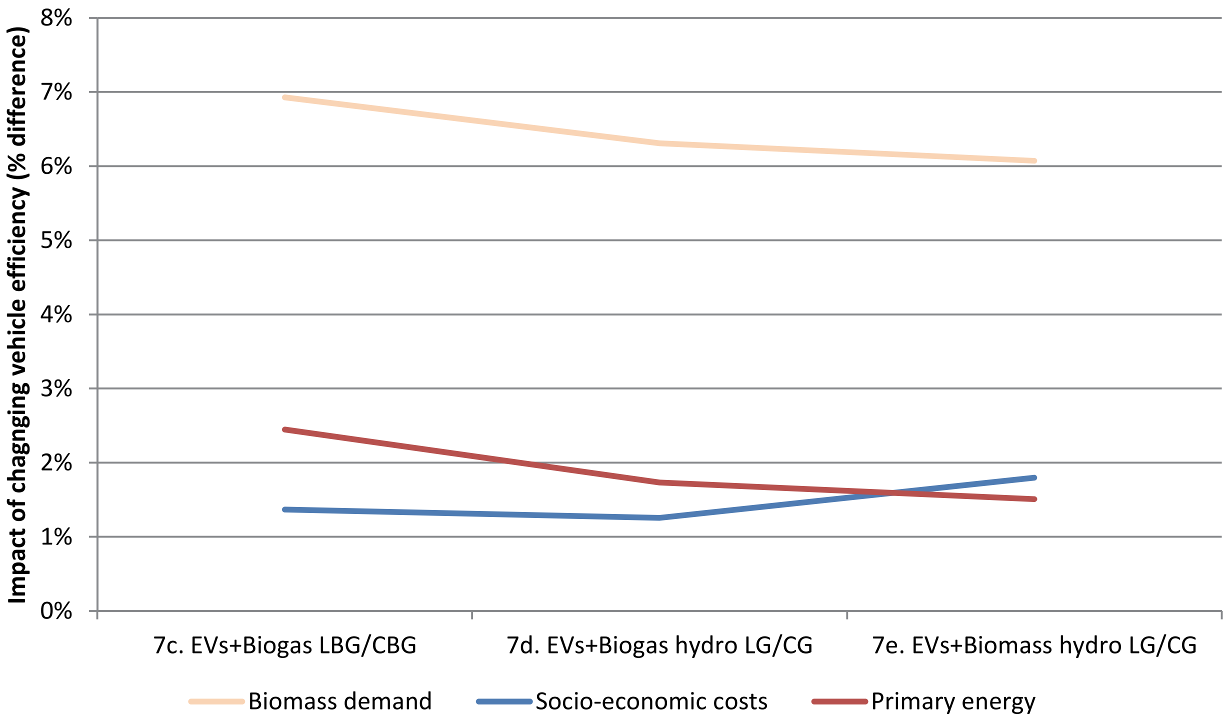

Figure 35: Impacts of reducing the gas vehicle efficiencies on biomass demand, socio-economic costs and primary energy demand

As the biomass resources are already under pressure in some of the scenarios it is therefore important to be aware of the technological developments of this might also impact the fuel demands and exceed the available resources.

5.5.3. Replacing all district heating with individual heat pumps

In order to investigate the feasibility of district heating and since high potentials of wind resources are available on Samsø it has been investigated if it would be preferable to implement individual heat pumps instead of all district heating including the current network. This analysis is included as if it is implemented after step 2 (heat savings) and replaces the considerations about district heating expansions and large heat pumps. When comparing the three steps: 2b. Heat Savings 20%, only individual heat pumps and 4. Large heat pumps in the district heating network, it is evident that the individual heat pumps create a more efficient system with a lower fuel demand, but on the other hand increases the costs due to the significant investments in heat pumps in all buildings. Furthermore, district heating allows for the integration of other sources such as solar thermal or excess heat from industries.

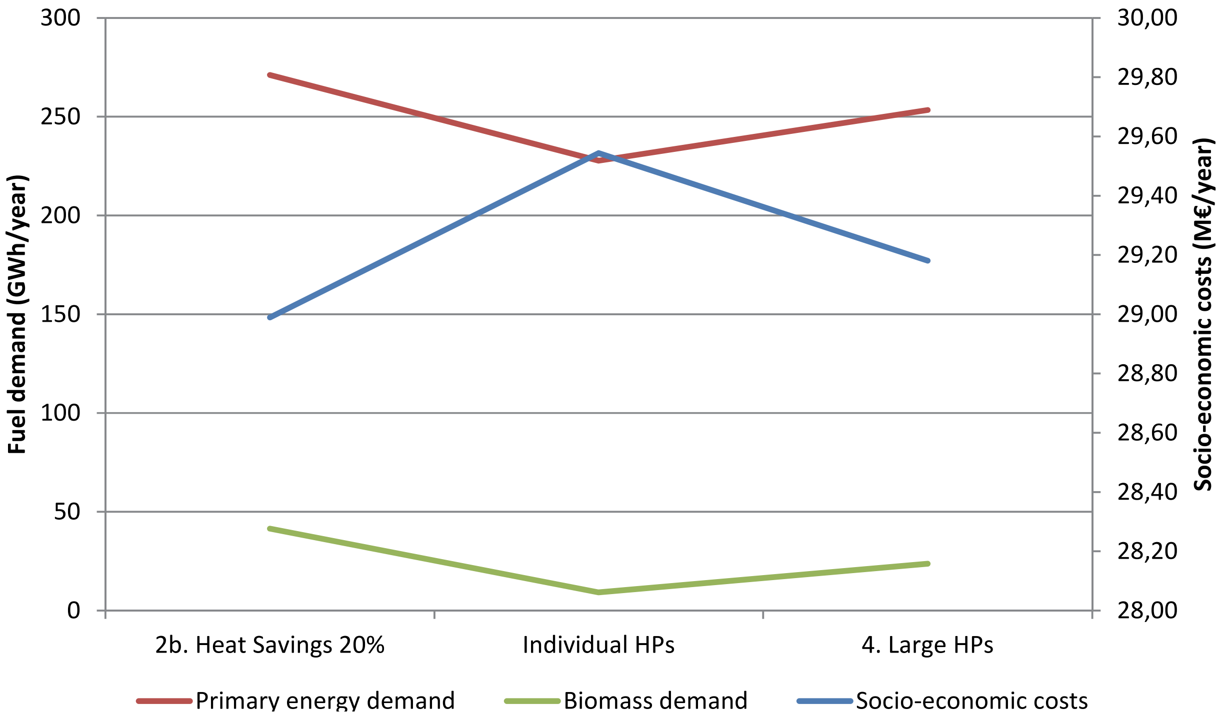

Figure 36: The impacts of replacing all district heating networks with individual heat pumps. The comparison is between scenario 2b with the current district heating network, a system with no district heating and scenario 4 with an expanded district heating network and large heat pumps.

5.5.4. Increased transport demand

In the analysis in this report no aviation demand has been included as this is not carried out inside the municipality of Samsø, but it must still be expected that the inhabitants of Samsø travel by air even though it is not included as fuel demand. In addition, the fuel prices on Samsø are slightly higher than in other parts of Denmark meaning that the inhabitants of Samsø might fuel their cars when traveling outside of Samsø. This will result in an additional fuel demand that have not been possible to include in the analysis. For these reasons a sensitivity analysis have been carried out increasing the transport fuel demand by 20% across all transport modes to indicate the impacts of an increased transport demand regardless of it is for aviation or road transport. Only the fuel demand has been altered so no additional costs for more vehicles have been included.

Figure 37 illustrates the impacts of increasing the transport fuel demand by 20% for the scenarios *7a-7f*. The largest impacts of increasing the transport fuel demand is on biomass demand for the steps *7b-7f* that increases by between 14-18%. In scenario *7a* no biomass is used for the transport sector and instead the demand for electricity and fossil fuels increases. The total primary energy demand increase for all scenarios between 4-8% while the socio-economic costs grow by 2-4%.

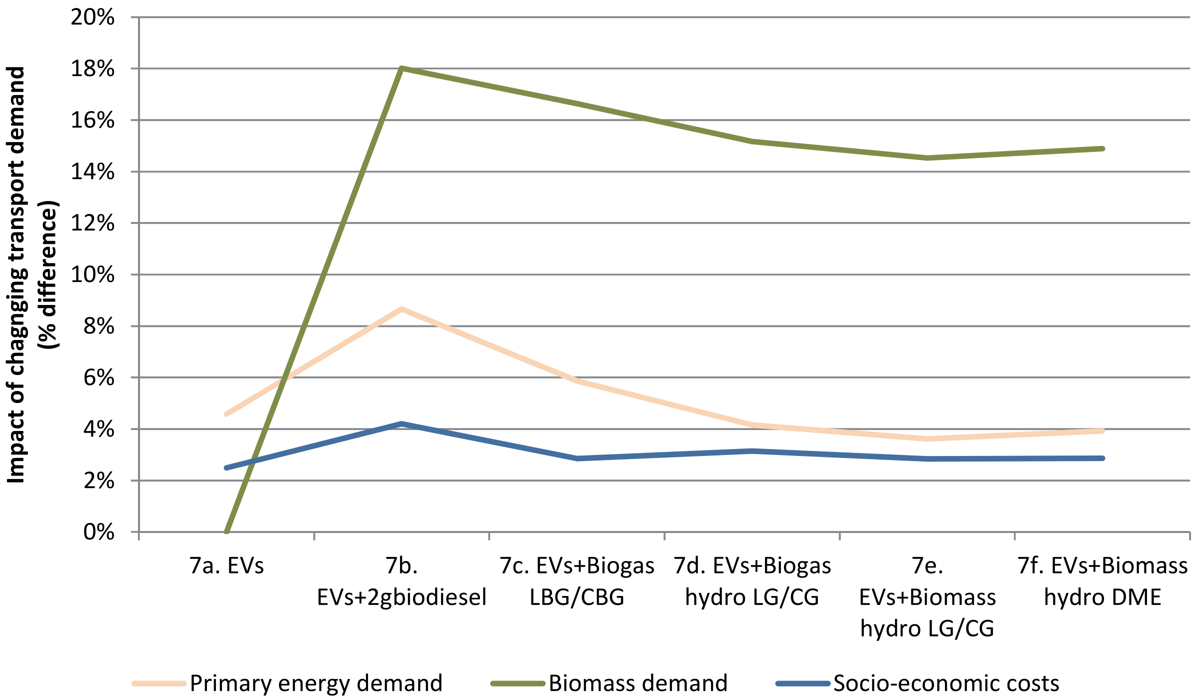

Figure 37: Impacts of increasing the transport fuel demand by 20% on primary energy demand, biomass demand and socio-economic costs

This shows that the delimitations and demands considered has an impact on the overall findings and especially that the biomass demand is sensitive to this and might exceed the available resources if the transport demand increases.

5.5.5. Sensitivity with alkaline costs and efficiencies instead of SOEC (*7d-7f*)

The SOEC technology is still in the development and research stage and it can therefore be difficult to predict how the technology characteristics will be in the future. Therefore, a sensitivity analysis have been performed installing alkaline electrolysers instead of SOECs as this technology is already available on the market and has been used for a number of years. The only factors that are changed are the investments, lifetime and O&M costs as well as the efficiency of the technology, see Table 13. Hence, no changes in capacities of the electrolysers or electricity production have been included despite the changes in these demands.

Table 13: Technology data for SOEC and alkaline electrolysers

	Investments	Lifetime	Operation and maintenance	Efficiency-$_{LHV}$
Unit	M€/MW	years	% of investment	%
SOEC	0.35	15	3	73
Alkaline	0.87	27.5	4	63.7

The results of converting to a different electrolyser technology can be seen in Figure 38 highlighting the impacts on hydrogen and electricity demand as well as the socio-economic costs. When installing alkaline electrolysers the hydrogen demand increases by 15%, the electricity demand is 5-7% higher and the socio-economic costs increase by 1-2% compared to when using SOECs.

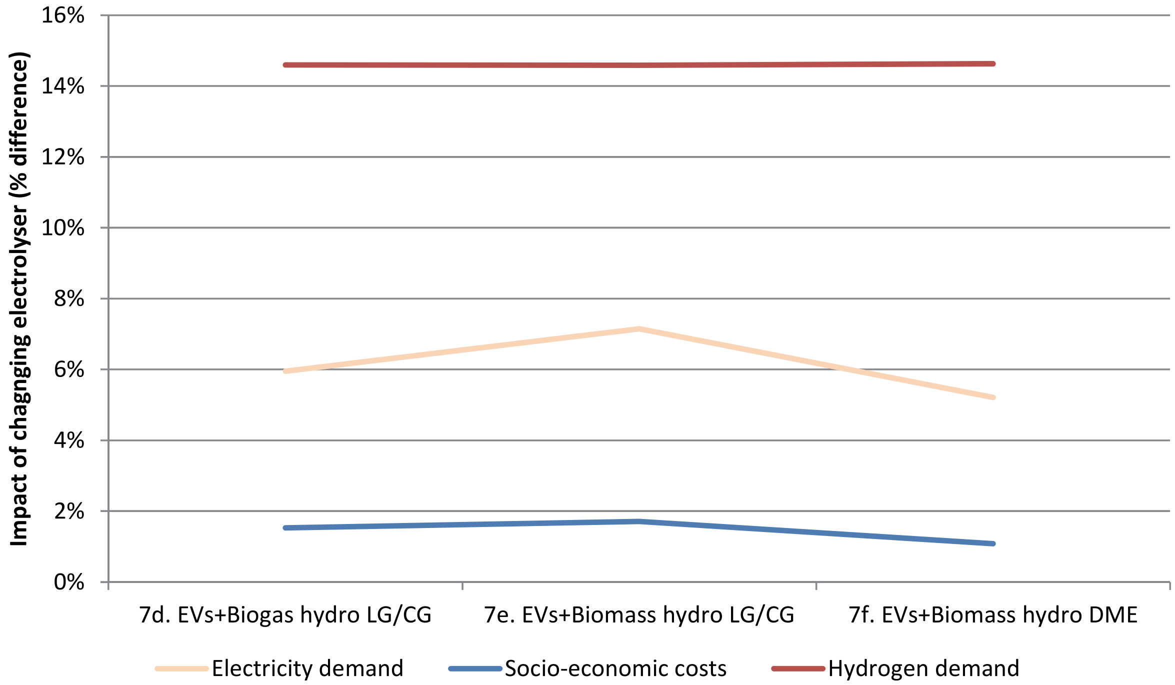

Figure 38: Impacts of changing from SOEC technology to alkaline on electricity and hydrogen demand and socio-economic costs.

It is therefore preferable to use SOEC technology in a future system relying on electrolysers, but the impacts of changing to alkaline technology are relatively low, especially since more electricity resources are available.

5.5.6. Summary of sensitivity analysis

To summarise the impact of the different assumptions the table below has been drawn. It shows the percentage change when altering some of the key assumptions.

Table 14: Summary of impacts of the various sensitivity analyses

Sensitivity analysis (% change)	Reduction in electricity export	Gas vehicle efficiency	Individual heat pumps*	Increased transport demand	Alkaline technology
Scenarios analysed	All	*7c-7e*	Replacing district heating	*7a-7f*	*7d-7f*
Socio-economic costs	1-2%	1-3%	1%	2-4%	1-2%
Primary energy demand	-	1-3%	-10%	4-8%	-
Biomass demand	-	6-7%	-60%	14-18%	-
Electricity demand	-	-	4%	-	5-7%
Hydrogen demand	-	-	-	-	15%

** Compared to scenario 4 with large heat pumps and district heating*

Notice, that the percentage changes in the table are not directly comparable because they represent different scenarios, but rather the changes can indicate trends about their significance on the overall findings.

The assumptions with the largest impacts are the increased transport demand influencing the biomass demand and the total costs the most. The analysis also shows that individual heat pumps could be considered, but leads to higher socio-economic costs and was therefore disregarded in the scenario development.

6. Evaluation and discussion of scenarios

This chapter will touch upon resources used in the analysed scenarios, their potentials and if they are sufficient to meet the demands in the scenarios. Moreover, the implementation and technological risks associated with the scenarios in relation to their implementation on the island, other impacts that they could have on the system such as job creation, security of supply for the island and the role of Samsø in the Danish context is discussed and elaborated below.

6.1. Electricity resources

Samsø is a net exporter of electricity currently and will also be so in the scenarios analysed. The renewable energy production, electricity demand and the net export of electricity is presented in the table below. It shows that in all scenarios Samsø will remain a net exporter of electricity despite having an electricity demand three times higher than the current in some of the scenarios.

Table 15: Wind and PV production, electricity demand and net export share for the scenarios

	Wind and PV production	Electricity demand	Net exporter of electricity
	GWh/year	GWh/year	%
0. 2013	106	31	338%
1. 2030	140	31	454%
2b. Heat Savings 20%	140	30	471%
3. DH connected	140	30	471%
4. Large HPs	140	36	388%
5a. Expansion 1	140	37	376%
6. Small HPs + industry	140	40	348%
7a EVs	140	46	303%
7b EVs+2gbiodiesel	140	46	303%
7c EVs+Biogas LBG/CBG	140	46	303%
7d EVs+Biogas hydro LG/CG	140	78	149%
7e EVs+Biomass hydro LG/CG	140	91	154%
7f EVs+Biomass hydro DME	140	73	194%

6.2.Biomass resources

The table below indicates the types of biomass that can be used in the different transport pathways. This is important because not all biomass types can be used for all the transport fuel technologies and hence some of the biomass potentials will remain unused (and possible for export). This is called the used biomass in the tables and figures in this section, i.e. the biomass potential that can be used within a specific biomass pathway and with the technologies from the specific transport scenario. Table 16 shows the biomass types that can be used by the different technologies in the scenarios and the total biomass demand not taking the local biomass potentials into consideration.

Table 16: Biomass types and demand in the different transport scenarios not taking local biomass resources into account

Transport paths and biomass	Total biomass demand (GWh/year)	Biomass types that can be used with transport technologies	Vehicles covered
7a EVs	13.5"	-	Busses, Personal vehicles and vans (Δ)
7b 2gbiodiesel	132.8	Straw, wood and energy crops	Δ+ ferries, trucks and tractors*
7c Biogas LBG/CBG	78.2	Energy crops, waste, waste water, manure, straw residues	Δ+ ferries and trucks**
7d Biogas hydro LG/CG	54.2	Energy crops, waste, waste water, manure, straw residues	Δ+ ferries and trucks**
7e Biomass hydro LG/CG	47.6	Wood, straw and energy crops	Δ+ ferries and trucks**
7f Biomass hydro DME	51.3	Wood, straw and energy crops	Δ+ ferries, trucks and tractors*

" This is the biomass demand for industry and heating sectors

** These pathways are able to cover the entire transport fuel demand*

*** Trucks on gaseous fuels may have a shorter range depending on the fuel tank and costs*

In Table 16 the biomass demand is listed as 78 GWh while it in Table 3 is only 34 GWh. The difference is that Table 3 is based on analyses from other WPs about a potentials biogas plant on Samsø and the resources that this consume while Table 16 includes the total biomass demand in the scenarios for converting the entire energy system into renewable sources (the biomass demand for producing sufficient biogas for covering the entire transport sector is calculated to be 65 GWh).

As previously presented four different biomass paths (A, B, C, and D) have been selected and entitled; A. the current potentials, B. the potentials with conversion to energy crops, C. the potentials with biogas using energy crops and D. the potentials with biogas using straw. Two of these include conversion to energy crops and therefore the overall biomass potentials are higher in these.

The maximum biomass potentials in each biomass pathway are listed below, but since not all biomass can be used by the technologies in the different scenarios the maximum biomass potentials can often not be achieved. The full breakdown of the biomass potentials can be found in Table 3.

Table 17: Maximum biomass potentials in the different biomass paths.

	Maximum biomass potentials (GWh/year)			
Biomass path	A. Biomass potentials - current	B. Biomass potentials with conversion to energy crops	C. Biomass potentials with biogas using energy crops	D. Biomass potentials with biogas using straw
Total	67	92	*92*	67

In Table 18 the biomass demands are combined with the potentials that can be used by the technologies in the transport scenarios indicating if there is sufficient biomass for the different scenarios and in which scenarios this could be the case. The comparisons only include the biomass types that can be used by the transport paths, i.e. in Biomass path A there are no technologies that can use wet biomasses and hence this resource is unused in this biomass path. If a biogas plant is installed as in Biomass path C and D it will become possible to use the wet biomasses, while other biomasses such as wood cannot be used for biogas production and hence some of this resource will remain unused. The numbers in the table therefore illustrate the maximum biomass potentials that can be used within a certain biomass path (e.g. with or without biogas production) and with the technology mix in the transport scenarios.

Table 18: Biomass demands in the different scenarios combined with the used biomass potentials in each biomass path

Biomass used and potentials		**Biomass used in path A**	**Biomass used in path B**	**Biomass used in path C**	**Biomass used in path D**	**Total biomass demand**
		GWh/year	GWh/year	GWh/year	GWh/year	GWh/year
***7b* 2gbiodiesel**	Used	53	78	56	31	133
	Unused	14	14	36	36	
***7c* Biogas LBG/CBG**	Used	14	14	53	52	78
	Unused	53	78	39	15	
***7d* Biogas hydro LG/CG**	Used	14	14	53	52	54
	Unused	53	78	39	15	
***7e* Biomass hydro LG/CG**	Used	53	78	56	31	48
	Unused	14	14	36	36	
***7f* Biomass hydro DME**	Used	53	78	56	31	51
	Unused	14	14	36	36	

When combining the biomass demands and the biomass potentials a matrix of 5x4 is created – five different transport scenarios (*7b-7f*) combined with four different biomass paths (A-D). A more detailed breakdown of these demands in combination with the potentials can be found in Appendix D. Biomass demands in combination with biomass potentials. Scenario *7a* is excluded from the table since this scenario does not directly use biomass for transport purposes, as electricity for EVs is produced by wind turbines on the island.

The following figures illustrates the biomass demands stated in Table 18 for the transport paths along with the biomass potentials in each pathway and the biomass types that can be used in each scenario. Biomass path A. represents the current potentials and it shows that transport scenarios *7e* and *7f* have sufficient biomass that they can use with their technology mix in comparison with their demand. None of the scenarios can utilize the maximum biomass potentials as the wet biomass resources are left unused. This is because no biogas is produced in biomass path A.

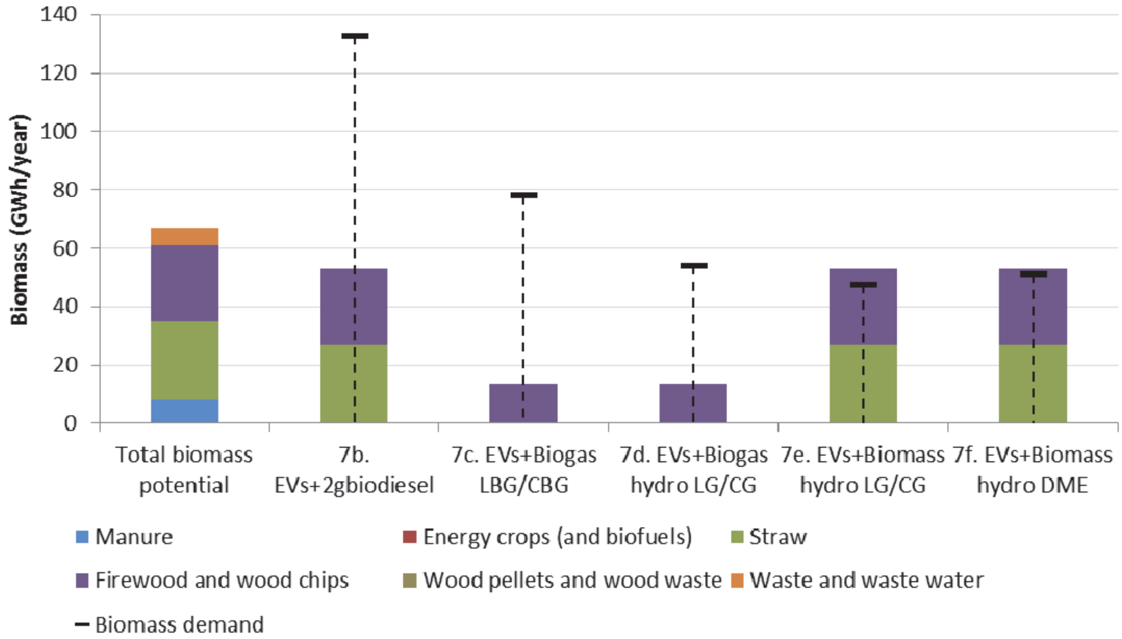

Figure 39: The biomass potentials usable by the different scenarios in biomass path A (current bioenergy potential)

In the next figure biomass path B is represented where some grain area is converted for growing energy crops. In this case similar to the previous biomass path scenarios *7e* and *7f* have sufficient biomass available that can be used compared to the biomass demands in the scenarios. Scenarios *7c* and *7d* can only utilize small amounts of the biomass potentials (for heating and industry) as they require biogas for transport which is not part of this biomass path.

