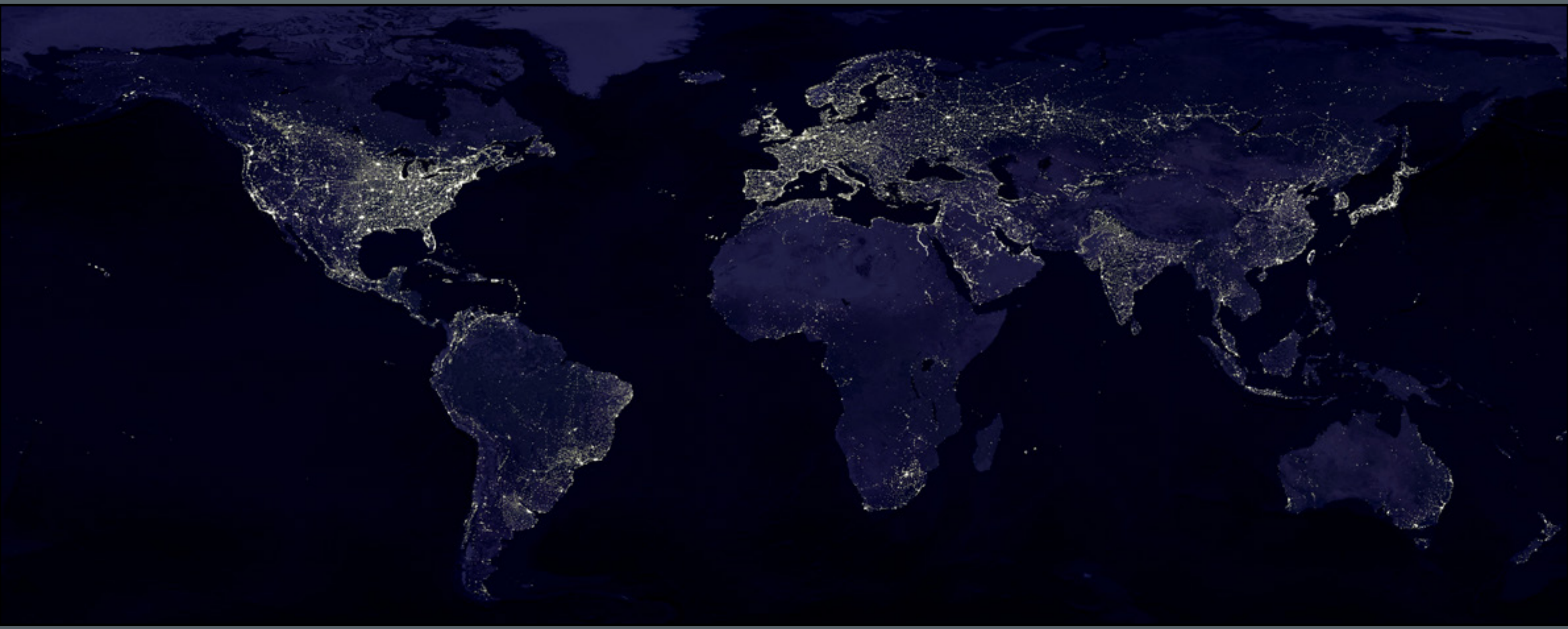
Integrating and Implementing Large-Scale Energy Savings

An Assessment of Suitable Integration Strategies in the current Danish Energy System and the Performance of the Danish Energy Savings Agreement



Master's Thesis

Jakob Zinck Thellufsen
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Abstract

This Master's Thesis investigates how large-scale energy savings should be integrated in the current Danish energy system with an offset in identifying how different types of savings affect each other. This leads to the identification of integration strategies towards a 100 % renewable energy system in 2050. The thesis compares these integration strategies with the Energy Savings Agreement to see whether it can be a driver in implementing the right energy savings.

This is done by having two analyses. The first uses energy system analysis to identify the relations between savings and combines this information with information on energy savings and the 2050 energy scenario to describe the strategies. The second compares the reported savings with estimations of the actual effect of the Energy Savings Agreement, and identifies what strategies the individual utility companies apply and how the agreement has changed the organization of the companies.

The conclusion from the first analyses becomes that the current Danish energy system requires coordination initiatives affecting CHP. The second analysis in comparison with the strategies concludes that while the Energy Savings Agreement does lead to savings it will not result in the displacement of fossil fuels, making it unsuitable for reaching the 2050 target of 100 % renewable energy

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Preface

This project is Master's Thesis concludes the two year M.Sc. program Sustainable Energy Planning and Management at the Department of Planning at Aalborg University. The period for making the thesis was 1st of April 2013 until 8th of August 2013.

The thesis contains nine chapters, which can be divided into four main parts. The first part is the introductory part that includes the introduction, theoretical framework and methodology. The second part is the energy system analysis that analyzes large-scale energy savings in the current Danish energy system. The third part is the assessment of the performance of the Energy Savings Agreement. The fourth and final part contains the two discussions and concludes the project. Fifteen appendices accompany the main report, which include background information and data such as summaries of interviews and input and output of the energy system analyses.

References in the thesis are Harvard Style.

The thesis could not have been carried out without the involvement of certain people. Therefore, the author wants to thank the following persons:
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Table of Contents

1 The Need for Energy Savings

Globally, the total energy consumption was in 2010 based on 81 % fossil fuels, 6 % nuclear and 6 % renewables, which mostly can be accounted to biomass and hydro (International Energy Agency 2012). There are issues with basing an economy on energy supply from coal, oil and natural gas. These issues include the environmental impacts, both regarding contribution to climate change through greenhouse gas emissions, and potential spills when extracting and transporting the resources. A second issue relates to the security of supply, both in terms of fossil fuels being a finite resource that with current proven reserves and production expires in 54.2 years for oil, 112 years for coal and 63.6 years for gas (British Petrol 2012). This also has a geopolitical perspective where the major reserves are located in a few countries, for instance, 66 % of the proven oil reserves are in Venezuela and the Middle East (British Petrol 2012).

Based on these issues, a reduction in the use of fossil fuels has the goal of securing long-term supply of energy, but also decreasing the environmental impacts of oil spills and global warming. Disregarding nuclear power, which carries its own environmental and resource problems, there are two tools for reducing the impacts of fossil fuels. First the option of replacing the current energy production with renewable energy such as wind, hydro and biomass that are either CO_2 -neutral or do not carry any carbon emissions. The second tool is reduction in the energy demand. This thesis separates this into two groups, either through increasing energy efficiency which means that the same service can be provided with less energy, or through energy conservation where energy consumption is reduced through behavior patterns, such as watching less TV or reducing the indoor temperature.

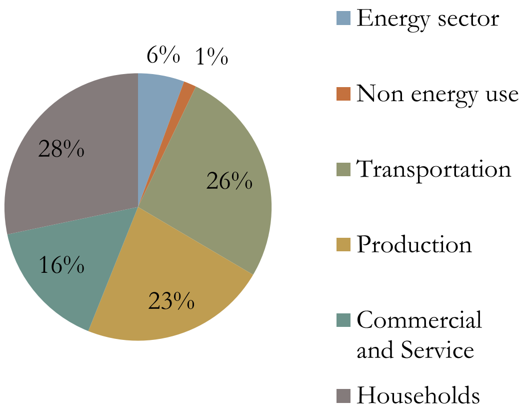

Figure 1.1 Percentage of Danish gross energy consumption divided by sector of use (Energistyrelsen 2012)

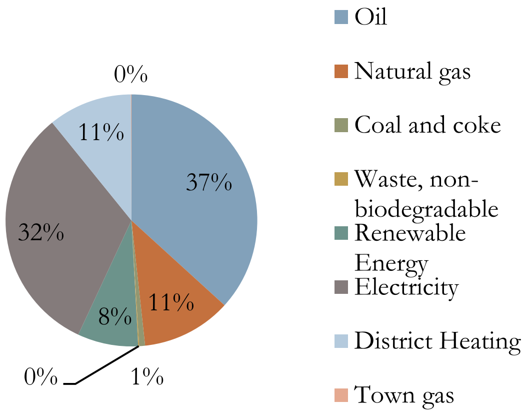

Figure 1.2 Percentage of Danish gross energy consumption divided by energy type (Energistyrelsen 2012)

To establish an energy system without basis in fossil fuels, both energy savings and more renewable energy must be implemented. Renewable energy must provide the needed energy, but by creating lesser demands the switch from fossil fuels to renewables become easier (Lund et al. 2011b). Moving away from fossil fuels has to have a focus on developed countries, which are responsible for over 50 % of the total primary energy consumption in the globe (British Petrol 2012). Therefore, this report focuses on promoting energy savings in the western world, more specifically Denmark as a country within the European Union. The report acknowledges the need for developing and increasing the amount of renewables as well.

The savings needed has to be in the context of the goal of reaching a 100 % renewable energy society. The current gross energy consumption in Denmark was in 2011 807 PJ (Energistyrelsen 2012), Figures 1.1 and 1.2 highlights how it is divided between respectively use and energy type. The Danish Government has a target to make the transition to a 100 % renewable energy system by 2050 (Klima- Energi- og Bygningsministeriet 2012b). Thus, several reports and studies have been made to highlight how such a transition can be made. Included in these scenarios are also targets for reduction in energy consumption. The CEESA study recommends a reduction in primary energy supply to be 669 PJ in 2020, 564 PJ in 2030, 519 in 2040 and 473 PJ in 2050 (Lund et al. 2011b). The Danish Climate Commission is another example of such a study; they have a target that energy savings have to reduce the gross energy consumption to approximately 580 PJ if biomass cannot be imported or approximately 720 PJ if biomass can be imported (Klimakommissionen 2010a). This report is operating with the assumption that other countries want to make a transition towards renewable energy thus making it hard to import large quantities of biomass. As such, the expectation must be, based on these two reports that a reduction of primary energy use between 28 % and 41 % in the Danish energy system is necessary. The next section therefore looks at the current tools implemented in Denmark that focus on increased energy efficiency and motivates conservation.

1.1 Current efforts towards savings and the 2050 goal

The Danish government has installed several tools to promote renewable energy, which directly creates incentive for building carbon free or neutral energy production units. This might be economic schemes subsidizing wind turbines (Klima- Energi- og Bygningsministeriet 2011), or special rules for farmers delivering manure to biogas plants (Ministeriet for Fødevarer Landbrug og Fiskeri 2007)

(Ministeriet for Fødevarer Landbrug og Fiskeri 2007)

. All of these create, through governance systems, a framework for promoting technological change, and all of which are rather direct.

When the focus shifts to energy savings, the Danish Government and the European Union implements the current tools in Denmark are:

- Labeling of appliances, cars and buildings to inform users about energy consumption and possible pollution levels. Thus the consumers can make better decisions but are not forced to make them
- Building codes that defines what standards new buildings must oblige to. These updates regularly but leaves out the vast majority of the building mass, the already built. It does, however directly influence the energy consumption, and potentially a reduction.
- Energy targets for reduction in public and official buildings.
- Yearly targets for reduction in end user consumption, where the current utility companies and the Climate, Energy and Building Ministry organizes savings through the Energy Savings Agreement.
  (Bach 2010)

Of these both the building codes and the energy reduction targets in public and official buildings have a very limited scope, and the labeling of appliances, buildings and cars does not directly create incentive or targets. Only the Energy Savings Agreement between the utility companies and the Danish Government creates a framework that, on paper, allows several types of end users to get involved, and can create incentive and targets to save in industry, households and official buildings. The yearly targets have furthermore increased steadily, from 2.95 PJ in 2006 to 12.2 PJ in 2015 (Transport- og Energiministeriet 2006, Klima- Energi- og Bygningsministeriet 2012a), which highlights the increased emphasis on this tool. A key point is that the Ministry of Climate, Energy and Buildings and the various utility companies in Denmark reaches the targets through a mutual agreement.

The Energy Savings Agreement however puts the sole responsibility of promoting and creating savings on the utility companies; companies that historically have had the sole focus of supplying energy, through fossil fuels, electricity or heat. Potentially a conflict might arise here between the utility companies' primary purpose of producing energy, and on the other hand reducing end user demand, that in the end will decrease the need for production of energy. Thus, this thesis seeks out to identify whether organizing energy savings under the utility companies ends up with the longevity needed to be able to reach the 2050 target of 100 % renewable energy.

1.2 Defining the Problem

The problem that therefore becomes apparent is that first, not many tools exists in Denmark that have a broad target that directly influence the reduction of energy demand. Thus, putting such organizations in place can help reaching the 2050 target. Especially in relation to integrating savings in the right way, because the lifetime of different installments may very between different projects.

Second, there has since 2006 been a system in place that has organized the promotion of energy savings under the utility companies, a model that is now being implemented on a general European Level (Holm 2012). As described, this leads to the question of whether the potential conflict of interest and the target of cost efficient savings results in neither a good organization of energy savings nor the right savings being made.

Therefore, the thesis seeks out to analyze the most suitable way of integrating large-scale energy savings, which sets the basis for assessing the structure of the Energy Savings Agreement, the utility companies' attitudes toward it and the agreements current and potential future impact on the Danish energy system. This helps answering whether there are issues in the current organization of energy savings or if it has created a path towards the 2050 targets. Included in this, the report also seeks out the possibility of changes and alternatives to the organization of energy savings through the Energy Savings Agreement. Since the system has been in place for 6 years in Denmark, the Danish Energy Savings Agreement thus becomes a reasonable case to identify the potential strengths and weaknesses of institutionalizing savings in energy producing companies.

Thus the following research questions guides the flow of the thesis:

How does the Danish energy system effect the integration of large-scale energy savings and what are the consequences in terms of defining suitable integration strategies of savings towards the goal of 100 % renewable energy in 2050. Is the current Energy Savings Agreement helpful towards implementing such strategies?

Some key words to understand in relation this thesis are that integration is the technical aspect and implementation the political and societal aspect. When the thesis applies the terminology "coordination", it assesses savings performed in the same system, which are typically compared with the same savings added together, but not done in the same system. The result of such coordination is sometimes labeled as "synergy" between two activities.

The thesis operates with following main delimitations. It focuses on analyzing the consequences of savings in the current Danish energy system, and this is within three types of savings, electricity, heat and industrial energy. Therefore, the thesis target households, industry, official buildings, commerce and service. It disregards transportation because of the lack of connection to the current energy system. Section 1.3 describes the current Danish Energy system, which is important background information to understand the analysis in the thesis.

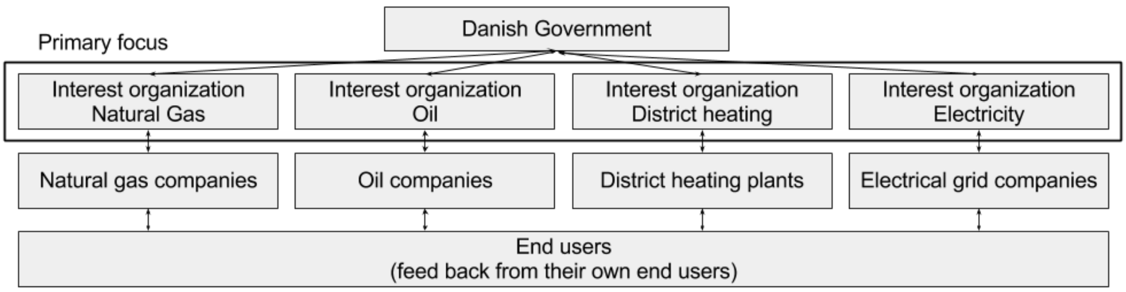

Figure 1.3 Primary focus of the interviews in relation to the Energy Savings Agreement

As the introduction indicates, and Chapter 4 expands on, the Energy Savings Agreement creates a concord between the interest organizations of the utility companies and the Danish government in making the utility companies responsible for energy savings. In the identification of whether the Energy Savings Agreement is helpful towards implementing the 2050 goal, the thesis focus on the involvement of the utility companies by primarily centering on the interest organizations supplemented by information from individual utility companies. Reflections from end-user interest groups are also included. The analysis does not include the perspective of the Government. Figure 1.3 illustrates this delimitation based on Figure 4.1.

1.3 The Current Danish Energy System

Combined heat and power (CHP) production is the primary foundation of the Danish energy system. The system contains two types of plants, centralized CHP and decentralized CHP. In Denmark, 15 central CHP that primarily runs on coal has the primary task of electricity production. Situated around the major cities they also contribute heat to these cities. The decentralized CHP plants also produce both heat and power; however, their primary goal is to supply heat to the local villages, cities and towns and secondary to regulate the Danish electricity supply. This is especially because of the amount of wind power in the Danish energy system. Denmark furthermore also has a number of district heating plants that only produce heat. Furthermore, wind turbines play a significant part in electricity production, and other energy producers such as biomass and waste incineration are a part of the Danish energy system. (Energistyrelsen 2013)

Figure 1.4 show how much electricity the different types of power plants deliver to the Danish energy system. This highlights that centralized CHP, as mentioned, are the primary electricity producers. Around 20 % of the production comes from wind energy, and approximately the same is coming from decentralized and private CHP plants together (Energistyrelsen 2012).

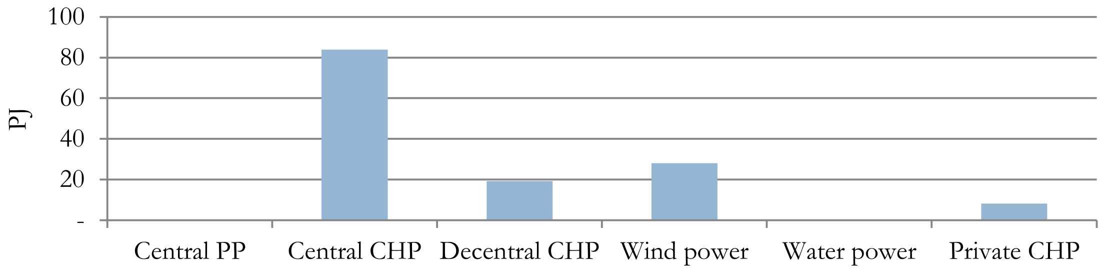

Figure 1.4 Danish Electricity production in 2010 by plant type (Energistyrelsen 2012)

Regarding heat production, a significant part is from district heating produced on either CHP plants or district heating plants (DH). However, there are also individual stoves and boilers that run on oil, biomass or gas. Figure 1.5 shows the district heating production, which identifies that unlike the electricity production, the central CHP plants are responsible for the less than half of the heat production. Instead, both decentralized CHP and dedicated district heating plants combines for a production of 57 PJ, and privately owned CHP and DH produces over 20 PJ together (Energistyrelsen 2012).

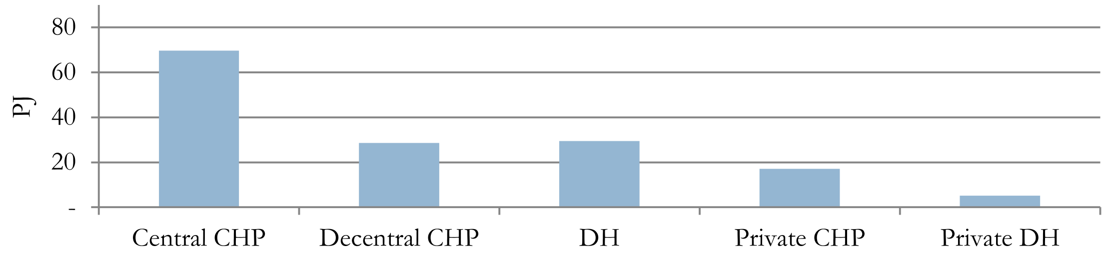

Figure 1.5 Danish district heating production in 2010 by plant type (Energistyrelsen 2012)

It is also important to understand how different groups use the energy. This thesis focuses on energy used in households, industry, commerce and official buildings. Therefore, Figure 1.6 shows the consumption in each of these sectors based on how they get their electricity and heat.