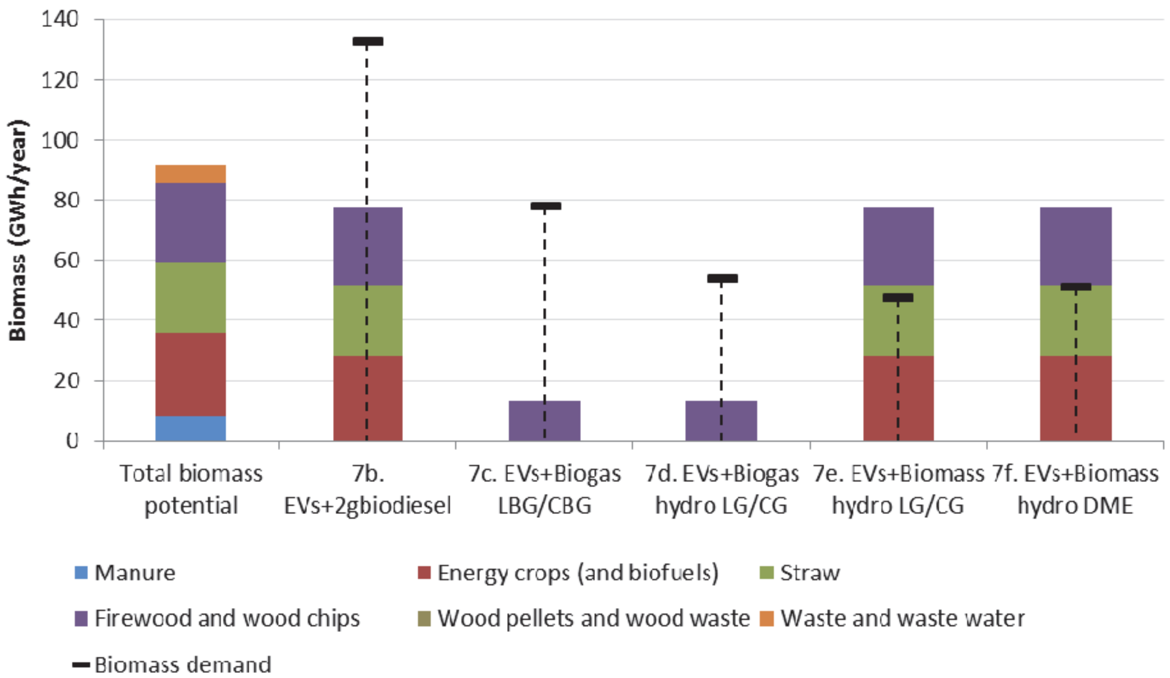

Figure 40: The biomass potentials usable by the different scenarios in biomass path B (bioenergy potential with conversion to energy crops)

For biomass path C a large share of the energy crops are used for biogas production. The biomass used for scenarios *7c* and *7d* is now higher as the scenario also uses a share of the wood for heating and industry purposes. Scenarios *7e* and *7f* can use the wood and straw that is already available and in addition the energy crops that are not used for biogas production.

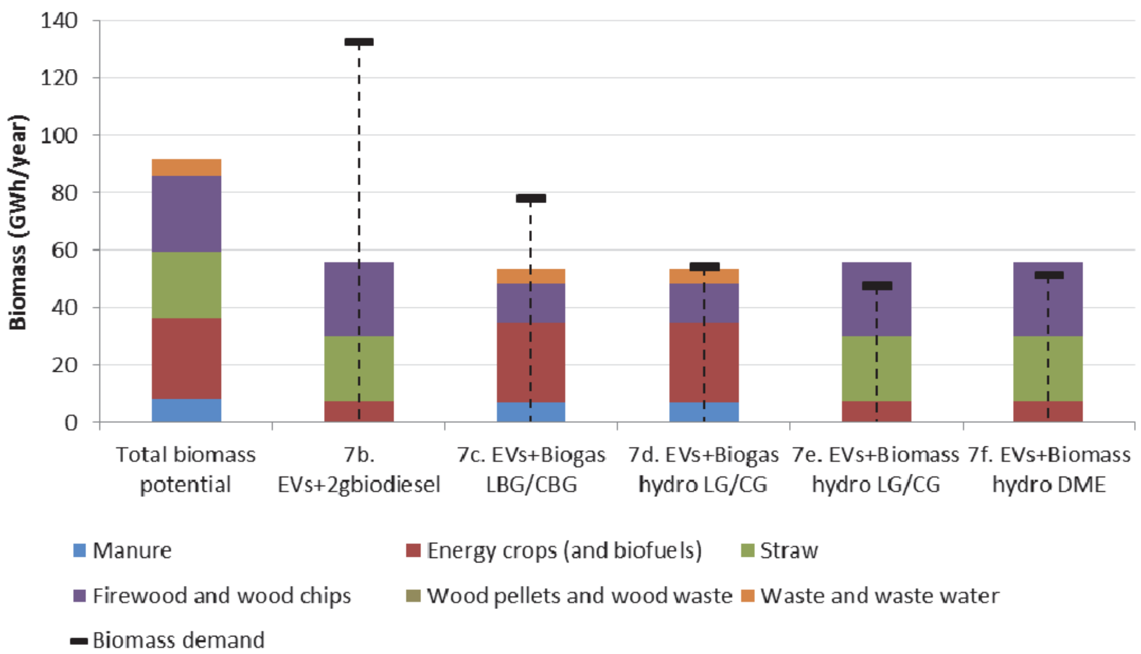

Figure 41: The biomass potentials usable by the different scenarios in biomass path C (bioenergy potential with biogas using energy crops)

In the last biomass path, path D, no energy crops are produced and hence the overall biomass potential is lower. Instead, straw is used for biogas production reducing the straw potential available for scenarios *7e* and *7f* as the majority of this resource is used for biogas production in this biomass path. The wood consumption in scenarios *7c* and *7d* is for heating and industry.

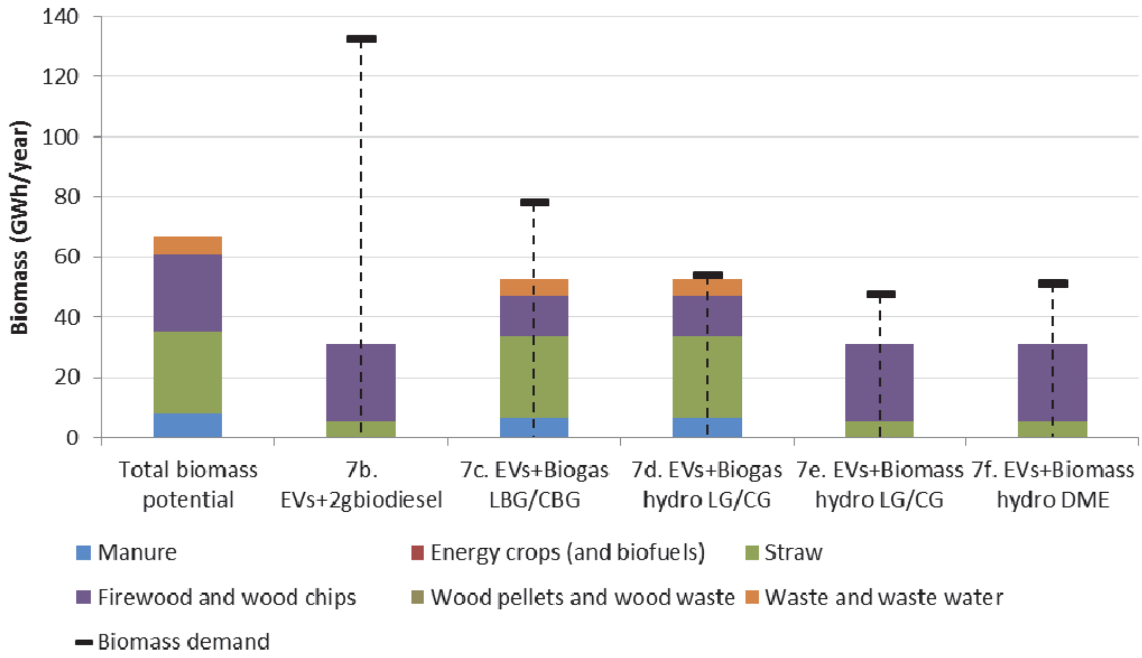

Figure 42: The biomass potentials usable by the different scenarios in biomass path D (bioenergy potential with biogas using straw (no energy crops)

If we try to summarise these different biomass paths and the potentials available two different options become apparent: an option with energy crops and one without. In Figure 43 and Figure 44 these two options are depicted showing that scenarios *7d-7f* seems more likely to stay within local biomass potentials.

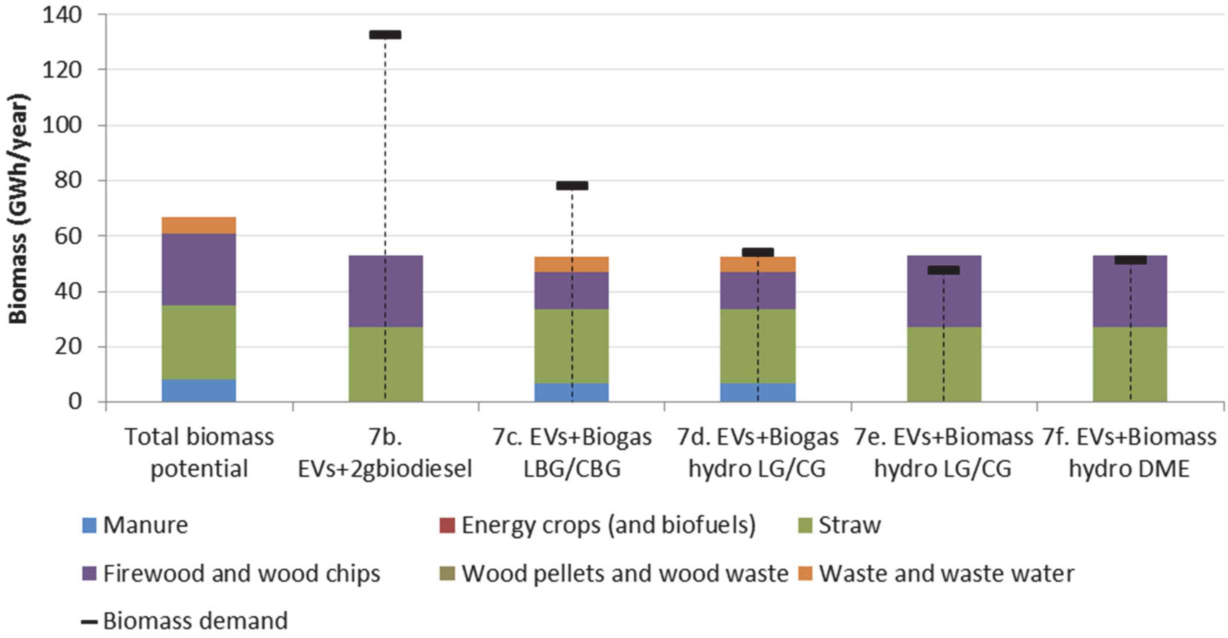

Figure 43: The scenarios combined with the biomass demands without implementation of energy crops

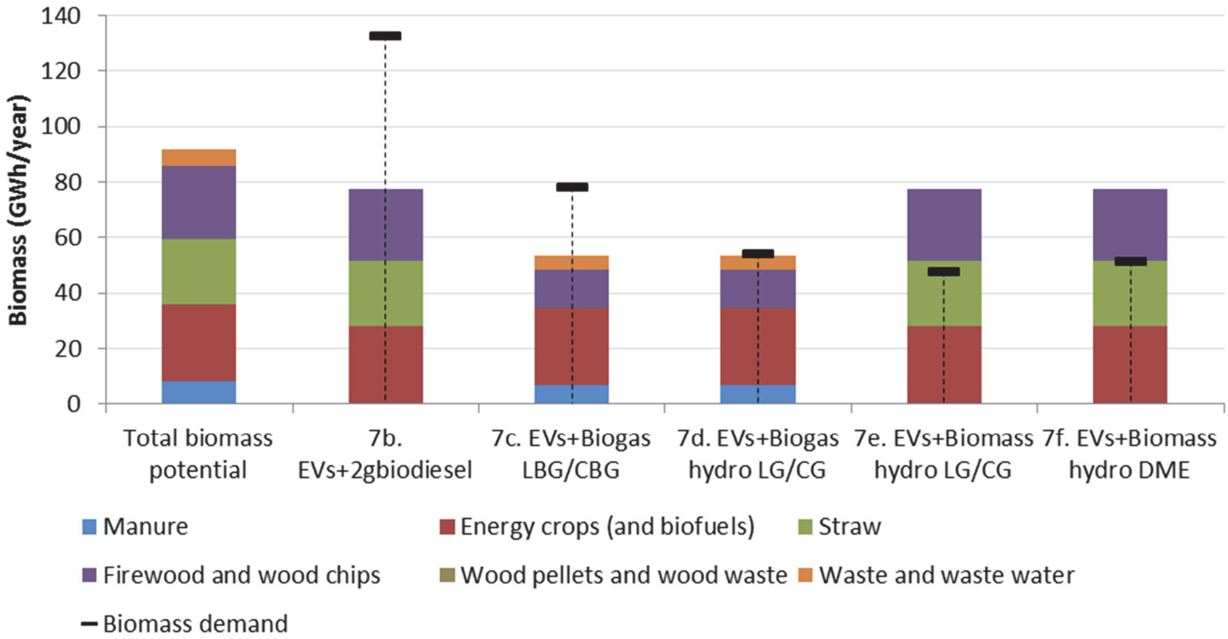

Figure 44: The scenarios combined with the biomass demands when we do convert some of the grain area to energy crops

Based on the presented figures and discussions, it is not straightforward to conclude which transport scenario is recommendable when comparing the biomass resources used and their potentials. It was however found that the scenarios *7e* and *7f* are able to meet their biomass demands by using only local biomass potentials in some of the transport paths. The same applies for scenario *7d* when producing biogas from either biogas or straw. The scenarios *7b* and *7c* have biomass demands higher than the biomass potentials they use for fuel production in all the biomass paths and if these scenarios are to be chosen for Samsø then import of biomass will be required.

6.3. Technological and implementation risks

The scenarios developed will inherently lead to a number of risks that might influence the economy or implementation of the scenario on Samsø.

Some of the factors that might create risks are: development stage of technologies, size requirements of plants and uncertainties regarding costs of certain technologies.

Some of the risks in the development of the heating sector in the scenarios can be the amount of heat savings through building renovations. These heat savings require that renovations are carried out in individual buildings and this can be influenced by the local building owners. In line with this is the implementation of a large share of heat pumps in the individual buildings as this is decided by the local building owner and not by the municipality. Some building owners might prefer different heating options if alternative sources are available nearby or at cheap costs.

For most of the scenarios the large capital investments might also create a risk, especially for local communities, as renewable technologies often are characterized by large investments and small costs throughout the remainder of the lifetime as no additional fuels are required. This risk has to be taken into consideration before any new investments are carried out. In addition it is relevant to be aware of the image that Samsø has created as a renewable energy island and therefore the future developments should be taken with this in consideration.

The table below describes the key technologies required in the transport scenarios as this is a key factor regarding whether these facilities can be established on Samsø or if import of fuels would be necessary. Some of the risks associated with the different transport paths are also listed and should be taken into consideration when planning for a future energy system.

General risks for all the scenarios with advanced technologies might be the need for proper educated and trained personnel that can be difficult to attract.

Scenario *7a* is not considered as a fully renewable energy system as the HDV transport still relies on fossil fuels. The risk is that the electricity grid needs to be enhanced when the demands increase and this additional cost has not been assessed in the analyses.

The risks for scenario *7b* are that the biodiesel plants usually are rather large and with the calculated biofuel demand the size of a potential plant on Samsø is smaller than what is usually feasible for this type of plant. Hence, it seems highly unlikely that this type of plant can be established on Samsø and it would therefore be necessary to export biomass from Samsø to a biofuel plant elsewhere and then importing this produced biodiesel afterwards.

Table 19: Scenario risks in terms of implementation, technology development, etc.

Transport paths	Key technologies	Implementation on Samsø	Risks
7a EVs	Batteries	Yes, but not 100% RE	Enhancement of the electricity grid
7b 2G biodiesel	Biomass gasification, gas-cleaning, gas-reforming and Fischer Tropsch synthesis (BTL-biomass to liquid)	Highly unlikely	Plant size too small
7c Biogas LBG/CBG	Biogas production, upgrade to methane and gas liquification/gas compression (LBG/CBG)	Yes	Cost of gas liquification/gas compression
7d Biogas hydro LG/CG	Biogas production, steam electrolysis/water electrolysis, hydrogenation/methanation, (conversion of the CO_2 part of the biogas to methane by reacting with hydrogen) and gas liquification/gas compression (LBG/CBG)	Possibly	1. No turnkey solutions available 2. Size and optimization may be a problem for cost and efficiency
7e Biomass hydro LG/CG	Biomass gasification, steam electrolysis/water electrolysis, hydrogenation/methanation (reacting the produced syngas with hydrogen) and gas liquification/gas compression (LBG/CBG).	Possibly	1. No turnkey solutions available 2. Size and optimization may be a problem for cost and efficiency
7f Biomass hydro DME	Biomass gasification, steam electrolysis/water electrolysis, hydrogenation (reacting the produced syngas with hydrogen) and chemical synthesis DME).	Possibly	1. No turnkey solutions available 2. Size and optimization may be a problem for cost and efficiency

In scenario *7c* a biogas plant is established followed by a liquification/compression of this gas to make it useful for the transport sector. The risks for this scenario are assessed to be the costs of this liquification/compression as these can potentially be increased. Apart from this (and not considering the biomass resources) no further risks have been identified and it should therefore be possible to implement this scenario on Samsø.

Scenarios *7d-7f* rely on technologies that are still not fully developed and hence no turnkey solutions are available today. In addition, the size and optimization of the potential plants can be a challenge in relation to the cost and efficiency of the plant. The potential plants on Samsø are of a size where economy-of-scale is not fully utilized. However, these three scenarios could possibly be implemented on Samsø with the aforementioned risks in mind.

6.4. Other impacts

Some of the impacts of the scenarios have not been quantified and are instead discussed below. These impacts are security of supply, job creation and local impacts and whether Samsø can function as a model society for the rest of Denmark.

6.4.1. Security of supply

Security of supply is important both in a national context and for an energy system such as the one on Samsø. The main concerns regarding security of supply are the fuel resources that need to be imported which primarily are fossil fuel resources in the case of Samsø. These fossil fuels are imported from oil-rich regions of the world or might stem from the Danish reserves that will be depleted within a short period of time. Hence, the transition in the scenarios from a reliance on fossil fuels to renewable energy sources that can be locally produced contribute to reducing the dependence of fuels. In the final scenarios all the energy consumed are from local production in the forms of wind, solar power and biomass and smaller shares of electricity import.

However, the majority of the local resources such as wind and solar power do not produce energy according to demand patterns, but rather when the energy is available. Hence, storage options have been implemented: thermal storage and electricity storage in form of fuel where either gas/liquid fuels are produced for transportation by converting electricity resources into other energy carriers. In addition, Samsø already relies on the electricity interconnection for import and export of electricity and this will also be the case in a future energy system. In the hours where there is no intermittent electricity production import might be necessary from other parts of the country. The wind production on Samsø is however so large that there is an excess of electricity and as an example scenario *7e* has the highest electricity demand of all the scenarios and need import of electricity in 1564 hours of the year (18% of all hours) with a peak demand of 12 MW. On the other hand the same scenario exports electricity in 7220 hours (82% of all hours) with a peak export of 25 MW. The necessity of import is though closely connected to the electricity production on Samsø as a lower wind power capacity would lead to additional demand for import.

The only type of energy carrier that Samsø will need to import is electricity and, depending on the transport technologies implemented, it might not be necessary to import other fuels.

6.4.2. Job creation and local impacts

The job creation and local impacts on Samsø from converting into more renewable energy can be complex and difficult to assess. However, when discussing the job creation potential the key driver is local investments, e.g. in building renovations, installation of new technologies such as heat pumps, operation and maintenance of new heating and transport technologies, etc.

In Table 20 is an overview of the increasing and decreasing investments and O&M costs on an annual basis showing that the investments compared to the 2030 scenario increases in all scenarios. These investments and O&M costs can contribute to create local jobs, even though it is difficult to quantify the exact number of new jobs. On the other hand the increased investments replace current fuel and CO2 costs as well as reducing the income from electricity export compared to the 2030 scenario.

Table 20: An overview of the increasing and declining investments and O&M in energy system technologies in the different scenarios compared to the 2030 scenario

Changing investments and O&M compared to the 2030 scenario (1,000 €/year)	Heat savings	DH and large HPs	Small HPs	Transport	Heating technologies*	Vehicles**	Total
2b. Heat Savings 20%	1134	0	0	0	-266	0	868
3. DH connected	1134	212	0	0	-283	0	1063
4. Large HPs	1134	465	0	0	-283	0	1316
5a. Expansion 1	1134	1117	0	0	-496	0	1755
6. Small HPs + industry	1134	1117	2088	0	-1503	0	2836
***7a* EVs**	1134	1117	2088	0	-1503	-268	2568
***7b* EVs+2gbiodiesel**	1134	1117	2088	3341	-1503	-268	5909
***7c* EVs+Biogas LBG/CBG**	1134	1117	2088	2654	-1503	-268	5222
***7d* EVs+Biogas hydro LG/CG**	1134	1117	2088	3793	-1503	-268	6361
***7e* EVs+Biomass hydro LG/CG**	1134	1117	2088	2699	-1503	-268	5267
***7f* EVs+Biomass hydro DME**	1134	1117	2088	2018	-1503	-268	4586

** Individual boilers, District heating boilers, Electric heating, individual solar thermal*
*** There is a slight decrease in vehicle costs when converting to EVs in line with* [24]

Table 21: An overview of the declining variable costs in the different scenarios compared to the 2030 scenario

Declining variable costs compared to 2030 scenario (1,000 €/year)	Fuels	CO_2	Electricity export	Total
2b. Heat Savings 20%	-398	-18	43	-459
3. DH connected	-398	-18	43	-459
4. Large HPs	-908	-18	-202	-724
5a. Expansion 1	-1029	-27	-248	-808
6. Small HPs + industry	-2069	-142	-361	-1850
***7a* EVs**	-3973	-384	-576	-3781
***7b* EVs+2gbiodiesel**	-3985	-746	-576	-4155
***7c* EVs+Biogas LBG/CBG**	-4371	-746	-576	-4541
***7d* EVs+Biogas hydro LG/CG**	-4985	-746	-1821	-3910
***7e* EVs+Biomass hydro LG/CG**	-4704	-746	-2332	-3118
***7f* EVs+Biomass hydro DME**	-5426	-746	-1599	-4573

Table 21 lists the changing costs with large savings in fossil fuel costs that are today imported from outside of Samsø. If these two changing costs groups, investments and O&M and variable costs, are compared it is visible in Table 22 that the overall costs increase (see also Figure 29), but that investments are replacing fuel costs.

Table 22: Summary of the changed investments and variable costs for each scenario compared to the 2030 scenarios

Summary of costs compared to 2030 scenario (1,000 €/year)	Increased investments	Declining variable costs	Total change in costs
2b. Heat Savings 20%	868	-459	409
3. DH connected	1063	-459	604
4. Large HPs	1316	-724	592
5a. Expansion 1	1755	-808	947
6. Small HPs + industry	2836	-1850	986
***7a* EVs**	2568	-3781	-1213
***7b* EVs+2gbiodiesel**	5909	-4155	1754
***7c* EVs+Biogas LBG/CBG**	5222	-4541	681
***7d* EVs+Biogas hydro LG/CG**	6361	-3910	2451
***7e* EVs+Biomass hydro LG/CG**	5267	-3118	2149
***7f* EVs+Biomass hydro DME**	4586	-4573	13

The ownership structure of these new investments is crucial as this affects the local benefits of the new investments. A recent study has proven that local ownership of renewable energy technologies ensures that the revenue from electricity sales stays within the local community and that the local ownership also benefits the municipality through additional taxes [32]. This is also expected to be the case on Samsø and if possible local ownership of new technologies should be pursued to benefit the local community.

6.4.3. Can Samsø be a model society for the rest of Denmark

In the project it was discussed whether the developments on Samsø can be used as a model society for the rest of Denmark. This discussion is complex as the energy system on Samsø is rather different from the national Danish energy system. The energy system demands on Samsø are almost negligible compared to the national system with electricity, heating and transport demands being around 0.1% of the national demands, see Table 23. The renewable electricity production share is larger with almost 1% of the national renewable electricity production in 2013.

Table 23: Comparison of the scale of the energy system on Samsø and in Denmark

Samsø vs. Danish system	Samsø 2013	Denmark 2013	Samsø Share of national
	GWh	TWh	%
Electricity demand	31	34.6	0.09%
Heating demand	62.5	49.9	0.13%
Transport demand	74.5	60.2	0.12%
Renewable Electricity production	106	11.5	0.92%
Biomass resources	67	66.7*	0.10%
Population	3,806**	5,602,628**	0.07%
Biomass resources/capita (kWh/capita)	17.6	11.9	

* [33], ** [34]

In addition to the demand differences some of the key differences between the energy system on Samsø and in Denmark are that on Samsø there are no central electricity production plants as almost all the electricity demand can be covered by wind power production thereby reducing the need for backup capacity. Furthermore, the heating sector is simpler on Samsø as the district heating is produced to a large degree from boilers currently as there are no central or decentralized CHP plants. Moreover, the renewable electricity resources on Samsø are much larger compared to the demands in general in Denmark while the biomass resources are slightly higher per capita compared to an average Danish citizen.

Despite these differences some of the experiences by converting Samsø to a 100% renewable system can be transferred to other parts of Denmark. These experiences might be related to the development of a renewable transport system as these also on a larger scale could look quite similar to the systems analysed in this report. However, this also depends on the scenario followed as analysis for the national system has proven that electrofuels will be necessary [2].

Instead of using Samsø as a model society for the rest of Denmark this report suggests that it is more relevant to discuss what the role of Samsø can be in regards to the rest of Denmark. Samsø is located with favorable conditions for renewable electricity production when compared to the potentials for the rest of Denmark. Hence, Samsø should produce more renewable electricity than it consumes in order to feed into the national system as other parts of Denmark do not have the same renewable potentials. In the 2030 scenario analysed in this report the renewable electricity production is 140 GWh/year from wind and solar power meaning that they are 450% net exporter of electricity (Samsø produce 4.5 times their own demand). With this production the maximum electricity export in any hour of the year is 32 MW out of the maximum cable capacity of 50 MW. Hence, this means that Samsø could produce even more electricity and still use the existing interconnection capacity. In scenario *7e*, which is the scenario with the highest electricity demand of 91 GWh/year, the maximum electricity export is 25 MW in any hour and so the electricity production could be even higher. The PV capacity could be increased by around 36 MW (total PV production of 41 GWh/year) before the electricity interconnection would be fully utilized. All these considerations are however only reflections, but shows the potential of Samsø to be an even larger net exporter of electricity thereby benefitting other areas of Denmark with scarcer renewable electricity resources.