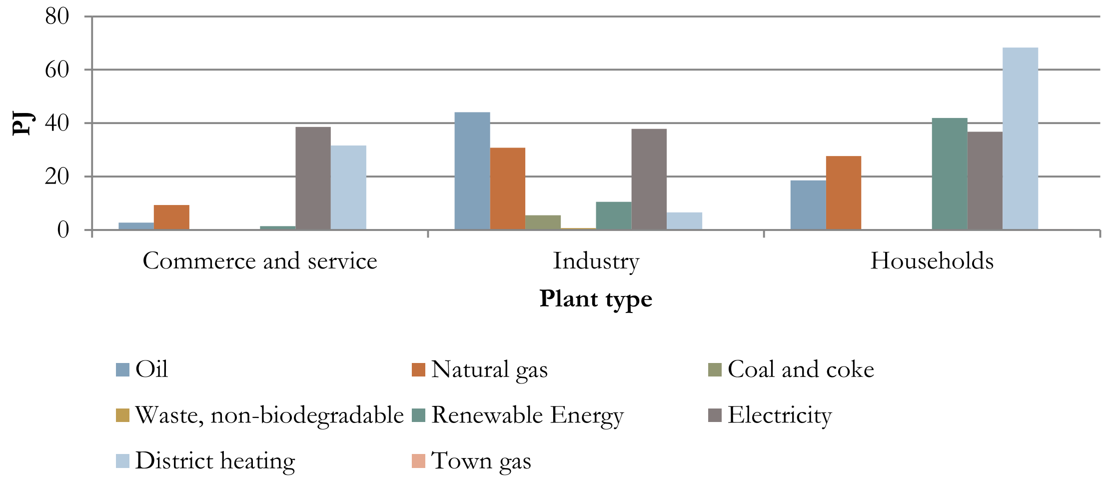

Figure 1.6 Danish net energy consumption in households, commerce and service, and industry in 2010 divided by fuel type (Energistyrelsen 2012)

Figure 1.6 illustrates that all three sectors have a rather equal consumption of electricity. However, the three sectors use energy for heating very differently. Regarding commerce and service district heating provides almost all heat, with a little amount of individual heating from natural gas and oil. In households district heating also plays an important role but here there is also a huge individual heating demand from oil, natural gas and biomass stoves. In industry, district heating supply almost none of the heat demand. Instead, individual oil and natural gas boilers, with a slight use of coal and biomass, provide the heat and energy needed.

This difference becomes very relevant when defining how to make savings, because different end-users have different needs and therefore uses different types of fuels. Thus, there might be a need for applying different strategies depending on whether doing savings in individual heating scenarios or in many small households connected to a larger district-heating grid. The Danish energy system thus is a system that very much relies on coordination between heat and electricity production, but also where energy used in industry is largely individual supply.

CEESA and the Climate Commission both suggest scenarios for how the Energy System should look like in 2050. The 100 % renewable energy system in 2050 is according to them based on a large integration of heat pumps to supply both individual and district heating. The electricity production comes from primarily wind turbines and solar panels, supplemented from electricity production from CHP running on biogas. Biomass is in both scenarios ideally reduced to only industrial energy and a very little amount in. The amount of energy delivered from district heating is furthermore increased in both studies. (Lund et al. 2011b; Klimakommissionen 2010a) These assumptions are important in relation to identifying strategies that have to move towards a 100 % renewable energy system. Figure 1.7 show the primary energy supply in CEESA 2050.

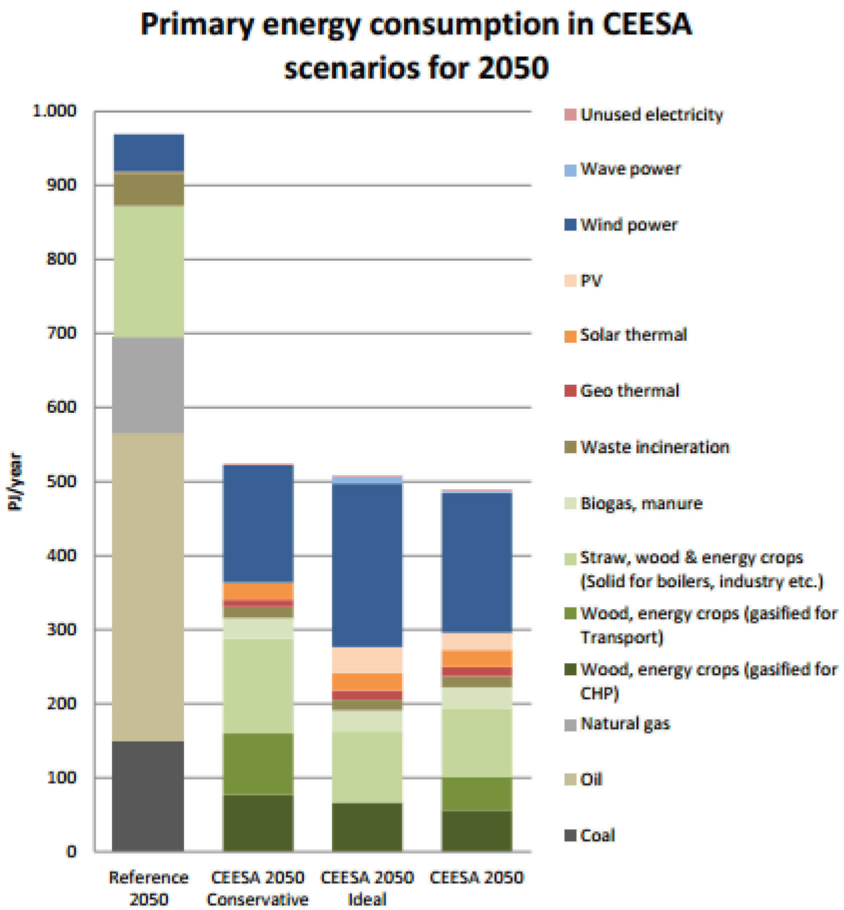

Figure 1.7 Primary energy supply for CEESA 2050 (Lund et al. 2011b)

2 Theoretical Framework

Conducting energy savings both in form of efficiency increases and conservation forms the point of departure for the report. As highlighted in the research question, this thesis has both a focus on developing the right type of energy savings and assessing whether the current level of implementation moves the energy system towards these types of savings. Therefore, this chapter has two sections, one focusing on the theory behind developing a system to define the right type of savings, and the other focusing on creating a theoretical framework for the implementation of energy savings.

2.1 Framework for Defining the Technological Approach

When analyzing the right way of integrating energy savings the goal is to have a holistic approach to the energy system. This means that to identify the right amount of savings on a large scale, one has to take into account the context of the whole energy system. Therefore, heat savings might mean different things when being done in district heating produced by combined heat and power plants compared to systems where CHP is not as predominant.

This holistic approach of taking several aspects of the energy system into account has been important when creating models for the integration of renewable energy. Lund (Lund 2009) has applied this when identifying both large-scale integrations of renewable energy and when building 100 % renewable energy scenarios. These cases highlights how it is relevant to understand both the technology itself, but also how it reacts in the energy system. Thus, implementing wind power has to be in comparison with available storage techniques, the amount of combined heat and power in the system and the electricity demand. From these studies, one of the main points is that the implementation of renewable energy should not be by blindly expanding the amount of wind energy in the system. (Lund 2009) Instead, to reach a large-scale integration of renewable energy much more efficiently, the objective should be to have an understanding of the whole system and technologies through a holistic approach.

This thesis expands this holistic approach towards energy savings. The argument is that to understand the integration of energy savings in the energy system, the context becomes just as relevant as the savings. This holistic approach means that not only are energy demands reduced to lower the energy needed, the goal is also to see effect on the energy system when less energy is needed in certain areas.

Just as in the Lund (2009) cases, by understanding the right way of integrating savings in an energy system, it can lead to a more efficient implementation where in fact fewer initiatives are needed, if they are done in the right way.

Another element is when pairing energy savings with the expansion of renewable energy other conflicts might emerge. In those cases, this also has come into account, when identifying a suitable way of integrating savings. However, this thesis primarily focus on savings as a separate issue, although it recognizes that it has to go hand in hand with an increased amount of renewable energy if the goal is a 100 % renewable energy system in 2050.

The overall hypothesis from this framework is that it becomes very important to identify how the different elements in the energy systems affect each other, also called synergies in this report. Through that, the needed savings in primary energy supply can happen in a way that does not require the same demand reduction compared to if the identification of synergies had not happened. These synergies have to be looked at both in terms of different energy types but also between different end users.

2.2 Framework for the Implementation of Large Scale Energy Savings

Chapter 1 mentions that the amount of savings required reaching the 2050 target of 100 % renewable energy is rather big, with a need for reducing the primary energy supply by almost 50 %. Therefore, this thesis argues that savings of this amount require technological change, since such an increase most likely is going to alter the way man reproduces and expands its living conditions (Lund 2009, 20). As such, technology and technological change, both radical and non-radical, creates the foundation for this section. To supplement this, elements of institutional and organizational understanding and governance systems are also included. Based on these, this section ends with four hypotheses based on technology changes, organizations and implementation. The later analysis thus seeks to show whether the current performance of the utility companies confirms this theory.

2.2.1 Technology and Technological Changes

Müller, Remmen and Christensen (1986) define technology as consisting of four elements, technique, knowledge, organization and product. Technique covers the performance needed to produce the technology such as work processes and tools. Knowledge is the practical knowhow and scientific insight required for the technology. Organization spans two different concepts, both the technical organization of the production phase and the social organization. Finally, the product is the result of these other three elements.

In this framework, the understanding can be on both a micro level in a local company and a macro level that ties to bigger systems, such as the energy system (Müller, Remmen & Christensen 1984). On a macro level, the concept becomes more abstract but the four elements still works in larger systems. This thesis is using the macro understanding of technology to identify the concepts of changing technology. The current energy system represents one technology, which has certain production techniques, certain practical and scientific knowledge, certain production organization between the various plants, and the final product of energy. An energy system with the integration of large amounts of savings is a different technology, the product is still delivering energy, but it is at a much smaller amount. The expectation should be that such an energy system require at least some different techniques and different knowledge about the energy system. The question is whether the same organizations can be responsible in both types of systems. Therefore, it becomes relevant to look at the elements of technological change.

Müller, Remmen and Christensen (1986) reach a number of technology theoretical theses. In regards of technology change the first one become very relevant, translated it states:

> *"The four elements of technology are connected in such way that a qualitative change in just one of the elements will require a qualitative change in the other three elements."*
> *(Müller, Remmen & Christensen 1984, p. 25)*

These changes might not happen right away, but they have to happen, otherwise the argument is that the change in technology will fail. This statement becomes important towards understanding what it takes to move from a current energy system towards to one with a largely reduced energy demands. This means that not only is a change in technique and knowledge needed, this statement argues that all elements have to follow hence a change in the organization of the energy system is important too.

Lund (2009) applies a different interpretation, and limits the argument towards that if one of the four elements in technology changes, at least one of the other elements has to follow as well. He, based on Hvelplund, however has a concept of radical technological change. A radical technological change is when two or more of the elements changes at the same time. (Lund 2009) Within this framework, the move towards a system with large amounts of energy savings is a radical technological change.

One of the main emphasis in understanding radical technological changes is that they need a different organization to be successful. Therefore, organization becomes more emphasized than what was the case in Müller, Remmen and Christensen. Lund and Hvelplund are making these arguments within an energy context and specifically with the argument that the current organization of utility companies cannot handle a large integration of renewable energy (Lund 2009). These assumptions therefore become relevant to include in understanding whether the current organization of utility companies can handle large amounts of energy savings in relation to the 2050 goal. The argument furthermore is that the current organizations have established themselves without a desire to change technologies, thus seeking to maintain the status quo. This draws comparisons to what Müller, Remmen and Christensen calls a radical monopoly, which is when the extent on one technology hinders the demands and needs of others (Müller, Remmen & Christensen 1984). In other terms, one technology might exclude other technologies. Therefore, the next section delves into the possibility of changing the organization, and identifying how the current players seek to maintain a technological status quo. This is specifically from an energy system point of view.

2.2.2 Maintaining the Status Quo and Changing Organizational Structures

It is important to understand that both maintaining the technological status quo or technological change with changes to the organizational structure is reliant on the political, historical and institutional context. Here, Lund argues that this context often favors the existing technology. Therefore, companies who exist and succeed within the current technological system will seek to maintain the current institutional structures. (Lund 2009)

This observation becomes very relevant when working within the energy system and energy savings. District heating plants, large-scale CHP plants, and oil and gas companies supplying individual households operates the current energy supply system in terms of both electricity and heat production. The Energy Savings Agreement centers on the same organizations and makes them responsible for energy savings. Therefore, an argument could be that by giving the plants the responsibility for savings, the technology change needed for having a reduced energy demand cannot be reached. It therefore becomes relevant to look into whether the companies are changing their organization or if the current Energy Savings Agreement instead is as a strategy towards maintaining an institutional status quo, thus maintaining a technological status quo.

Hvelplund (2001) identifies an example of how current utility companies maintain their own position by accepting a system that requires renewable energy quotas instead of creating a market. Hvelplund compares a system where a political determined price for wind energy determines the right amount to invest in, with a system that determines the amount of wind energy and let the market determine the price. Hvelplund (2001) concludes that the latter model plays into the hand of the already established companies, which leads to fewer investments. On the other hand, the political determined price leads to a more open market with new investors, which leads to an organizational change that in turn results in more investments in wind energy. (Hvelplund 2001) As such, the decision on which governance system to choose affects both the concrete production result but also determines the organizational and institutional context. These conclusions become relevant to remember because the current Energy Savings Agreement resembles a quota system, although a notation must be that there are key differences such as the saving targets in the Energy Savings Agreement are fixated to the utility companies, where there are no official bindings in the system described by Hvelpund (2001).

2.2.3 Framework and hypotheses

Based on Section 2.2.1 and 2.2.2 this leads to a certain set of hypotheses that this thesis have to test, when it comes to the implementation of a technological change that leads towards a system with large reductions in energy demand that relates to the 2050 goal of 100 % renewable energy

First, all elements of a technological system must change, but certain emphasis must be put on the organizational change.

Second, because of the first hypothesis it becomes relevant to identify whether the organizations are changing and if so if that change results in reduced energy demands.

Third, the activity of the current organizations might not focus on reducing energy demand the right way but instead towards protecting themselves and maintaining a technological status quo.

Fourth, the Energy Savings Agreement might be set up in a way that gives the utility companies a possibility of maintaining the status quo.

These hypotheses define the main framework for the analysis of the current implementation of energy savings under the Energy Savings Agreement. The hypotheses base themselves on the available theory and as such, the thesis sets out to test them, not to confirm them.

2.3 Choice Awareness and Alternatives

Sections 2.1 and 2.2 highlight how this thesis needs both a framework for the technological determination and a framework for the societal implementation. The concepts of a holistic system approach and technological change is in line with Choice Awareness theory, which makes it relevant to highlight a few concepts from this theory as it helps framing the content after determining the technological integration and societal implementation. Choice Awareness theory bases itself on a couple of statements, the first one resembling the hypotheses in this thesis.

> *"When society defines and seeks to implement objectives implying a radical technological change, the influence and discourse of existing institutions will affect the implementation. Such impact will hinder the development of new solutions and eliminate such alternatives and will seek to create a perception indicating that society has NO CHOICE but to implement technologies which will save and constitute the existing positions." (Lund 2009, p. 48)*

This quote also identifies the key component of Choice Awareness, it seeks to create choices and move away from situations where existing institutions limits the development of new technology. This thesis mainly uses this element of choice awareness as an overall framework, but in the later parts, it lends from the methodological approach of the theory.

To create choices, Choice Awareness operates with four elements, where the three first rests on top of the fourth element, as Figure 2.1 illustrates. The first three elements are; design of concrete technical alternatives, feasibility studies based on institutional economics, and public regulation measures. The fourth element is the promotion of a new democratic infrastructure.

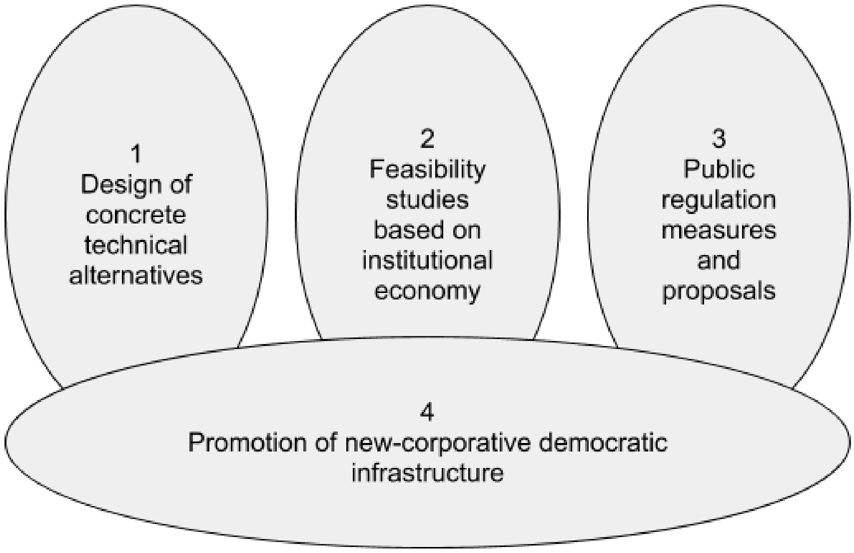

Figure 2.1 The concept of Choice Awareness (Lund 2009)

The thesis has a technical approach but it does not analyze technical alternatives. However, it does implement the key concepts of a holistic approach to the energy system. The report leaves out the economic element due to time restraints. It does however focus on public regulations but primarily analyzes the current Energy Savings Agreement. The last element is also present in the report as the hypotheses in Section 2.2.3 partly seeks to identify whether the Energy Savings Agreement is an institutional change or if it instead functions as a way of maintaining the status quo, and by that testing the democratic infrastructure that creates the foundation for the Energy Savings Agreement.

It is important to note that Choice Awareness in all four elements seeks to identify alternatives and suggestions (Lund 2009). Because of the resemblance with the background for Choice Awareness and the theoretical framework in this thesis, this thesis suggests changes in relation to the critique of the Energy Savings Agreement. These suggested changes might make it easier to realize the technological change needed to have an energy system with a heavily reduced energy demand that is in line with the 2050 goal.

3 Methodology

This chapter focuses on creating the methodology of the analyses so the thesis can assess and answer both the research question and the hypotheses. Chapter 1 and 2 argues that the thesis has both a technical aspect where a suitable integration strategy of energy savings is the target, and a qualitative assessment that seeks to identify the implementation of the savings with a basis in the current Energy Savings Agreement. The goal is to analyze whether the Energy Savings Agreement is a suitable tool towards reaching the identified integration strategy. To make this connection it becomes relevant to understand the elements and paragraphs in the Energy Savings Agreement. Chapter 4 therefore describes the targets and tools stated by the Energy Savings Agreement.

Chapter 5 covers the technical aspect of the report. This has the target of analyzing the coordination of different energy savings with the goal of reaching the most suitable integration of energy savings. The savings analyzed revolves around two types of activity, demand reductions and conversions, because these are within the framework of the Energy Savings Agreement. This therefore has to be in context with the holistic approach that takes into account the whole energy system. By applying a holistic approach with the goal of identifying synergies between different types of savings, this thesis seeks out do something that normally is not the focus when looking at energy savings. Typical the focus of analyses done on energy savings revolve around what the potential of this type of savings is, in example Wittchen (2009) that covers the potential of savings in the existing building mass (Wittchen 2009). This thesis does not try to identify potentials but instead looks specifically at how different types of savings affect each other when done in the same system. Chapter 5 therefore covers the first analysis, which is an energy system analysis of energy savings. The calculations made in Chapter 5 primarily focus on the effects between different types of savings, in example heat savings and electricity savings, and the effects in conversions from individual heating to district heating and savings in other sectors. It is important to note that a coordination between savings and installation of renewable energy also makes sense to analyze, but these are only qualitatively described in this thesis, since the primary focus are on savings and how governance tools can create an increased amount of suitable amount of energy savings in relation to the 2050 goal. Chapter 5 therefore identifies suitable integration strategies of renewable energy by calculating them in a Danish context with the goal of analyzing the performance of the Energy Savings Agreement. This analysis is based on data from CEESA and the Climate Commission.

Chapter 6 measures the performance of the Energy Savings Agreement both on an overall scale and divided by each sector of utility companies in the Danish energy system. This analysis has to elements. The first is a comparison between the savings, both the reported number and a number corrected for some of the potential errors in the Energy Savings Agreement, and the strategy identified in Chapter 5. This comparison primarily focuses on the overall level of Energy Savings Agreement, but also identifies what savings each group of utility companies makes. Based on the numbers for each group of utility companies the second part of the analysis becomes the identification of whether the companies implement certain strategies when they perform savings. This part of the analysis thus includes numbers for the performance of each energy sector, but more importantly analyzes results from interviews with representatives from each energy sector. This qualitative approach helps answering the hypotheses stated in Chapter 2 on, whether current organizations can be involved in promoting technology change or if they apply protective schemes and tries to maintain the status quo. The data for this analysis comes from interviewing the interest organizations for the utility companies and data over the utility companies' performance.

The discussion phase covers Chapters 7, 8 and 9. Chapter 7 discusses the connection between Chapters 4, 5 and 6 and highlights the elements where the Energy Savings Agreement performs well, and where the Energy Savings Agreement does not perform desirably. Here some suggestion towards change are therefore also suggested, which is partially based on interviews with outside actors.

Chapter 8 discuss how the report helps in solving the identified problem, with a focus on connecting the analyses with the theoretical framework and hypotheses, and discussing the uncertainties in the analyses. Chapter 9 concludes the report by presenting the main findings and answering the research question. Figure 3.1 sketches this overall structure.

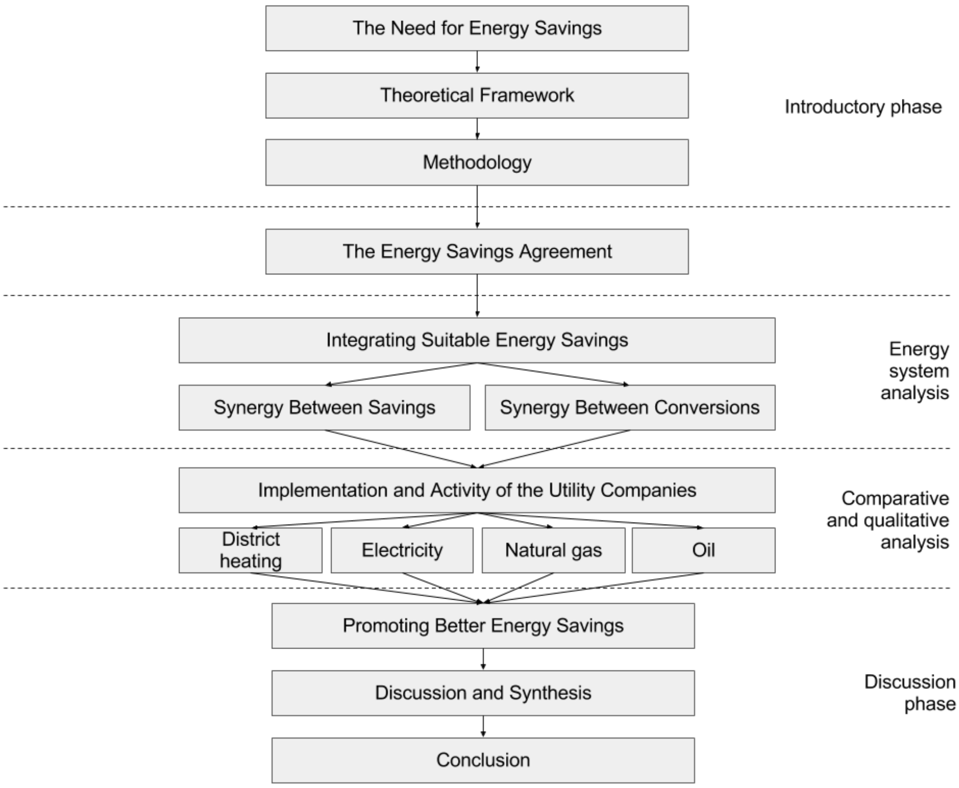

Figure 3.1 Report structure

To be able to follow this structure and conduct the described analyses three methods act as the primary tools. These are literature studies, energy system analysis and interviews. Section 3.1, 3.2 and 3.3 describe each of them representatively, how they are used and the more concrete formation of energy systems and questions that lies within the theoretical framework.

3.1 Literature Studies

The report uses literature studies throughout, but it has four main uses. First, when establishing already existing theory on which the theoretical framework of this thesis is established, and second, when characterizing background information regarding both the Danish energy system and the potentials for energy savings. The third use of literature studies is used for the description of the Energy Savings Agreement, where reviewing the three editions of the Energy Savings Agreement and gathering results from other reports on the Energy Savings Agreement become relevant. The final use of this methodology is in gathering data for building energy systems for the energy system analyses.

In this report, literature studies is a broader term for secondary data, which means that it covers not only written material but also certain kinds of outreach such as email and interviews without character of analysis. This means personal correspondence where the sole purpose is gathering data. Therefore, data gathering is within the context of literature studies. The data on the Energy Savings Agreement received from the Danish Energy Agency is an example of this.

The sources of literature used in this thesis primarily covers legal material, data from the Danish Energy Agency, scientific material in form of articles and theses, other statistical data and reports on Danish energy systems, potential for savings and renewable energy scenarios in 2050.

3.2 Energy System Analysis and EnergyPLAN

The goal of the energy system analysis is to test a methodology for identifying suitable amount of savings and calculate this within a context of the Danish energy system. Energy system analysis exists in both large-scale and small-scale perspective, but the focus of this thesis is a large-scale analysis that applies the holistic approach mentioned in Chapter 2.

To do these kind of large-scale analyses several tools are available, but since the need in this thesis is calculations where quick change can be made without necessarily having the right numbers needed it applies the tool EnergyPLAN. EnergyPLANs main purpose is to assist in modeling energy strategies both in current systems towards future scenarios, and it works on regional and national level (Lund 2009). As such, it fits within the need of this thesis. Furthermore, EnergyPLAN has the purpose of analyzing radical technological change, which is also in line with the theoretical framework of the thesis. The final reason for choosing EnergyPLAN over other tools is that it allows for including all energy sectors, and optimizes on a technical parameters that focus on the whole system. This is important when creating an understanding for relations between savings in different sectors of the energy system. Section 3.2.1 describes the EnergyPLAN tool in more details.

Because the thesis approaches energy saving from the perspective of how they affect each other in relation to the energy system, which other studies have not focused on, it becomes necessary to define an approach for such measurements. This becomes with the intention of identifying integration of suitable large-scale energy savings.

The first step necessary is to identify what system to model the energy savings in, and hereafter model conceptual savings to identify how the savings and the system reacts to each other. In this step, it becomes relevant to understand the uncertainties of the model system, thus preferably these calculations should be made in multiple representations of the energy system. The result of this step should be the identification of strategies and operations within the current energy system.

The second step is the identification of potentials for savings. These partly have a basis in the feasibility of the savings and technological possibilities. This identification of potentials is the typical focus when assessing the implementation of energy savings, but they have to relate to the system context. For instance, when including possible synergies between electricity and heat savings.

Step 3 becomes the integration of steps 1 and 2. Based on the potentials and strategies, the third step models the implementation of the actual potentials. Here it becomes important to identify the strategy for rate of implementation towards reaching the best performance. This requires both coordination with possible changes to the energy system, which might also alter the results from step 1 and 2, but also the way the end-users act in terms of performing savings. In a Danish context, step 3 is in relation to the implementation of 100 % renewable energy system in 2050. Therefore, step 3 makes this approach into an iterative process, where compromises between savings, energy production and potentials have to be found. Therefore, the result cannot produce one precise answer, which is also in line with the holistic approach.

All of these approaches are an analysis in itself, and to answer the research question in this thesis only step 1 is necessary to perform. Therefore, this thesis identifies relations and synergies between different types of savings and conversions in relation to the current Danish energy system. The thesis includes perspectives in relation to the other two steps, meaning assessed potentials and information on the energy system in 2050. However, the information is not reached under the condition of steps 2 and 3.

The calculations made therefore have the primary focus of establishing possible synergies between how different saving types affect each other in the current energy system. This makes it possible to compare between the strategy identified and the performance of the utility companies in accordance with the Energy Savings Agreement.

To do this the calculations implement two models of the current energy system. The thesis does not base the calculations on forecasts, projections and potentials as it has a qualitatively description of these in Chapter 5. The calculations have the goal of identifying synergies, thus the numbers are conceptual and not rooted in already established analyses. This is the reason for using two systems when calculating the primary effects and synergies. Since the numbers are not from other studies, it does not make sense to test the sensitivity of the numbers. Instead, because of the holistic approach, the thesis tests for the system sensitivity.

The models used for the current energy system bases themselves on the CEESA report and the Climate Commission's report. Section 3.2.2 describes the model based in CEESA and Section 3.2.3 describes the model based on the Climate Commission.

3.2.1 The Use of EnergyPLAN as a Modeling Tool

EnergyPLAN is an input/output model, which means that by inputting certain energy data such as demand, installed capacities and efficiencies it calculates the outputs of the energy system such as primary energy supply (PES), CO_2 emissions, costs and renewable energy share (RES).(Lund 2009) This thesis measures the performance based on the three mentioned parameters, PES, CO_2 emissions and renewable energy share. This is based on the goal of a 100 % renewable energy share in 2050, which has to be reached by lowering the primary energy supply, decrease CO_2 emissions and increase the RES. The better performance in terms of this, the better the system operates.

EnergyPLAN works deterministic which means that the same inputs always results in the same outputs. EnergyPLAN generates these outputs based on hourly data, thus it takes into account that demand shifts between night and day, and between winter and summer. EnergyPLAN aggregates the different energy types into one, for example, it shows all installed wind energy as one number. It does, however divide district heating into three categories to allow for some differences, district heating group 1 contains district heating plants without electricity production, district heating group 2 are decentralized CHP plants and district heating group 3 are centralized CHP. (Lund 2009) This is an advantage for the analysis needed in the thesis because it allows for rather quick calculations with the possibility of changing each technology quickly. EnergyPLAN can optimize based on the operation of a system instead of investments. This is very important when calculating the technical most suitable integration strategy.

Therefore, to build a model of an energy system in EnergyPLAN it becomes important to first define the energy demands, which includes electricity demand, demand for district heating divided into three district heating groups, demand for individual heating based on different fuel types, demand in industry and transportation is needed. (Lund 2009)

After this, the next step is building the reference scenario, this means inputting the installed capacities of power and heat production, both in individual and district heating scenarios. In addition, add the installed capacities of renewable energy and other energy-producing units. Furthermore, the overall efficiencies of each energy producing element has to be included and also the division between fuel types used in power and district heating plants are important. (Lund 2009)

By choosing an operation strategy, the model balances each energy type towards reaching the desired optimum. (Lund 2009) EnergyPLAN includes various technical and economical optimization strategies but the one used for the analyses in the thesis is Technical Regulation Strategy 3, which balances both heat and electricity demands (and reduces CHP when partly needed for stabilization). This strategy is preferred because it fits estimating the technical most suitable amount of savings.

Based on these inputs it is important to test the reference system up against already established numbers. This can be, and are, done by comparing the outputs with the Danish Energy Agency's yearly statistics.

The way of calculating energy savings in EnergyPLAN is to change the defined energy demands. This means that electricity savings are reductions in electricity demands, heat savings are reductions in demands in district heating and demands in individual heating. By reducing the demand for fuel in industry, the savings here are calculated. To identify the effects between these kinds of savings, the method is to first calculate savings done in each sector one by one and measure the effect of these. Hereafter, the goal is to combine savings in the same system and again measure the effect. By comparing these results, it becomes visible where savings have to be coordinated and where a more individual path could be suitable.

The thesis applies the same approach when trying to identify strategies for conversions between different fuel types and savings. However, to model conversions, the goal is to maintain the same energy demand, but transfer it between the fuel types. The focus of conversions targets the heating sector. In these cases, it becomes relevant to have the efficiency between different energy types in focus. Since the goal is to maintain a demand, it might need more fuel to apply a different technology.

The next two sections describe the two models used for the calculations.

3.2.2 The CEESA Model

The Coherent Energy and Environmental System Analysis, or CEESA, is a study made by researchers that seeks to identify how to implement a 100 % renewable energy scenario (Lund et al. 2011b). For this, several energy system analysis were made, but this thesis primarily targets the 2010 reference system. (Lund et al. 2011b). Towards 2050, CEESA targets a reduced energy demand, all energy coming from renewable energy sources, and that the system prefers heat from heat pumps compared to biomass, since biomass have some problems in terms of availability and indirect land-use change.(Lund et al. 2011b)

Because CEESA uses EnergyPLAN to calculate the scenarios, there has not been a need for modeling the reference scenario. Instead it uses the already build model. The only exemption to this is that the thesis defines a certain amount of electricity used for heating in the 2010 scenario, because traditionally in CEESA, electricity for heating has been a part of the overall electricity demand. This is key when calculating savings in individual electrical heating, and conversions from electrical heating to other fuel types. The number subtracted from the overall electricity demand and added to the heat demand in electrical heating is 1.94 TWh, which originates from the estimate made in the Climate Commission's report (Risø DTU, Ea Energianalyse 2010a). Otherwise, the system is the same as is used in CEESA. Appendix A shows the input and output pages from the CEESA 2010 model. Some of the key numbers from the 2010 model can however be seen below in Table 3.1 where it is compared to the actual numbers from 2010 as measured by the Danish Energy Agency.

The goal for the model is to come rather close to the given year, but because the EnergyPLAN has certain calculation methods, a precise correlation can be hard to reach. Therefore, these numbers just have to show a rather precise correlation that indicates that the system resembles the Danish energy system.

	CEESA 2010 Model (Lund et al. 2011a)	Danish Energy Agency 2010 – climate corrected (Energistyrelsen 2012)	Danish Energy Agency 2010 – actual numbers (Energistyrelsen 2012)
Electricity Demand	35.62	31.87	32.12
Individual heat demand [TWh]	23.90	27.703	30.89
District heating demand [TWh]	35.87	29.61	32.98
Industry fuel consumption [TWh]	36.03	25.48	26.06
PES [TWh]	241.49	226.30	233.41
- Oil	102.63	86.34	87.33
- Renewable energy	44.87	45.74	47.23
- Natural gas	50.35	48.88	51.19
- Coal	43.63	40.80	42.89
RES [%]	18.58	20.21	20.23
CO_2 emissions [Mton]	53.67	47.21	49.60

Table 3.1 Primary inputs and outputs from CEESA 2010 reference model

3.2.3 The Climate Commission Model

The Danish Government established the Climate Commission with the goal of creating a 100 % renewable energy scenario in 2050 because of security of supply and release of CO_2 into the atmosphere (Klimakommissionen 2010b). The Climate Commission consists of researchers from various Danish universities. As such, the overall goal was the same as in CEESA, but the tools used are somewhat different and slightly different assumptions acts as foundation for the suggested 2050 scenarios. The key differences are that CEESA is more pessimistic in term of the available biomass that results in CEESA requiring a larger overall reduction in primary energy supply, and that international flights and shipping are not included in the Climate Commission's energy system.

The Climate Commission uses several tools to model their energy system, but none of them is EnergyPLAN. Among others, they use STREAM and Balmorel. (Risø DTU, Ea Energianalyse 2010a). Both of these have slightly different functions than EnergyPLAN, so to be able to calculate and compare the two models this thesis converts the Climate Commission model into EnergyPLAN. Some of the inputs are easier to transfer while certain assumptions create the bases for other inputs. Appendix B describes the modeling of the Climate Commissions

2008 reference model in EnergyPLAN. The demands are all based in the Climate Commission numbers, but because certain inputs such as fuels for the different CHP plants and boiler efficiencies are lacking from the description, these have been taken from the CEESA report. This creates some similarities between the two systems, but the assessment is that transferring these numbers do not have great influence on the system, and the uncertainties relates to the demands instead.

Appendix C shows the result of the final energy system after tweaking the numbers to fit. Table 3.2 below show the key parameters comparable to the ones in Table 3.1. Table 3.2 compares the output from EnergyPLAN with the output from the Climate Commission. These are cross-referenced with the actual numbers from the Danish Energy Agency in 2008.

The systems described in Section 3.2.2 and 3.2.3 thereby creates the foundation for the analysis in Chapter 5, together with the CEESA system representing year 2050.

	Climate Commission EnergyPLAN	Climate Commission actual numbers (Risø DTU, Ea Energianalyse 2010a)	Danish Energy Agency 2008 (- air travel and shipping) (Energistyrelsen 2012)
Electricity Demand	33.12	33.06	33.23
Individual heat demand [TWh]	32.45	32.49	31.78
District heating demand [TWh]	30.62	28.61	29.50
Industry fuel consumption [TWh]	30.1	23.33	28.67
PES [TWh]	218.77	218.61	225.00
- Oil	84.53	81.11	85.00
- Renewable energy	42.44	44.44	39.74
- Natural gas	40.48	41.38	49.16
- Coal	51.41	51.94	51.80
RES [%]	17.9	20.32	17.66
CO_2 emissions [Mton]	49.44	49.00	50.00

Table 3.2 Key parameters of Climate Commission 2010 compared to the climate corrected DEA 2008

3.3 Interviews

This section covers the use of interviews to identify the strategies of the utility companies. This is an important element in assessing the hypotheses from Chapter 2, but also in concluding whether the Energy Savings Agreement works in regards of implementing large-scale energy savings. The interviews covered in this section are primary data. Section 3.1 describes interviews with the sole purpose of gathering energy data and statistics. Therefore, the interviews here are, based on both the context of the interviewee and the purpose of the question, interpreted. The purpose of this section is therefore to highlight the design of the interview guide to be able to answer the research question and the hypotheses.

The first element is to identify whom to include in the qualitative approach (Andersen 2008). This part of the thesis centers on the organizations and the applied strategies. Therefore the most relevant part to interview becomes the current organizations in charge of the performing the savings. This means that the interest organizations of both district heating, electricity, oil and natural gas are included. Since the district heating sector consists of many individual plants, the thesis also uses information from interviews with district heating plants carried out on the project "Challenges to Heat Savings in District Heating" (El-Khatib et al. 2012). To reflect on the findings and suggesting improvements, the analysis includes an interview with Energitjenesten who is an organization that helps end-users performing energy savings.

Not all the interest organizations and companies who signed the Energy Savings Agreement are included in the interviews. However, the interviews include those of them who are the biggest within their field, and cover all energy sectors. Therefore, the interviews represent most of the utility companies in Denmark. The included companies are:

- DONG Energy (Natural gas and electricity)
- Danish Energy (Electricity)
- Danish District Heating Association (District heating)
- HMN Natural Gas (Natural Gas)
- Danish Oil Industry Association (Oil)
- Energitjenesten (Energy counseling firm)

The next step is to identify what type of parameters the interview has to examine (Andersen 2008). In this case, the parameters are the research question and hypotheses from Chapter 2. Based on these, the key element of the questionnaire become to identify; the role of the companies in the design of the Energy Savings Agreement; how they handle the current agreement; whether they have any strategy towards handling the savings required; if and how the agreement have changed their internal organization; if they reflect on possible changes and alternatives. By asking these questions, and comparing them to the performance of the savings it becomes possible to discuss what role the current organizations have in performing these savings and if they are capable of handling the responsibility of promoting energy savings at the end user.

One of the challenges in these types of interviews is that it focuses on the current organizations who might defend their current position and the current agreement. Furthermore, the interviewee is often a leading person in the organization who might seek to steer the interview in certain directions (Andersen 2008). Therefore, the interview sticks to a guide that contains all the important questions. Furthermore, to make sure to get the needed reflections on the topic, the interview guide includes several questions that revolve around the same topic. This also helps when analyzing the interviews and comparing the results with the hypotheses. Appendix D contains the interview guide, where it is possible to see the elements mentioned in the previous paragraph and how it approaches a topic from different angles.