When comparing the available renewable electricity resources and the demands it becomes clear that Samsø should prioritise integrating as much electricity as possible. On the other hand, the biomass resources are also larger per capita than an average Dane and even despite of this it will be difficult to achieve a 100% renewable energy system only utilizing local biomass potentials.

Samsø has for a number of years had an image as a green island or a green laboratory inspiring other parts of Denmark or internationally to follow the same renewable energy pathway. This role is important and Samsø should continue this image as a frontrunner within energy planning.

7. Conclusion and recommendations

The purpose of this report is to develop possible scenarios for converting Samsø into a 100% renewable energy system taking the local biomass resources and the socio-economic costs into consideration.

The report found that Samsø today is CO_2-neutral and net 100% renewable due to the offsetting of fossil fuels with the renewable electricity, but this also depends on the method for calculating the marginal electricity replaced. In 2030 this situation will however be changed as it is expected that the replaced electricity through export to the national system will no longer be based on fossil fuels. If Samsø wants to be 100% renewable in 2030 it is required to convert the entire Samsø energy system into renewable energy sources. Currently, the transport sector has the largest fossil fuel demand followed by the heating and industrial sectors.

The renewable energy potentials in the forms of electricity and biomass have been assessed finding that there is a high potential for renewable electricity on Samsø while the biomass resources are scarcer. Four different biomass pathways were developed of which two contain the production of energy crops from the conversion of grain area.

To analyse how the conversion of Samsø to 100% renewable energy can take place a number of scenarios were developed for a 2030 Samsø energy system, firstly reducing the heating demand and converting the heating into electricity based sources. This resulted in reducing the use of biomass resources in the heating sector so that could be used elsewhere and preferably in the transport sector for heavy-duty transportation. Five different transport scenarios for heavy-duty transport fuel production was developed showing the different consequences on biomass demand, primary energy demand and socio-economic costs.

The results of the energy systems analyses proved that it is possible to create a 100% renewable energy system on Samsø depending on the transport technologies implemented and the biomass pathways followed. In order to reduce the use of the biomass resources, it was found that hydrogenation of the biomass enables lower biomass consumption for fuel production in comparison to scenarios that do not use this technology. The scenarios proved that the socio-economic costs in a 100% renewable energy system on Samsø are similar to the 2013 scenario with higher investments and reduced fuel costs. It is however not clear which of the transport scenarios should be preferred, as this depends on the availability of biomass resources in the future. Scenarios 2-6 about the heating sector are safe to start implementing with the exact levels of heat savings and the share of individual/district heating solutions still up for further research while the transport scenarios are more uncertain in regards to which technology to choose.

Samsø is currently a net exporter of electricity because of the large wind power production and this role is also suggested for Samsø in a future system due to the high potential of renewable electricity resources. Samsø will therefore not be 100% renewable as an isolated system, but will still depend on electricity exchange in the hours where there is no wind or solar power production as there is no backup capacity such as power plants on Samsø.

The renewable electricity resources on Samsø are significant and Samsø will remain a net exporter electricity exporter in all the scenarios. Also regarding biomass resources Samsø have larger potentials than in the national system when measured in terms of potentials per capita. Despite of these biomass potentials the analysis showed that it will be difficult to remain within local resources and this has also been found when investigating the national energy system.

The analyses showed that investments in technologies will increase, while the costs from fuel import will reduce thereby potentially benefitting the local community. It is however important that these new investments will be carried out by local stakeholders to ensure the greatest local economic benefit of the conversion. The transition to more renewable resources in all sectors might also enhance the security of supply due do less reliance on import of fuels from outside the municipality.

Some of the risks from the conversion to 100% renewable energy are: the capital intensive technologies, the implementation of the heat savings and heat pumps, the required sizes of some of the transport fuel plants, the future development of some of the transport technologies and the future uncertainties regarding technology and fuel costs.

7.1. Recommendations

The recommendations from the project are listed below and summarized into.

7.1.1. Heat savings

Heat savings are recommended as a first step to reduce energy demands and reduce carbon dioxide emissions even though they do slightly reduce the system costs. In this project 20% heat savings have been carried out limited by the implementation challenges, but if further heat savings become available they should be promoted. The heat savings should be implemented over a long time-horizon in combination with other building renovations.

7.1.2. District heating

The existing district heating networks in the southern part of the island can be interconnected to improve the conditions for installing large heat pumps. The district heating network reduces the biomass demand, but might lead to slight increases in the socio-economic costs depending on future fuel prices. In addition the expansion and interconnection of the district heating network allows for the integration of more renewable resources such as solar thermal and excess industrial heat. The district heating network in the scenarios are expanded from a heating share of 31% to 39%.

7.1.3. Electrification of heating in district heating areas

The heating supply in district heating areas should convert from a supply based on biomass to a supply based on electricity through the use of large heat pumps. The primary reason for this is to free the biomass resources used for heating so that they can be utilized in the transport sector. Samsø has a large wind power resource and this should also be utilized in the heating sector. Furthermore, heat pumps can contribute to integrating the electricity and heating sectors and by this creating more flexibility in the system, e.g. through storing electricity in the form of heat. The results in the report show that the electrification of the heating sector resulted in the same level of socio-economic costs while at the same time reducing the biomass consumption.

7.1.4. Electrification of heating outside district heating areas

In the areas that do not have district heating supply it is recommended to install small heat pumps in each building and in the analyses it was found that around 3,000 individual heat pumps could be installed on Samsø. The arguments for small heat pumps are rather similar to the large heat pumps: lowering the use of biomass resources, utilizing the large local wind power resources and creating flexibility. It seems unrealistic to achieve 100% heat pump supply outside district heating areas and smaller shares of biomass boilers and solar thermal might be installed as well. The analyses did not investigate solar thermal in details, but this technology might also be feasible to use in the heating sector as a supplement to electricity.

7.1.5. Electrification of personal vehicles, vans and busses

The transport sector is highly dependent on fossil fuels currently and it is recommended to electrify as much of the transport sector as possible. The electrification of the sector should be done by using electric vehicles. Maximizing the use of direct electricity technologies for personal vehicle, vans and busses should be prioritized. This enables the integration of local electricity sources, reduction of fossil fuel and biomass demands. Additionally as electric driven vehicles are much more efficient than ICE technologies the entire energy system efficiency is improved.

7.1.6. Electrification of heavy-duty transport vehicles

The majority of the biomass resources that have been saved in the heating sector by implementing heat savings and using different more efficient technologies, should be utilized for heavy-duty transport. This should be carried out by creating various types of electrofuels by using electricity for boosting the energy content in the transport fuels based on biomass. The exact transport scenario that should be followed is still not clear, but several of these scenarios allows for keeping the biomass demands within the limits of the local biomass potentials.

7.1.7. Prioritise and boost the bioenergy resources

The biomass resources on Samsø are scarce and in the current energy system import of biomass is necessary to meet the demands. The current biomass consumption consisting of straw and wood for heating should be prioritized for where it delivers the greatest benefit. It is therefore recommended that the use of biomass should primarily take place in the transport sector and to boost this biomass with electricity through hydrogenation technologies to get higher fuel output with lower biomass input. The biomass demands in the heating sector should be reduced and replaced with more renewable electricity. Also, biogas technologies are required in order to be able to use all wet fractions of the biomass potential.

7.1.8. Additional energy efficiency measures might be feasible

This study did not investigate all potentials for energy efficiency measures as reduction potentials in the electricity, industry and transport sectors were not included. It is therefore recommended to investigate these potentials as these might reduce the energy demands further and ease some of the pressure on the biomass resources. In particular the transport demand has a large influence on the overall energy and biomass demand.

7.1.9. Electrification of industry

The previous recommendations directed towards electrification of the demand which might also be the case within the industrial sector. This was not investigated further, but could benefit a future system as the impact would be a reduction in solid fuel demands.

7.1.10. The role of Samsø in the national context

The renewable electricity resources on Samsø are much larger than the demands and it is recommended that Samsø take advantage of these potentials and become an even larger net electricity exporter as this can benefit other parts of Denmark with lower renewable electricity resources. Samsø should also reduce its heat demand and the fossil fuel consumption in the transport sector as part of a national effort to reduce energy demands. Finally, it is required that the national regulation framework for energy supports these measures on Samsø.

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9. Appendix A. Baggrundsnotat for energiregnskaber

Baggrundsnotat

Vedrørende:	Energiregnskaber for kommuner i Region Midtjylland 2013
Dato:	15-03-2015
	Anders Michael Odgaard, Jørgen Lindgaard Olesen og Simon Stendorf Sørensen

9.1.1. Indledning og baggrund

PlanEnergi har tidligere udarbejdet energiregnskaber for en række kommuner i Jylland.

2013-regnskaberne for kommunerne i Region Midtjylland er udarbejdet efter de samme principper som de tidligere energiregnskaber. Forudsætninger og metoder følger Energistyrelsens beskrevne metoder i '*Vejledning i kortlægningsmetoder og datafangst til brug for kommunal strategisk energiplanlægning – Metodebeskrivelse'* (Energistyrelsen, 2012).

Regnskaberne ledsages af en række bilag, som viser udregningen af de enkelte poster i regnskabet. Disse bilag fremgår af bilagsoversigten sidst i dette notat.

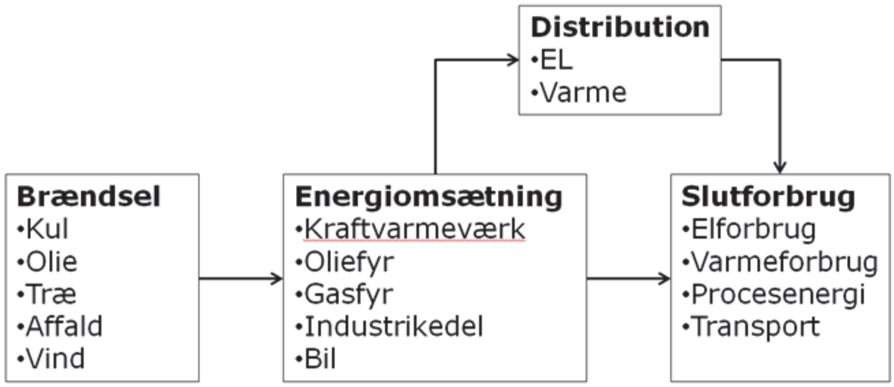
Dette notat beskriver bl.a.:

- Princippet for et lokalt geografisk energiregnskab
- Regneark med bilagshenvisning til indsatte data i energiregnskabet
- Generelle forudsætninger, der kan påvirke regnskabsresultatet
- Datakvalitet i energiregnskabet

9.1.2. Princip for et lokalt energiregnskab

Princippet i det udarbejdede energiregnskab er illustreret i figur 2.1. Figuren læses som energiregnskabet fra venstre mod højre:

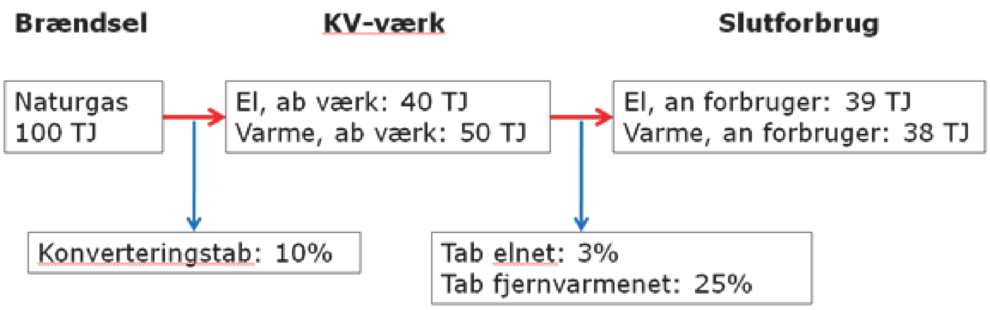
I venstre side af regnskabet indfyres brændslet i en energiomsætningsenhed, der konverterer brændslet til procesenergi, varme eller el.
Såfremt el- eller varme produceres til det kollektive forsyningssystem fordeles el og varme til slutbrugeren med en angivet effektivitet for el- og fjernvarmenettet.
Længst til højre i regnskabet angives slutbrugerens energiforbrug, eksklusiv de tab der måtte være forbundet med at levere en given energitjeneste.



Figur 2.1 *Principskitse for energiregnskab*

Eksempel på energiomsætning i energiregnskabet

Figur 2.2 illustrerer, hvorledes naturgas i energiregnskabet omsættes til et slutforbrug gennem et kraftvarmeværk. Det ses, at der med disse systemafgrænsninger er en samlet energieffektivitet på 77% i nedenstående energisystem.



Figur 2.2 *Eksempelberegning til illustration af princip i energiregnskab*

9.1.3. Overblik over baggrundsdata til energiregnskabet

Energiregnskabet består af en række celler, hvoraf flere indeholder indsatte og udregnede værdier.

For at skabe et hurtigt overblik over de indsatte værdier, er der udarbejdet et "energiregnskab" med bilagshenvisninger i de enkelte celler i stedet for data i **bilag 19**. Dette giver et hurtigt overblik for de, der måtte ønske at se baggrundsdata til en regnskabspost. I regnearket er der indsat koder som vist i tabel 4.1. I bilagene er de indsatte data markeret med grøn.

Kode	Kilde til celleværdi
1-18	Henviser til bilag 1-18. Indsatte værdier er markeret med grøn i bilagene.
E	Energistyrelsens Energistatistik 2013
M	Energinet.dks Miljørapport 2014 og Miljødeklarationen for el 2013
F	Formelcelle, er udregnes fra værdier i andre celler i energibalancen
V	Estimeret virkningsgrad jf. afsnit 3.1.

Tabel 3.1 *Koder i regneark med bilagshenvisninger (bilag 19)*

Virkningsgrader for omsætningsenheder ("V")

Virkningsgraderne er et udtryk for, hvor effektivt de enkelte omsætningsenheder anvender det indfyrede brændsel. Virkningsgraderne er opdelt på el, proces og varme.

For en række omsætningsenheder kan den faktiske virkningsgrad ikke bestemmes ud fra målte data. I disse tilfælde estimeres en virkningsgrad til brug for udregning af et slutforbrug i højre side af energiregnskabet.

Tabel 4.1 viser energiregnskabets faste estimerede virkningsgrader. Disse virkningsgrader er markeret med "V" i oversigtsregnearket (bilag 19).

Omsætningsenhed	Nyttevirkning	Kilde
Gaskomfur	0,38	Miljørigtigt valg af komfur, Energi og Miljø, 1999
Elkomfur	0,44	Miljørigtigt valg af komfur, Energi og Miljø, 1999
Elvandvarmer	0,90	En 60 liters vandvarmer skønnes at have et varmetab på 100 W. Om sommeren udgår tabet typisk 120h x 100 W = 288 kWh. Varmtvandsforbruget er på ca. 800 kWh/person/år. Tabet udgør således ca. 10%.
Elradiator	1,0	Der regnes ikke med konverteringstab for elopvarmning.
Belysning	0,5	Virkningsgraden varierer fra 14% (glødelamper) til 85% eller mere for lysstofrør og LED-belysning. Der regnes med 50% som et gennemsnit
Elkompressor	1,5	Nyttevirkning for køling
Elmotorer	0,85	Elmotorer har typisk virkningsgrader på 80-95%
Solvarmeanlæg	1,0	Solvarmeanlæggets ydelse måles som nyttiggjort energi. Der regnes derfor ikke med konverteringstab.
Varmepumper, indv.	2,5	Gennemsnitlig nyttevirkning for varmepumper til opvarmning jf. Energistyrelsens Standardværdikatalog 2008
Gasoliekedel, indv.	0,80	Strategisk energiplanlægning i kommunerne, Energistyrelsen 2012
Naturgaskedel, indv.	0,85	Strategisk energiplanlægning i kommunerne, Energistyrelsen 2012
Træpillekedel, indv.	0,75	Strategisk energiplanlægning i kommunerne, Energistyrelsen 2012
Brændekedel/ovn indv.	0,65	Strategisk energiplanlægning i kommunerne, Energistyrelsen 2012
Halmfyr, indv.	0,65	Strategisk energiplanlægning i kommunerne, Energistyrelsen 2012
Proces, naturgas	0,90	PlanEnergis skøn
Proces, gasolie	0,90	PlanEnergis skøn
Solcelleanlæg	1,0	Solcellers ydelse måles an net. Der regnes derfor ikke med konverteringstab.

Vindkraftanlæg	1,0	Vindmøllers ydelse måles an net. Der regnes derfor ikke med konverteringstab.
Vandkraftanlæg	1,0	Vandkraftanlægs ydelse måles an net. Der regnes derfor ikke med konverteringstab.
Bølgekraftanlæg	1,0	Bølgekraftanlægs ydelse måles an net. Der regnes derfor ikke med konverteringstab.
Benzinbiler, små	0,20	Alternative drivmidler i transportsektoren 2.1, 2014
Dieselbiler, små	0,25	Alternative drivmidler i transportsektoren 2.1, 2014
Varebiler	0,25	Alternative drivmidler i transportsektoren 2.1, 2014
Busser	0,33	Alternative drivmidler i transportsektoren 2.1, 2014
Lastbiler/sættevogne/entreprenørmaskiner	0,33	Alternative drivmidler i transportsektoren 2.1, 2014
Traktorer	0,33	Teknologisk Institut, Motorteknik

Tabel 3.2 *Estimerede gennemsnitlige virkningsgrader for omsætningsenheder*

Elimport

I forbindelse med en forestående opdatering af Energistyrelsens vejledning til håndtering af el-import i energiregnskaberne, er det fremadrettet besluttet at inkludere elproduktion fra havvindmøller. Den importerede elektricitet antages således at være residual-el, som produceres ved kondensdrift på de centrale kraftværker og ved havvind. Valget af residual-el giver et væsentligt lavere CO_2-emission fra elimport i forhold til tidligere, hvor havvind ikke var inkluderet. Ligeledes er der en højere andel af vedvarende energi fra elimport i forhold til tidligere.

Residual-el for 2015 er benyttet som elimport for alle årene, da "deklarationen" for residual-el for 2013 – såvel som de foregående år – ikke er tilgængelig på offentliggørelsestidspunktet.

Nettab for elnettet ("M")

Det samlede nettab består dels af et distributionstab og dels af et transmissionstab. Jævnfør Energinet.dk's Baggrundsdata til Miljørapport 2014 sættes distributionstabet for elnettet til 5%.

Nettabet i transmissionsnettet kan beregnes ud fra miljødeklarationen for Vestdanmark som: Nettab i transmissionsnettet/salg an transmission og bliver 2,52 % for 2013.

Det samlede tab i elnettet bliver jf. ovenstående på 7,52 %, svarende til en virkningsgrad for elnettet på 92,41 % for 2013.

Fjernvarmeimport

I de fleste kommuner i Region Midtjylland sker fjernvarmeproduktion i samme kommune som varmen forbruges.

I nogle kommuner er fjernvarmeforsyningen dog forbundet på tværs af kommunegrænser. Det gælder for:

- Herning- og Ikast-Brande Kommuner
- Holstebro og Struer Kommuner
- Århus, Odder, Skanderborg og Syddjurs Kommuner

Når fjernvarmeforsyningen sker på tværs af kommunegrænser udregnes en gennemsnitlig fjernvarmesammensætning, som fordeles på kommunerne i forsyningsområdet efter deres fjernvarmeforbrug i overensstemmelse med Energistyrelsens vejledning (Energistyrelsen, 2012, s. 15).

Fordelingsnøgler for brændselsforbruget på værkerne fremgår af bilag 11.

Lokal elproduktion fra centrale kraftværker

Studstrupværket i Aarhus er et såkaldt udtagsværk, som kan operere både som et kraftvarmeværk med produktion af både el og varme eller som et elværk, der kun producerer el og køler varmen bort. Brændselsforbrug, der knytter sig til ren elproduktion uden samtidig produktion af varme indgår ikke i udregningen af brændselssammensætningen for fjernvarme for kommunerne i Aarhus-området. Denne allokering af brændselsforbruget sker efter anbefalingerne i Energistyrelsens vejledning.

Beregning af CO2-emmission (”E”)

CO_2-emisioner for fossile brændsler

Nederst i energiregnskabet ses CO_2-emisionen for en række fossile brændsler, opgjort som ton pr. TJ. Data er for brændslernes vedkommende hentet i Energistatistik 2013.

Jf. *Lov om CO_2-kvoter* regnes affald for at være CO_2-neutralt. Dog indeholder affald store mængder plast, der er fremstillet af fossilt olie. Energistyrelsen har udarbejdet en særskilt opgørelse af CO_2-emissionen fra afbrænding af ikke bionedbrydeligt affald i Energistatistik 2013. Baggrunden for den særskilte opgørelse fremgår bl.a. af ”Notat vedrørende CO_2-emissioner fra affaldsforbrænding” fra DMU, 2008. Således er energiregnskabet opdelt i ikke bionedbrydeligt- og bionedbrydeligt affald på hhv. 45 % og 55 % jf. Energistatistik 2013.

Beregningsmæssigt svarer det til at benytte en emissionsfaktor på 37,0 tons/TJ for CO_2 fra affald, derfor sættes emissionsfaktoren til 82,2 tons/TJ for den ikke bionedbrydelige del af affaldet og 0 tons/TJ for den bionedbrydelige.

CO2-emission for el i Danmark

CO_2-emisionen for elimport fremgår af ”deklarationen” for residual-el i Energistyrelsens vejledning. Den samlede emissionsfaktor for elimport med residual-el er jf. Energistyrelsen på 119 tons/TJ i år 2015 og består af 45 % vedvarende energi.

Emissionsfaktoren for el er eksklusiv transmissions- og distributionstab, da det faktiske energiforbrug fra elimport i energiregnskaberne har indregnet tabet af energi fra transmissions- og distributionstab.

Udregning af VE%

I EU’s VE-målsætninger anvendes det udvidede endelige energiforbrug til beregning af andelen af vedvarende energi. Det udvidede endelige energiforbrug fremkommer ved at tage det endelige energiforbrug ekskl. forbrug til ikke energiformål og hertil lægge elektricitets- og fjernvarmedistributionstab samt egetforbrug af elektricitet og fjernvarme ved produktion af samme. Se endvidere ’Vejledning i kortlægningsmetoder og datafangst til brug for kommunal strategisk energiplanlægning – Metodebeskrivelse’ (Energistyrelsen, 2012, s. 21).

9.1.4. Beskrivelse af bilag

Ikke alle beregningsforudsætninger fremgår umiddelbart af de vedhæftede bilag. Med udgangspunkt i bilagene beskrives i dette kapitel de forudsætninger, som benyttes.

Bilag 1 – Energiproducenttælling 2013

Til brug for udarbejdelsen af energiregnskabet har PlanEnergi rekvireret data vedr. energiproducenter i Region Midtjylland fra Energistyrelsen. Energistyrelsens Energiproducenttælling 2013 giver et overblik over de enkelte energiproducenters energiproduktion fordelt på el og varme, brændselstype, anlægstype mm.

Brændselspriser, elpriser og priser på regulerkraft har stor betydning for, hvor meget kommunernes decentrale værker kører med deres motoranlæg. Få driftstimer vil give en ringe brændselsudnyttelse, og give anledning til elimport, med en større CO_2-udledning pr. kWh end lokalproducere kraftvarme på naturgas.

Energistyrelsens data i bilag 1 må kun anvendes til internt brug som dokumentation for de udarbejdede energiregnskaber. Data må ikke offentliggøres eller benyttes til andet formål uden forudgående aftale med Energistyrelsen.

Eksempel på udregning af virkningsgrader

Der indfyres i det viste eksempel 1.000 TJ i forbrændingsmotorer på decentrale kraftvarmeværker. Virkningsgraden for forbrændingsmotorerne udregnes som et gennemsnit for de anvendte brændsler på følgende måde:

Varmevirkningsgrad:
Varmelevering (Varmelev_TJ) delt med den indfyrede energimængde (Brutto_TJ). I dette tilfælde udregnes varmevirkningsgraden som: 500 TJ / 1.000 TJ x 100% = 50,7%.

Elvirkningsgrad:
Elvirkningsgraden udregnes som el leveret til nettet (Ellev_TJ) delt med (Brutto_TJ). I det aktuelle eksempel bliver elvirkningsgraden således: 400 TJ /1.000 TJ x 100% = 40%

De indfyrede brændsler på de industrielle kraftvarmeværker fremgår af energiproducenttællingen. Store dele af energiproduktionen på de industrielle værker vil ofte gå til eget forbrug af el og varme.

Virkningsgraderne udregnes som samlede virkningsgrader for el og varme. Dvs. at virkningsgraderne for el og varme både indeholder egetforbrug og energi leveret til henholdsvis fjernvarme og elnettet. Egetforbruget trækkes ud af varme leveret til nettet.

Bilag 2 – LPG og petroleum 2013

Forbruget af LPG (flaskegas) og petroleum er relativt begrænset på landsplan jf. Energistatistik 2013. LPG udgør langt det største energiforbrug af de to brændsler og anvendes bl.a. til fremstillingsvirksomhed, boliger og privat service.

Forbruget af LPG og Petroleum i energiregnskaberne findes ved at vægte det nationale forbrug med befolkningstallet i kommunerne som vist i bilag 2.

Bilag 3 – Diesel, benzin, fuelolie for skibe og tog 2013

Der anvendes fuelolie til skibstransport. Landstallet for anvendelsen i fuelolie til søtransport findes i Energistatistik 2013 og fordeles efter indbyggertal som vist i bilag 3, også til kommuner uden havne.

Dieselforbruget til tog og skibe, inkl. fiskeri, er udregnet i bilag 3 ved at fordele landstal for dieselforbrug fra Energistatistik 2013 efter befolkningstal i de enkelte kommuner.

Benzinforbruget (flybenzin) til fly er udregnet i bilag 3 ved at fordele landstal for dieselforbrug fra Energistatistik 2013 efter befolkningstal i de enkelte kommuner.

Bilag 4 – JP1 2013

Forbruget af JP1 (flybrændstof) findes på landsplan i Danmarks Statistik. Forbruget fordeles efter indbyggertal i kommunen i forhold det nationale indbyggertal. Udregningen fremgår af bilag 4.

Bilag 5 – Brændstof til vejtransport 2013

Forbruget af dieselolie og benzin til vejtransport er med undtagelse af rutebusser baseret på opgørelser over bestanden af køretøjer i kommunen. Energiforbruget udregnes som en andel af det samlede forbrug til vejtransport opgjort i Energistatistik 2013. Udregningen baseres på nationale data for kørselskilometer pr. køretøjstype (Vejdirektoratet, 2014) samt gennemsnitlige normforbrug pr. køretøjstype (DCE, 2014).

Fordelingen af rutebusser er i de nye energiregnskaber baseret på indbyggertallet i den enkelte kommune. Rutebussernes kørsel til den offentlige servicetrafik i Region Midtjylland har tidligere været fordelt på baggrund af indregistrerede rutebusser ligesom de øvrige køretøjer.
Da rutebusserne til offentlig servicetrafik primært er indregistreret i enkelte kommuner, giver denne fordeling dog en højere andel af brændstofforbruget til disse kommuner. Den indbyggerbaserede fordeling afspejler i højere grad den egentlige rutebustrafik i kommunerne og energiforbruget til denne post. Den nye fordelingsmetode er samtidig anvendt i regnskaberne bagudrettet og korrigeret.

Varebiler er i energiregnskaberne for 2013 adskilt fra lastbiler og sættevogne, da varebilernes virkningsgrad er lavere. Denne adskillelse er ligeledes korrigeret for energiregnskaberne bagudrettet.

I Danmark består 5,7 % af benzinforbruget af bioethanol og 5,7 % af dieselforbruget af biodiesel i 2013. I energiregnskaberne er der således allokeret 5,7% til bioethanol og 5,7 % til biodiesel af de enkelte brændstofforbrug til vejtransport.

Bilag 6 – Vindkraft 2013

Vindkraftproduktionen for 2013 er baseret på data fra Energistyrelsens stamdataregister for vindmøller og indeholder alle vindmøller og deres placering i de enkelte kommuner.

Vindkraftproduktionen fra landvindmøller i den enkelte kommune fremgår direkte af Energistyrelsens stamdataregister. 50 % af vindkraftproduktionen fra kystnære vindmøller allokeres desuden jf. Energistyrelsens vejledning til tilstødende kommuner. Således er det kun vindkraftproduktion fra vindmøller placeret til lands i en kommune samt evt. en andel fra kystnære vindmøller, som indgår i kommunens egen vindkraftproduktion, mens alle havvindmøller indgår i residual-el jf. *3.2 Elimport*.

Bilag 7 – Solcelleanlæg 2013

Elproduktionen fra solcelleinstallationer i Region Midtjylland beregnes på baggrund af Energinet.dk's database for solcelleanlæg "Solcelleanlæg i Danmark august 2014" (Energinet.dk, 2014). Årsproduktionen per kWp sættes til 800 kWh/kWp jf. "Technology Data for Energy Plants. Generation of Electricity and District Heating, Energy Storage and Energy Carrier Generation and Conversion" (Energistyrelsen, 2012, s. 96) og "Renewable Energy RD&D Priorities .Insights from IEA Technology Programmes" (International Energy Agency, 2006, s. 117).

Bilag 8 – Biogas 2013

Den samlede biogasproduktion på kommunens biogasanlæg fremgår af henholdsvis Energistyrelsens Energiproducenttælling, samt særskilt Biogasstatistik 2013 fra Energistyrelsen.
Biogasproduktionen er dels baseret på husdyrgødning og dels på organisk affald fra industrien. Biogasproduktionen er fordelt mellem gasproduktion fra biomasse og fra husdyrgødning i energiregnskabet. Denne fordeling er baseret på tal fra 2005 fra anlæggene i Region Midtjylland. Ifølge disse tal udgør gas fra husdyrgødning i gennemsnit 46% i biogasfællesanlæg, mens gasproduktionen fra organisk industriaffald i gennemsnit udgør 54%. Denne fordeling er benyttet for biogasfællesanlæg og gårdbiogasanlæg i Region Midtjylland.

Bilag 9 – Biomassepotentiale 2013

Aarhus Universitet har udarbejdet en særskilt opdateretopgørelse over lokale biomassepotentialer i 2012. Biomassepotentialet er indført under lokale biomassepotentialer nederest i energiregnskabet.

- Energiafgrøder indeholder: energiafgrøder på 15 % af nuværende kornareal
- Halm indeholder: rapshalm og kornhalm
- Brænde og træflis indeholder: hegn, haver og skov
- Biogas indeholder: gas fra husdyrgødning og udnyttelse af ekstensivt græs fra lavbundsarealer

For yderligere beskrivelse af opgørelsesmetoden henvises til ”Energi fra biomasse – Ressourcer og teknologier vurderet i et regionalt perspektiv” fra Det Jordbrugsvidenskabelige Fakultet, Aarhus Universitet, 2008.

Bilag 10 – Elforbrug 2013

Kommunens elforbrug er udregnet i bilag 10 med udgangspunkt i data leveret af elnetselskaberne i Region Midtjylland. Elforbruget fordeles i energiregnskabet på forbrugerkategorier i regnskabets højre side.

Fordelingen af slutforbruget på omsætningsenheder sker via data fra ”Teknologikatalog, potentialer for energibesparelser” (Energistyrelsen, 1995). Energistyrelsen skønner at elforbruget har ligget rimelig stabilt siden 1995 med en stigning i forbruget til IT og et fald til belysning (Sparenergi.dk 2014). Data er gengivet i tabel 4.2.

Slutforbrug	Elkomfur	Belysning	Køle-maskiner	Motorer, mv.
Husholdninger	15,5 %	15,5 %	18 %	51 %
Landbrug		15 %	3 %	82 %
Gartneri		15 %	3 %	82 %
Handel		25 %	28 %	47 %
Privat service		25 %	28 %	47 %
Off. Service		27 %	0 %	73 %
Bygge og anlægsvirksomhed		6 %	8 %	86 %
Fremstillingsvirksomhed		6 %	8 %	86 %

Tabel 4.2 *Fordeling af slutforbrug for el på omsætningsenheder.*

Forbruget af el til opvarmning for boliger med elvarme eller varmepumpe er opdelt på "almindeligt forbrug" og "forbrug til opvarmning" ved at beregne forskellen i enhedsforbrug for boliger med elvarme eller varmepumpe og enhedsforbrug for boliger uden. Forskellen i enhedsforbrug er antaget at være elforbruget til opvarmningsformål. For fritidshuse er 65% af elforbruget allokeret til opvarmning jf. "Potentialebeskrivelse – individuelle varmepumper" (Teknologisk Institut, 2010). Elforbruget til opvarmning er fordelt med 82,5 % til rumvarme og 17,5 % til varmt brugsvand.

Elforbrugsdataene er opdelt på kategorier, hvor inddelingen er behæftet med nogen usikkerhed, især inden for underkategorier. På de i energiregnskaberne benyttede overordnede kategorier er usikkerheden dog begrænset. Denne usikkerhed på data har ingen indflydelse på kommunens samlede elforbrug, og således heller ikke på det samlede energiforbrug, CO_2-udledning, VE% mv.

Bilag 11 – Fjernvarmenet 2013

Der kan være store lokale udsving i nettabet på fjernvarmeværkerne og der er derfor tidligere indhentet data for nettab fra fjernvarmenettet i de enkelte kommuner. Til energiregnskaberne 2013 er nettabet i fjernvarmenettene fremskrevet for hver enkelt kommune på baggrund af Dansk Fjernvarmes benchmarking statistikker for 2012/2013 og 2013/2014, hvori der findes data for omkring halvdelen af fjernvarmeværkerne. For de værker der ikke figurerer i benchmarking statistikkerne anvendes senest tilgængelige data. Det endelige nettab i de kommunale fjernvarmenet er herefter estimeret ud fra et gennemsnit af 2012/2013- og 2013/2014-fremskrivningerne.

De udregnede nettab er indført i kommunens energiregnskab. Flere kommuner har desuden indhentet data for fordelingen af fjernvarmeforbruget på slutforbrugskategorier. For kommuner der ikke har indhentet disse data fordeles fjernvarmeforbruget efter forbrugsfordelingen i Energistatistik 2013.

Bilag 12 – Dieselforbrug i landbruget 2013

Forbruget af dieselolie i landbruget til traktorer mm. udregnes i bilag 12. Dieselforbruget udregnes via normforbrug for forskellige afgrødetyper efter "Energy Consumption an input-output relations of field operations" (Nielsen, 1989). Afgrødefordelingen for kommunerne i Region Midtjylland for 2013 findes i Danmarks Statistik, 2015.

Bilag 13 – Gassalg 2013

Naturgasforbruget på de energiproducerende anlæg fremgår af bilag 1. Gassalget for boliger og erhverv er opgjort af HMN Gassalg A/S og DONG Energy A/S. Forbruget hos kategorierne erhverv og andet er opdelt ved at fratrække naturgasforbruget i energiproducenttælling 2013 fra det totale gassalgog anføre det underkategorien andet og derefter tildele restforbruget i kommunen til kategorien erhverv.

Bilag 14 – Skorstensfejerdata 2013

Skorstensfejernes kartoteker er altid opdaterede, og de benyttede udtræk er derfor baseret på antal fyringsenheder primo 2015. Brændselsforbruget er udregnet ud fra estimerede forbrug pr. enhed. Enhedsforbruget pr. oliefyr er nedjusteret til 75 GJ/år fra 120 GJ/år. Enhedsforbruget har tidligere været sat højt for at imødekomme, at Danmarks Statistiks industristatistik ikke indeholder data for virksomheder med under 20 ansatte. Nedjusteringen er også foretaget i regnskaberne bagudrettet.

Ifølge Skorstensfejerdata er det seneste dataudtræk blevet mere retvisende, da der er indført nye takster for registrering af brændeovne samt nye regler om eftersyn af oliefyr, der betyder, at det er lovpligtigt for ejere af oliefyr at få lavet en årlig energimåling. Dette betyder, at flere fyringsenheder bliver registeret af skorstensfejerne - særligt under brændeovne og oliefyr.

1.1.1 *Eksempel på estimering af enhedsforbrug*

Der anvendes til udregningen af det samlede brændeforbrug enhedsforbrug fra undersøgelsen "Brændeforbrug i Danmark 2011" udarbejdet af Energistyrelsen og Force Technology.

Med henvisning til undersøgelsen fastsættes følgende gennemsnitlige enhedsforbrug:

- Brændeovne i beboede boliger: 30,4 GJ/år
- Brændeovne i sommerhuse: 18,4 GJ/år
- Brændekedler: 112,1 GJ/år

Enhedsforbruget for halmfyr og pillefyr er nedjusteret med 5 % i forhold til tidligere regnskaber for at imødekomme den øgede virkningsgrad på disse kedeltyper.

Enhedsforbruget for halmfyr er udregnet med udgangspunkt i data fra Teknologisk Institut. Teknologisk institut vurderer, at der er 7-8000 halmkedler i Danmark med et samlet halmforbrug på ca. 330.000 ton/år. Brandværdien for halm er ifølge Energistatistik 2013 på 14,5 GJ/ton.

Det gennemsnitlige enhedsforbrug for halmfyr udregnes som:
330.000 ton/år/ 7500 x 14,5 GJ/ton = 638 GJ/år

Enhedsforbruget for pillefyr er udregnet med udgangspunkt i, at Teknologisk Institut vurderer, at et pillefyr i gennemsnit bruger 10-12 tons træpiller pr. år. Brandværdien for træpiller er ifølge Energistatistik 2013 på 17,5 GJ/ton.

Enhedsforbruget for pillefyr kan udregnes som: 11 ton/år x 17,5 GJ/ton = 193 GJ/år

Bilag 15 – Industriens energiforbrug 2013

Der er indhentet data vedr. industriens energiforbrug 2012 fra Danmarks Statistik. Industristatistikken er som førnævnt behæftet med usikkerhed, da statistikken kun vedrører industriarbejdssteder med mere end 20 ansatte.

Industristatistikken indeholder data for forbruget af gas, flydende brændsel og fast brændsel, og er yderligere underopdelt f.eks. på gasdiesel, træpiller eller affald. Af data for affald fremgår det dog ikke, om der er tale om bionedbrydeligt affald (CO_2-neutralt).

Brændselsforbrug i industrien under kategorien 'Affald' allokeres på 'Organisk affald, industri' og 'Affald, ikke bionedbrydeligt' med henholdsvis 45 % og 55 %. Se endvidere afsnit 3.6.1 CO_2-emisioner for fossile brændsler for yderligere information om affald.

Sammenlignet med industristatistikken for 2009 viser det nye udtræk generelt en væsentlig nedgang i energiforbruget blandt disse virksomheder i Region Midtjylland (tilsammen 1.449 TJ mindre end for 2009). Reduktionen fordeler sig primært på virksomhedernes forbrug af fossile brændsler som gasdiesel (871 TJ mindre), naturgas (447 TJ mindre) og fuelolie (340 TJ mindre). Virksomhedernes forbrug af fjernvarme er samtidig steget væsentligt (496 TJ større), hvilket generelt tegner et billede af en øget virksomhedstilslutning til fjernvarmenettet. Elforbruget er ifølge den nye statistik steget en smule (84 TJ), mens antallet af medarbejdere er faldet med 300 svarende til 23 %.

Bilag 16 – Energiproduktion solfangere 2013

Landstal for energiproduktion fra solfangere jf. Energistatistik 2013 er fordelt på antal bygninger med individuel forsyning i hver kommune.

Bilag 17 – Drivhusgasser fra landbrugssektoren i 2013

Emissionerne fra landbrugssektoren er beregnet i KL's CO_2-beregner. Da CO_2-beregneren ved offentliggørelsestidspunktet er under opdatering, er tal for 2013 ikke udarbejdet.

9.1.5. Datakvalitet

Energiregnskabet bygger på en række data af forskellig kvalitet. Nogle data er målte, nogle er estimerede med udgangspunkt i lokale data, og nogle få er baseret på fordelinger af nationale forbrug efter indbyggertal.

Tabel 5.1 viser energiregnskabets væsentligste data prioriteret efter datakvalitet. Industristatistikken er lavt placeret på trods af, at den er baseret på indberetning af målte forbrug. Kvaliteten på industridata fra Danmarks Statistik forventes væsentligt forbedret i forbindelse med den kommende opdatering baseret på 2012-data.

Datakvalitet	Område	Dataleverandør
Høj, **Målt forbrug / produktion**	Elproduktion fra vindkraft	Energistyrelsen
	Fjernvarmeforbrug og nettab	Lokale fjernvarmeværker
	Brændselsforbrug til kollektiv el- og varmeforsyning	Energistyrelsen
	Elforbrug	Lokale elnetselskaber
	Naturgasforbrug	HMN Gassalg A/S og DONG Energy
Middel **Estimat lokale data**	Elproduktion fra solceller	Energinet.dk
	Individuel opvarmning (ikke naturgas)	Lokale skorstensfejermestre, antal opvarmningsenheder
	Vejtransport	Danmarks Statistik, antal indregistrede køretøjer
	Industriens brændselsforbrug (ikke naturgas)	Danmarks Statistik, oplysninger fra industrier med mere end 20 ansatte
Lav **Estimat indbyggertal mm.**	Transport nonroad, Flybrændstof (JP1), fuelolie (skibe), diesel (tog).	Energistyrelsens energistatistik og Danmarks Statistik
	Individuel solvarme	Energistyrelsens energistatistik og Danmarks Statistik.

Tabel 5.1: *Oversigt over datakvalitet for de primære data til udarbejdelse af kommunale energiregnskaber*

9.1.6. Bilagsoversigt

Bilag 1:
El- og varmeproduktion fra energiproducenter i Region Midtjyllandfordelt på kommuner, værkstyper, anlægstyper og anvendte brændsler. Energiproducenttælling 2013 (Energistyrelsen, 2014)

Bilag 2:
Fordeling af landstal for forbrug af LPG og Petroleum, jf. Energistatistik 2013 og Danmarks Statistik, 2015

Bilag 3:
Fordeling af landstal for forbrug af benzin, diesel og fuelolie på fly, skibe og tog, jf. Energistatistik 2013 og Danmarks Statistik, 2015

Bilag 4:
Fordeling af landstal for forbrug af JP1 (flybrændstof), jf. Energistatistik 2013 og Danmarks Statistik, 2015

Bilag 5:
Brændstofforbrug til vejtransport fordelt på kommuner, jf. Danmarks Statistik, 2015, DMU, 2014 og Vejdirektoratet, 2014

Bilag 6:
Vindkraftproduktion fordelt på kommuner, jf. stamdataregister for vindmøller jf. Energistyrelsen, 2015

Bilag 7:
Elproduktionen fra solcelleanlæg, jf. Energinet.dk, 2014, Energistyrelsen, 2012 og IEA, 2006.

Bilag 8:
Fordeling af gasproduktion på henholdsvis gylle og anden biomasse samt biogasproduktion fra anlæg, som ikke er indeholdt i Energiproducenttælling 2013, jf. Energistyrelsen, 2014

Bilag 9:
Biomassepotentiale fordelt på kommuner, jf. Aarhus Universitet, 2012

Bilag 10:
Regionale elforbrug fordelt på kommune, hovedkategorier og omsætningsenheder, jf. oplysninger fra elnetsselskaber.

Bilag 11:
Nettab for de kommunale fjernvarmenet og fjernvarmeimport på tværs af kommuner, jf. oplysninger fra fjernvarmeselskaberne og benchmarking statistikker 2012/2013 og 2013/2014, Dansk Fjernvarme, 2014.

Bilag 12:
Dieselforbrug til traktorer mm. i landbruget fordelt på kommuner efter data for sammensætningen af afgrøder i 2013, jf. Danmarks Statistik, 2015 samt Nielsen, V. mfl.

Bilag 13:
Salg af naturgas i kommuner i Region Midtjylland jf. oplysninger fra HMN Gassalg og DONG Energy, 2014

Bilag 14:
Opgørelse over private ovne og fyr i kommunerne i Region Midtjylland jf. oplysninger fra skorstensfejere i Region Midtjylland, 2015

Bilag 15:
Opgørelse over industriens energiforbrug i 2012 jf. oplysninger fra Danmarks Statistik, 2014

Bilag 16:
Fordeling af landstal for energiproduktion fra solfangeranlæg fordelt på kommuner i Region Midtjylland jf. Energistatistik 2013 og Danmarks Statistik, 2015

Bilag 17:
Drivhusgasser fra landbrugssektoren i 2013, resultater fra CO_2-beregner på baggrund af opgørelse over arealer og antal dyr på kommuneniveau for 2011, jf. DMU 2012.

Bilag 18:
XML-fil med udregning af drivhusgasemissioner fra landbrugssektoren til indlæsning i CO_2-beregner

Bilag 19:
Energiregnskab med oversigt og brug af bilag, formelceller mm.

10. Appendix B. Energy account for 2013

Number of inhabitants: 3.806
Efficiency elec. grid: 92 %
Units: GWh, tonne

Geographic Energy Balance for
Samsø Municipality 2013

Import of electricity	LPG and kerosene	Coal	Fuel oil	Heating oil	Diesel fuel	Jet fuel (JP1)	Petrol	Natural gas	Wind power	Hydro and wave power	Solar power	Geothermal power	Heat sources for heat pumps	Manure	Biofuel and energy crops	Straw	Wood and woodchips	Wood pellets and wood waste	Organic waste, industry	Organic waste, households	Landfill, sludge, waste water	Waste, non-biodegradable	Energy consumption, observed	Plant type
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Electric cooker
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Electric hot water
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Electric radiator
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Lighting
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Electric compressor
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Electric motor etc.
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,7	Heat pumps, individual
-76,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-76,7	Electricity import
0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	Gas cooker, process, etc.
0,0	0,0	0,0	0,0	13,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	13,6	Oil-fired boiler, individual
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Natural gas boiler, individual
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	7,2	0,0	0,0	0,0	0,0	7,2	Wood pellets furnace, individual
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	19,4	0,0	0,0	0,0	0,0	0,0	19,4	Wood furnace and -stove, individual
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,7	0,0	0,0	0,0	0,0	0,0	0,0	1,7	Straw furnace, individual
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,2	Solar heating
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Oil-fired boiler, business
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Natural gas boiler, business
0,0	0,0	0,0	0,0	5,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	5,0	Industrial boiler, business
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,1	Photovoltaics
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	27,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	27,1	Wind turbines, land
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	77,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	77,8	Wind turbines, coastal (50 %)
0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	22,9	4,4	0,0	0,0	0,0	0,0	0,0	27,4	District heating plants, boiler
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	District heating plants, solar
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	District heating plants, district heating production
0,0	0,0	0,0	0,0	0,0	0,0	0,0	11,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	12,5	Cars, petrol
0,0	0,0	0,0	0,0	0,0	7,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	7,5	Cars, diesel
0,0	0,0	0,0	0,0	0,0	7,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	7,5	Delivery vans
0,0	0,0	0,0	0,0	0,0	0,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,8	Busses
0,0	0,0	0,0	0,0	0,0	6,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	6,4	Trucks, semi-trailers, bulldozers etc.
0,0	0,0	0,0	0,0	0,0	9,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	9,7	Tractors
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Trains
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	Aircrafts
0,0	0,0	0,0	0,1	0,0	30,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	30,1	Ships
-77	0	0	0	19	60,7	0	11,8	0	105	0	4	0	2	0	2	25	24	7	0	0	0	0	183,4	**Total**
-33	0	0	0	5	16	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-9	**CO_2-emissions (1.000 tonne)**
														8	28	21	18						75	**Local biomass potential**
														0	7	118	129						67	**Utilisation percentage of local biomass potential**

Elimp 100 %)	LPG and kerosene	Coal	Fuel oil	Heating oil	Diesel fuel	Jet fuel (JP1)	Petrol	Natural gas	Wind power	Hydro and wave power	Solar power	Geothermal power	Heat sources for heat pumps	Manure	Biofuel and energy crops	Straw	Wood and woodchips	Wood pellets and wood waste	Organic waste, industry	Organic waste, households	Landfill, sludge, waste water	Waste, non-biodegradable	
430	227	339	281	266	266	259	263	204	0	0	0	0	0	0	0	0	0	0	0	0	0	296	CO_2-emission (tons/GWh)

Geographic Energy Balance for

Samsø Municipality 2013

Plant type	Efficiency				Electricity grid		District heating			End-use								
	Electricity	Process	Heat	District heating grid	Ex plant	At consumer	Ex plant	At consumer	**Total**	Houses, incl. holiday houses	Public service sector	Private service sector	Trade sector (retail and wholesale)	Building and construction sector	Manufacturing sector	Nursery garden	Agriculture	Transport
Electric cooker		44			-1,3	1,2			**0,5**	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Electric hot water			90		-0,7	0,6			**0,6**	0,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Electric radiator			100		-2,8	2,6			**2,6**	2,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Lighting		50			-4,3	4,0			**2,0**	0,6	0,4	0,1	0,3	0,0	0,1	0,0	0,4	0,0
Electric compressor		150			-2,9	2,7			**4,0**	2,1	0,0	0,4	1,0	0,0	0,2	0,0	0,3	0,0
Electric motor etc.		85			-16,0	14,8			**12,5**	3,4	2,0	0,3	1,0	0,1	1,4	0,3	4,1	0,0
Heat pumps, individual			250		-4,4	4,1			**10,3**	10								
Electricity import	100				-73,5				**0,0**									
Gas cooker, process, etc.			38						**0,2**	0,0					0,1			0,0
Oil-fired boiler, individual			80						**10,9**	10,9								
Natural gas boiler, individual			85						**0,0**	0,0								
Wood pellets furnace, individual			75						**5,4**	5,4								
Wood furnace and -stove, individual			65						**12,6**	12,6								
Straw furnace, individual			65						**1,1**	1,1								
Solar heating			100						**2,2**	2,2								
Oil-fired boiler, business		90							**0,0**						0,0			
Natural gas boiler, business		90							**0,0**						0,0			
Industrial boiler, business		90							**4,5**						4,5			
Photovoltaics	100				1,1				**0,0**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wind turbines, land	100				27,1				**0,0**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Wind turbines, coastal (50 %)	100				77,8				**0,0**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
District heating plants, boiler			95				26,1		**0,0**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
District heating plants, solar			100				1,0		**0,0**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
District heating plants, district heating production				75			-27,2	20,4	**20,4**	20,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Cars, petrol		20							**2,5**	0,0	0,0	0,0	0,0	0,0	0,0	0,0		3
Cars, diesel		25							**1,9**	0,0	0,0	0,0	0,0	0,0	0,0	0,0		2
Delivery vans		25							**1,9**	0,0	0,0	0,0	0,0	0,0	0,0	0,0		2
Busses		33							**0,3**	0,0	0,0	0,0	0,0	0,0	0,0	0,0		0
Trucks, semi-trailers, bulldozers etc.		33							**2,1**	0,0	0,0	0,0	0,0	0,0	0,0	0,0		2
Tractors		33							**3,2**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3	
Trains		33			0,0				**0,0**	0,0	0,0	0,0	0,0	0,0	0,0	0,0		0
Aircrafts		33							**0,0**	0,0	0,0	0,0	0,0	0,0	0,0	0,0		0
Ships		33							**9,9**	0,0	0,0	0,0	0,0	0,0	0,0	0,0		10
Total					0,0	29,9	0,0	20,4	**111,5**	73	2	1	2	0	6	0	8	19
CO_2-emissions (1.000 tonne)	-2,3 tonne/inhabitants																	
Local biomass potential	50,6 % RE global (EU)																	
Utilisation percentage of local biomass potential	91,8 % RE local																	

PlanEnergi regionmidtjylland midt

11. Appendix C. Cost database

Preface

The EnergyPLAN cost database is created and maintained by the Sustainable Energy Planning Research Group at Aalborg University, Denmark. It is constructed based on data from a wide variety of sources, with many of the inputs adjusted to fit with the required fields in the EnergyPLAN model. Below is a list of all the different sources currently used to construct the cost database. The result is a collection of investment, operation & maintenance, and lifetimes for all technologies for the years 2020, 2030, and 2050. Where data could not be obtained for 2030 or 2050, a 2020 cost is often assumed.