The interview setting used in the report is based on the before mentioned interview guide. This interview guide is in the offset of a semi-structured interview. Thus, the questions in the guide have to be covered, but there is room for moving more freely between the different questions and for the interviewee to add other points that are beyond what the interview guide frames (Andersen 2008). This makes the interview flow more freely, and the researcher might get extra information, but it also requires a good overview and the researcher have to determine when to skip a question because it had already been answered. The interview, based on notes and recordings, amount to a summary with important quotes. Appendices E to J contain the summaries.

Because of the distances between the researcher and the interviewee, all the interviews were via telephone, and one had some follow up questions answered via an email correspondence. There are, however, some concerns when using telephone interviews, and they include that it can be hard to interpret the interviewee only based on voice; it becomes harder to focus on all elements of an interview; and that it can be harder to establish contact with the interviewee (Andersen 2008). Since the questions does not focus on emotions, and that contact had already been established through email most of the challenges are avoided and therefore telephone interviews are seen as appropriate for the type of questions asked in relation to this thesis.

By applying these methods, it becomes possible to analyze and discuss the role of the utility companies in finding savings, and identifying how they act because of the Energy Savings Agreement.

4 The Energy Savings Agreement

The Energy Savings Agreement has, as mentioned in the introduction been expanding and changing since its introduction in 2006, first in 2009 and later in 2012. This includes both the reduction targets but also how the different energy sectors split the burden, and what tools are available to meet the reductions. This chapter seeks to describe both the elements of the current agreement, but also the evolution leading to it. By doing that, the goal is to highlight the methodology inherent in the Energy Savings Agreement. This is required to both understand and analyze the data and the interviews with the utility companies.

4.1 Target Savings

The Energy Savings Agreement defines targets for the yearly reduction of energy consumption – in other words energy saving quotas. The quotas are based on end user consumption, which means that the utility companies have to make the reduction in relation to the end user. The companies that have signed the current agreement are Danish power grid companies, natural gas companies, district heating companies and oil companies.(Klima- Energi- og Bygningsministeriet 2012a) The district heating companies were not a part of the agreement in 2006 but still had reduction targets (Transport- og Energiministeriet 2006). In 2008, the oil companies left the agreement but did return the following year. Because the oil companies are free of Danish legislature, they did not have any targets that year. This means that the power grid companies, the natural gas companies and district heating companies are bound to the agreement on a much stricter basis than the oil companies are. In all three agreements this is shown through that the oil companies are exempt from certain paragraphs and that grid, natural gas and district heating companies that are outside the agreement can be imposed certain reduction targets anyway.

The utility companies and the Danish Ministry of Energy, Climate and Buildings have updated the Energy Savings Agreement two times and both times increased the required amount of savings significantly. Table 4.1 shows the development reduction targets from the first to the third Energy Savings Agreement. The current, and third Energy Savings Agreement, is the first to have two sets of targets, the first for the years 2013-2014 and the second for 2015 where the agreement is also up for renewal. The savings made are only accounted the first year and as such, the companies need to find new savings every year.(Klima- Energi- og Bygningsministeriet 2012a)

	2006-2009	2010-2012	2013-2014	2015
Electrical companies	1.40 PJ	2.90 PJ	4.50 PJ	5.00 PJ
Natural gas companies	0.50 PJ	1.10 PJ	2.00 PJ	2.30 PJ
District heating companies	0.90 PJ	1.90 PJ	3.70 PJ	4.30 PJ
Oil companies	0.15 PJ	0.20 PJ	0.50 PJ	0.60 PJ
Total	**2.95 PJ**	**6.10 PJ**	**10.7 PJ**	**12.2 PJ**

Table 4.1 Reduction targets for the utility companies in the three Energy Savings Agreement. 2006-2009 (Transport- og Energiministeriet 2006), 2010-2012 (Klima- og Energiministeriet 2009) and 2013-2015 (Klima- Energi- og Bygningsministeriet 2012a)

4.2 The Energy Savings Agreement's Methodology

The agreement states clearly at what level the utility companies can be involved. The companies have to focus the savings at the end users, which limits them from registering efficiency increases at the plant as a saving. With the development of the agreement, it has however become possible to register solar panels and increased efficiency in the transmission grids and networks as savings. (Transport- og Energiministeriet 2006, Klima- Energi- og Bygningsministeriet 2012a) Another element of the agreement that restricts the activity of the utility companies is that they cannot perform the activity that creates the saving, such as refurbishing a house. To do that they have to either create a sister company or seek third party involvement. The utility companies have the option of being responsible for energy counseling, finding the projects and doing installations related to metering. The agreement has furthermore evolved into allowing the companies to be the one responsible for increasing grid efficiency (Klima- Energi- og Bygningsministeriet 2012a, Klima- og Energiministeriet 2009). In total, this means that what counts as a saving is:

- Reduction in end user demand
- Efficiency increases in transmission grids and networks and individual equipment
- Installation of collective solar panels
- Conversion from one type of energy to another
  (Klima- Energi- og Bygningsministeriet 2012a)

The utility companies are through the Energy Savings Agreement given two methods for accounting the accomplished savings. The first method is through specific measurement. Here every project has to go through an individual measurement with an assessment of the efficiency increase of every activity. This method targets primarily larger projects such as energy increases in industries, companies and public buildings. The second method that the utility companies can use is standard values. The standard value chart works by giving every possible activity a fixed reduction, for instance replacing a window. Thus the companies, when doing an activity, just have to look up what they and add up all activities in the given project. The utility companies should only use standard values on small projects such as single-family houses. (Klima- Energi- og Bygningsministeriet 2012a) Therefore, the standard value chart does not take into account how different savings affect each other.

The overall target has since the implementation of the first Energy Savings Agreement been that: *"The utility companies promote cost efficient savings of benefit to end users, companies and society."* (Klima- Energi- og Bygningsministeriet 2012a) To do this the key component in the agreement is that the utility companies have the freedom to do the savings outside of own supply area and outside of own fuel type – a free choice of method. This means that a district heating plant can buy a saving done in an industry in a natural gas area if it fits with the district heating plants wishes. The 2012 agreement added to the wording of the paragraph that it should aim towards existing buildings and business (Klima- Energi- og Bygningsministeriet 2012a). It is important to mention that the companies also can do the savings within own supply area and fuel type.

Because of the free choice of method, there is no guarantee that the companies are going to have savings activities all over Denmark. In the 2006 agreement, there was, however, an intent towards that the companies sought a balancing approach:

> *"The savings activities should be rather equally implemented when it comes to different end user groups, energy type and geographical area. The companies must as such offer a certain effort in all consumer groups. (Transport- og Energiministeriet 2006)*

Such an intent is not present in both the 2009 agreement and the current Energy Savings Agreement, hence removing any limits to the free choice of method (Klima- Energi- og Bygningsministeriet 2012a, Klima- og Energiministeriet 2009).

The free choice of method is the founding element for the creation of a market for energy savings. The defined quotas create the demand, which means the utility companies and plants hereafter have to identify the best fitting supply. This interaction defines the prices for the given energy saving. It is important to remember those third parties are responsible for creating majority of the savings. This is because the power grid companies, district heating companies, and natural gas companies are monopolies and as such has to oblige to the "self-balancing principle" meaning they cannot earn money. Third party companies therefore help in creating a more secure market.

Following the idea of cost efficient savings, the Energy Savings Agreement allows for having either a deficit or a surplus of savings each year as long as the average yearly savings matches target for the given period. This practically means that the utility companies can carry savings from one year over to the next and as such stockpile savings. Both the 2009 and 2012 Energy Savings Agreement also states that the companies can carry over savings performed under the old agreement. (Klima- Energi- og Bygningsministeriet 2012a, Klima- og Energiministeriet 2009) This creates a potential incentive for the utility companies to perform more savings than needed as early as possible. In the 2006 agreement, this line therefore followed the principle of carrying over savings:

"At the end of year 2008, when the agreement is up for revision, balance shall be strived towards" (Transport- og Energiministeriet 2006)

The agreements from 2009 and 2012 have not included this type of wording and instead this paragraph now only covers that a yearly deficit cannot be below 35 % of the reduction target.(Klima- Energi- og Bygningsministeriet 2012a)

To maintain the free choice of method and guide savings in a certain direction, the Energy Savings Agreement includes parameters to prioritize certain types of savings.

In the 2006 agreement, conversion from one energy type to another was the only place where a parameter was seen fit. Furthermore, it was a rather simple since the parameter only was in place to incentives a move away from electrical heating (Transport- og Energiministeriet 2006). This meant that when converting between electricity and any other energy type the utility company had to multiply the electricity use by 2.5, resulting in increased differences between the energy use before and the energy use after when converting from electricity, and a smaller difference when converting to electricity. This has since expanded and the current Energy Savings Agreement contains a long list that states a parameter for every energy type and conversion sector (Klima- Energi- og Bygningsministeriet 2012a). Appendix O contains the current list of conversion parameters.

Lifetime of a given energy saving is incorporated in the energy savings by applying parameters. The 2006 agreement did not contain any lifetime parameters but only declared that the savings should at least have the longevity of the agreement (Transport- og Energiministeriet 2006). Both the 2009 and the current agreement do however contain parameters which primarily seeks to move focus away from savings with a lifetime shorter than 4 years. Appendix O shows the lifetime parameters. These parameters indicate that the Energy Savings Agreement generally does not prioritize projects with long lifetime over projects with a lifetime of 4 to 15 years. Only in projects that involve fuels outside the CO_2 quota system, normally used for individual heating, is projects with lifetimes over 15 years prioritized with a factor of 1.5.

The final parameters promote certain activities and deprioritize other. These are also find in Appendix O. This shows that the agreement deprioritizes maintenance and service plans and energy management while it prioritizes energy renovation and new boilers in oil and natural gas heated buildings, and installation of heat pumps that replaces oil and natural gas.

The many parameters have alongside the details in paperwork needed to document the savings and the data required to report the savings increased the level of bureaucracy in the agreement. The 2006 agreement had three appendices covering where to make savings and how to report them, whereas the current agreement has 13 appendices covering the same topics. This illustrates the expansion of elements and points of emphasis in the agreement.

4.3 Actual Efficiency of the Energy Savings Agreement

To conclude this chapter on energy savings it is important to note that the reported savings are not the actual effect that the Energy Savings Agreement has on the energy system. This is primarily due to several elements, technical over estimation, additionality and the prioritization parameters in the agreement.

Ea Energy Analyses (2012) estimates that the reported savings are over estimations compared to the actual effect savings (Ea Energianalyse, Viegand og Maagøe & Niras 2012b). This, especially, ties to projects using standard values. The average reported savings in a single-family house is 31.3 kWh/m^2, but the actual savings in those houses averaged out to 24.8 kWh/m^2 and furthermore 10.9 kWh/m^2 of those where due to general tendencies and not because of the Energy Savings Agreement. This means that the agreement results in a reduction 13.9 kWh/m^2 or 44 % of the reporting saving. Ea argues that the standard values do not take into account that combining several activities could lead to reduced total savings. (Ea Energianalyse, Viegand og Maagøe & Niras 2012b) The second element that can reduce the overall efficiency of the Energy Savings Agreement is additionality. The Energy Savings Agreement says that savings from an activity performed has to be specifically due to the utility companies' involvement otherwise they cannot report it – the savings has to be additional. However, Ea Energy Analyses has assessed whether the savings are in fact additional. When looking at the large-scale business projects Ea Energy Analyses estimates the additionality to be between 42 % and 46 % whereas in household projects it is only between 6 % and 8 %. It also varies between which utility company is responsible for the savings. The electrical grid, natural gas and district heating companies all perform savings with an additionality between 45 % and 68 % whereas the oil companies only perform savings with an additionality around 10 % (Ea Energianalyse, Viegand og Maagøe & Niras 2012b) The final element is that the reported savings include the prioritization parameters. It means that for instance projects with a short lifetime or projects that convert electrical heating to district heating reports for the former half of the actual saving and for the latter more than what is the actual effect of the saving.

What is also important to remember is that the fundamental basis for savings agreement is savings at the end user. The measurements therefore also take place at the end user, which is key because, a kWh saved electricity saves more fuel than a kWh saved heat. In total, all these elements are important to remember when analyzing the actual effect of the Energy Savings Agreement from an energy point of view, which is the goal of Chapter 6.

To summarize Chapter 4, Figure 4.1 shows the structure of the Energy Savings Agreement and Table 4.2 shows the main elements covered regarding the elements of the Energy Savings Agreement. It describes the development of the reduction targets, involved partners, methodological approach and the overall concerns in the agreement mentioned in this Chapter.

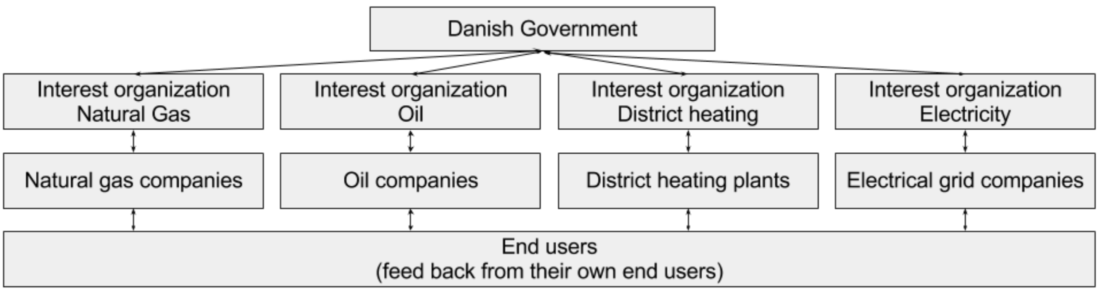

Figure 4.1 Structure of the Energy Savings Agreement

	2006-2009	2010-2012	2013-2015
Reduction target	2.95 PJ	6.10 PJ	10.7 PJ to 12.2 PJ
Involved utility companies	Power grid companies, Natural gas companies, Oil companies	Power grid companies, Natural gas companies, District heating companies, Oil companies	Power grid companies, Natural gas companies, District heating companies, Oil companies
Methodological possibilities	Free choice of method, specific measurement and standard values, savings at end users, grid and metering optimization, collective solar, conversion from one energy type to another	Free choice of method, specific measurement and standard values, savings at end users, grid and metering optimization, collective solar, conversion from one energy type to another	Free choice of method, specific measurement and standard values, savings at end users, grid and metering optimization, collective solar, conversion from one energy type to another, Savings in transportation
Lifetime of projects	No specific focus on project lifetime other than an intent towards having project lifetime equal to the agreement period	Lifetime incentivized through prioritization parameters	Lifetime incentivized through prioritization parameters
Awareness on diversity	An intent towards savings in all energy sectors, at all types of end-users and savings dispersed all over Denmark	No intent towards diversity	No intent towards diversity
Conversion	Conversion factor between electricity and any other fuel types	Conversion factor between electricity and district heating or fuels under the CO_2 quota system	Conversion factor between all conversions

Table 4.2 Summary of the Energy Savings Agreement

5 Integration of Suitable Energy Savings

This chapter contains three elements towards analyzing the Danish energy system in terms of identifying suitable energy savings. Defining the application of the methodology described in Section 3.2 to the case of energy savings in Denmark; highlighting what characterizes different types of savings; and calculating the consequences of different kind of savings in the context of the current Danish energy system. The 2010 CEESA model and 2008 Climate Commission model represents the current Danish energy system.

5.1 Towards the Identification of Synergies

This section has the goal of transforming the overall methodology described in Chapter 3 into some operational calculations on the identification of synergies between different saving types.

The methodology's basis in the holistic approach emphasizes the need for having as many factors included as possible. This thesis however has to make a delimitation, thus, it only focuses on the elements of savings targeted by the Energy Savings Agreement. These are heat savings, electricity savings and industrial savings, and conversions between different fuel types. The current energy system becomes the framework of these calculations. The calculations do have a holistic approach because it takes into account the whole energy system and not only the few sectors on which it calculates. Therefore, the parameters for measuring the performance are the whole systems primary energy supply (PES), CO_2 emissions and renewable energy share (RES). Another important result is the distribution of demands on how savings affect the use in the winter compared to the summer, as these might help explaining the benefits of certain savings.

Because this is the first step in the identification of suitable energy savings, the calculations are conceptual. This means that current potentials, targets and feasibility do not define the numbers. Instead, Section 5.2 describes them qualitatively, and in the end of this chapter, the elements combined with the strategy towards 2050 described in Chapter 1 are included in framing the strategy for savings.

The elements analyzed in this chapter therefore becomes reducing energy demand, in form of insulating, new appliances and installing new stoves and grids, and conversions between different types of heating productions. EnergyPLAN is the basis for calculation in both instances, where gradually reducing the energy demand models the energy savings, and gradually transferring an energy demand from one type of fuel to the other models conversions. Hereafter, the goal is the identification of possible synergies within the current system. Section 5.3

highlights the key results and synergies found between savings, whereas Section 5.4 shows the same just with the focus on conversions in relation to savings. Appendix L accompanies Section 5.3 and Appendix M accompanies Section 5.4, which contains tables of results used before presenting the figures of Sections 5.3 and 5.4. A key notion in terms of calculating conversions is that because of the targets of future energy systems, both described in Chapter 1 and discussion 3.2, the analysis of savings disregard biomass, and the analysis of conversions disregard biomass and heat pumps. This is because they are necessary in the future energy system, making it redundant to test for conversions from for instance biomass to fossil fuels.

Because of the possible sensitivity in the calculations, the thesis calculates the analyses both in the model defined by CEESA and the model constructed based on the Climate Commission's report.

Since the calculations are conceptual, the possible conclusions should not depend on the specific inputs as long as the tested scenarios are the same. Nevertheless, to specify what numbers this thesis uses, Appendix K shows tables with all the numbers inputted. The overall concept is that by using the same percentage reductions for all possible savings and conversions, it becomes possible to create several data points, have the numbers on the x-axis and overall make easier comparisons in terms of synergies.

The elements calculated and analyzed for synergies are:

- Savings in district heating demand
- Savings in electricity demand
- Savings in individual heating
- Savings in industrial energy
- Conversions form oil to natural gas, biomass and district heating
- Conversions from electricity to natural gas, biomass and district heating
- Conversions from natural gas to biomass and district heating

Finally, the calculations also covers the possible synergy between converting from oil to district heating and heat pumps at the same time compared to converting just to heat pumps or district heating.

In the calculations for savings in district heating, all three groups are in the same calculation and therefore the results show for overall district heating savings and not savings in first group 1, then group 2 and finally group 3. In individual heat savings and industrial savings, each fuel type has its own calculation and results.

The tables showing conversions have the focus of maintaining the current demand. Therefore, the numbers inputted in EnergyPLAN take into account the different efficiencies of the different individual heating technologies. These are 90 % for natural gas stoves, 85 % for oil stoves and 80 % for biomass stoves. When calculating the conversions each energy type converted to has its own results. For example, when converting from electrical heating there is a calculation assessing the effect if converting to natural gas, one to biomass, one to district heating group 1, one to district heating group 2 and finally one to district heating group 3.

5.2 Characteristics of Savings

This section describes the type of savings analyzed in this chapter. This included how the savings and conversions typically look like, and what the lifetimes are. It also characterizes overall goals for these types of savings.

5.2.1 Heat savings

When focusing on heat savings it is important to recognize that individual heating and district heating makes up the total heat demand. This means that there are two very different ways of approaching heating. Combined heat and power plants make up most of the district heating plants, as seen in Section 1.3 thus linking heat production to electricity production, whereas areas with individual heating produce their own heating thus separating heat and electricity production. The Danish Energy Agency estimates the current heat demand to be 59 TWh with 29 TWh district heating and 30 TWh individual heating (Energistyrelsen 2012). The Climate Commission estimates that in 2050 the heat demand in district heating is 23 TWh and 17 TWh in buildings with individual heating (Risø DTU, Ea Energianalyse 2010a). This means a reduction from an overall heat demand of 59 TWh to 40 TWh or a reduction 32 %. In CEESA the demand for heat from district heating is 38 TWh and in individual buildings 9 TWh in 2050. This totals a demand 47 TWh and a reduction of 20 % (Lund et al. 2011b).

To reduce the heat demand in buildings there are two focus areas, existing buildings and new buildings. In existing buildings, the possible tools for refurbishment are re-insulation of outer walls, roofs and ceilings, and foundations; installation of new and better windows; new ventilation systems; and insulation of technical installations. Of these, the biggest potential for reducing the heat demand is by re-insulating buildings, especially those built before 1979. (Risø DTU, Ea Energianalyse 2010b)

The potential for heat savings in existing buildings, with the inclusion of new ventilation, are without an economic concern estimated to be around 70 %, however when including economic costs the potential drops to 23 %, but could increase to 47 % (Wittchen 2009). This depends on factors such as payback time and desired standards for the savings. Another key component in securing the feasibility of the savings is that costs are significantly lower if done while the building is having other renovations done.

In new buildings, it becomes important to secure the right level of insulation, windows and ventilation during the construction phase. One of the ways to do this is by tightening the building codes, an example could be that buildings built after 2015 cannot have a heating demand. This would result in 2050, 25 % of the buildings would not require heating. (Risø DTU, Ea Energianalyse 2010b)

Compared to electricity savings, the lifetime of heat saving projects become relevant. Initiatives to reduce heat savings often have a long lifetime. Building envelopes can surpass 30 years of lifetime (Schmidt 2012), which means that to reach the target of 100 % renewable energy in 2050 the consumers must do the right amount of savings in a household now when renovating a building. Overall, this description indicates that it should not be impossible to reach the required reductions as defined by CEESA and the Climate Commission.

5.2.2 Electricity savings

The Danish energy agency estimates the current electricity demand to be around 36 TWh. (Energistyrelsen 2012) Towards a 100 % renewable energy future both CEESA and the Climate Commission suggests an overall increase in electricity demand, this is however due to increased amounts of heat pumps and electricity used in industry. The Climate Commission's ambitious scenario estimates the total electricity demand in 2050 to be 49 TWh, however, this includes an electricity demand of 5 TWh for heat pumps and 9 TWh of increased electricity in industry compared to 2010 (Risø DTU, Ea Energianalyse 2010a. This means that the Climate Commission is calling for an unchanged electricity demand in the already established sectors. When disregarding transport and heating from the CEESA scenario they call for a reduction of the electricity demand to be 20.57 TWh (Lund et al. 2011b).

The potential for electricity savings primarily comes from installing appliances that are more efficient and more conservatory use (Risø DTU, Ea Energianalyse 2010b). Of technical improvements, the Climate Commission points toward that typical electricity savings are focusing on lighting, electronics, appliances, pumps and ventilation (Risø DTU, Ea Energianalyse 2010b, Risø DTU, Ea Energianalyse 2009). These type of savings all have a rather short lifetime which both creates a need for maintaining a certain level of savings, but also allows for a flexibility in terms of having the right solutions for the 2050 targets, in other words, the short lifetime makes it possible to correct possible implementation errors.

5.2.3 Industrial savings

The Danish Energy Agency estimates the current energy demand in industries to be 38 TWh though it is 25 TWh if disregarding the use of electricity and district heating in industry (Energistyrelsen 2012). The Climate Commission's ambitious scenario estimates that the energy demand for industry has to be 36 TWh (Risø DTU, Ea Energianalyse 2010a), however if disregarding a need for electricity and district heating the demand has to be reduced to 10 TWh. CEESA estimates that the energy demand in industry in 2050 has to be 19.03 TWh (Lund et al. 2011b). In total, this means that if disregarding electricity and district heating, the reduction has to be between 25 % and 50 %.

To reduce energy demand in production industry several elements are in focus. This includes transportation, space heating, drying of products, heating and burning need in production. Thus, industrial savings spans over wider types of possibilities including both electricity and heat savings. There are however certain types that are common for most industrial units. These include lightning, pumps and electrical engines. (Risø DTU, Ea Energianalyse 2009) Economically the estimates are right now that 8 % to 30 % are feasible, and this might increase to 43 % in 2030 (Risø DTU, Ea Energianalyse 2009). Because of these various types of initiatives, it becomes hard to estimate lifetimes. Vehicles for transportation and electrical installations might have a lifetime around 5 years, whereas engines and furnaces might have longer life times. Danish Energy however estimates that industrial savings made in accordance with the Energy Savings Agreement typically have lifetimes around 7 years (Thingvad 2013).

5.2.4 Conversions

The final element is conversions. This covers some overall transitions needed in the Danish energy system to reach the goal of a 100 % renewable energy system. In the current agreement, the conversion can happen between several energy types, though with certain types preferred over others. One can also disregard conversion and keep an end user within the same energy framework.

The conversions, which CEESA and the Climate Commission focus on, in relation to this thesis, are the conversion of households, commercial units and industries from individual heating to district heating. In CEESA, the district heating demand of the total heating demand is 61 % in 2010 but this increases to 78 % in 2050 (Lund et al. 2011b). The Climate Commission estimates the current share of district heating to be 45 % of the total heating demand, and this increases to 57 % in 2050 (Risø DTU, Ea Energianalyse 2010a). Thus, both system operates with an increase of around 25 % in the district heating share of the total heating demand.

The second element that is relevant to this thesis is that individual households and buildings, and industry have to move away from fossil fuels. Therefore, individual heating transitions to biomass, solar heat and heat pumps, and industries makes the same transition, with more energy coming from electricity and district heating and the only separate fuel being biomass (Lund et al. 2011b, Risø DTU, Ea Energianalyse 2010a). These conversions are important to keep in mind when understanding that not only are savings needed, they also have to go be targeted towards the right sectors.

5.3 Relations between Different Kinds of Savings

Based on the inputs described in Section 5.1 calculations have been made with the goal of identifying relations and effects between savings in different energy sectors. The background results for doing this are available in Appendix L. The focus of this analysis is specifically on possible relations, synergies and effects between savings in district heating and electricity, savings in individual heating and electricity and savings in industry and electricity. It is important to note that, as the last section highlighted, all savings are important but the goal here is to identify where these savings affect each other.

To understand the first aspect of possible savings between district heating and electricity it is important to understand that demand varies between winter and summer, these differences are especially noticeable in heating demand, whereas electricity demand is more constant over a year. Therefore, when reducing demands it especially targets the winter period since most heating is done here. Figure 5.1 and 5.2 show the development in district heating demands and electricity demands dependent at respectively 0 % savings and 54 % savings.

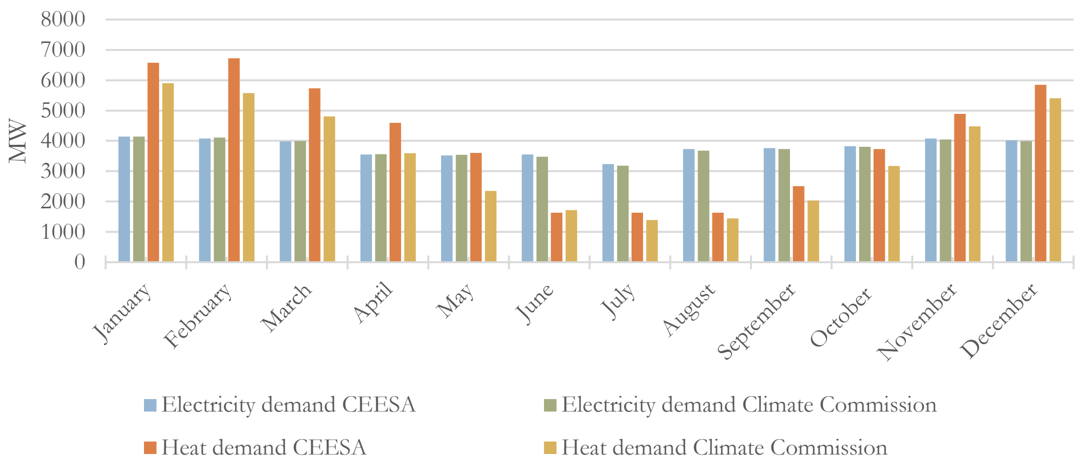

Figure 5.1 Heat and electricity demands with 0 % savings

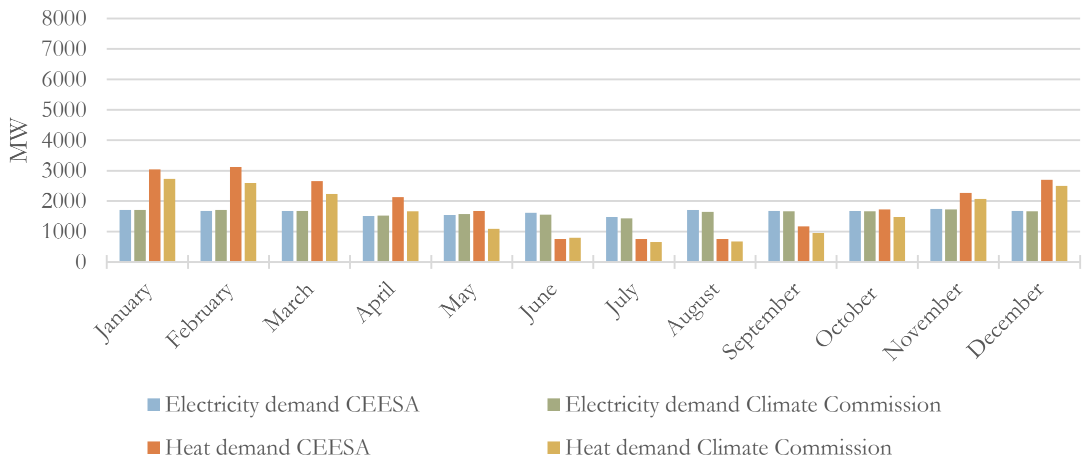

Figure 5.2 Heat and electricity demands with 54 % savings

These graphs show that by reducing the overall demand it lowers the difference between the maximum heat demand and minimum heat demand from approximately 5000 MW to 2200 MW. Figure 5.1 and 5.2 also show that savings do not affect the variance in electricity demand as much. Thus, by doing savings, heat demands and electricity demands become more aligned. This is important in understanding why a coordination of reductions can create more efficient results, because production units based on CHP can run more evenly in this case.

Figures 5.3 and 5.4 show the results for the identification of how demand reductions in district heating are affected by electricity savings. The graphs are for the three parameters, primary energy supply (PES), CO_2 emissions and renewable energy share (RES) on which the comparison between savings without coordination and savings with coordination.

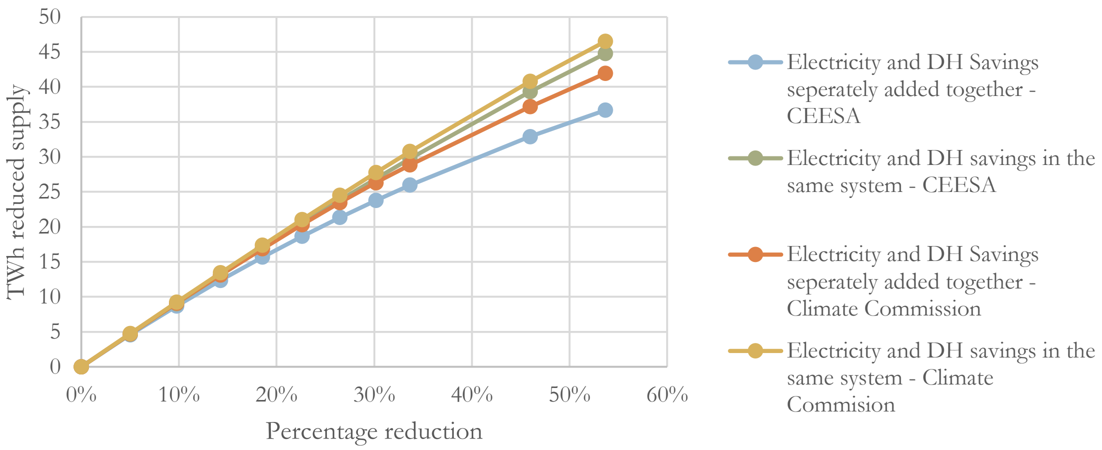

Figure 5.3 TWh reduced PES supply when performing electricity and district heating savings

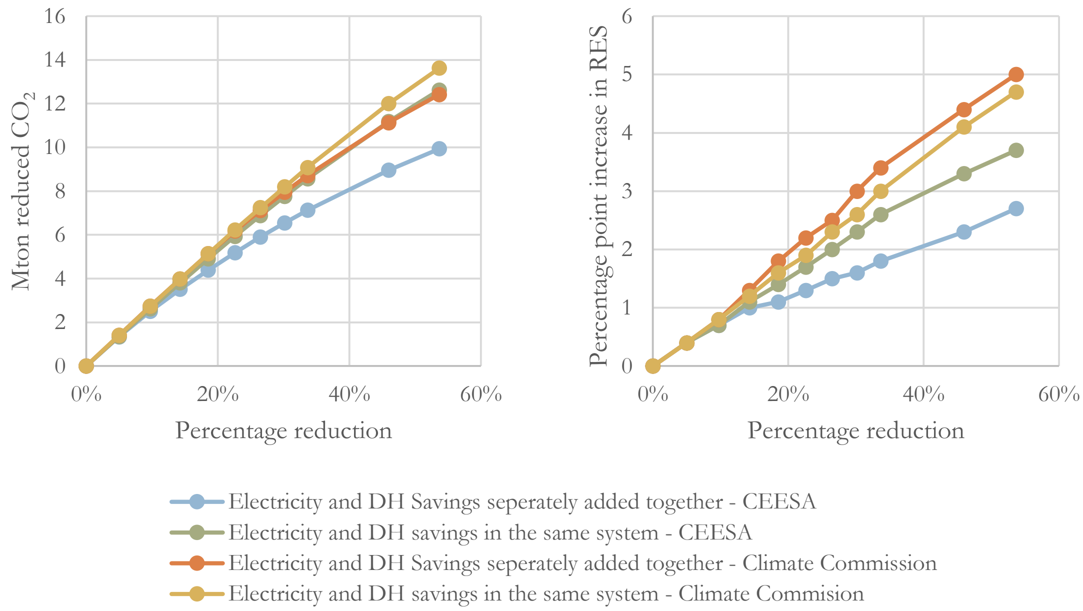

Figure 5.4 Reduced CO_2 and percentage point increase in RES when doing electricity and district heating savings

From these two figures, it becomes apparent that electricity savings affect savings within the district heating sector. In CEESA, a 54 % reduction in demand in both sectors lead to an 8.10 TWh lower PES, 2.7 Mton less CO_2 emitted and 1 percentage point more renewable energy in the system than if the savings were not in the same system. In the Climate Commission model, a 54 % reduction in demand leads to 4.6 TWh lower RES, 1.2 Mton less CO_2 and 0.3 percentage point lower RES. The difference between the two systems results are due to more heat demand in district heating in the CEESA model, compared to the Climate Commission model. However, all results besides RES in the Climate Commission model leads to the conclusion that electricity and district heating savings have to in relation to each other and coordinated in the current Danish energy system, because of the amount of CHP.

Because of the separation between production units based on fuels in individual heating and electricity, it is not possible to find any measurable synergies between those two. The representation in Figure 5.5 shows the PES and CO_2 for the system with and without coordination, which illustrates the total similarity. The numbers shown in Figure 5.5 are only for the CEESA model but calculations show the same effect in the Climate Commission model, which Appendix L illustrates. In the cases of electricity used for heating, the reduction is similar to a reduction in overall electricity demand. As such, it does not make sense to calculate individual electricity savings and check for synergies between two types of electricity savings. Since it is an electricity saving, it must be noted that savings in electrical heating also has to be made in coordination with district heat savings.

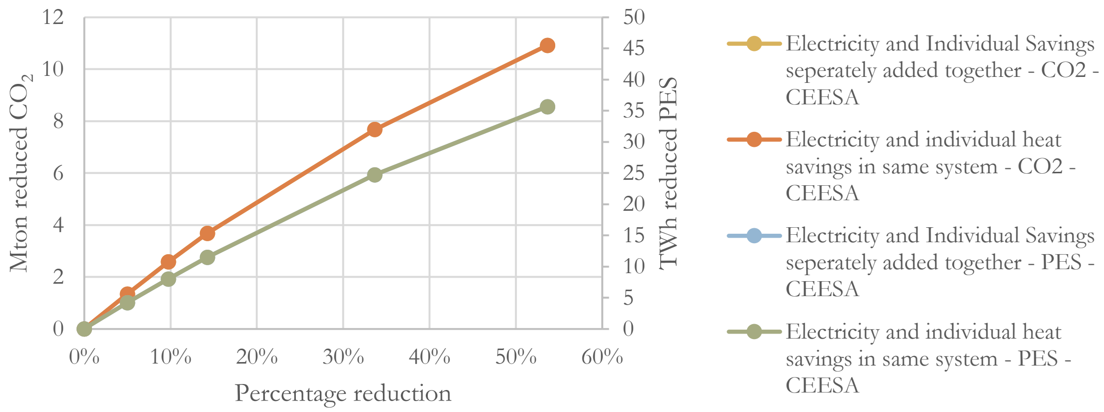

Figure 5.5 Saved CO_2 and PES when doing electricity and individual heat savings

The final element analyzed for possible advantages by coordinating savings is a synergy between industrial savings and electricity savings. As was the case for individual heating, the fuel used in industry is separate from the fuel used for producing electricity and heating. Therefore, there are no immediate relations between savings in industry and savings in electricity. Figure 5.6 illustrates this, by showing the reduction in CO_2 and PES with and without coordination with electricity production. The calculations shown are in CEESA but the Climate Commission model show the same results. Appendix L illustrates this.

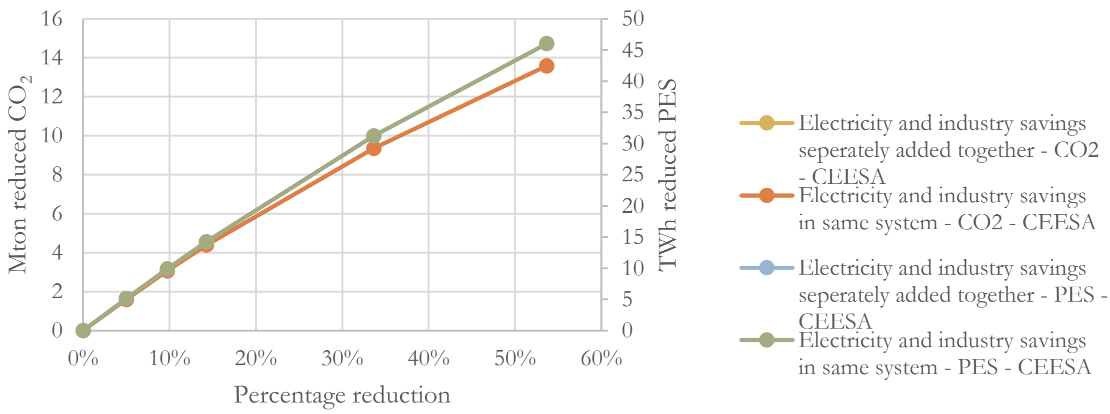

Figure 5.6 Saved CO_2 and PES when doing electricity and industrial savings

However, there is a slight overlap between industry and electricity and heat production, but quick calculations show that these are almost insignificant. When performing 54 % savings, calculations in CEESA, it suggests that coordination with electricity saves 0.2 Mton CO_2 and 0.5 TWh PES. When coordinating with reduced demand in district heating it saves 0.01 Mton CO_2 and 0.01 TWh PES.

Based on these analyses, Section 5.5 summarizes strategies for coordination and integration of suitable energy savings.

5.4 Relations between Conversions and Savings

This section covers the analysis of what happens to the energy system with the integration of conversions between different energy types used for heating. As mentioned in Section 1.3 and Section 5.2, the conversions analyzed are in accordance with the overall strategies of the CEESA and Climate Commission reports. Therefore, no calculations are made of conversions from biomass since both CEESA and the Climate Commission increase the demand for biomass. Furthermore, no conversions to oil and electrical heating are calculated since the target is to phase out these rather quickly. Natural gas is included with both the possibility of conversion to and from, since both CEESA and the Climate Commission include this fuel on a longer term for supplying heat, but also by 2050 suggest a complete move away from natural gas. Finally, the possible synergies with heat pumps are tested. The calculations only focus on heating, but because industrial energy to a certain extent resemble the individual heating sector the learnings from this section also applies to conversions from industrial energy to district heating.