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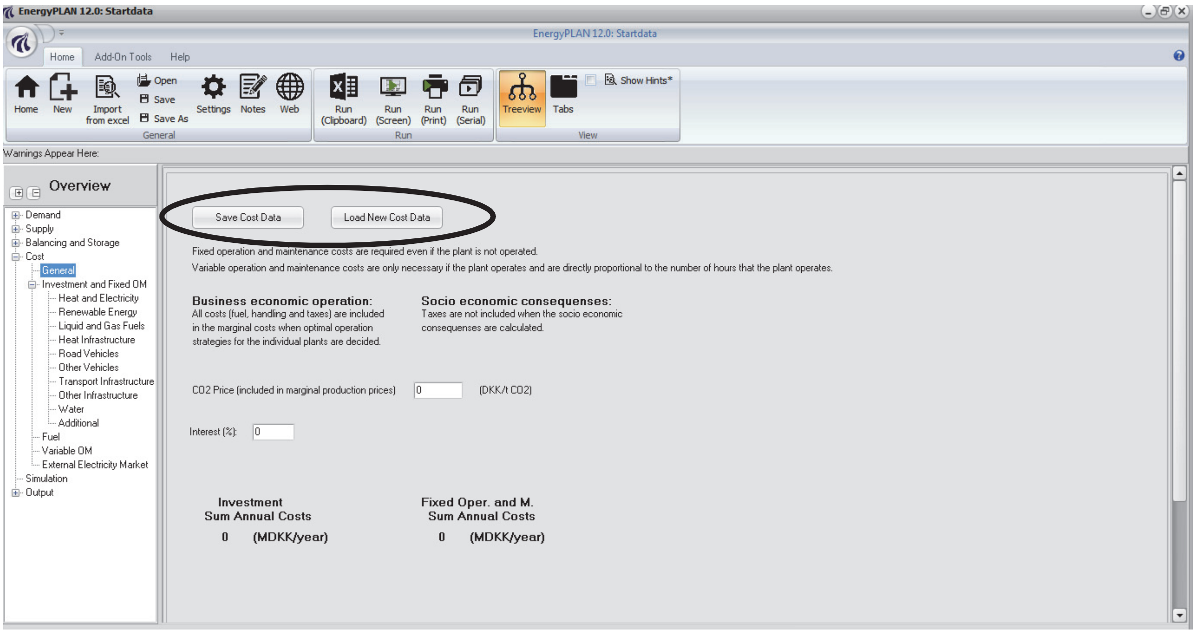
Introduction

The EnergyPLAN tool contains five tabsheets under the main 'Cost' tabsheet, which are:

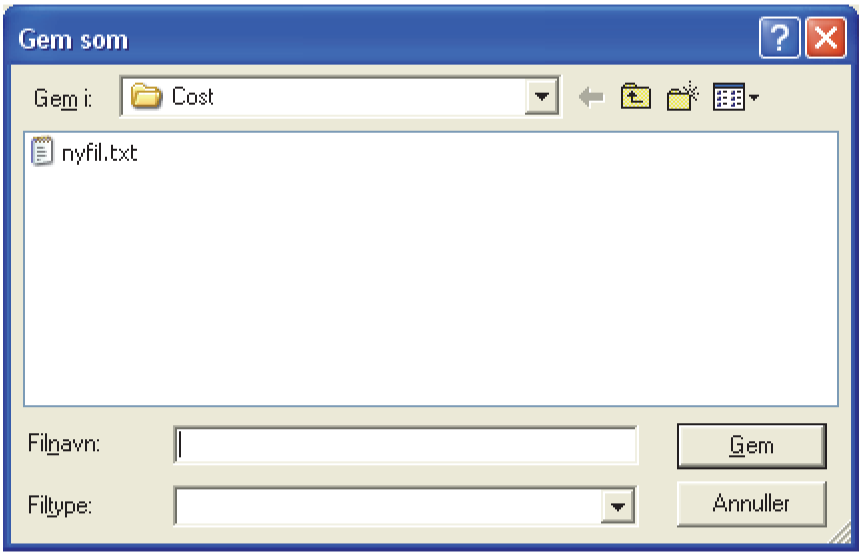
- General
- Investment and Fixed OM
- Fuel
- Variable OM
- External electricity market

The Investment and Fixed OM tabsheet further contains ten sub-tabsheets that relates to different technology groups such as Heat and Electricity, Renewable Energy, Heat infrastructure, Road vehicles, Additional, etc.

Within each of these, the user can enter over 200 inputs depending on the range of technologies being considered in an analysis. When completing an energy systems analysis, it is often necessary to change the cost data in EnergyPLAN for a variety of reasons: for example, to analyse the same system for a different year or to analyse the sensitivity of the system to different costs. To accommodate this, EnergyPLAN enables the user to change the cost data within a model, without changing any of the data under the other tabsheets. To do so, one has to go to the Cost-> General tabsheet and activate one of the two buttons "Save Cost Data" or "Load New Cost Data".



When activating one of these buttons, the user will be brought to the 'Cost' folder where one can either save a new cost data file or load an existing one. It is important to note that when you are saving a file, you should always specify a filename with .txt at the end of the name, as otherwise it may not save correctly.



Even with this function, collecting cost data is still a very time-consuming task and hence, the EnergyPLAN Cost Database has been developed. This database includes cost data for almost all of the technologies included in EnergyPLAN based primarily on publications released by the Danish Energy Agency. This document gives a brief overview of this data.

EnergyPLAN Cost Database

To date, the EnergyPLAN Cost Database consists of the following files:

- 2020EnergyPLANCosts.txt
- 2030EnergyPLANCosts.txt
- 2050EnergyPLANCosts.txt

The file name represents the year which the costs are for. These are recommended based on the literature reviewed by the EnergyPLAN team and it is the users responsibility to verify or adjust them accordingly. To date, the principal source for the cost data has been the Danish Energy Agency (DEA) [1], although a variety of other sources have been used where the data necessary is not available. Below is an overview of the data used to create the EnergyPLAN Cost Database, although it should be noted that this data is updated regularly, so there may be slight differences in the files provided.

Fuel Costs

The fuel prices assumed in the EnergyPLAN Cost Database are outlined in Table 24. Since the DEA only project fuel prices to 2030, the fuel prices in 2040 and 2050 were forecasted by assuming the same trends as experiences in the period between 2020 and 2030. These forecasts can change dramatically from one year to the next. For example, between January and August of 2012, the average oil price was $106/bbl, which is much closer to the oil price forecasted for 2020 than for the 2011 oil price.

Table 24: Fuel prices for 2011, 2020, 2030, 2040, and 2050 in the EnergyPLAN Cost Database [2, 3].

(2009-€/GJ) Year	Oil (US$/bbl)	Natural Gas	Coal	Fuel Oil	Diesel	Petrol	Jet Fuel	Straw	Wood Chips	Wood Pellets	Energy Crops	Nuclear
2011	82.0	5.9	2.7	8.8	11.7	11.9	12.7	3.5	4.5	9.6	4.7	1.5
2020	107.4	9.1	3.1	11.9	15.0	15.2	16.1	3.9	5.1	10.2	4.7	1.5
2030	118.9	10.2	3.2	13.3	16.6	16.7	17.6	4.3	6.0	10.9	5.2	1.5
Projected assuming the same trends as in 2020-2030												
2040	130.5	11.2	3.3	14.7	18.1	18.2	19.1	4.7	6.8	11.5	5.7	1.5
2050	142.0	12.2	3.4	16.1	19.6	19.7	20.6	5.1	7.6	12.2	6.3	1.5

Fuel handling costs were obtained from the Danish Energy Agency [3]. They represent the additional costs of handling and storing fuels for different types of consumers as well as expected profit margins.

Table 25: Fuel handling costs for 2020 in the EnergyPLAN Cost Database [3].

2009 - €/GJ Fuel	Centralised Power Plants	Decentralised Power Plants & Industry	Consumer
Natural Gas	0.412	2.050	3.146
Coal	-	-	-
Fuel Oil	0.262	-	-
Diesel/Petrol	0.262	1.905	2.084
Jet Fuel	-	-	0.482
Straw	1.754	1.216	2.713
Wood Chips	1.493	1.493	
Wood Pellets	-	0.543	3.256
Energy Crops	1.493	1.493	

The cost of emitting carbon dioxide is displayed in Table 26 and the CO_2 emission factors used for each fuel are outlined in Table 27.

Carbon Dioxide Costs and Emissions

Table 26: Carbon dioxide prices for 2011, 2020, 2030, 2040, and 2050 in the EnergyPLAN Cost Database [3].

2009-€/Ton	CO_2 Price
2011	15.2
2020	28.6
2030	34.6
Projected assuming the same trends as in 2020-2030	
2040	40.6
2050	46.6

Table 27: Carbon dioxide emission factors for different fuels in the EnergyPLAN Cost Database [4].

Fuel	Coal/Peat	Oil	Natural Gas	Waste	LPG
Emission Factor (kg/GJ)	98.5	72.9	56.9	32.5	59.64

Variable Operation and Maintenance Costs

In the Operation tabsheet, the user inputs the variable operation and maintenance costs for a range of technologies. Variable O&M costs account for the additional costs incurred at a plant when the plant has to run such as more replacement parts and more labour. Those available in the EnergyPLAN Cost Database are outlined in Table 28.

Table 28: Variable operation and maintenance costs assumed for 2020 in the EnergyPLAN Cost Database.

Sector	Unit	Variable O&M Cost (€/MWh)
District Heating and CHP Systems	Boiler*	0.15
	CHP*	2.7
	Heat Pump	0.27
	Electric Heating	0.5
Power Plants	Hydro Power	1.19
	Condensing*	2.654
	Geothermal	15
	GTL M1	1.8
	GTL M2	1.008
Storage	Electrolyser	0
	Pump	1.19
	Turbine	1.19
	V2G Discharge	
	Hydro Power Pump	1.19
Individual	Boiler	Accounted for under individual heating costs in the Additional tabsheet
	CHP	
	Heat Pump	
	Electric Heating	

***These costs need to be calculated based on the mix of technologies in the energy system, which can vary substantially from one system to the next.**

Investment Costs

Table 29 outlines the investment costs in the EnergyPLAN Cost Database for the different technologies considered in EnergyPLAN. Note that different technology costs are expressed in different units, so when defining the capacity of a technology, it is important to use the same unit in for the technical input as in the cost input.

Table 29: Investment costs for 2020, 2030, and 2050 in the EnergyPLAN Cost Database.

	Unit: M€/Unit	Unit	2020	2030	2050
Heat & Electricity	Small CHP	MWe	1.2	1.2	1.2
	Large CHP	MWe	0.8	0.8	0.8
	Heat Storage CHP	GWh	3.0	3.0	3.0
	Waste CHP	TWh/year	215.6	215.6	215.6
	Absorption Heat Pump	MWth	0.4	0.4	0.4
	Heat Pump Group 2	MWe	3.4	3.4	2.9
	Heat Pump Group 3	MWe	3.4	3.3	2.9
	DHP Boiler Group 1	MWth	0.100	0.100	0.100
	Boilers Group 2 & 3	MWth	0.075	0.100	0.100

	Electric Boiler	MWth	0.100	0.075	0.075
	Large Power Plants	MWe	0.99	0.98	0.9
	Nuclear	MWe	3.6	3.6	3.0
	Interconnection	MWe	1.2	1.2	1.2
	Pump	MWe	0.6	0.6	0.6
	Turbine	MWe	0.6	0.6	0.6
	Pump Storage	GWh	7.5	7.5	7.5
	Industrial CHP Electricity	TWh/year	68.3	68.3	68.3
	Industrial CHP Heat	TWh/year	68.3	68.3	68.3
Renewable Energy	Wind Onshore	MWe	1.3	1.3	1.2
	Wind Offshore	MWe	2.4	2.3	2.1
	Photovoltaic	MWe	1.3	1.1	0.9
	Wave Power	MWe	6.4	3.4	1.6
	Tidal	MWe	6.5	5.3	5.3
	CSP Solar Power	MWe	6.0	6.0	6.0
	River Hydro	MWe	3.3	3.3	3.3
	Hydro Power	MWe	3.3	3.3	3.3
	Hydro Storage	GWh	7.5	7.5	7.5
	Hydro Pump	MWe	0.6	0.6	0.6
	Geothermal Electricity	MWe	4.6	4.0	4.0
	Geothermal Heat	TWh/year	0.0	0.0	0.0
	Solar Thermal	TWh/year	386.0	307.0	307.0
	Heat Storage Solar	GWh	3.0	3.0	3.0
	Industrial Excess Heat	TWh/year	40.0	40.0	40.0
Liquid and Gas Fuels	Biogas Plant	TWh/year	240	240	240
	Gasification Plant	MW Syngas	0.4	0.3	0.3
	Biogas Upgrade	MW Gas Out	0.3	0.3	0.3
	Gasification Gas Upgrade	MW Gas Out	0.3	0.3	0.3
	2nd Generation Biodiesel Plant	MW-Bio	3.4	2.5	1.9
	Biopetrol Plant	MW-Bio	0.8	0.6	0.4
	Biojetpetrol Plant	MW-Bio	0.8	0.6	0.4
	CO2 Hydrogenation Electrolyser	MW-Fuel	0.9	0.6	0.4
	Synthetic Methane Electrolyser	MW-Fuel	0.0	0.0	0.0
	Chemical Synthesis MeOH	MW-Fuel	0.6	0.6	0.6
	Alkaline Electrolyser	MWe	2.5	0.9	0.9
	SOEC Electrolyser	MWe	0.6	0.4	0.3
	Hydrogen Storage	GWh	20.0	20.0	20.0
	Gas Storage	GWh	0.1	0.1	0.1

	Oil Storage	GWh	0.0	0.0	0.0
	Methanol Storage	GWh	0.1	0.1	0.1
Heat Infrastructure	Individual Boilers	1000 Units	6.1	0.0	0.0
	Individual CHP	1000 Units	12.0	0.0	0.0
	Individual Heat Pump	1000 Units	14.0	0.0	14.0
	Individual Electric Heat	1000 Units	8.0	0.0	0.0
	Individual Solar Thermal	TWh/year	1700.0	1533.3	1233.3
Road Vehicles	Bicycles	1000 Vehicles	0.0	0.0	0.0
	Motorbikes	1000 Vehicles	6.0	6.0	6.0
	Electric Cars	1000 Vehicles	18.1	18.1	18.1
	Conventional Cars	1000 Vehicles	20.6	20.6	20.6
	Methanol/DME Busses	1000 Vehicles	177.2	177.2	177.2
	Diesel Busses	1000 Vehicles	177.2	177.2	177.2
	Methanol/DME Trucks	1000 Vehicles	99.2	99.2	99.2
	Diesel Trucks	1000 Vehicles	99.2	99.2	99.2
Water	Desalination	1000 m3 Fresh Water/hour	0.1	0.1	0.1
	Water Storage	Mm3	0.0	0.0	0.0

***Power plant costs need to be calculated based on the mix of technologies in the energy system, which can vary substantially from one system to the next.**

Fixed Operation and Maintenance Costs

	Unit: % of Investment	Unit	2020	2030	2050
Heat & Electricity	Small CHP	MWe	3.75	3.75	3.75
	Large CHP	MWe	3.66	3.66	3.80
	Heat Storage CHP	GWh	0.70	0.70	0.70
	Waste CHP	TWh/year	7.37	7.37	7.37
	Absorption Heat Pump	MWth	4.68	4.68	4.68
	Heat Pump Group 2	MWe	2.00	2.00	2.00
	Heat Pump Group 3	MWe	2.00	2.00	2.00
	DHP Boiler Group 1	MWth	3.70	3.70	3.70
	Boilers Group 2 & 3	MWth	1.47	3.70	3.70
	Electric Boiler	MWth	3.70	1.47	1.47
	Large Power Plants	MWe	3.12	3.16	3.26
	Nuclear	MWe	2.53	2.49	1.96
	Interconnection	MWe	1.00	1.00	1.00
	Pump	MWe	1.50	1.50	1.50
	Turbine	MWe	1.50	1.50	1.50

	Pump Storage	GWh	1.50	1.50	1.50
	Industrial CHP Electricity	TWh/year	7.32	7.32	7.32
	Industrial CHP Heat	TWh/year	7.32	7.32	7.32
Renewable Energy	Wind Onshore	MWe	3.05	2.97	3.20
	Wind Offshore	MWe	2.97	3.06	3.21
	Photovoltaic	MWe	2.09	1.38	1.15
	Wave Power	MWe	0.59	1.04	1.97
	Tidal	MWe	3.00	3.66	3.66
	CSP Solar Power	MWe	8.21	8.21	8.21
	River Hydro	MWe	2.00	2.00	2.00
	Hydro Power	MWe	2.00	2.00	2.00
	Hydro Storage	GWh	1.50	1.50	1.50
	Hydro Pump	MWe	1.50	1.50	1.50
	Geothermal Electricity	MWe	3.50	3.50	3.50
	Geothermal Heat	TWh/year	0.00	0.00	0.00
	Solar Thermal	TWh/year	0.13	0.15	0.15
	Heat Storage Solar	GWh	0.70	0.70	0.70
	Industrial Excess Heat	TWh/year	1.00	1.00	1.00
Liquid and Gas Fuels	Biogas Plant	TWh/year	6.96	6.96	6.96
	Gasification Plant	MW Syngas	5.30	7.00	7.00
	Biogas Upgrade	MW Gas Out	15.79	17.65	18.75
	Gasification Gas Upgrade	MW Gas Out	15.79	17.65	18.75
	2nd Generation Biodiesel Plant	MW-Bio	3.01	3.01	3.01
	Biopetrol Plant	MW-Bio	7.68	7.68	7.68
	Biojetpetrol Plant	MW-Bio	7.68	7.68	7.68
	CO2 Hydrogenation Electrolyser	MW-Fuel	2.46	3.00	3.00
	Synthetic Methane Electrolyser	MW-Fuel	0.00	0.00	0.00
	Chemical Synthesis MeOH	MW-Fuel	3.48	3.48	3.48
	Alkaline Electrolyser	MWe	4.00	4.00	4.00
	SOEC Electrolyser	MWe	2.46	3.00	3.00
	Hydrogen Storage	GWh	0.50	0.50	0.50
	Gas Storage	GWh	1.00	1.00	1.00
	Oil Storage	GWh	0.63	0.63	0.63
	Methanol Storage	GWh	0.63	0.63	0.63
Heat Infrastructure	Individual Boilers	1000 Units	1.79	0.00	0.00
	Individual CHP	1000 Units	0.00	0.00	0.00
	Individual Heat Pump	1000 Units	0.98	0.00	0.98
	Individual Electric Heat	1000 Units	1.00	0.00	0.00

	Individual Solar Thermal	TWh/year	1.22	1.35	1.68
Road Vehicles	Bicycles	1000 Vehicles	0.00	0.00	0.00
	Motorbikes	1000 Vehicles	5.00	5.00	5.00
	Electric Cars	1000 Vehicles	6.99	4.34	4.34
	Conventional Cars	1000 Vehicles	4.09	4.09	4.09
	Methanol/DME Busses	1000 Vehicles	9.14	9.14	9.14
	Diesel Busses	1000 Vehicles	9.14	9.14	9.14
	Methanol/DME Trucks	1000 Vehicles	21.10	21.10	21.10
	Diesel Trucks	1000 Vehicles	21.10	21.10	21.10

Lifetimes

	Unit: Years	Unit	2020	2030	2050
Heat & Electricity	Small CHP	MWe	25	25	25
	Large CHP	MWe	25	25	25
	Heat Storage CHP	GWh	20	20	20
	Waste CHP	TWh/year	20	20	20
	Absorption Heat Pump	MWth	20	20	20
	Heat Pump Group 2	MWe	25	25	25
	Heat Pump Group 3	MWe	25	25	25
	DHP Boiler Group 1	MWth	35	35	35
	Boilers Group 2 & 3	MWth	20	35	35
	Electric Boiler	MWth	35	20	20
	Large Power Plants	MWe	27	27	27
	Nuclear	MWe	30	30	30
	Interconnection	MWe	40	40	40
	Pump	MWe	50	50	50
	Turbine	MWe	50	50	50
	Pump Storage	GWh	50	50	50
	Industrial CHP Electricity	TWh/year	25	25	25
	Industrial CHP Heat	TWh/year	25	25	25
Renewable Energy	Wind Onshore	MWe	20	25	30
	Wind Offshore	MWe	20	25	30
	Photovoltaic	MWe	30	30	40
	Wave Power	MWe	20	25	30
	Tidal	MWe	20	20	20
	CSP Solar Power	MWe	25	25	25
	River Hydro	MWe	50	50	50
	Hydro Power	MWe	50	50	50

	Hydro Storage	GWh	50	50	50
	Hydro Pump	MWe	50	50	50
	Geothermal Electricity	MWe	20	20	20
	Geothermal Heat	TWh/year	0	0	0
	Solar Thermal	TWh/year	30	30	30
	Heat Storage Solar	GWh	20	20	20
	Industrial Excess Heat	TWh/year	30	30	30
Liquid and Gas Fuels	Biogas Plant	TWh/year	20	20	20
	Gasification Plant	MW Syngas	25	25	25
	Biogas Upgrade	MW Gas Out	15	15	15
	Gasification Gas Upgrade	MW Gas Out	15	15	15
	2nd Generation Biodiesel Plant	MW-Bio	20	20	20
	Biopetrol Plant	MW-Bio	20	20	20
	Biojetpetrol Plant	MW-Bio	20	20	20
	CO2 Hydrogenation Electrolyser	MW-Fuel	20	15	15
	Synthetic Methane Electrolyser	MW-Fuel	0	0	0
	Chemical Synthesis MeOH	MW-Fuel	20	20	20
	Alkaline Electrolyser	MWe	28	28	28
	SOEC Electrolyser	MWe	20	15	15
	Hydrogen Storage	GWh	30	30	30
	Gas Storage	GWh	50	50	50
	Oil Storage	GWh	50	50	50
	Methanol Storage	GWh	50	50	50
Heat Infrastructure	Individual Boilers	1000 Units	21	0	0
	Individual CHP	1000 Units	10	0	0
	Individual Heat Pump	1000 Units	20	0	20
	Individual Electric Heat	1000 Units	30	0	0
	Individual Solar Thermal	TWh/year	25	30	30
Road Vehicles	Bicycles	1000 Vehicles	0	0	0
	Motorbikes	1000 Vehicles	15	0	15
	Electric Cars	1000 Vehicles	16	16	16
	Conventional Cars	1000 Vehicles	16	16	16
	Methanol/DME Busses	1000 Vehicles	6	6	6
	Diesel Busses	1000 Vehicles	6	6	6
	Methanol/DME Trucks	1000 Vehicles	6	6	6
	Diesel Trucks	1000 Vehicles	6	6	6

Additional Tabsheet

The additional tabsheet under the Investment and Fixed OM tabsheet can be used to account for costs which are not included in the list of technologies provided in the other tabsheets. Typically these costs are calculated outside of the EnergyPLAN tool and subsequently inputted as a total. In the past, this section has been used to include the costs of the following technologies:

- Energy efficiency measures
- Electric grid costs
- Individual heating costs
- Interconnection costs
- Costs for expansion of district heating and cooling

Some of these costs vary dramatically from one energy system to the next and hence they are not included in the cost files which can be loaded into EnergyPLAN. However, below are some costs which may provide a useful starting point if additional costs need to be estimated.

Heating

Individual heating can be considered automatically by EnergyPLAN or added as an additional cost. To use the automatic function, you must specify an average heat demand per building in the Individual heating tabsheet. Using this, in combination with the total heat demand, EnergyPLAN estimates the total number of buildings in the energy system. This is illustrated in the Cost->Investment and Fixed OM ->Heat infrastructures window. The price presented in Table 29 above represents the average cost of a boiler in a single house, which is used to automatically estimate the cost of the heating infrastructure. This is a fast method, but it can overlook variations in the type of boilers in the system. For example, some boilers will be large common boilers in the basement of a building rather than an individual boiler in each house.

To capture these details, we recommend that you build a profile of the heating infrastructure outside of the EnergyPLAN tool and insert the costs as an additional cost. Below in Table 30 are a list of cost assumptions you can use if you do this.

Table 30: Individual heating unit costs for 2020 in the EnergyPLAN Cost Database [17].

Parameter	Oil boiler	Natural gas boiler	Biomass boiler	Heat pump air-to-water	Heat pump brine-to-water	Electric heating	District heating substation
Capacity of one unit (kW_{th})	15-30	3-20	5-20	10	10	5	10
Annual average efficiency (%)	100	100-104	87	330	350	100	98
Technical lifetime (years)	20	22	20	20	20	30	20
Specific investment (1000€/unit)	6.6	5	6.75	12	16	4	2.5
Fixed O&M (€/unit/year)	270	46	25	135	135	50	150
Variable O&M (€/MWh)	0.0	7.2	0.0	0.0	0.0	0.0	0.0

Table 31: District heating network costs for 2020 in the EnergyPLAN Cost Database [17].