Appendix M highlights the results from the individual calculations of conversions from each fuel to another. These show that, because biomass is CO_2 neutral but also the least efficient compared to oil and natural gas stoves, it results in, when converting from oil and natural gas to biomass, an increase in PES, but lower CO_2 emissions and higher RES. Electrical heating is the least efficient heating technology thus converting from that to another energy type always results in better performance on all three parameters.

When converting to technologies that in the current system have shares of fossil fuels they perform differently depending the different technologies. Therefore, the following ranking describes which technology are the best targets for the conversion. Local district heating plants without electricity production perform the worst on CO_2 emissions whereas natural gas stoves results in the highest primary energy supply. Both are equal in renewable energy share. Converting to district heating group 3, which are centralized CHP plants, are the second best option in terms of conversions in the current energy system. When converting 54 % of oil consumption to this group it reduces, in the CESSA model, the CO_2 emissions 0.21 Mton more than in district heating group 1, and 1.3 TWh more in the PES compared to natural gas. The best conversion option is however district heating group 2, which are decentralized CHP plants. Here CO_2 is reduced 0.83 Mton more than in district heating group 1, and the PES 1.4 TWh more than converting to natural gas.

Overall, the recommendations are that the focus on conversions should be to convert from oil, natural gas and electrical heating to biomass and district heating with CHP units. The next step therefore becomes to analyze the synergies between these types of conversions and electricity savings. The analysis disregards electrical heating savings due to its relation to the overall electricity demand. Furthermore, it is possible to deduct from analysis in the previous chapter that transitions between the different individual heating devices based on fossil fuels do not have synergies with electricity savings. Thus, the calculations primary focus becomes the synergies between electricity savings and conversions to district heating. The graphs shown in this section therefore focus on the key parameters when making these conversions in relation to electricity savings.

Figures 5.7, 5.8 and 5.9 show the parameters in converting from oil to district heating, and Figures 5.10, 5.11 and 5.12 show it in converting from natural gas to district heating. All Figures show the result with and without coordination with electricity savings.

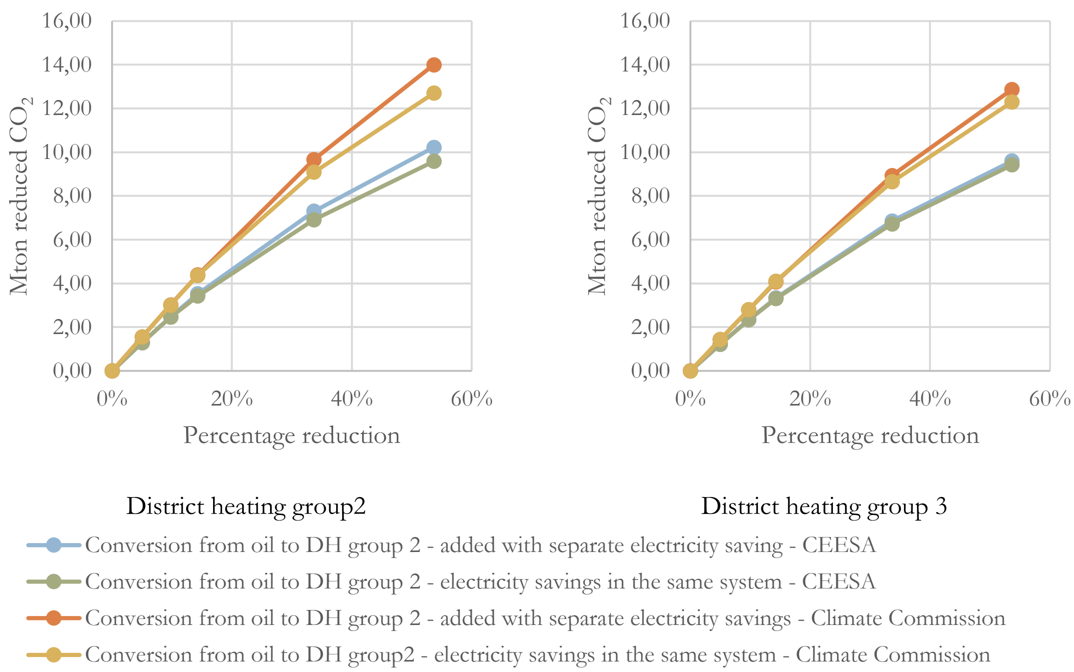

Figure 5.7 Reduced CO_2 emissions when converting from oil to district heating group 2 and district heating group 3 in relation to electricity savings

Figures 5.7 to 5.9 illustrate how conversions from individual heating based on oil to district heating, either based on decentralized CHP (district heating group 2) or centralized CHP (district heating group 3) operates in a context with electricity savings. All Figures, both in the CEESA model and the Climate Commission model, show that when putting the context of reductions in electricity demand the performance of the system is not as good as if the two tools were looked at separately and then added together. Furthermore, whereas conversion to decentralized CHP performed the best when looking at the different conversions independently, but when adding the element of electricity savings conversions to centralized CHP is less affected by the electricity savings.

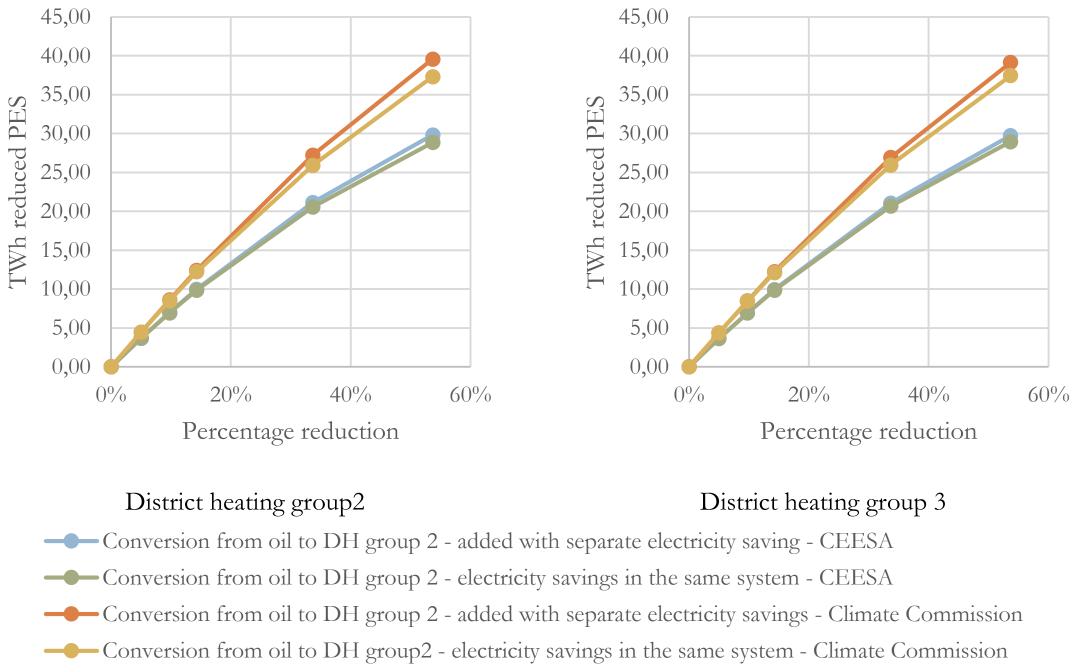

Figure 5.8 Reduced PES when converting from oil to district heating group 2 and district heating group 3 in relation to electricity savings

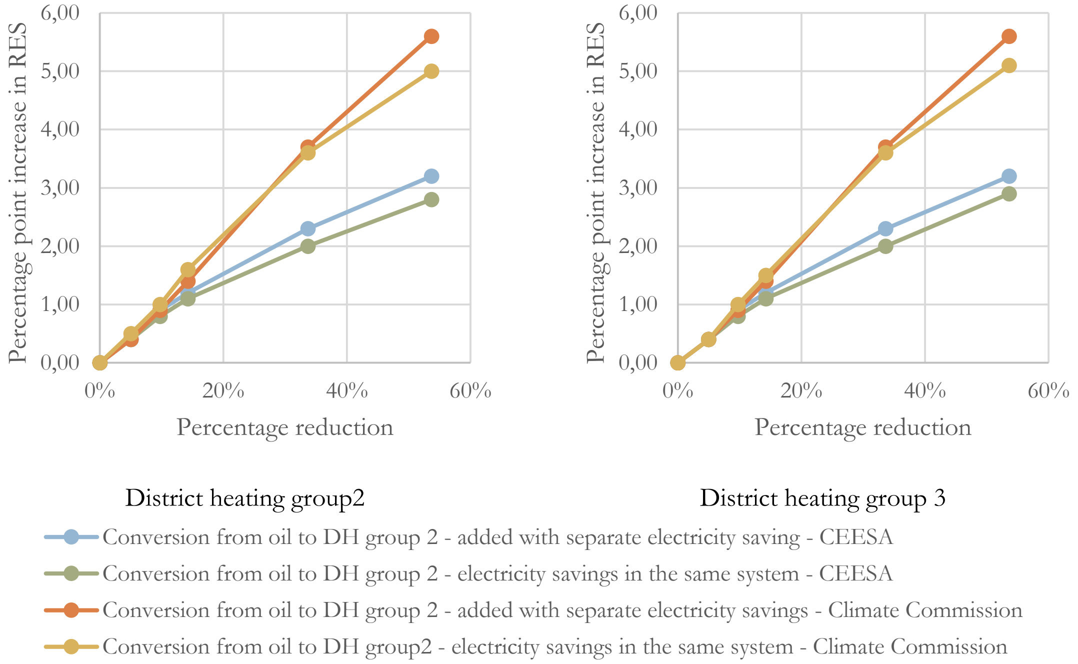

Figure 5.9 Percentage point increase in RES when converting from oil to district heating group 2 and district heating group 3 in relation to electricity savings

The reason for the system performing less optimal is due to the explanation illustrated by Figures 5.1 and 5.2, but instead of creating a balance between district heating demand and electricity demand, converting to district heating creates a greater imbalance, thus the CHP plants need to operate even in situations where there is no need for electricity. Therefore, when converting to district heating it becomes relevant to maintain a balance between electricity demand and heating demand. A suggestion could be to do conversions to heat pumps running on electricity as well. These will increase the electricity demand, but also generate heat in individual housing. Thus, converting to district heating from CHP might perform better if other households with individual heating convert to heat pumps.

Figures 5.10 to 5.12 show the conversion from individual natural gas heating to district heating in both decentralized CHP and centralized CHP for both the CEESA model and Climate Commission model. They show how these conversions operate in context with electricity savings, and compare it with a perspective where the savings is without context to each other, but only added together. The conclusions from these calculations are the same as the conclusions from converting to oil. All Figures show that conversions within a context of electricity savings reduce the reductions in RES, PES and CO_2 than without accounting for this context. In addition, the impact is less when converting to centralized CHP than converting to decentralized CHP. Again, the weaker performance is due to greater imbalance between the electricity demand and heat demand, thus the recommendation should be to strive towards a balance here. A way to achieve this, and move away from the use of fossil fuels for individual heating is heat pumps.

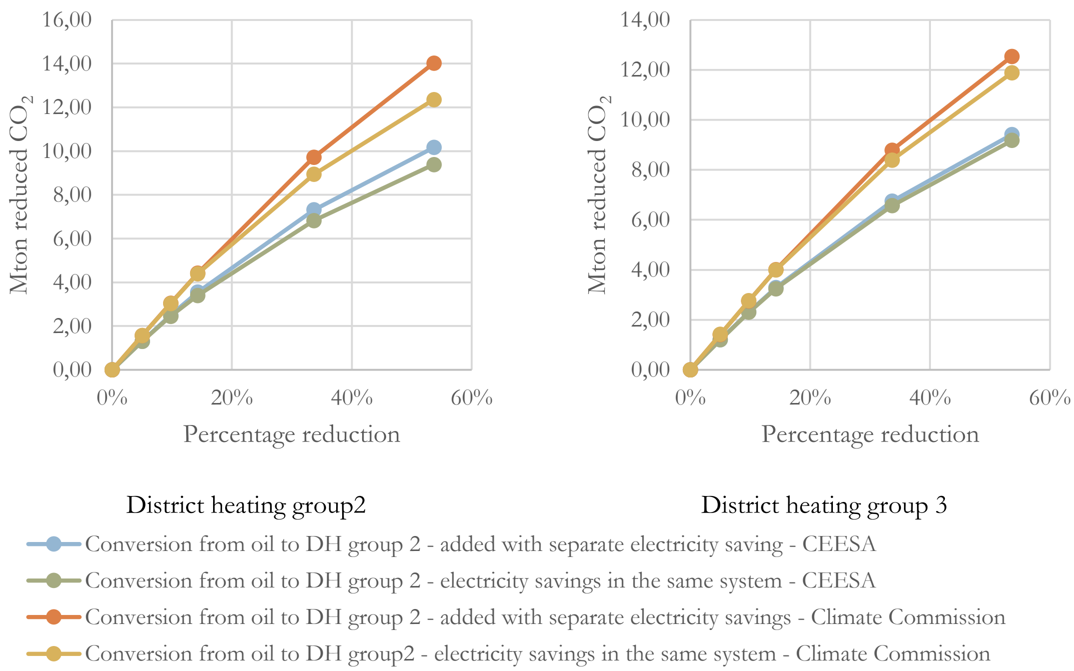

Figure 5.10 Reduced CO_2 emissions when converting from natural gas to district heating group 2 and district heating group 3 in relation to electricity savings

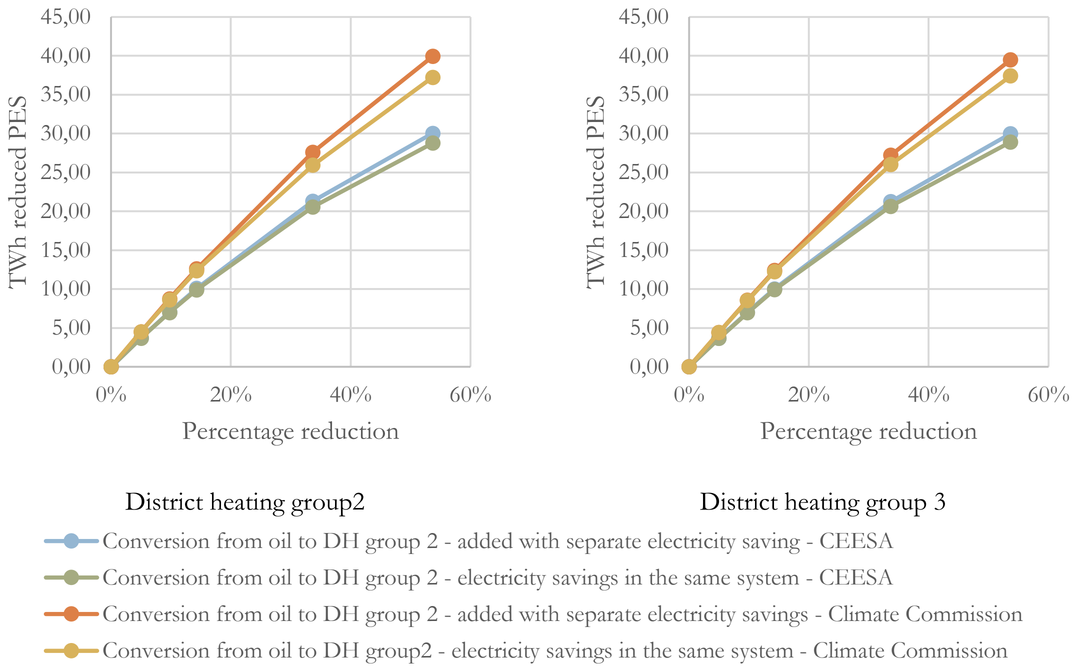

Figure 5.11 Reduced CO2 emissions when converting from natural gas to district heating group 2 and district heating group 3 in relation to electricity savings

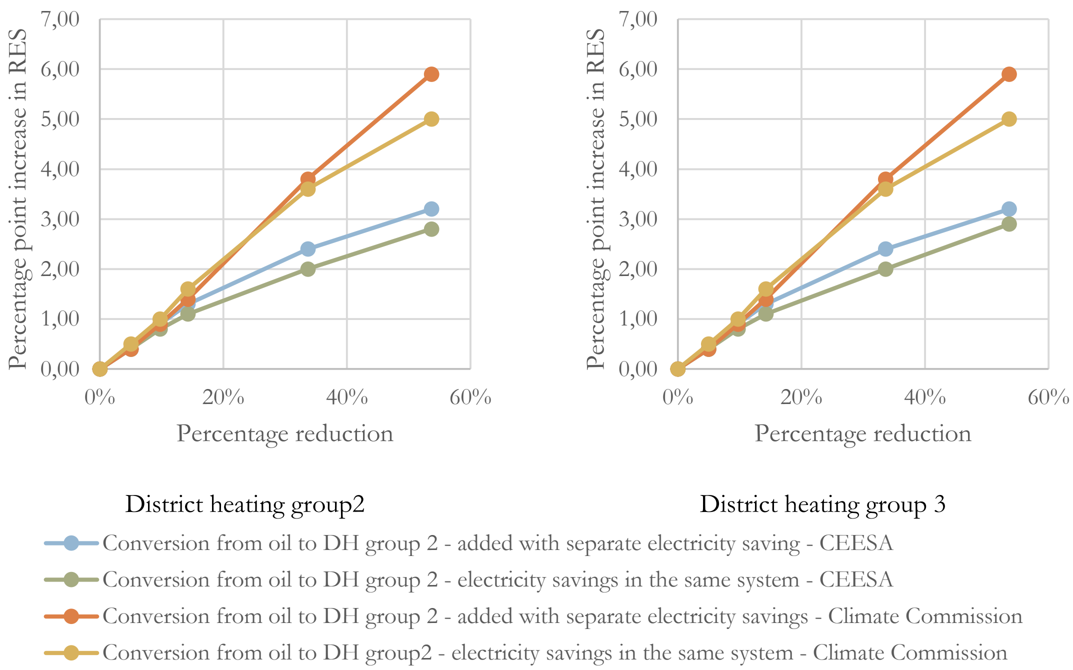

Figure 5.10 Reduced CO_2 emissions when converting from natural gas to district heating group 2 and district heating group 3 in relation to electricity savings

Both oil conversions and natural gas conversions suggest coordination with heat pumps. Therefore, Table 5.1 show the savings when half of the conversion from natural gas goes to heat pumps and the other half to district heating group 2 in the CEESA scenario, in relation to electricity savings and compares it to conversions only to heat pumps and conversions only to district heating group 2. Table 5.2 shows the same for the Climate Commission.

Percent reduced/converted	0%	5%	10%	14%	34%	54%
Conversion from natural gas to DH 2 - electricity savings in the same system – CEESA						
CO2 [Mton]	0	1.297	2.45	3.402	6.822	9.387
RES [Percentage point]	0	0.4	0.8	1.1	2	2.8
PES [TWh]	0	3.68	6.96	9.89	20.54	28.77
Conversions from natural gas to DH2 and heat pumps - electricity savings in the same system - CEESA						
CO2 [Mton]	0	1.243	2.386	3.349	6.845	9.564
RES [Percentage point]	0	0.4	0.8	1.1	2.1	3
PES [TWh]	0	3.68	7.02	10.01	21.19	30.08
Conversions from natural gas to heat pumps in - electricity savings in the same system - CEESA						
CO2 [Mton]	0	1.189	1.837	3.286	6.848	9.697
RES [Percentage point]	0	0.4	0.8	1.1	2.2	3.1
PES [TWh]	0	3.68	7.05	10.12	21.82	31.33

Table 5.1 Conversion from natural gas to heat pumps with electricity savings in CEESA

Percent reduced/converted	0%	5%	10%	14%	34%	54%
Conversion from natural gas to DH 2 - electricity savings in the same system - Climate Commission						
CO2 [Mton]	0	1.561	3.026	4.392	8.935	12.358
RES [Percentage point]	0	0.5	1	1.6	3.6	5
PES [TWh]	0	4.49	8.6	12.35	25.92	37.21
Conversion from natural gas to DH 2 and heat pumps - electricity savings in the same system - Climate Commission						
CO2 [Mton]	0	1.449	2.816	4.09	8.815	0
RES [Percentage point]	0	0.4	0.9	1.5	3.6	0
PES [TWh]	0	4.43	8.47	12.19	26.49	0
Conversion from natural gas to heat pumps - electricity savings in the same system - Climate Commission						
CO2 [Mton]	0	1.334	2.601	3.784	8.49	12.38
RES [Percentage point]	0	0.4	0.8	1.3	3.3	5.3
PES [TWh]	0	4.25	8.27	11.99	26.96	39.77

Table 5.2 Conversion from natural gas to heat pumps with electricity savings in Climate Commission

From Tables 5.1 and 5.2 the results state that the implementation of heat pumps works best with very high conversion rates and reduction in electricity demand. The lower these numbers are the lesser effect the heat pumps have. This is because discrepancies get bigger every time the amount of conversions and savings increases. Therefore, the combination of conversions to heat pumps and district heating has the best overall performance because it limits worse effect in the small conversions, but also has the increased when the amount converted gets bigger.

What is important to remember with the calculations presented in Sections 5.3 and 5.4 is that they do not represent “true” comparisons since savings always are in relation to each other. However, what they do show are that how the combination of savings in certain cases give different results than looking at savings without an understanding of the whole system. In some cases, the system show that savings can actually affect each other to create a greater effect of both savings, but in other cases savings and conversions results in a lower effect than the expectation from doing them separately shows. Therefore, the calculations become important in understanding how to create a strategy for the integration of energy savings in a Danish energy system, because they shed light on how different types of savings interact with each other. Furthermore, there are many other calculations to be made, but these are the most important in assessing the performance of the Energy Savings Agreement.

5.5 Strategies and Other Considerations

Based on the qualitative descriptions in Section 5.2, the calculation and analyses in Sections 5.3 and 5.4, and some of the notions in the earlier chapters it is now possible to summarize these into strategies for the integration of suitable energy savings. One brief notion is that the calculations had the goal of identifying certain effects in the system because they would have intertwined and therefore would not give meaningful results. It is however both expected and needed in the actual integration of large-scale energy savings.

The bullet points below identify the five strategies and considerations regarding integration energy savings:

- Heat savings in general have longer lifetimes than both industrial and electricity savings. Therefore, it is important to be aware of reducing heat demand in households correctly already now, since these houses might not be refurbished again before 2050. Furthermore, it is also important to start doing it now and not wait. Electricity savings and industrial savings have shorter lifetimes and can therefore better endure some poor choices, since these can be corrected. On the other hand, these require a constant involvement from the companies in making sure they are reducing energy consumption.
- The energy system should strive towards being fossil free in 2050, thus electrical heating, oil and natural gas should preferably be converted to heat pumps, biomass or district heating. This is required both in individual heating and industrial energy. The conversion to biomass has to be under the consideration of it being a limited resource and the CO_2 emissions from indirect land use change. On the short term, it might make sense to replace inefficient oil and natural gas boilers with updated efficient equipment but in the long term, this is not the right strategy because this might delay the conversion. The Climate Commission recommends in its unambitious scenario increased amounts of biomass, district heating and heat pumps, whereas CEESA and the Climate Commission in its ambitious scenario try to restrict the increase in biomass, and focus on heat pumps and district heating.
- When converting to district heating it has to be coordinated with the reductions of electricity demand, since the conversions potentially could increase the imbalance between heat and electricity demand, which would affect the way CHP plants run. A way of balancing these out is by implementing heat pumps. Therefore, heat pumps become important in relation to conversions to district heating.

- It is preferable to reduce heat demand in district heating and electricity demand combined as this generates synergies, which leads to greater amount of savings. This is due to that coordination lowers the discrepancy between the distribution of heat demand and the distribution of electricity demand. Therefore, it is important to make savings in both places and not only within one of the sectors, even though reducing the electricity demand 1 TWh has greater effect than reducing the heat demand 1 TWh.
- Since there is a separation between the need for energy in industry and the individual heating demand and the electricity demand, both industrial savings and savings in individual heating demand can largely be made without attention to reduction in other energy sectors. However, it should still be in consideration with overall goals such as 100 % renewable energy in 2050 and the lifetime of the different types of savings.

With an offset in these strategies, Chapter 7 compare the results from this analysis with the actual performance of the Energy Savings Agreement, which is the focus of Chapter 6, to be able to understand whether the Energy Savings Agreement moves the Danish energy system in the right direction in terms of integrating savings.

6 The Performance of the Utility companies

This chapter analyzes the actual reported savings and what consequences the Energy Savings Agreement has had for the utility companies. The first part focus on the overall performance, taking into account the reported savings and trying to give an estimate of how much the reported savings is actual savings. The second part of this chapter is the analysis of the performance of each individual utility company. Each of the companies have a section, which combines what type of savings they have made with information from interviews that highlights the consequences of energy savings for the company and whether they have any strategies towards fulfilling the targets in the agreement.

6.1 Reported Savings and Estimates of Actual Savings

As described in Chapter 4 the savings reported by the utility companies are not necessarily the actual savings caused by Energy Savings Agreement. Furthermore, there is a slight lack of detail in the reporting of conversions between fuels because it does not specify fuel type. Therefore, this section both presents the reported savings, and try to estimate the actual savings and conversions due to the Energy Savings Agreement. The basis for the analysis are the reported savings and conversions in 2010 (Danish Energy Agency 2011) and 2012 (Danish Energy Agency 2013). Thereby it also becomes possible to see the progression in the utility companies' activity. The notions to the Energy Savings Agreement and arguments made by Ea Energy Analyses mentioned in Chapter 4 create the foundation for the estimation.

There are several factors, which influence the reported savings, and not all are currently possible to correct for in relation to this thesis since either there has been no study on the field, or the data available do not have the right amount of details. Some of the elements that are possible to consider in terms of the agreement are, additionality, prioritizing parameters for specific types of savings, prioritizing parameters for life time of projects and parameters when converting from one on fuel to another. As mentioned in Chapter 4, the parameters are in place for guiding the agreement in a certain direction without compromising the free choice of method, but they result in that the reported savings do not necessarily equal actual savings. In terms of additionality it is important to remember that the savings are done, the question is just whether they are done due to the agreement or not. A third factor is overestimation in general.

6.1.1 From Reported Savings to Estimates

This analysis focus on two elements in terms of identifying estimates of the actual savings due to the Energy Savings Agreement. These are the additionality of the savings, and the parameters used when converting from one fuel type to another. This selection is due to that there is reasonable data available, both in terms of what the additionality factor is, and what conversions are made. The other parameters become hard to correct for without too many assumptions, such as differences in projects lifetimes. It is important to note that there is still a certain need for assumptions also when correcting for additionality and conversion parameters.

When looking at additionality, Ea Energy Analyses' analyzes it (Ea Energianalyse, Viegand og Maagøe & Niras 2012b), but also states that the qualitative approach they use have a fair amount of uncertainty. They furthermore identify the additionality based on different scopes, such as from the perspective of who does the savings and where the savings are done. Table 6.1 and 6.2 represent these respectively. Because of the lack of combination between these numbers, Table 6.1 is the foundation for one approach to estimating the actual savings and Table 6.2 the foundation for another way. By presenting both results, it creates a better foundation for discussing the effect of the Energy Savings Agreement. Because Table 6.2 does not included additionality for conversions, Table 6.3 shows the additionality for conversions, based on a later table in the same analysis from Ea Energy Analyses. The tables all represents additionality based on the payback periods of either 1 year or 3 years, but in terms of this report the average in the third column based on number of respondents is used.

	Additionality 1 year	Additionality 3 year	Weighted average
District heating	43 %	31 %	38 %
Natural gas	50 %	37 %	44 %
Oil	12 %	11 %	12 %
Electricity	58 %	56 %	57 %

Table 6.1 Additionality based o then utility company performing the savings. Average based on the amount of cases 1 year and 3 year cases (Ea Energianalyse, Viegand og Maagøe & Niras 2012a, p. 79)

	Additionality 1 year	Additionality 3 year	Weighted average
Industry and production	52 %	60 %	56 %
Public sector	45 %	18 %	36 %
Households	8 %	6 %	32 %
Commerce and service	31 %	33 %	7 %
Other	2 %	2 %	2 %

Table 6.2 Additionality based where the savings are made. Average based on the amount of cases 1 year and 3 year cases (Ea Energianalyse, Viegand og Maagøe & Niras 2012a, p. 76)

	Additionality 1 year	Additionality 3 year	Weighted average
Specific measurement	24 %	24 %	24 %

Table 6.3 Additionality for conversions, renovation, rebuilding and other. Average based on the amount of cases 1 year and 3 year cases (Ea Energianalyse, Viegand og Maagøe & Niras 2012a, p. 88)

When correcting for the parameters used when converting from one energy type to another there are a few assumptions. First, based on Ea Energy Analyses' study, when the utility companies are converting, they primarily convert to their own energy type (Ea Energianalyse, Viegand og Maagøe & Niras 2012a). Therefore, the assumption is that all savings are of this type, besides when the numbers show that the conversion is away from their own energy type. These assumptions are important because it then becomes possible to determine the fuel converted to and from due in each case. Normally the data provided by the Danish Energy Agency only provides the saved fuel, or in other terms, the fuel used before the conversion. In the cases where the utility companies are converting from their own fuel type, the calculations use an average parameter based on the other companies' conversion activities to this fuel, therefore these are different in 2010 and 2012.

By knowing the fuels on both sides of the conversions, it is possible to identify the prioritization parameters used, which are the target of the corrections. Appendix O shows the parameters in the savings agreement, but the way they are described, specific measurements before and after are the conversion are required, which are not available. Therefore, the parameters are defined with basis in the standard value chart. Because of the assumption of using the standard values chart, which focuses on households, and because Chapter 5 focused on conversions in individual heating, the non-quota fuels parameters create the foundation for converting from and to oil, natural gas and coal. The parameters used are found by dividing the "from parameter" with the "to parameter" showed in Appendix O. By comparing the standard value chart (Energistyrelse et al. 2013) and typical energy savings (Videnscenter for energibesparelser i bygninger 2010), the thesis assess that this is methodology by the utility companies applied when combining standard values with conversion parameters.

Tables 6.4 and 6.5 highlight the parameters used. The use of parameters causes either over or under estimations, which is why removing the effect becomes important. The way of doing this is by dividing the reported conversions with the parameter. One important note is that the parameters guides the savings made, and therefore they are important within the political framework. Without them, it might have been completely different conversions reported. This analysis only seeks to subtract the effect of the parameters, to be able to see a clearer picture of the actual performance of the Energy Savings Agreement. Because of the size of the parameters, it is also important to note that the conversions might actually not lead to savings but just transferring a demand from one fuel to another.

		Conversions to			
		District heating	Natural gas	Oil	Electricity
Conversions from	District heating		0.80	0.80	0.40
	Natural gas	1.25		1.00	1.00
	Oil	1.25	1.00		1
	Electricity	2.50	1.0	1.00	
	Coal	1.25	1.00	1.00	1.00
	Biomass	1.25	1.00	1.00	0.40
	Other	1.00	1.00	1.00	1.00

Table 6.4 Parameters divided with the reported conversions from each utility company. Based on (Klima- Energi- og Bygningsministeriet 2012a)

	District heating	Natural gas	Oil	Electricity
2010	0.40	1.21	1.09	1.46
2012	0.72	1.10	1.06	2.21

Table 6.5 Identified parameters when performing savings in own fuel type. Calculated by dividing the estimated conversions by the other utility companies with their reported conversions.

The described assumptions and inputs create the framework for estimating realized savings. The reported savings are however still very important because of the uncertainties tied to the calculated estimates. The descriptions, analyses and conclusions in this section all uses the reference and the two estimates, based on the two ways of calculating additionality. Figure 6.1 shows the total reported savings (I-2010), the estimation based on the Table 6.1 (II-2010), and the estimation based on Table 6.2 and 6.4 (III-2010) all for 2010. Figure 6.2 shows the same for 2012 (I-2012, II-2012 and III-2012). All estimates include corrections for conversion parameters. The important information in the analyses is not the numbers but the tendencies shown. The results from Section 6.1.2 and 6.1.3 are shown in tables in Appendix N.

6.1.2 Reported Savings and Estimates in 2010

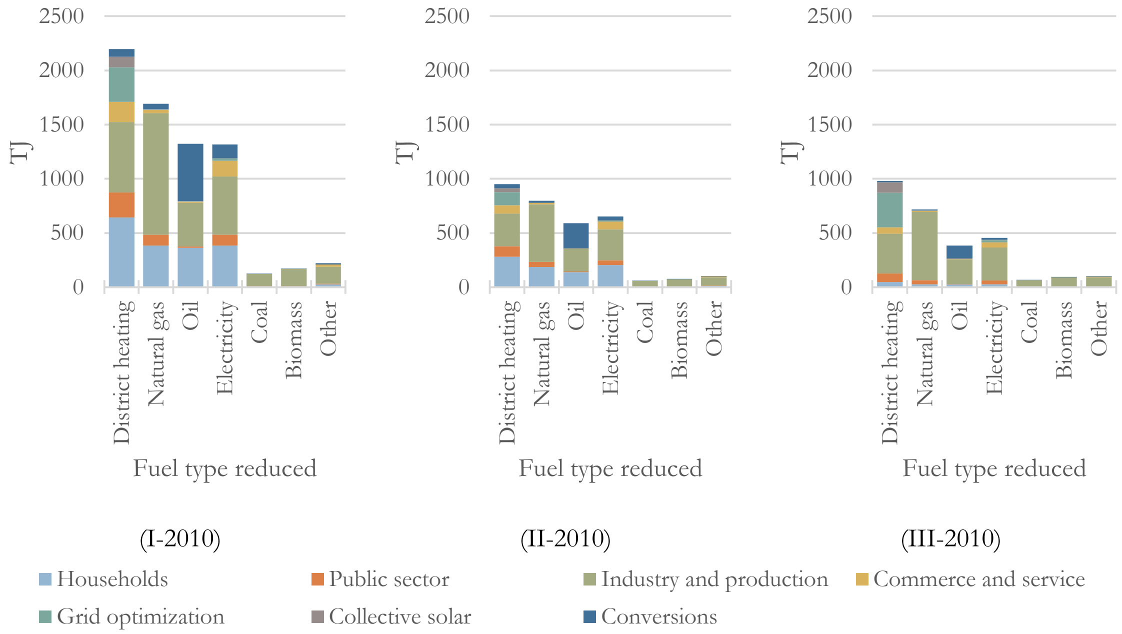

Figure 6.1 Reported savings (I) (Danish Energy Agency 2011), estimated savings from additionality based on who reduces (II) and estimated savings from additionality based on where savings are reduced (III) in 2010

From Figure 6.1 it is seen that the overall amount of savings are reduced from a total of 7,040 TJ to 3,226 TJ in scenario II-2010 and 2,793 TJ in scenario III-2010. In all cases, industrial savings are the predominant type of saving, but it varies from being 45 % in the reported savings I-2010, to 47 % in II-2010 and 63 % in III-2010. The reason III-2010 has such a higher share of industrial savings is that the additionality of households drops dramatically due to very low additionality factor used here. It goes from 26 % of the savings in I-2010 to 5 % of the savings III-2010. This indicates that there are high uncertainties about how many of the savings in households are actually due to the Energy Savings Agreement. In III-2010, 5 % of district heating savings are in households, which is 4 % of natural gas, 7 % of oil and 6 % of electricity.

In the reported savings, 28 % of district heating are in households, which is 23 % in natural gas, 28 % in oil and 30 % in electricity. In all cases in 2010, district heating is the one that provides the most savings, and it is the one that varies the tools used for savings the most, with in all cases finding savings in industries, commerce and households. Furthermore, it seems that only savings in district heating include solar panels and optimizing distribution networks (92 % of all grid and network optimizations and solar panels are reported here). Savings in the electrical sector also have a rather great variation to it. Natural gas savings have the greatest focus on industrial savings, which goes all the way up to 88 % of all natural gas savings in scenario III-2010. Oil savings focus on industry, households and conversions and especially conversions from oil to other fuels have a great impact. In total, oil conversions are 67 % of all conversions in I-2010, this number is 61 % in II-2010 and 65 % in III-2010. In the reported savings, electricity is the second highest with 16 % of all conversions being from electricity, but this drops to 11 % in II-2010 and 10 % in III-2010. These drops are due to the disregard of the prioritization parameters, which also explain why conversions from district heating increase.

Overall, the scenarios affect primarily the amount of total savings and the share of savings in households.

6.1.3 Reported Savings and Estimates in 2012

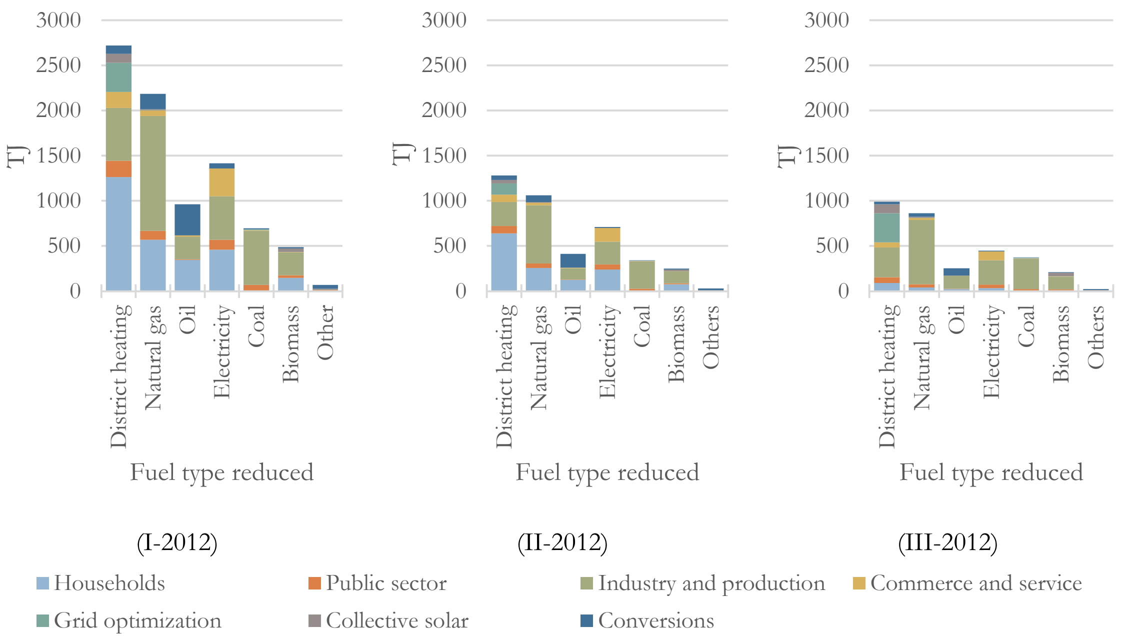

Figure 6.2 Reported savings (I) (Danish Energy Agency 2013), estimated savings from additionality based on who reduces (II) and estimated savings from additionality based on where savings are reduced (III) in 2010

In 2012, I-2012 indicate that the total reported savings are 8,523 TJ, which, because of additionality, drops to 4,083 in II-2012 and 3,159 TJ in III-2012. Industry is the primary place for reducing energy demand in all scenarios, with 40 % of all savings in I-2012, 42 % in II-2012 and 61 % in III-2012. The reason for III-2012 being significantly higher is that additionality for savings in households used in III-2012. The amount of savings drop from 33 % of all savings done in households in I-2012, to 6 % in III-2013. In 2012, district heating provides the most savings, with 32 % of the reported savings, and 31 % done by district heating in both II-2012 and III-2012. Natural gas is the sector with the second most reductions, electricity being third and oil being fourth. Savings in district heating have basis in all types because they utilize the option for optimizing the network and installing collective solar panels. In the other sectors, savings are from reducing demands in industry, households, commerce and public sector and conversions. Besides savings in district heating and oil, industrial savings are in all cases the primary place to find reductions. This is also the case for district heating in III-2012, because the share of savings from households drops from 47 % in I-2012 to 9 % in III-2012, but in I-2012 and II-2012 households are the primary places to find savings in district heating. Oil savings also have important shares of household and industrial savings, but oil savings are, largely, conversions to other types of fuels. In I-2012, 36 % of oil savings are because of conversion, 37 % in II-2012, and 31 % in III-2012. This means that respectively, 47 %, 47 % and 45 % of all conversions are moving away from oil. Natural gas is the second most converted from fuel, with district heating being third and electricity fourth.