Technology	Low-temperature DH network
Heat density an consumer (TJ/km^2 land area)	45-50
Net loss (%)	13-16
Average Technical lifetime (years)	40
Average Investment costs (1000 €/TJ)	145
Average Fixed O&M (€/TJ/year)	1100
Branch Piping (1000€/substation)	3

12. Appendix D. Biomass demands in combination with biomass potentials

The tables show the biomass paths in combination with the biomass used in the scenarios. These can be compared with the total biomass demand.

Biomass path A. Biomass potentials - current

Biomass used in scenarios (GWh/year)	Manure	Energy crops (and biofuels)	Straw	Firewood and wood chips	Wood pellets and wood waste	Waste and waste water	Total biomass used	Biomass demand
7b. EVs+2gbiodiesel	0	0	27	26	0	0	53	133
7c. EVs+Biogas LBG/CBG	0	0	0	14	0	0	14	78
7d. EVs+Biogas hydro LG/CG	0	0	0	14	0	0	14	54
7e. EVs+Biomass hydro LG/CG	0	0	27	26	0	0	53	48
7f. EVs+Biomass hydro DME	0	0	27	26	0	0	53	51
Total biomass potential	8	0	27	26	0	6	67	

Biomass path B. Biomass potentials with conversion to energy crops

Biomass used in scenarios (GWh/year)	Manure	Energy crops (and biofuels)	Straw	Firewood and wood chips	Wood pellets and wood waste	Waste and waste water	Total biomass used	Biomass demand
7b. EVs+2gbiodiesel	0	28	24	26	0	0	78	133
7c. EVs+Biogas LBG/CBG	0	0	0	14	0	0	14	78
7d. EVs+Biogas hydro LG/CG	0	0	0	14	0	0	14	54
7e. EVs+Biomass hydro LG/CG	0	28	24	26	0	0	78	48
7f. EVs+Biomass hydro DME	0	28	24	26	0	0	78	51
Total biomass potential	8	28	24	26	0	6	92	

Biomass path C. Biomass potentials with biogas using energy crops

Biomass used in scenarios (GWh/year)	Manure	Energy crops (and biofuels)	Straw	Firewood and wood chips	Wood pellets and wood waste	Waste and waste water	Total biomass used	Biomass demand
7b. EVs+2gbiodiesel	0	7	23	26	0	0	56	133
7c. EVs+Biogas LBG/CBG	7	28	0	14	0	5	53	78
7d. EVs+Biogas hydro LG/CG	7	28	0	14	0	5	53	54
7e. EVs+Biomass hydro LG/CG	0	7	23	26	0	0	56	48
7f. EVs+Biomass hydro DME	0	7	23	26	0	0	56	51
Total biomass potential	8	28	24	26	0	6	92	

Biomass path D. Biomass potentials with biogas using straw

Biomass used in scenarios (GWh/year)	Manure	Energy crops (and biofuels)	Straw	Firewood and wood chips	Wood pellets and wood waste	Waste and waste water	Total biomass used	Biomass demand
7b. EVs+2gbiodiesel	0	0	5	26	0	0	31	133
7c. EVs+Biogas LBG/CBG	7	0	27	14	0	5	52	78
7d. EVs+Biogas hydro LG/CG	7	0	27	14	0	5	52	54
7e. EVs+Biomass hydro LG/CG	0	0	5	26	0	0	31	48
7f. EVs+Biomass hydro DME	0	0	5	26	0	0	31	51
Total biomass potential	8	0	27	26	0	6	67	

13. Appendix E. Printouts of EnergyPLAN models

13.1. 0. Reference 2013

Input 0. ref2013-samsoe-20150729.txt — The EnergyPLAN model 12.0

Electricity demand (GWh/year):		Flexible demand	0,00
Fixed demand	24,32	Fixed imp/exp.	0,00
Electric heating + HP	6,92	Transportation	0,00
Electric cooling	0,00	Total	31,24

District heating (GWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	27,20	0,00	0,00	27,20
Solar Thermal	1,11	0,00	0,00	1,11
Industrial CHP (CSHP)	0,00	0,00	0,00	0,00
Demand after solar and CSHP	26,09	0,00	0,00	26,09

Wind	11359 kW	27,05 GWh/year	0,00	Grid
Offshore Wind	23000 kW	77,59 GWh/year	0,00	stabili-
Photo Voltaic	1248 kW	1,08 GWh/year	0,00	sation
River Hydro	0 kW	0 GWh/year	0,00	share
Hydro Power	0 kW	0 GWh/year		
Geothermal/Nuclear	0 kW	0 GWh/year		

	Capacities kW-e	Capacities kJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0,39	0,46	
Heat Pump	0	0			3,00
Boiler		0		1,01	
Group 3:					
CHP	0	0	0,40	0,50	
Heat Pump	0	0			3,00
Boiler		0		0,90	
Condensing	0		0,45		

Heatstorage: gr.2: 0 MWh gr.30 MWh
Fixed Boiler: gr.2:0,0 Per cent gr.0,0 Per cent

Electricity prod. from	CSHP	Waste (GWh/year)
Gr.1:	0,00	0,00
Gr.2:	0,00	0,00
Gr.3:	0,00	0,00

Regulation StrategTechnical regulation no. 2
KEOL regulation 20000000
Minimum Stabilisation share 0,00
Stabilisation share of CHP 0,00
Minimum CHP gr 3 load 0 kW
Minimum PP 0 kW
Heat Pump maximum share 1,00
Maximum import/export 50000 kW

20141203-distr-elpris-EUR-dkvest-v1.txt
Addition factor 0,00 EUR/MWh
Multiplication factor 1,00
Dependency factor 0,00 EUR/MWh pr. MW
Average Market Price 39 EUR/MWh
Gas Storage 0 MWh
Syngas capacity 0 kW
Biogas max to grid 0 kW

Fuel Price level:

	Capacities kW-e	Storage MWh	Efficiencie elec.	Ther.
Hydro Pump:	0	0	0,80	
Hydro Turbine:	0		0,90	
Electrol. Gr.2:	0	0	0,80	0,10
Electrol. Gr.3:	0	0	0,80	0,10
Electrol. trans.:	0	0	0,80	
Ely. MicroCHP:	0	0	0,80	

CAES fuel ratio: 0,000

(GWh/year)	Coal	Oil	Ngas	Biomass
Transport	0,00	72,50	0,00	0,00
Household	0,00	13,60	0,00	28,30
Industry	0,00	5,00	0,00	0,00
Various	0,00	0,00	0,00	0,00

Output

	District Heating										Electricity																			Exchange	
	Demand	Production									Consumption						Production							Balance						Payment	
	Distr. heating kW	Solar kW	Waste CSHP kW	DHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Balance kW	Elec. demand kW	Flex.& Transp kW	HP kW	Electrolyser kW	EH kW	Hydro Pump kW	Turbine kW	RES kW	Hydro kW	Geothermal kW	Waste CSHP kW	CHP kW	PP kW	Stab-Load %	Imp kW	Exp kW	CEEP kW	EEP kW		Imp 1000 EUR	Exp 1000 EUR
January	4983	11	22	4972	0	0	0	0	0	-22	2752	0	755	0	513	0	0	12274	0	0	0	0	0	100	103	8358	0	8358		4	266
February	5098	59	22	5039	0	0	0	0	0	-22	2679	0	772	0	525	0	0	10422	0	0	0	0	0	100	131	6577	0	6577		4	183
March	4343	82	22	4261	0	0	0	0	0	-22	2722	0	658	0	447	0	0	10962	0	0	0	0	0	100	57	7191	0	7191		2	213
April	3480	206	22	3274	0	0	0	0	0	-22	2488	0	527	0	358	0	0	11091	0	0	0	0	0	100	76	7794	0	7794		3	240
May	2731	230	22	2500	0	0	0	0	0	-22	2596	0	414	0	281	0	0	12581	0	0	0	0	0	100	9	9299	0	9299		0	255
June	1237	225	22	1013	0	0	0	0	0	-22	2884	0	187	0	127	0	0	11211	0	0	0	0	0	100	25	8036	0	8036		1	337
July	1237	216	22	1021	0	0	0	0	0	-22	2602	0	187	0	127	0	0	11928	0	0	0	0	0	100	27	9038	0	9038		1	247
August	1237	216	22	1021	0	0	0	0	0	-22	3041	0	187	0	127	0	0	12142	0	0	0	0	0	100	37	8823	0	8823		1	266
September	1900	149	22	1751	0	0	0	0	0	-22	2960	0	288	0	196	0	0	12883	0	0	0	0	0	100	42	9481	0	9481		1	302
October	2829	78	22	2751	0	0	0	0	0	-22	2852	0	429	0	291	0	0	14370	0	0	0	0	0	100	45	10844	0	10844		1	282
November	3712	24	22	3688	0	0	0	0	0	-22	2915	0	562	0	382	0	0	12714	0	0	0	0	0	100	46	8900	0	8900		1	221
December	4432	14	22	4419	0	0	0	0	0	-22	2733	0	671	0	456	0	0	11729	0	0	0	0	0	100	111	7980	0	7980		3	163
Average	3097	126	22	2970	0	0	0	0	0	-22	2769	0	469	0	319	0	0	12035	0	0	0	0	0	100	59	8537	0	8537		Average price	
Maximum	8702	1301	22	8702	0	0	0	0	0	-22	4546	0	1318	0	896	0	0	34563	0	0	0	0	0	100	5108	31466	0	31466		(EUR/MWh)	
Minimum	1084	0	22	867	0	0	0	0	0	-22	1013	0	164	0	112	0	0	0	0	0	0	0	0	100	0	0	0	0		41	40
GWh/year	27,20	1,11	0,19	26,09	0,00	0,00	0,00	0,00	0,00	-0,19	24,32	0,00	4,12	0,00	2,80	0,00	0,00	105,71	0,00	0,00	0,00	0,00	0,00		0,52	74,99	0,00	74,99		2100	E2974

FUEL BALANCE (GWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste	CAES Elc.ly.	BioConversion	Synthetic Fuel	Wind	Offsh.	PV	Hydro	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Imp/Exp Corrected Netto	CO2 emission (kt): Total	CO2 emission (kt): Netto
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	-82,75	-82,75	0,00	-28,30
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	72,50	12,85	5,00	90,35	0,00	90,35	24,07	24,07
N.Gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biomass	27,47	-	-	-	-	-	-	-	-	-	1,06	-	-	-	-	-	-	-	25,98	-	54,51	-82,75	-28,24	0,00	0,00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	27,05	77,59	1,08	-	3,29	-	-	-	109,00	0,00	109,00	0,00	0,00
H2 etc.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	-	-	-	-	-	-	-	-	-2,00	-	-	-	-	-	-	2,00	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	27,47	-	-	-	-	-	-	-	-	-	-0,94	-	27,05	77,59	1,08	-	3,29	74,50	38,83	5,00	253,86	-165,50	88,36	24,07	-4,23

08-september-2015 [13:07]

Output specifications   0. ref2013-samsoe-20150729.txt   The EnergyPLAN model 12.0

District Heating Production

	Gr.1 District heating kW	Gr.1 Solar kW	Gr.1 CSHP kW	Gr.1 DHP kW	Gr.2 District heating kW	Gr.2 Solar kW	Gr.2 CSHP kW	Gr.2 CHP kW	Gr.2 HP kW	Gr.2 ELT kW	Gr.2 Boiler kW	Gr.2 EH kW	Gr.2 Storage kW	Gr.2 Balance kW
January	4983	11	0	4972	0	0	0	0	0	0	0	0	0	0
February	5098	59	0	5039	0	0	0	0	0	0	0	0	0	0
March	4343	82	0	4261	0	0	0	0	0	0	0	0	0	0
April	3480	206	0	3274	0	0	0	0	0	0	0	0	0	0
May	2731	230	0	2500	0	0	0	0	0	0	0	0	0	0
June	1237	225	0	1013	0	0	0	0	0	0	0	0	0	0
July	1237	216	0	1021	0	0	0	0	0	0	0	0	0	0
August	1237	216	0	1021	0	0	0	0	0	0	0	0	0	0
September	1900	149	0	1751	0	0	0	0	0	0	0	0	0	0
October	2829	78	0	2751	0	0	0	0	0	0	0	0	0	0
November	3712	24	0	3688	0	0	0	0	0	0	0	0	0	0
December	4432	14	0	4419	0	0	0	0	0	0	0	0	0	0
Average	3097	126	0	2970	0	0	0	0	0	0	0	0	0	0
Maximum	8702	1301	0	8702	0	0	0	0	0	0	0	0	0	0
Minimum	1084	0	0	867	0	0	0	0	0	0	0	0	0	0
Total for the whole year GWh/year	27,20	1,11	0,00	26,09	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		0,00

	Gr.3 District heating kW	Gr.3 Solar kW	Gr.3 CSHP kW	Gr.3 CHP kW	Gr.3 HP kW	Gr.3 ELT kW	Gr.3 Boiler kW	Gr.3 EH kW	Gr.3 Storage kW	Gr.3 Balance kW	RES1 Wind kW	RES2 Offshc kW	RES3 Photo kW	RES 4-7 sic kW	Total kW
January	0	0	22	0	0	0	0	0	0	-22	3218	9042	15	0	12274
February	0	0	22	0	0	0	0	0	0	-22	2626	7752	45	0	10422
March	0	0	22	0	0	0	0	0	0	-22	2755	8104	102	0	10962
April	0	0	22	0	0	0	0	0	0	-22	2761	8145	185	0	11091
May	0	0	22	0	0	0	0	0	0	-22	3196	9163	222	0	12581
June	0	0	22	0	0	0	0	0	0	-22	2779	8174	257	0	11211
July	0	0	22	0	0	0	0	0	0	-22	3011	8699	218	0	11928
August	0	0	22	0	0	0	0	0	0	-22	3072	8878	191	0	12142
September	0	0	22	0	0	0	0	0	0	-22	3340	9417	126	0	12883
October	0	0	22	0	0	0	0	0	0	-22	3816	10489	65	0	14370
November	0	0	22	0	0	0	0	0	0	-22	3331	9354	29	0	12714
December	0	0	22	0	0	0	0	0	0	-22	3015	8699	15	0	11729
Average	0	0	22	0	0	0	0	0	0	-22	3079	8833	123	0	12035
Maximum	0	0	22	0	0	0	0	0	0	-22	11359	23000	1248	0	34563
Minimum	0	0	22	0	0	0	0	0	0	-22	0	0	0	0	0
Total for the whole year GWh/year	0,00	0,00	0,19	0,00	0,00	0,00	0,00	0,00		-0,19	27,05	77,59	1,08	0,00	105,71

Own use of heat from industrial CH0,00 GWh/year

ANNUAL COSTS (1000 EUR)

Total Fuel ex Ngas exchange =		7273
Uranium =	0	
Coal =	0	
FuelOil =	248	
Gasoil/Diesel=	4537	
Petrol/JP =	778	
Gas handling =	0	
Biomass =	1710	
Food income =	0	
Waste =	0	
Total Ngas Exchange costs =		0
Marginal operation costs =		4
Total Electricity exchange =		-2953
Import =	21	
Export =	-2974	
Bottleneck =	0	
Fixed imp/ex=	0	
Total CO2 emission costs =		688
Total variable costs =		5012
Fixed operation costs =		3639
Annual Investment costs =		21044
TOTAL ANNUAL COSTS =		29695

NATURAL GAS EXCHANGE

	DHP & Boilers kW	CHP2 CHP3 kW	PP CAES kW	Indi-vidual kW	Trans port kW	Indu. Var. kW	Demand Sum kW	Bio-gas kW	Syn-gas kW	CO2Hy gas kW	SynHy gas kW	SynHy gas kW	Stor-age kW	Sum kW	Im-port kW	Ex-port kW
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Average	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

RES Share: 64,4 Percent of Primary Energ434,7 Percent of Electricity 105,7 GWh electricity from RES

08-september-2015 [13:07]

13.2. 1. 2030 scenario

Input — 1. ref2030-samsoe-20150729.txt — The EnergyPLAN model 12.0

Electricity demand (GWh/year):		Flexible demand	0,00
Fixed demand	25,36	Fixed imp/exp.	0,00
Electric heating + HP	5,58	Transportation	0,00
Electric cooling	0,00	Total	30,94

District heating (GWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	27,20	0,00	0,00	27,20
Solar Thermal	1,11	0,00	0,00	1,11
Industrial CHP (CSHP)	0,00	0,00	0,00	0,00
Demand after solar and CSHP	26,09	0,00	0,00	26,09

			Grid stabilisation share
Wind	11359 kW	36,25 GWh/year	0,00
Offshore Wind	23000 kW	102,79 GWh/year	0,00
Photo Voltaic	1248 kW	1,36 GWh/year	0,00
River Hydro	0 kW	0 GWh/year	0,00
Hydro Power	0 kW	0 GWh/year	
Geothermal/Nuclear	0 kW	0 GWh/year	

	Capacities kW-e	Capacities kJ/s	Efficiencies elec.	Efficiencies Ther	Efficiencies COP
Group 2:					
CHP	0	0	0,39	0,46	
Heat Pump	0	0			3,00
Boiler		0		1,01	
Group 3:					
CHP	0	0	0,40	0,50	
Heat Pump	0	0			3,00
Boiler		0		0,90	
Condensing	0		0,52		

Heatstorage: gr.2: 0 MWh gr.3 0 MWh
Fixed Boiler: gr.2: 0,0 Per cent gr.3: 0,0 Per cent

Electricity prod. from	CSHP	Waste (GWh/year)
Gr.1:	0,00	0,00
Gr.2:	0,00	0,00
Gr.3:	0,00	0,00

Regulation Strategy: Technical regulation no. 2
KEOL regulation 20000000
Minimum Stabilisation share 0,00
Stabilisation share of CHP 0,00
Minimum CHP gr 3 load 0 kW
Minimum PP 0 kW
Heat Pump maximum share 1,00
Maximum import/export 50000 kW

20141203-distr-elpris-EUR-dkvest-v1.txt
Addition factor 0,00 EUR/MWh
Multiplication factor 1,00
Dependency factor 0,00 EUR/MWh pr. MW
Average Market Price 39 EUR/MWh
Gas Storage 0 MWh
Syngas capacity 0 kW
Biogas max to grid 0 kW

Fuel Price level:

	Capacities kW-e	Storage MWh	Efficiencies elec.	Efficiencies Ther.
Hydro Pump:	0	0	0,80	
Hydro Turbine:	0		0,90	
Electrol. Gr.2:	0	0	0,80	0,10
Electrol. Gr.3:	0	0	0,80	0,10
Electrol. trans.:	0	0	0,80	
Ely. MicroCHP:	0	0	0,80	
CAES fuel ratio:	0,000			

(GWh/year)	Coal	Oil	Ngas	Biomass
Transport	0,00	42,62	30,00	0,00
Household	0,00	10,88	0,00	24,30
Industry	0,00	5,00	0,00	0,00
Various	0,00	0,00	0,00	0,00

Output

District Heating

	Demand: Distr. heating kW	Production: Solar kW	Waste-CSHP kW	DHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Balance kW
January	4983	11	18	4972	0	0	0	0	0	-18
February	5098	59	18	5039	0	0	0	0	0	-18
March	4343	82	18	4261	0	0	0	0	0	-18
April	3480	206	18	3274	0	0	0	0	0	-18
May	2731	230	18	2500	0	0	0	0	0	-18
June	1237	225	18	1013	0	0	0	0	0	-18
July	1237	216	18	1021	0	0	0	0	0	-18
August	1237	216	18	1021	0	0	0	0	0	-18
September	1900	149	18	1751	0	0	0	0	0	-18
October	2829	78	18	2751	0	0	0	0	0	-18
November	3712	24	18	3688	0	0	0	0	0	-18
December	4432	14	18	4419	0	0	0	0	0	-18
Average	3097	126	18	2970	0	0	0	0	0	-18
Maximum	8702	1301	18	8702	0	0	0	0	0	-18
Minimum	1084	0	18	867	0	0	0	0	0	-18
GWh/year	27,20	1,11	0,15	26,09	0,00	0,00	0,00	0,00	0,00	-0,15

Electricity and Exchange

	Consumption: Elec. demand kW	Flex.& Transp kW	HP kW	Elec-trolyser kW	EH kW	Hydro Pump kW	Production: Tur-bine kW	RES kW	Hy-dro kW	Geo-thermal kW	Waste-CSHP kW	CHP kW	PP kW	Balance: Stab-Load %	Imp kW	Exp kW	CEEP kW	EEP kW	Exchange Payment Imp 1000 EUR	Exp 1000 EUR
January	3046	0	510	0	513	0	0	16048	0	0	0	0	0	100	40	12018	0	12018	2	377
February	2989	0	522	0	525	0	0	14218	0	0	0	0	0	100	57	10239	0	10239	2	284
March	2959	0	445	0	447	0	0	14888	0	0	0	0	0	100	24	11061	0	11061	1	328
April	2659	0	356	0	358	0	0	15072	0	0	0	0	0	100	30	11729	0	11729	1	360
May	2691	0	279	0	281	0	0	16653	0	0	0	0	0	100	1	13403	0	13403	0	367
June	2822	0	127	0	127	0	0	15195	0	0	0	0	0	100	9	12128	0	12128	0	484
July	2557	0	127	0	127	0	0	15912	0	0	0	0	0	100	8	13109	0	13109	0	359
August	2969	0	127	0	127	0	0	16187	0	0	0	0	0	100	10	12975	0	12975	0	390
September	2955	0	194	0	196	0	0	16878	0	0	0	0	0	100	24	13557	0	13557	1	431
October	2940	0	290	0	291	0	0	18372	0	0	0	0	0	100	17	14868	0	14868	0	389
November	3081	0	380	0	382	0	0	16598	0	0	0	0	0	100	18	12772	0	12772	1	320
December	2978	0	454	0	456	0	0	15664	0	0	0	0	0	100	58	11834	0	11834	1	246
Average	2887	0	317	0	319	0	0	15984	0	0	0	0	0	100	24	12486	0	12486	Average price (EUR/MWh)	
Maximum	4576	0	891	0	896	0	0	34642	0	0	0	0	0	100	4997	31595	0	31595		
Minimum	1495	0	111	0	112	0	0	0	0	0	0	0	0	100	0	0	0	0	41	40
GWh/year	25,36	0,00	2,78	0,00	2,80	0,00	0,00	140,40	0,00	0,00	0,00	0,00	0,00		0,21	109,68	0,00	109,68	1900	E4335

FUEL BALANCE (GWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste	CAES Elc.ly.	BioCon-version	Synthetic Fuel	Wind	Offsh.	PV	Hydro	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Netto	CO2 emission (kt): Total	Netto
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42,62	10,28	5,00	57,90	0,00	57,90	15,42	15,42
N.Gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30,00	-	-	30,00	0,00	30,00	6,12	6,12
Biomass	24,16	-	-	-	-	-	-	-	-	-	2,90	-	-	-	-	-	-	-	22,30	-	49,37	-210,50	-161,13	0,00	0,00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	36,25	102,79	1,36	-	3,28	-	-	-	143,68	0,00	143,68	0,00	0,00
H2 etc.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	-	-	-	-	-	-	-	-	-2,00	-	-	-	-	-	-	2,00	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	24,16	-	-	-	-	-	-	-	-	-	0,90	-	36,25	102,79	1,36	-	3,28	74,62	32,58	5,00	280,95	-210,50	70,45	21,55	21,55

08-september-2015 [13:07]

Output specifications — 1. ref2030-samsoe-20150729.txt — The EnergyPLAN model 12.0

District Heating Production

	Gr.1 District heating kW	Gr.1 Solar kW	Gr.1 CSHP kW	Gr.1 DHP kW	Gr.2 District heating kW	Gr.2 Solar kW	Gr.2 CSHP kW	Gr.2 CHP kW	Gr.2 HP kW	Gr.2 ELT kW	Gr.2 Boiler kW	Gr.2 EH kW	Gr.2 Storage kW	Gr.2 Balance kW
January	4983	11	0	4972	0	0	0	0	0	0	0	0	0	0
February	5098	59	0	5039	0	0	0	0	0	0	0	0	0	0
March	4343	82	0	4261	0	0	0	0	0	0	0	0	0	0
April	3480	206	0	3274	0	0	0	0	0	0	0	0	0	0
May	2731	230	0	2500	0	0	0	0	0	0	0	0	0	0
June	1237	225	0	1013	0	0	0	0	0	0	0	0	0	0
July	1237	216	0	1021	0	0	0	0	0	0	0	0	0	0
August	1237	216	0	1021	0	0	0	0	0	0	0	0	0	0
September	1900	149	0	1751	0	0	0	0	0	0	0	0	0	0
October	2829	78	0	2751	0	0	0	0	0	0	0	0	0	0
November	3712	24	0	3688	0	0	0	0	0	0	0	0	0	0
December	4432	14	0	4419	0	0	0	0	0	0	0	0	0	0
Average	3097	126	0	2970	0	0	0	0	0	0	0	0	0	0
Maximum	8702	1301	0	8702	0	0	0	0	0	0	0	0	0	0
Minimum	1084	0	0	867	0	0	0	0	0	0	0	0	0	0
Total for the whole year GWh/year	27,20	1,11	0,00	26,09	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		0,00

	Gr.3 District heating kW	Gr.3 Solar kW	Gr.3 CSHP kW	Gr.3 CHP kW	Gr.3 HP kW	Gr.3 ELT kW	Gr.3 Boiler kW	Gr.3 EH kW	Gr.3 Storage kW	Gr.3 Balance kW	RES1 Wind kW	RES2 Offshc kW	RES3 Photo kW	RES 4-7 aic kW	Total kW
January	0	0	18	0	0	0	0	0	0	-18	4238	11788	21	0	16048
February	0	0	18	0	0	0	0	0	0	-18	3603	10552	62	0	14218
March	0	0	18	0	0	0	0	0	0	-18	3770	10983	134	0	14888
April	0	0	18	0	0	0	0	0	0	-18	3788	11055	230	0	15072
May	0	0	18	0	0	0	0	0	0	-18	4282	12098	274	0	16653
June	0	0	18	0	0	0	0	0	0	-18	3802	11084	309	0	15195
July	0	0	18	0	0	0	0	0	0	-18	4059	11582	271	0	15912
August	0	0	18	0	0	0	0	0	0	-18	4143	11805	239	0	16187
September	0	0	18	0	0	0	0	0	0	-18	4411	12302	164	0	16878
October	0	0	18	0	0	0	0	0	0	-18	4936	13347	89	0	18372
November	0	0	18	0	0	0	0	0	0	-18	4385	12172	41	0	16598
December	0	0	18	0	0	0	0	0	0	-18	4060	11582	22	0	15664
Average	0	0	18	0	0	0	0	0	0	-18	4126	11703	155	0	15984
Maximum	0	0	18	0	0	0	0	0	0	-18	11359	23000	1248	0	34642
Minimum	0	0	18	0	0	0	0	0	0	-18	0	0	0	0	0
Total for the whole year GWh/year	0,00	0,00	0,15	0,00	0,00	0,00	0,00	0,00		-0,15	36,25	102,79	1,36	0,00	140,40

Own use of heat from industrial CHP0,00 GWh/year

ANNUAL COSTS (1000 EUR)
Total Fuel ex Ngas exchange = 6177
Uranium = 0
Coal = 0
FuelOil = 274
Gasoil/Diesel= 2835
Petrol/JP = 841
Gas handling = 605
Biomass = 1622
Food income = 0
Waste = 0

Total Ngas Exchange costs = 1102

Marginal operation costs = 4

Total Electricity exchange = -4326
Import = 9
Export = -4335
Bottleneck = 0
Fixed imp/ex= 0

Total CO2 emission costs = 746

Total variable costs = 3702
Fixed operation costs = 3238

Annual Investment costs = 21647

TOTAL ANNUAL COSTS = 28587

NATURAL GAS EXCHANGE

	DHP & Boilers kW	CHP2 CHP3 kW	PP CAES kW	Individual kW	Transport kW	Indu. Var. kW	Demand Sum kW	Biogas kW	Syngas kW	CO2Hy gas kW	SynHy gas kW	SynHy gas kW	Storage kW	Sum kW	Import kW	Export kW
January	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
February	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
March	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
April	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
May	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
June	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
July	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
August	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
September	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
October	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
November	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
December	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
Average	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
Maximum	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
Minimum	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	30,00	0,00	30,00	0,00	0,00	0,00	0,00	0,00	0,00	30,00	30,00	0,00

RES Share: 68,7 Percent of Primary Energ498,7 Percent of Electricity 140,4 GWh electricity from RES 08-september-2015 [13:07]

13.3. 6. Small Heat pumps + industry

Input 6. 2030-samsoe-savings 20%+expansion 1+large HPs+expansi(The EnergyPLAN model 12.0150729

Electricity demand (GWh/year):		Flexible demand	0,00
Fixed demand	25,36	Fixed imp/exp.	0,00
Electric heating + HP	6,95	Transportation	0,00
Electric cooling	0,00	Total	32,31

District heating (GWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0,00	29,72	0,00	29,72
Solar Thermal	0,00	1,13	0,00	1,13
Industrial CHP (CSHP)	0,00	0,00	0,00	0,00
Demand after solar and CSHP	0,00	28,58	0,00	28,58

Wind	11359	kW	36,25	GWh/year	0,00	Grid
Offshore Wind	23000	kW	102,79	GWh/year	0,00	stabili-
Photo Voltaic	1248	kW	1,36	GWh/year	0,00	sation
River Hydro	0	kW	0	GWh/year	0,00	share
Hydro Power	0	kW	0	GWh/year		
Geothermal/Nuclear	0	kW	0	GWh/year		

	Capacities kW-e	Capacities kJ/s	Efficiencies elec.	Efficiencies Ther	Efficiencies COP
Group 2:					
CHP	0	0	0,39	0,46	
Heat Pump	1253	3759			3,00
Boiler		11408		1,08	
Group 3:					
CHP	0	0	0,40	0,50	
Heat Pump	0	0			3,00
Boiler		0		0,90	
Condensing	0		0,52		

Heatstorage: gr.2:37 MWh gr.30 MWh
Fixed Boiler: gr.2:2,0 Per cent gr.0,0 Per cent

Electricity prod. from	CSHP	Waste (GWh/year)
Gr.1:	0,00	0,00
Gr.2:	0,00	0,00
Gr.3:	0,00	0,00

Regulation Strate(Technical regulation no. 2		
KEOL regulation	20000000	
Minimum Stabilisation share	0,00	
Stabilisation share of CHP	0,00	
Minimum CHP gr 3 load	0	kW
Minimum PP	0	kW
Heat Pump maximum share	1,00	
Maximum import/export	50000	kW

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Addition factor	0,00	EUR/MWh
Multiplication factor	1,00	
Dependency factor	0,00	EUR/MWh pr. MW
Average Market Price	39	EUR/MWh
Gas Storage	0	MWh
Syngas capacity	0	kW
Biogas max to grid	0	kW

Fuel Price level:

	Capacities kW-e	Storage MWh	Efficiencie elec.	Ther.
Hydro Pump:	0	0	0,80	
Hydro Turbine:	0		0,90	
Electrol. Gr.2:	0	0	0,80	0,10
Electrol. Gr.3:	0	0	0,80	0,10
Electrol. trans.:	0	0	0,80	
Ely. MicroCHP:	0	0	0,80	
CAES fuel ratio:	0,000			

(GWh/year)	Coal	Oil	Ngas	Biomass
Transport	0,00	42,50	30,00	0,00
Household	0,00	0,00	0,00	3,86
Industry	0,00	0,00	0,00	5,50
Various	0,00	0,00	0,00	0,00

Output

District Heating

	Demand: Distr. heating kW	Production: Solar kW	Waste-CSHP kW	DHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Ba-lance kW
January	5444	11	0	0	0	3759	0	1674	0	0
February	5570	59	0	0	0	3759	0	1750	0	1
March	4745	82	0	0	0	3758	0	899	0	5
April	3802	206	0	0	0	3449	0	169	0	-23
May	2983	230	0	0	0	2737	0	6	0	9
June	1352	230	0	0	0	1122	0	0	0	0
July	1352	221	0	0	0	1130	0	0	0	0
August	1352	221	0	0	0	1131	0	0	0	0
September	2075	149	0	0	0	1926	0	0	0	0
October	3091	78	0	0	0	2975	0	29	0	9
November	4056	24	0	0	0	3712	0	320	0	-1
December	4842	14	0	0	0	3758	0	1045	0	25
Average	3383	127	0	0	0	2765	0	488	0	2
Maximum	9507	1381	0	0	0	3759	0	5748	0	1631
Minimum	1184	0	0	0	0	961	0	0	0	-1052
GWh/year	29,72	1,12	0,00	0,00	0,00	24,29	0,00	4,29	0,00	0,02

Electricity / Exchange

	Consumption: Elec. demand kW	Flex.& Transp kW	HP kW	Elec-trolyser kW	EH kW	Hydro Pump kW	Production: Tur-bine kW	RES kW	Hy-dro kW	Geo-thermal kW	Waste-CSHP kW	CHP kW	PP kW	Balance: Stab-Load %	Imp kW	Exp kW	CEEP kW	EEP kW	Payment Imp 1000 EUR	Payment Exp 1000 EUR
January	3046	0	2604	0	0	0	0	16048	0	0	0	0	0	100	106	10504	0	10504	4	332
February	2989	0	2621	0	0	0	0	14218	0	0	0	0	0	100	149	8756	0	8756	4	243
March	2959	0	2391	0	0	0	0	14888	0	0	0	0	0	100	63	9600	0	9600	2	284
April	2659	0	2021	0	0	0	0	15072	0	0	0	0	0	100	76	10469	0	10469	3	321
May	2691	0	1564	0	0	0	0	16653	0	0	0	0	0	100	5	12403	0	12403	0	340
June	2822	0	608	0	0	0	0	15195	0	0	0	0	0	100	12	11777	0	11777	0	473
July	2557	0	623	0	0	0	0	15912	0	0	0	0	0	100	12	12744	0	12744	0	349
August	2969	0	633	0	0	0	0	16187	0	0	0	0	0	100	16	12601	0	12601	0	379
September	2955	0	1104	0	0	0	0	16878	0	0	0	0	0	100	37	12856	0	12856	1	409
October	2940	0	1733	0	0	0	0	18372	0	0	0	0	0	100	34	13733	0	13733	1	359
November	3081	0	2235	0	0	0	0	16598	0	0	0	0	0	100	45	11326	0	11326	1	283
December	2978	0	2453	0	0	0	0	15664	0	0	0	0	0	100	110	10343	0	10343	3	213
Average	2887	0	1713	0	0	0	0	15984	0	0	0	0	0	100	55	11439	0	11439	Average price	
Maximum	4576	0	3621	0	0	0	0	34642	0	0	0	0	0	100	6467	30842	0	30842	(EUR/MWh)	
Minimum	1495	0	338	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	41	40
GWh/year	25,36	0,00	15,05	0,00	0,00	0,00	0,00	140,40	0,00	0,00	0,00	0,00	0,00		0,48	100,48	0,00	100,48	2000	E3985

FUEL BALANCE (GWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste	CAES Elc.ly.	BioCon-version	Synthetic Fuel	Wind	Offsh.	PV	Hydro	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Netto	CO2 emission (kt): Total	Netto
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42,50	-	-	42,50	0,00	42,50	11,32	11,32
N.Gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30,00	-	-	30,00	0,00	30,00	6,12	6,12
Biomass	-	-	-	3,97	-	-	-	-	-	-	2,90	-	-	-	-	-	-	-	3,65	5,50	16,03	-192,30	-176,27	0,00	0,00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	36,25	102,79	1,36	-	2,98	-	-	-	143,38	0,00	143,38	0,00	0,00
H2 etc.	-	-	-	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	-	-	-	-	-	-	-	-	-2,00	-	-	-	-	-	-	2,00	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	-	-	-	3,97	-	-	-	-	-	-	0,90	-	36,25	102,79	1,36	-	2,98	74,50	3,65	5,50	231,90	-192,30	39,61	17,45	17,45

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Output specifications 6. 2030-samsoe-savings 20%+expansion 1+largThe EnergyPLAN model 12.0s+sma

District Heating Production

	Gr.1 District heating kW	Gr.1 Solar kW	Gr.1 CSHP kW	Gr.1 DHP kW	Gr.2 District heating kW	Gr.2 Solar kW	Gr.2 CSHP kW	Gr.2 CHP kW	Gr.2 HP kW	Gr.2 ELT kW	Gr.2 Boiler kW	Gr.2 EH kW	Gr.2 Storage kW	Gr.2 Balance kW
January	0	0	0	0	5444	11	0	0	3759	0	1674	0	25967	0
February	0	0	0	0	5570	59	0	0	3759	0	1750	0	25912	1
March	0	0	0	0	4745	82	0	0	3758	0	899	0	24655	5
April	0	0	0	0	3802	206	0	0	3449	0	169	0	19481	-23
May	0	0	0	0	2983	230	0	0	2737	0	6	0	30325	9
June	0	0	0	0	1352	230	0	0	1122	0	0	0	30243	0
July	0	0	0	0	1352	221	0	0	1130	0	0	0	30246	0
August	0	0	0	0	1352	221	0	0	1131	0	0	0	30246	0
September	0	0	0	0	2075	149	0	0	1926	0	0	0	30246	0
October	0	0	0	0	3091	78	0	0	2975	0	29	0	32518	9
November	0	0	0	0	4056	24	0	0	3712	0	320	0	18354	-1
December	0	0	0	0	4842	14	0	0	3758	0	1045	0	5772	25
Average	0	0	0	0	3383	127	0	0	2765	0	488	0	25335	2
Maximum	0	0	0	0	9507	1381	0	0	3759	0	5748	0	37200	1631
Minimum	0	0	0	0	1184	0	0	0	961	0	0	0	0	-1052
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	29,72	1,12	0,00	0,00	24,29	0,00	4,29	0,00		0,02

	Gr.3 District heating kW	Gr.3 Solar kW	Gr.3 CSHP kW	Gr.3 CHP kW	Gr.3 HP kW	Gr.3 ELT kW	Gr.3 Boiler kW	Gr.3 EH kW	Gr.3 Storage kW	Gr.3 Balance kW
January	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0
Average	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		0,00

	RES specification RES1 Wind kW	RES2 Offshc kW	RES3 Photo kW	RES 4-7 sic kW	Total kW
January	4238	11788	21	0	16048
February	3603	10552	62	0	14218
March	3770	10983	134	0	14888
April	3788	11055	230	0	15072
May	4282	12098	274	0	16653
June	3802	11084	309	0	15195
July	4059	11582	271	0	15912
August	4143	11805	239	0	16187
September	4411	12302	164	0	16878
October	4936	13347	89	0	18372
November	4385	12172	41	0	16598
December	4060	11582	22	0	15664
Average	4126	11703	155	0	15984
Maximum	11359	23000	1248	0	34642
Minimum	0	0	0	0	0
Total for the whole year GWh/year	36,25	102,79	1,36	0,00	140,40

Own use of heat from industrial CH0,00 GWh/year

ANNUAL COSTS (1000 EUR)

Total Fuel ex Ngas exchange = 4108
Uranium = 0
Coal = 0
FuelOil = 0
Gasoil/Diesel= 2121
Petrol/JP = 841
Gas handling = 605
Biomass = 541
Food income = 0
Waste = 0

Total Ngas Exchange costs = 1102

Marginal operation costs = 3

Total Electricity exchange = -3965
Import = 20
Export = -3985
Bottleneck = 0
Fixed imp/ex= 0

Total CO2 emission costs = 604

Total variable costs = 1851
Fixed operation costs = 3713

Annual Investment costs = 23918

TOTAL ANNUAL COSTS = 29482

NATURAL GAS EXCHANGE

	DHP & Boilers kW	CHP2 CHP3 kW	PP CAES kW	Individual kW	Transport kW	Indu. Var. kW	Demand Sum kW	Biogas kW	Syngas kW	CO2Hy gas kW	SynHy gas kW	SynHy gas kW	Storage kW	Sum kW	Import kW	Export kW
January	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
February	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
March	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
April	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
May	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
June	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
July	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
August	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
September	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
October	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
November	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
December	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
Average	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
Maximum	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
Minimum	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	30,00	0,00	30,00	0,00	0,00	0,00	0,00	0,00	0,00	30,00	30,00	0,00

RES Share: 68,7 Percent of Primary Energ394,1 Percent of Electricity 140,4 GWh electricity from RES 08-september-2015 [13:11]

13.4. 7a. EVs

Input   7a. 2030-samsoe-savings 20%+expansion 1+large HPs+expansThe EnergyPLAN model 12.0EVs-20

Electricity demand (GWh/year):		Flexible demand	0,00
Fixed demand	25,34	Fixed imp/exp.	0,00
Electric heating + HP	6,95	Transportation	5,94
Electric cooling	0,00	Total	38,23

District heating (GWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0,00	29,72	0,00	29,72
Solar Thermal	0,00	1,13	0,00	1,13
Industrial CHP (CSHP)	0,00	0,00	0,00	0,00
Demand after solar and CSHP	0,00	28,58	0,00	28,58

Wind	11359 kW	36,25	GWh/year	0,00	Grid
Offshore Wind	23000 kW	102,79	GWh/year	0,00	stabili-
Photo Voltaic	1248 kW	1,36	GWh/year	0,00	sation
River Hydro	0 kW	0	GWh/year	0,00	share
Hydro Power	0 kW	0	GWh/year		
Geothermal/Nuclear	0 kW	0	GWh/year		

	Capacities kW-e	kJ/s	Efficiencies elec.	Ther	COP
Group 2:					
CHP	0	0	0,39	0,46	
Heat Pump	1253	3759			3,00
Boiler		11408		1,08	
Group 3:					
CHP	0	0	0,40	0,50	
Heat Pump	0	0			3,00
Boiler		0		0,90	
Condensing	0		0,52		

Heatstorage: gr.2:37 MWh gr.30 MWh
Fixed Boiler: gr.2:2,0 Per cent gr.0,0 Per cent

Electricity prod. from	CSHP	Waste (GWh/year)
Gr.1:	0,00	0,00
Gr.2:	0,00	0,00
Gr.3:	0,00	0,00

Regulation Strategy:	Technical regulation no. 2	
KEOL regulation	20000000	
Minimum Stabilisation share	0,00	
Stabilisation share of CHP	0,00	
Minimum CHP gr 3 load	0	kW
Minimum PP	0	kW
Heat Pump maximum share	1,00	
Maximum import/export	50000	kW
20141203-distr-elpris-EUR-dkvest-v1.txt		
Addition factor	0,00	EUR/MWh
Multiplication factor	1,00	
Dependency factor	0,00	EUR/MWh pr. MW
Average Market Price	39	EUR/MWh
Gas Storage	0	MWh
Syngas capacity	0	kW
Biogas max to grid	0	kW

Fuel Price level:

Capacities Storage Efficiencies	kW-e	MWh	elec.	Ther.
Hydro Pump:	0	0	0,80	
Hydro Turbine:	0		0,90	
Electrol. Gr.2:	0	0	0,80	0,10
Electrol. Gr.3:	0	0	0,80	0,10
Electrol. trans.:	0	0	0,80	
Ely. MicroCHP:	0	0	0,80	
CAES fuel ratio:	0,000			

(GWh/year)	Coal	Oil	Ngas	Biomass
Transport	0,00	16,30	30,00	0,00
Household	0,00	0,00	0,00	3,86
Industry	0,00	0,00	0,00	5,50
Various	0,00	0,00	0,00	0,00

Output   WARNING!!: (5) V2G connection too small

	District Heating: Demand	Production								Balance	Electricity: Consumption						Production							Balance					Exchange: Payment	
	Distr. heating kW	Solar kW	Waste-CSHP kW	DHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Ba-lance kW	Elec. demand kW	Flex.& Transp kW	HP kW	Elec-trolyser kW	EH kW	Hydro Pump kW	Tur-bine kW	RES kW	Hy-dro kW	Geo-thermal kW	Waste-CSHP kW	CHP kW	PP kW	Stab-Load %	Imp kW	Exp kW	CEEP kW	EEP kW	Imp 1000 EUR	Exp 1000 EUR
January	5444	11	0	0	0	3759	0	1674	0	0	3045	676	2604	0	0	0	0	16048	0	0	0	0	0	100	148	9871	0	9871	5	315
February	5570	59	0	0	0	3759	0	1750	0	1	2987	676	2621	0	0	0	0	14218	0	0	0	0	0	100	235	8167	0	8167	6	228
March	4745	82	0	0	0	3758	0	899	0	5	2958	676	2391	0	0	0	0	14888	0	0	0	0	0	100	98	8961	0	8961	3	267
April	3802	206	0	0	0	3449	0	169	0	-23	2657	676	2021	0	0	0	0	15072	0	0	0	0	0	100	119	9838	0	9838	4	303
May	2983	230	0	0	0	2737	0	6	0	9	2689	676	1564	0	0	0	0	16653	0	0	0	0	0	100	16	11740	0	11740	0	323
June	1352	230	0	0	0	1122	0	0	0	0	2820	676	608	0	0	0	0	15195	0	0	0	0	0	100	21	11112	0	11112	0	451
July	1352	221	0	0	0	1130	0	0	0	0	2555	676	623	0	0	0	0	15912	0	0	0	0	0	100	30	12088	0	12088	1	332
August	1352	221	0	0	0	1131	0	0	0	0	2967	676	633	0	0	0	0	16187	0	0	0	0	0	100	36	11947	0	11947	1	361
September	2075	149	0	0	0	1926	0	0	0	0	2953	676	1104	0	0	0	0	16878	0	0	0	0	0	100	58	12203	0	12203	2	390
October	3091	78	0	0	0	2975	0	29	0	9	2938	676	1733	0	0	0	0	18372	0	0	0	0	0	100	43	13068	0	13068	1	343
November	4056	24	0	0	0	3712	0	320	0	-1	3079	676	2235	0	0	0	0	16598	0	0	0	0	0	100	70	10676	0	10676	2	267
December	4842	14	0	0	0	3758	0	1045	0	25	2976	676	2453	0	0	0	0	15664	0	0	0	0	0	100	137	9695	0	9695	3	201
Average	3383	127	0	0	0	2765	0	488	0	2	2885	676	1713	0	0	0	0	15984	0	0	0	0	0	100	84	10793	0	10793	Average price	
Maximum	9507	1381	0	0	0	3759	0	5748	0	1631	4574	1352	3621	0	0	0	0	34642	0	0	0	0	0	100	6807	30416	0	30416	(EUR/MWh)	
Minimum	1184	0	0	0	0	961	0	0	0	-1052	1494	240	338	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	39	40
GWh/year	29,72	1,12	0,00	0,00	0,00	24,29	0,00	4,29	0,00	0,02	25,34	5,94	15,05	0,00	0,00	0,00	0,00	140,40	0,00	0,00	0,00	0,00	0,00		0,74	94,80	0,00	94,80	2900	E3779

FUEL BALANCE (GWh/year):	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste	CAES Elc.ly.	BioCon-version	Synthetic Fuel	Wind	Offsh.	PV	Hydro	Solar.Th.	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Netto	CO2 emission (kt): Total	Netto
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16,30	-	-	16,30	0,00	16,30	4,34	4,34
N.Gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30,00	-	-	30,00	0,00	30,00	6,12	6,12
Biomass	-	-	-	3,97	-	-	-	-	-	-	0,38	-	-	-	-	-	-	-	3,65	5,50	13,50	-180,90	-167,40	0,00	0,00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	36,25	102,79	1,36	-	2,98	-	-	-	143,38	0,00	143,38	0,00	0,00
H2 etc.	-	-	-	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	-	-	-	-	-	-	-	-	-0,36	-	-	-	-	-	-	0,36	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	-	-	-	3,97	-	-	-	-	-	-	0,02	-	36,25	102,79	1,36	-	2,98	46,66	3,65	5,50	203,17	-180,90	22,27	10,47	10,47

08-september-2015 [13:11]

Output specifications — 7a. 2030-samsoe-savings 20%+expansion 1+larThe EnergyPLAN model 12.0Ps+sma

District Heating Production

	Gr.1 District heating kW	Gr.1 Solar kW	Gr.1 CSHP kW	Gr.1 DHP kW	Gr.2 District heating kW	Gr.2 Solar kW	Gr.2 CSHP kW	Gr.2 CHP kW	Gr.2 HP kW	Gr.2 ELT kW	Gr.2 Boiler kW	Gr.2 EH kW	Gr.2 Storage kW	Gr.2 Balance kW
January	0	0	0	0	5444	11	0	0	3759	0	1674	0	25963	0
February	0	0	0	0	5570	59	0	0	3759	0	1750	0	25908	1
March	0	0	0	0	4745	82	0	0	3758	0	899	0	24651	5
April	0	0	0	0	3802	206	0	0	3449	0	169	0	19480	-23
May	0	0	0	0	2983	230	0	0	2737	0	6	0	30325	9
June	0	0	0	0	1352	230	0	0	1122	0	0	0	30243	0
July	0	0	0	0	1352	221	0	0	1130	0	0	0	30246	0
August	0	0	0	0	1352	221	0	0	1131	0	0	0	30246	0
September	0	0	0	0	2075	149	0	0	1926	0	0	0	30246	0
October	0	0	0	0	3091	78	0	0	2975	0	29	0	32518	9
November	0	0	0	0	4056	24	0	0	3712	0	320	0	18354	-1
December	0	0	0	0	4842	14	0	0	3758	0	1045	0	5770	25
Average	0	0	0	0	3383	127	0	0	2765	0	488	0	25334	2
Maximum	0	0	0	0	9507	1381	0	0	3759	0	5748	0	37200	1631
Minimum	0	0	0	0	1184	0	0	0	961	0	0	0	0	-1052
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	29,72	1,12	0,00	0,00	24,29	0,00	4,29	0,00		0,02

	Gr.3 District heating kW	Gr.3 Solar kW	Gr.3 CSHP kW	Gr.3 CHP kW	Gr.3 HP kW	Gr.3 ELT kW	Gr.3 Boiler kW	Gr.3 EH kW	Gr.3 Storage kW	Gr.3 Balance kW	RES1 Wind kW	RES2 Offshc kW	RES3 Photo kW	RES 4-7 kW	Total kW
January	0	0	0	0	0	0	0	0	0	0	4238	11788	21	0	16048
February	0	0	0	0	0	0	0	0	0	0	3603	10552	62	0	14218
March	0	0	0	0	0	0	0	0	0	0	3770	10983	134	0	14888
April	0	0	0	0	0	0	0	0	0	0	3788	11055	230	0	15072
May	0	0	0	0	0	0	0	0	0	0	4282	12098	274	0	16653
June	0	0	0	0	0	0	0	0	0	0	3802	11084	309	0	15195
July	0	0	0	0	0	0	0	0	0	0	4059	11582	271	0	15912
August	0	0	0	0	0	0	0	0	0	0	4143	11805	239	0	16187
September	0	0	0	0	0	0	0	0	0	0	4411	12302	164	0	16878
October	0	0	0	0	0	0	0	0	0	0	4936	13347	89	0	18372
November	0	0	0	0	0	0	0	0	0	0	4385	12172	41	0	16598
December	0	0	0	0	0	0	0	0	0	0	4060	11582	22	0	15664
Average	0	0	0	0	0	0	0	0	0	0	4126	11703	155	0	15984
Maximum	0	0	0	0	0	0	0	0	0	0	11359	23000	1248	0	34642
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		0,00	36,25	102,79	1,36	0,00	140,40

Own use of heat from industrial CH0,00 GWh/year

ANNUAL COSTS (1000 EUR)

Total Fuel ex Ngas exchange =	2204
Uranium =	0
Coal =	0
FuelOil =	0
Gasoil/Diesel=	1124
Petrol/JP =	0
Gas handling =	605
Biomass =	476
Food income =	0
Waste =	0
Total Ngas Exchange costs =	1102
Marginal operation costs =	3
Total Electricity exchange =	-3750
Import =	29
Export =	-3779
Bottleneck =	0
Fixed imp/ex=	0
Total CO2 emission costs =	362
Total variable costs =	-79
Fixed operation costs =	3749
Annual Investment costs =	23571
TOTAL ANNUAL COSTS =	27242

NATURAL GAS EXCHANGE

	DHP & Boilers kW	CHP2 CHP3 kW	PP CAES kW	Individual kW	Transport kW	Indu. Var. kW	Demand Sum kW	Biogas kW	Syngas kW	CO2Hy gas kW	SynHy gas kW	SynHy gas kW	Storage kW	Sum kW	Import kW	Export kW
January	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
February	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
March	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
April	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
May	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
June	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
July	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
August	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
September	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
October	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
November	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
December	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
Average	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
Maximum	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
Minimum	0	0	0	0	3415	0	3415	0	0	0	0	0	0	3415	3415	0
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	30,00	0,00	30,00	0,00	0,00	0,00	0,00	0,00	0,00	30,00	30,00	0,00

RES Share: 77,2 Percent of Primary Energ419,9 Percent of Electricity 140,4 GWh electricity from RES

08-september-2015 [13:11]

13.5. 7d. EVs+Biogas hydro LG-CG

Input 7d. 2030-samsoe-savings 20%+expansion 1+large HPs+expansThe EnergyPLAN model 12.0EVs+Bi

Electricity demand (GWh/year): Flexible demand 0,00
Fixed demand 25,34 Fixed imp/exp. 0,00
Electric heating + HP 6,95 Transportation 5,94
Electric cooling 0,00 Total 38,23

District heating (GWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0,00	29,72	0,00	29,72
Solar Thermal	0,00	1,13	0,00	1,13
Industrial CHP (CSHP)	0,00	0,00	0,00	0,00
Demand after solar and CSHP	0,00	28,58	0,00	28,58

Wind	11359 kW	36,25 GWh/year	0,00	Grid
Offshore Wind	23000 kW	102,79 GWh/year	0,00	stabili-
Photo Voltaic	1248 kW	1,36 GWh/year	0,00	sation
River Hydro	0 kW	0 GWh/year	0,00	share
Hydro Power	0 kW	0 GWh/year		
Geothermal/Nuclear	0 kW	0 GWh/year		

	Capacities kW-e	Capacities kJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0,39	0,46	
Heat Pump	1253	3759			3,00
Boiler		11408		1,08	
Group 3:					
CHP	0	0	0,40	0,50	
Heat Pump	0	0			3,00
Boiler		0		0,90	
Condensing	0		0,52		

Heatstorage: gr.2:37 MWh gr.30 MWh
Fixed Boiler: gr.2:2,0 Per cent gr.0,0 Per cent

Electricity prod. from	CSHP	Waste (GWh/year)
Gr.1:	0,00	0,00
Gr.2:	0,00	0,00
Gr.3:	0,00	0,00

Regulation Strategy: Technical regulation no. 2
KEOL regulation 20000000
Minimum Stabilisation share 0,00
Stabilisation share of CHP 0,00
Minimum CHP gr 3 load 0 kW
Minimum PP 0 kW
Heat Pump maximum share 1,00
Maximum import/export 50000 kW
20141203-distr-elpris-EUR-dkvest-v1.txt
Addition factor 0,00 EUR/MWh
Multiplication factor 1,00
Dependency factor 0,00 EUR/MWh pr. MW
Average Market Price 39 EUR/MWh
Gas Storage 0 MWh
Syngas capacity 0 kW
Biogas max to grid 0 kW

Fuel Price level:

	Capacities kW-e	Storage MWh	Efficiencies elec.	Ther.
Hydro Pump:	0	0	0,80	
Hydro Turbine:	0		0,90	
Electrol. Gr.2:	0	0	0,80	0,10
Electrol. Gr.3:	0	0	0,80	0,10
Electrol. trans.:	7000	500	0,73	
Ely. MicroCHP:	0	0	0,80	
CAES fuel ratio:	0,000			

(GWh/year)	Coal	Oil	Ngas	Biomass
Transport	0,00	0,00	58,61	0,00
Household	0,00	0,00	0,00	3,86
Industry	0,00	0,00	0,00	5,50
Various	0,00	0,00	0,00	0,00

Output WARNING!!: (5) V2G connection too small

	District Heating: Demand Distr. heating kW	Production Solar kW	Waste-CSHP kW	DHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Ba-lance kW	Electricity Consumption: Elec. demand kW	Flex.& Transp kW	HP kW	Elec-trolyser kW	EH kW	Hydro Pump kW	Production: Tur-bine kW	RES kW	Hy-dro kW	Geo-thermal kW	Waste-CSHP kW	CHP kW	PP kW	Balance: Stab-Load %	Imp kW	Exp kW	CEEP kW	EEP kW	Exchange Payment Imp 1000 EUR	Exp 1000 EUR
January	5444	11	0	0	0	3759	0	1674	0	0	3045	676	2604	3636	0	0	0	16048	0	0	0	0	0	100	598	6685	0	6685	18	218
February	5570	59	0	0	0	3759	0	1750	0	1	2987	676	2621	3636	0	0	0	14218	0	0	0	0	0	100	821	5117	0	5117	21	143
March	4745	82	0	0	0	3758	0	900	0	5	2958	676	2391	3636	0	0	0	14888	0	0	0	0	0	100	469	5696	0	5696	15	169
April	3802	206	0	0	0	3449	0	169	0	-21	2657	676	2020	3636	0	0	0	15072	0	0	0	0	0	100	461	6544	0	6544	14	202
May	2983	230	0	0	0	2737	0	6	0	9	2689	676	1564	3636	0	0	0	16653	0	0	0	0	0	100	197	8285	0	8285	5	228
June	1352	230	0	0	0	1122	0	0	0	0	2820	676	608	3636	0	0	0	15195	0	0	0	0	0	100	175	7630	0	7630	4	330
July	1352	221	0	0	0	1130	0	0	0	0	2555	676	623	3636	0	0	0	15912	0	0	0	0	0	100	204	8625	0	8625	5	238
August	1352	221	0	0	0	1131	0	0	0	0	2967	676	633	3636	0	0	0	16187	0	0	0	0	0	100	205	8480	0	8480	5	258
September	2075	149	0	0	0	1926	0	0	0	0	2953	676	1104	3636	0	0	0	16878	0	0	0	0	0	100	205	8713	0	8713	7	279
October	3091	78	0	0	0	2975	0	28	0	10	2938	676	1733	3636	0	0	0	18372	0	0	0	0	0	100	247	9636	0	9636	7	252
November	4056	24	0	0	0	3708	0	328	0	-4	3079	676	2234	3636	0	0	0	16598	0	0	0	0	0	100	402	7374	0	7374	11	184
December	4842	14	0	0	0	3758	0	1049	0	22	2976	676	2453	3636	0	0	0	15664	0	0	0	0	0	100	462	6385	0	6385	11	130
Average	3383	127	0	0	0	2765	0	489	0	2	2885	676	1713	3636	0	0	0	15984	0	0	0	0	0	100	369	7442	0	7442	Average price	
Maximum	9507	1381	0	0	0	3759	0	5748	0	1628	4574	1352	3821	3636	0	0	0	34642	0	0	0	0	0	100	10443	26780	0	26780	(EUR/MWh)	
Minimum	1184	0	0	0	0	961	0	0	0	-1052	1494	240	338	3636	0	0	0	0	0	0	0	0	0	100	0	0	0	0	38	40
GWh/year	29,72	1,12	0,00	0,00	0,00	24,28	0,00	4,30	0,00	0,02	25,34	5,94	15,05	31,94	0,00	0,00	0,00	140,40	0,00	0,00	0,00	0,00	0,00		3,24	65,37	0,00	65,37	12400	E2629

FUEL BALANCE (GWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste	CAES Elc.ly.	BioCon-version	Synthetic Fuel	Wind	Offsh.	PV	Hydro	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Netto	CO2 emission (kt): Total	Netto
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
N.Gas	-	-	-	-	-	-	-	-	-	-	-	-58,61	-	-	-	-	-	58,61	-	-	0,00	0,00	0,00	0,00	0,00
Biomass	-	-	-	3,98	-	-	-	-	-	-	41,09	-	-	-	-	-	-	-	3,65	5,50	54,22	-119,48	-65,26	0,00	0,00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	36,25	102,79	1,36	-	2,98	-	-	-	143,38	0,00	143,38	0,00	0,00
H2 etc.	-	-	-	0,00	-	-	-	-	-	-23,32	-41,09	64,41	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	-	-	-	3,98	-	-	-	-	-	-23,32	0,00	5,80	36,25	102,79	1,36	-	2,98	58,61	3,65	5,50	197,60	-119,48	78,11	0,00	0,00

08-september-2015 [13:12]

Output specifications 7d. 2030-samsoe-savings 20%+expansion 1+larThe EnergyPLAN model 12.0Ps+sm

District Heating Production

	Gr.1 District heating kW	Gr.1 Solar kW	Gr.1 CSHP kW	Gr.1 DHP kW	Gr.2 District heating kW	Gr.2 Solar kW	Gr.2 CSHP kW	Gr.2 CHP kW	Gr.2 HP kW	Gr.2 ELT kW	Gr.2 Boiler kW	Gr.2 EH kW	Gr.2 Storage kW	Gr.2 Balance kW
January	0	0	0	0	5444	11	0	0	3759	0	1674	0	26618	0
February	0	0	0	0	5570	59	0	0	3759	0	1750	0	26560	1
March	0	0	0	0	4745	82	0	0	3758	0	900	0	25361	5
April	0	0	0	0	3802	206	0	0	3449	0	169	0	19754	-21
May	0	0	0	0	2983	230	0	0	2737	0	6	0	30559	9
June	0	0	0	0	1352	230	0	0	1122	0	0	0	30502	0
July	0	0	0	0	1352	221	0	0	1130	0	0	0	30505	0
August	0	0	0	0	1352	221	0	0	1131	0	0	0	30505	0
September	0	0	0	0	2075	149	0	0	1926	0	0	0	30505	0
October	0	0	0	0	3091	78	0	0	2975	0	28	0	32689	10
November	0	0	0	0	4056	24	0	0	3708	0	328	0	17799	-4
December	0	0	0	0	4842	14	0	0	3758	0	1049	0	10274	22
Average	0	0	0	0	3383	127	0	0	2765	0	489	0	25981	2
Maximum	0	0	0	0	9507	1381	0	0	3759	0	5748	0	37200	1628
Minimum	0	0	0	0	1184	0	0	0	961	0	0	0	0	-1052
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	29,72	1,12	0,00	0,00	24,28	0,00	4,30	0,00		0,02

	Gr.3 District heating kW	Gr.3 Solar kW	Gr.3 CSHP kW	Gr.3 CHP kW	Gr.3 HP kW	Gr.3 ELT kW	Gr.3 Boiler kW	Gr.3 EH kW	Gr.3 Storage kW	Gr.3 Balance kW
January	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0
Average	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00		0,00

RES specification

	RES1 Wind kW	RES2 Offshc kW	RES3 Photo kW	RES 4-7 sic kW	Total kW
January	4238	11788	21	0	16048
February	3603	10552	62	0	14218
March	3770	10983	134	0	14888
April	3788	11055	230	0	15072
May	4282	12098	274	0	16653
June	3802	11084	309	0	15195
July	4059	11582	271	0	15912
August	4143	11805	239	0	16187
September	4411	12302	164	0	16878
October	4936	13347	89	0	18372
November	4385	12172	41	0	16598
December	4060	11582	22	0	15664
Average	4126	11703	155	0	15984
Maximum	11359	23000	1248	0	34642
Minimum	0	0	0	0	0
Total for the whole year GWh/year	36,25	102,79	1,36	0,00	140,40

Own use of heat from industrial CH0,00 GWh/year

ANNUAL COSTS (1000 EUR)

Total Fuel ex Ngas exchange =		2294
Uranium =	0	
Coal =	0	
FuelOil =	0	
Gasoil/Diesel=	0	
Petrol/JP =	0	
Gas handling =	1182	
Biomass =	1113	
Food income =	0	
Waste =	0	
Total Ngas Exchange costs =		0
Marginal operation costs =		3
Total Electricity exchange =		-2505
Import =	124	
Export =	-2629	
Bottleneck =	0	
Fixed imp/ex=	0	
Total CO2 emission costs =		0
Total variable costs =		-208
Fixed operation costs =		4746
Annual Investment costs =		26356
TOTAL ANNUAL COSTS =		30894

NATURAL GAS EXCHANGE

	DHP & Boilers kW	CHP2 CHP3 kW	PP CAES kW	Indi-vidual kW	Trans port kW	Indu. Var. kW	Demand Sum kW	Bio-gas kW	Syn-gas kW	CO2Hy gas kW	SynHy gas kW	SynHy gas kW	Stor-age kW	Sum kW	Im-port kW	Ex-port kW
January	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
February	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
March	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
April	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
May	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
June	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
July	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
August	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
September	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
October	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
November	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
December	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
Average	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
Maximum	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
Minimum	0	0	0	0	6672	0	6672	0	0	0	6672	0	0	0	0	0
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	58,61	0,00	58,61	0,00	0,00	0,00	58,61	0,00	0,00	0,00	0,00	0,00

RES Share: 100,0 Percent of Primary Energ356,6 Percent of Electricity 140,4 GWh electricity from RES 08-september-2015 [13:12]

13.6. 7f. EVs+Biomass hydro DME

Input 7f. 2030-samsoe-savings 20%+expansion 1+large HPs+expansiThe EnergyPLAN model 12.0Vs+Bio

Electricity demand (GWh/year):		Flexible demand	0,00
Fixed demand	25,72	Fixed imp/exp.	0,00
Electric heating + HP	6,95	Transportation	5,94
Electric cooling	0,00	Total	38,62

District heating (GWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	0,00	29,72	0,00	29,72
Solar Thermal	0,00	1,13	0,00	1,13
Industrial CHP (CSHP)	0,00	0,00	0,00	0,00
Demand after solar and CSHP	0,00	28,58	0,00	28,58

Wind	11359 kW	36,25	GWh/year	0,00	Grid
Offshore Wind	23000 kW	102,79	GWh/year	0,00	stabili-
Photo Voltaic	1248 kW	1,36	GWh/year	0,00	sation
River Hydro	0 kW	0	GWh/year	0,00	share
Hydro Power	0 kW	0	GWh/year		
Geothermal/Nuclear	0 kW	0	GWh/year		

	Capacities kW-e	Capacities kJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	0	0	0,39	0,46	
Heat Pump	1253	3759			3,00
Boiler		11408		1,08	
Group 3:					
CHP	0	0	0,40	0,50	
Heat Pump	0	0			3,00
Boiler		0		0,90	
Condensing	0		0,52		

Heatstorage: gr.2:37 MWh gr.30 MWh
Fixed Boiler: gr.2:2,0 Per cent gr.0,0 Per cent

Electricity prod. from	CSHP	Waste (GWh/year)
Gr.1:	0,00	0,00
Gr.2:	0,00	0,00
Gr.3:	0,00	0,00

Regulation Strate(	Technical regulation no. 2	
KEOL regulation	20000000	
Minimum Stabilisation share	0,00	
Stabilisation share of CHP	0,00	
Minimum CHP gr 3 load	0	kW
Minimum PP	0	kW
Heat Pump maximum share	1,00	
Maximum import/export	50000	kW

20141203-distr-elpris-EUR-dkvest-v1.txt

Addition factor	0,00	EUR/MWh
Multiplication factor	1,00	
Dependency factor	0,00	EUR/MWh pr. MW
Average Market Price	39	EUR/MWh
Gas Storage	0	MWh
Syngas capacity	3504	kW
Biogas max to grid	0	kW

Fuel Price level:

	Capacities kW-e	Storage MWh	Efficiencies elec.	Ther.
Hydro Pump:	0	0	0,80	
Hydro Turbine:	0		0,90	
Electrol. Gr.2:	0	0	0,80	0,10
Electrol. Gr.3:	0	0	0,80	0,10
Electrol. trans.:	4000	450	0,73	
Ely. MicroCHP:	0	0	0,80	
CAES fuel ratio:		0,000		

(GWh/year)	Coal	Oil	Ngas	Biomass
Transport	0,00	0,00	0,00	0,00
Household	0,00	0,00	0,00	3,86
Industry	0,00	0,00	0,00	5,50
Various	0,00	0,00	0,00	0,00

Output WARNING!!: (5) V2G connection too small

	District Heating: Demand	Production									Electricity: Consumption						Production							Balance					Exchange: Payment	
	Distr. heating kW	Solar kW	Waste-CSHP kW	DHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Ba-lance kW	Elec. demand kW	Flex.& Transp kW	HP kW	Elec-trolyser kW	EH kW	Hydro Pump kW	Tur-bine kW	RES kW	Hy-dro kW	Geo-thermal kW	Waste-CSHP kW	CHP kW	PP kW	Stab-Load %	Imp kW	Exp kW	CEEP kW	EEP kW	Imp 1000 EUR	Exp 1000 EUR
January	5444	11	217	0	0	3759	0	1674	0	-217	3088	676	2604	2942	0	0	0	16048	0	0	0	0	0	100	482	7219	0	7219	15	234
February	5570	59	217	0	0	3759	0	1750	0	-216	3031	676	2621	2942	0	0	0	14218	0	0	0	0	0	100	684	5631	0	5631	18	157
March	4745	82	217	0	0	3758	0	900	0	-212	3001	676	2391	2942	0	0	0	14888	0	0	0	0	0	100	367	6244	0	6244	12	185
April	3802	206	217	0	0	3449	0	169	0	-239	2700	676	2020	2942	0	0	0	15072	0	0	0	0	0	100	385	7118	0	7118	12	219
May	2983	230	217	0	0	2737	0	6	0	-208	2733	676	1564	2942	0	0	0	16653	0	0	0	0	0	100	139	8877	0	8877	4	244
June	1352	230	217	0	0	1122	0	0	0	-217	2863	676	608	2942	0	0	0	15195	0	0	0	0	0	100	125	8230	0	8230	3	351
July	1352	221	217	0	0	1130	0	0	0	-217	2599	676	623	2942	0	0	0	15912	0	0	0	0	0	100	156	9228	0	9228	4	254
August	1352	221	217	0	0	1131	0	0	0	-217	3010	676	633	2942	0	0	0	16187	0	0	0	0	0	100	158	9084	0	9084	4	276
September	2075	149	217	0	0	1926	0	0	0	-217	2996	676	1104	2942	0	0	0	16878	0	0	0	0	0	100	165	9324	0	9324	5	298
October	3091	78	217	0	0	2975	0	28	0	-208	2981	676	1733	2942	0	0	0	18372	0	0	0	0	0	100	191	10230	0	10230	5	268
November	4056	24	217	0	0	3709	0	327	0	-221	3123	676	2234	2942	0	0	0	16598	0	0	0	0	0	100	302	7925	0	7925	8	198
December	4842	14	217	0	0	3758	0	1048	0	-195	3019	676	2453	2942	0	0	0	15664	0	0	0	0	0	100	378	6951	0	6951	9	142
Average	3383	127	217	0	0	2765	0	489	0	-215	2928	676	1713	2942	0	0	0	15984	0	0	0	0	0	100	293	8016	0	8016	Average price	
Maximum	9507	1381	217	0	0	3759	0	5748	0	1411	4618	1352	3621	2942	0	0	0	34642	0	0	0	0	0	100	9793	27430	0	27430	(EUR/MWh)	
Minimum	1184	0	217	0	0	961	0	0	0	-1270	1537	240	338	2942	0	0	0	0	0	0	0	0	0	100	0	0	0	0	38	40
GWh/year	29,72	1,12	1,91	0,00	0,00	24,29	0,00	4,30	0,00	-1,89	25,72	5,94	15,05	25,84	0,00	0,00	0,00	140,40	0,00	0,00	0,00	0,00	0,00		2,57	70,42	0,00	70,42	9900	E2826

FUEL BALANCE (GWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste	CAES Elc.ly.	BioCon-version	Synthetic Fuel	Wind	Offsh.	PV	Hydro	Solar.Th	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Netto	CO2 emission (kt): Total	Netto
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Oil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
N.Gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biomass	-	-	-	3,98	-	-	-	-	-	-	38,17	-	-	-	-	-	-	-	3,65	5,50	51,30	-130,47	-79,17	0,00	0,00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	36,25	102,79	1,36	-	2,98	-	-	-	143,38	0,00	143,38	0,00	0,00
H2 etc.	-	-	-	0,00	-	-	-	-	-	-18,87	-30,78	49,65	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	-	-	-	-	-	-	-	-	-	-46,67	-	-	-	-	-	46,67	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear/CCS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	-	-	-	3,98	-	-	-	-	-	-18,87	7,39	2,98	36,25	102,79	1,36	-	2,98	46,67	3,65	5,50	194,68	-130,47	64,21	0,00	0,00

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Output specifications   7f. 2030-samsoe-savings 20%+expansion 1+lar(The EnergyPLAN model 12.0?s+sma

District Heating Production

Gr.1

	District heating kW	Solar kW	CSHP kW	DHP kW
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	0	0	0	0
May	0	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	0	0	0	0
November	0	0	0	0
December	0	0	0	0
Average	0	0	0	0
Maximum	0	0	0	0
Minimum	0	0	0	0
Total for the whole year GWh/year	0,00	0,00	0,00	0,00

Gr.2

	District heating kW	Solar kW	CSHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Storage kW	Balance kW
January	5444	11	0	0	3759	0	1674	0	26578	0
February	5570	59	0	0	3759	0	1750	0	26521	1
March	4745	82	0	0	3758	0	900	0	25321	5
April	3802	206	0	0	3449	0	169	0	19741	-21
May	2983	230	0	0	2737	0	6	0	30553	9
June	1352	230	0	0	1122	0	0	0	30496	0
July	1352	221	0	0	1130	0	0	0	30499	0
August	1352	221	0	0	1131	0	0	0	30499	0
September	2075	149	0	0	1926	0	0	0	30499	0
October	3091	78	0	0	2975	0	28	0	32692	10
November	4056	24	0	0	3709	0	327	0	17912	-4
December	4842	14	0	0	3758	0	1048	0	9470	22
Average	3383	127	0	0	2765	0	489	0	25909	2
Maximum	9507	1381	0	0	3759	0	5748	0	37200	1628
Minimum	1184	0	0	0	961	0	0	0	0	-1052
Total for the whole year GWh/year	29,72	1,12	0,00	0,00	24,29	0,00	4,30	0,00		0,02

Gr.3

	District heating kW	Solar kW	CSHP kW	CHP kW	HP kW	ELT kW	Boiler kW	EH kW	Storage kW	Balance kW
January	0	0	217	0	0	0	0	0	0	-217
February	0	0	217	0	0	0	0	0	0	-217
March	0	0	217	0	0	0	0	0	0	-217
April	0	0	217	0	0	0	0	0	0	-217
May	0	0	217	0	0	0	0	0	0	-217
June	0	0	217	0	0	0	0	0	0	-217
July	0	0	217	0	0	0	0	0	0	-217
August	0	0	217	0	0	0	0	0	0	-217
September	0	0	217	0	0	0	0	0	0	-217
October	0	0	217	0	0	0	0	0	0	-217
November	0	0	217	0	0	0	0	0	0	-217
December	0	0	217	0	0	0	0	0	0	-217
Average	0	0	217	0	0	0	0	0	0	-217
Maximum	0	0	217	0	0	0	0	0	0	-217
Minimum	0	0	217	0	0	0	0	0	0	-217
Total for the whole year GWh/year	0,00	0,00	1,91	0,00	0,00	0,00	0,00	0,00		-1,91

RES specification

	RES1 Wind kW	RES2 Offshc kW	RES3 Photo kW	RES 4-7 aic kW	Total kW
January	4238	11788	21	0	16048
February	3603	10552	62	0	14218
March	3770	10983	134	0	14888
April	3788	11055	230	0	15072
May	4282	12098	274	0	16653
June	3802	11084	309	0	15195
July	4059	11582	271	0	15912
August	4143	11805	239	0	16187
September	4411	12302	164	0	16878
October	4936	13347	89	0	18372
November	4385	12172	41	0	16598
December	4060	11582	22	0	15664
Average	4126	11703	155	0	15984
Maximum	11359	23000	1248	0	34642
Minimum	0	0	0	0	0
Total for the whole year GWh/year	36,25	102,79	1,36	0,00	140,40

Own use of heat from industrial CHP0,00 GWh/year

ANNUAL COSTS (1000 EUR)
Total Fuel ex Ngas exchange = 1853
Uranium = 0
Coal = 0
FuelOil = 0
Gasoil/Diesel= 353
Petrol/JP = 0
Gas handling = 0
Biomass = 1500
Food income = 0
Waste = 0

Total Ngas Exchange costs = 0

Marginal operation costs = 3

Total Electricity exchange = -2727
Import = 99
Export = -2826
Bottleneck = 0
Fixed imp/ex= 0

Total CO2 emission costs = 0

Total variable costs = -872
Fixed operation costs = 4849

Annual Investment costs = 24771

TOTAL ANNUAL COSTS = 28748

NATURAL GAS EXCHANGE

	DHP & Boilers kW	CHP2 CHP3 kW	PP CAES kW	Individual kW	Transport kW	Indu. Var. kW	Demand Sum kW	Biogas kW	Syngas kW	CO2Hy gas kW	SynHy gas kW	SynHy gas kW	Storage kW	Sum kW	Import kW	Export kW
January	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
March	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
April	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
May	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
June	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
August	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
September	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
October	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
November	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
December	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
Average	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
Maximum	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
Minimum	0	0	0	0	0	0	0	0	0	0	5313	-5313	0	0	0	0
Total for the whole year GWh/year	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	46,67	-46,67	0,00	0,00	0,00	0,00

RES Share: 100,0 Percent of Primary Energ166,2 Percent of Electricity   140,4 GWh electricity from RES   08-september-2015 [13:12]