Overall, from Figure 6.1 and 6.2 the observations are that the savings agreement favors savings in industry, with households only representing a reasonable share if the additionality of these is high. Furthermore, the amount of reported savings has increased from 2010 to 2012. District heating is the primary place of finding savings, but this is somewhat due to the possibility of grid and network optimization and solar panels. The Energy Savings Agreement causes almost double amount of savings reported in district heating compared to electricity, and even without solar panels and grid and network optimization more savings are still done in district heating compared to electricity. In terms of conversions, the primary focus of conversions is away from fossil fuels in form of natural gas and oil. Biomass is only the target of between 2 % and 4 % of conversions, depending on the scenario and year. There is however also between 13 % and 18 % of savings being due to conversions in district heating. These observations are in Chapter 7 compared with the strategies identified in Chapter 5, but before that a further understanding of the activities of each branch utility companies is needed.

To create this further understanding of the savings done, the next four sections assesses each branch of utility companies. These assessments have the focus of both identifying strategies applied by the companies, but also to understand why the companies are part of the savings agreement, what attitudes they have towards and it, and how the savings agreement have affected them as energy producers and organizations. The goal is therefore both to create a better understanding of the performance of the utility companies in accordance to the Energy Savings Agreement, and to make a connection between the utility companies' role in integrating large-scale energy savings, and the theoretical framework. To do this, each section includes the reported savings from 2010 and 2012, and information gathered through interviews. Since the focus is to identify strategies and not the specific amounts of savings by each company, the sections do not include estimates of actual savings since these are not important in this context.

6.2 The Performance of the District Heating Companies

When analyzing the performance of each individual companies it is important to remember the free of choice of methodology. Therefore, it becomes relevant understanding where the utility companies focus their savings. Figure 6.3 shows the reported savings by the district heating companies in 2010 and 2012. This amounted to 2,482 TJ reported savings in 2010 and 2,521 in 2012, both over the target of 1,900 TJ. These show that in both 2010 and 2012 the focus has primarily been on finding savings inside district heating (Danish Energy Agency 2011, Danish Energy Agency 2013). The three primary places of reporting savings are in households, industries and optimizing the district heating network. Totally, the reported savings within district heating amounts to 56 % in 2010 and 49 % in 2012. This slight decrease might indicate that it becomes harder, with the increased focus on savings, to keep finding savings primarily within district heating.

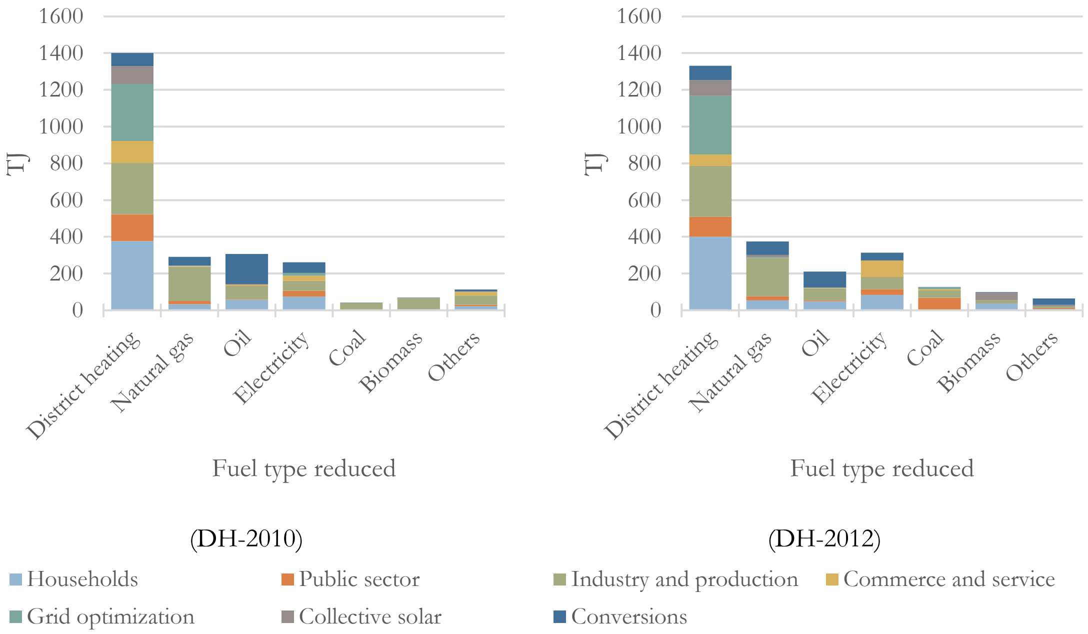

Figure 6.3 Reported Savings by the district heating companies in 2010 and 2010 (Danish Energy Agency 2011, Danish Energy Agency 2013)

The district heating companies perform various types of savings, but the two primary tools used are improving the heating equipment at the end user and increasing the insulation of buildings. Finally, there is a focus on conversions, primarily on reporting conversions in oil, electricity and natural gas to district heating, but also conversions away from district heating are being included (Danish Energy Agency 2011, Danish Energy Agency 2013).

Overall this indicate a strategy, where the district heating companies to a large extent seek to perform savings within district heating, the big focus here is however due to especially the possibility of performing optimizations to the district heating network. Secondly, there is also a focus on converting from oil, natural gas and electricity with the primary target being district heating (Danish Energy Agency 2011, Danish Energy Agency 2013).

Based on the interview with the Danish District Heating Association (DDHA), see Appendix G, there are no specific strategies from the district heating companies in terms of performing savings. The primary goal is to focus on cost efficient savings, but as the DDHA states, they do not determine any goals for the individual district heating plant:

> *"We don't have an opinion on how the individual plant reaches their given target. But there are great differences in the individual people's opinion on where to make the savings, and some thinks they should be done locally." (Jensen 2013a)*

That does not exclude that each plant cannot apply their own strategy, where they focus on for instance local savings. That is the case for both Albertslund (Jensen 2013a) and Brovst district heating plants (El-Khatib et al. 2012), where both thinks that because the costs for doing the savings are paid by the customers at the district heating plant, the savings should also focus on them. Other plants focus on getting the cheapest savings, so the end-users sees the lowest costs as possible. This has to be weighed against each other, because by focusing on local savings, the market for performing and buying savings becomes more limited thus increasing the price, which in the end is added to the local heat bills because of the self-balancing principle.

From earlier interviews with Brovst and Aabybro (El-Khatib et al. 2012)district heating companies, both plants had a focus on optimizing the district heating network because this was a cheap and accessible approach. The DDHA also mentions keeping the element of counting improved district heating pipes as an end user as an important element in the agreement.

In terms of conversion, both Brovst and Aabybro also mentions that they focus on making conversions from natural gas and oil to district heating in the local houses not on the district heating network. Furthermore, the end users are also interested in such conversion, especially when moving out, as this increase the property value.

Overall, even though there are no official strategies, it seems as if the district heating companies are focusing on performing savings within their own sector, especially in improving networks. It does however, looks like that different companies do apply different strategies, which means that not all district heating savings are local but might be done by other district heating plants. Conversions to district heating also seem to be in interest of the district heating plants. Finally, finding savings outside their own energy type help the plants reaching the overall targets set in the Energy Savings Agreement.

The DDHA expresses an overall happiness towards the Energy Savings Agreement, and acknowledges the district heating companies responsibility towards a 100 % renewable energy system in 2050 (Jensen 2013a). Brovst District Heating Plant however expresses that the savings agreement merely creates an extra tax on savings, which the customers have to pay (El-Khatib et al. 2012). Because this creates unevenness between the prices paid for energy depending on fuel delivery, Brovst prefers a system where the utility companies do not have the responsibility, but instead the money needed to promote savings could be from a certain property tax. Other district heating plants instead expresses satisfaction with the Energy Savings Agreement, and agrees with them having a responsibility. Aabybro is a case of this attitude.

The DDHA and the district heating plants have organized the savings by giving each company a share of the target, which they have to fulfil. In the DDHA, the organizational changes have focused on providing the right support for the district heating companies, but at the individual plant level the organizational consequences of the Energy Savings Agreement varies greatly. (Jensen 2013a)Large plant or supply companies have created divisions with focus on energy savings but small plants, where there might not be even one full time employee finding the savings have taken its toll on the district heating company. Here the goal become to find easiest and cheapest savings, because the operator primary focus still is to deliver the cheapest energy (El-Khatib et al. 2012). As such, making the right energy savings and finding a strategy for these are far from first priority. Therefore, the DDHA have great attention on keeping the free choice of method since it gives the most freedom to do local or cheap savings, it potentially keeps down the costs, and reduces the bureaucracy that might limit the operation of the small plants. By limiting the opportunities for free choice of method by introducing specific targets for households, industry and commerce, the DDHA argues that the result more expensive savings and more bureaucracy (Jensen 2013a).

6.3 The Performance of the Power Grid Companies

Figure 6.4 shows the reported savings by the electrical grid (electricity) companies in 2010 and 2012. They reveal that the power grid companies do non primarily focus on savings within the electricity sector but also finds savings in district heating, natural gas and oil. In 2010, 28 % of the savings made by the power grid companies were in the electrical sector. In 2012, this numbers was 22 %, and instead most savings were in district heating which accounted for 29 % of the savings made by the power grid companies (Danish Energy Agency 2011, Danish Energy Agency 2013).

Figure 6.4 Reported savings by the power grid companies in 2010 and 2012 (Danish Energy Agency 2011, Danish Energy Agency 2013)

The power grid companies increased the amount of savings made from 2010 to 2012, from 3,058 TJ to 4,412 TJ, both over the target of 2,900 TJ. In 2010 and 2012, most of the reported savings were in industries, but the share was 56 % in 2010, which decreased to 47 % in 2012, with the result of more reported savings being in households and service. Conversions were in 2010 primarily from oil, but in 2012 shifted to focus on conversions from both oil and natural gas. The conversions targeted converting from other fuels to the use of electricity, with around 50 % being these types of conversions (Danish Energy Agency 2011, Danish Energy Agency 2013).

Overall, it is hard to identify certain strategies from power grid companies based on the numbers presented in Figure 6.4, the companies spread out the activities to all sectors. The only elements are that they focus on industrial savings, and conversions to electricity, and the reported savings in households increased from 2010 to 2012.

Danish Energy (see Appendix F), who are responsible for reporting the power grid companies savings, state that the reason why the power grid companies spread out their savings to multiple sectors is that they have a tradition for savings, and that it does not make sense to only make electricity savings when helping a customer.

> *"The reason why we do not only focus on our own sector is partly due to historical reasons in that we have made energy counseling since the 90ies. Until 2006 we were only allowed to make electricity savings, but we could see that it did not make any sense to only focus on one type of energy." (Thingvad 2013)*

Therefore, Danish Energy does not impose certain strategies on the single power grid company; the only goal is to perform the savings the most cost efficient. Some of the companies do however have their own strategies, with a focus on local savings that the local customers benefit from. They do not see any conflict between delivering energy and reducing energy demands, and instead see the higher focus on savings as a strength to the savings activities (Thingvad 2013). DONG Energy applies the same overall strategy, of primarily focusing on the cost efficiency of the savings. DONG Energy does savings as a power grid company, but also as a natural gas company. They also operate all over the country, thus it is also very natural to focus savings in all energy sectors and geographical areas, because they also are responsible for oil and district heating production (Pedersen, Fuglsang & Broberg 2013).

Danish Energy expresses satisfaction with the Energy Savings Agreement. One of their focus areas are that there have to be a balance between the different energy types and that the target savings reflect the production of energy today (Thingvad 2013). The share of responsibility has historically been high at the power grid companies, and higher than their share of energy production to society. Thus, they have had a smaller increase of their target in the latest agreement. It also important for the future to maintain the free choice of method and a focus on cost efficiency.

"If a certain subsidiary aim is applied to the savings agreement, which breaks with the principals of cost efficiency and free choice method, we probably will not take part in a future voluntarily agreement." (Thingvad 2013)

They do however see some issues in handling savings in buildings through standard values as these do not account for the possible synergies between different kinds of savings. Therefore, relations and synergies do not become a focus in the same degree as in industrial savings.(Thingvad 2013) Thus, there might be a reason for changing how the Energy Savings Agreement handles buildings.

From an organizational point of view, Danish Energy has divided the responsibility of the power grid companies based on delivered energy. The companies have historically made savings since the 90' hence the Energy Savings Agreement have not changed the organization within each company dramatically, although the amount of employees working with energy savings in the power grid companies doubled in 2010 (Thingvad 2013). Another point of development in organizations is the increased focus on involving third parties to perform the savings. This result in the electrical companies not being directly involved in the savings but instead, counseling and craft firms identify the savings and report them to the companies. (Thingvad 2013) This organization becomes easier with the free choice of method resulting in a broader portfolio of savings. DONG Energy (see Appendix E) has applied certain energy savings units and points to that their suppliers have had to develop energy saving skills, since they are included in the overall saving efforts made by DONG Energy (Pedersen, Fuglsang & Broberg 2013).

6.4 The Performance of the Natural Gas Companies

The natural gas companies primarily, as Figure 6.5 illustrates, focus on savings within the natural gas sector, with 50 % of the savings done here in 2010 and 53 % in 2012. The natural gas companies find the most of their savings in industry with 49 % made here in 2010 and 46 % in 2012. In 2012, the amount of reported savings in households increased to 32 %, but within savings in natural gas the share of household savings were 50 %. Of the savings in households, 75 % were due to improvements and replacements of boilers and stoves within the same energy type (Danish Energy Agency 2011, Danish Energy Agency 2013).

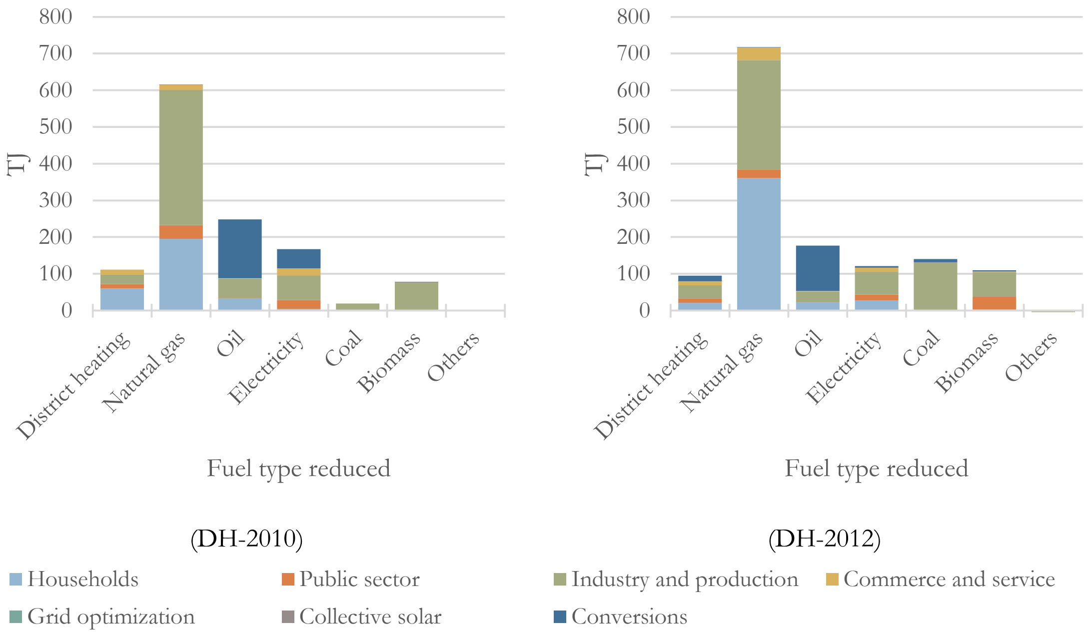

Figure 6.5 Reported savings by the natural gas companies in 2010 and 2012 (Danish Energy Agency 2011, Danish Energy Agency 2013)

In total, the amount of savings reported by the natural gas companies in 2010 was 1,239 TJ and 1,357 TJ in 2012, both over the target of 1,100 TJ. This is more or less the same amount of savings. These numbers make it the third biggest contributor of savings. Figure 6.5 shows that they found 100 TJ more savings within natural gas in 2012 than in 2010 and that savings in coal increased, whereas the district heating, oil, electricity and biomass had small drops. Conversions are primarily from oil and electricity in 2010, respectively 75 % and 24 % in electricity; in 2012 this is 79 % in oil and the rest spread out between district heating and coal, and to minor extent electricity. Based on the data from 2012 most of the conversions are to natural gas (Danish Energy Agency 2011, Danish Energy Agency 2013).

HMN Natural Gas (see Appendix H), who represents a major part of the natural gas companies in the Energy Savings Agreement, argues that even though the goal is to perform savings the most cost efficiently, there is an overall desire from them to perform savings within their own supply area. They however indicate that this becomes harder every year as the increased targets leads to the other utility companies to look more and more towards natural gas companies. Therefore, the natural gas companies do savings in other energy sectors too (Jensen 2013c).

The natural gas companies do not see a conflict between the savings agreement and delivering natural gas, because it allows for them to council on the choices they make so the consumers can choose and keep a more efficient delivery of natural gas. As they say:

"The best energy we have is the one that was never produced" (Jensen 2013c)

The natural gas companies are therefore satisfied with the Energy Savings Agreement. They focus on that the Energy Savings Agreement has to help towards completing projects that otherwise would not have been, and as such discouraging projects with very short payback periods. The free choice of method and cost efficiency are important elements. By limiting the free choice of method, the natural gas companies believe that the expenses will increase. These increased expenses fall back to the consumers who have to pay more for their energy. As of now, HMN Natural Gas expect the savings to be at reasonable level until 2017-2018, at that time a shortage cost-effective savings must be expected. (Jensen 2013c) Therefore, HMN Natural Gas has performed savings beyond the required targets, like the rest of the utility companies. This gives them a buffer the following years, which leads to more stable prices for their consumers.

In terms of organization within the natural gas companies, the Energy Savings Agreement has not required many changes because they have been doing savings since 1990. They concur that it is a good thing that the Energy Savings Agreement have led to a more defined framework for doing these savings with similar requirements for everybody. The Energy Savings Agreement have resulted in the organization with external collaborators, which means that instead of the natural gas companies finding the savings, the savings come, via external collaborators, to the natural gas companies. (Jensen 2013c)

6.5 The Performance of the Oil Companies

Figure 6.6 show the performance of the oil companies. The oil companies deliver by far the smallest contribution to the performed savings, which is due to them having the smallest targets as well (Klima- Energi- og Bygningsministeriet 2012a). The oil companies primarily report savings performed within the oil sector, with 49 % of the savings done here in 2010 and 62 % of the savings in 2012. The oil industry reported savings of 260 TJ in 2010 and 233 TJ in 2012, both over the target of 200 TJ. The oil companies bought more savings outside the oil sector in 2010 than in 2012. (Danish Energy Agency 2011, Danish Energy Agency 2013) The savings outside the oil sector resembles the activities of the other energy sectors, with the primary place to find savings is in industry. However, within the oil sector itself the main place of finding savings is households, which is 93 % of oil savings in 2010 and 86 % in 2012. The primary reason for this is that the oil companies perform a lot of replacement and renovation of existing oil boilers. In households, this explains 93 % of the reported savings in 2012 and 64 % of all savings reported by the oil companies. The numbers were 89 % and 57 % respectively in 2010. (Danish Energy Agency 2011, Danish Energy Agency 2013) This links to that the oil companies do not have the same legal framework as the other companies in form of having their customers pay for savings. This explains why they have such a small target for reductions.

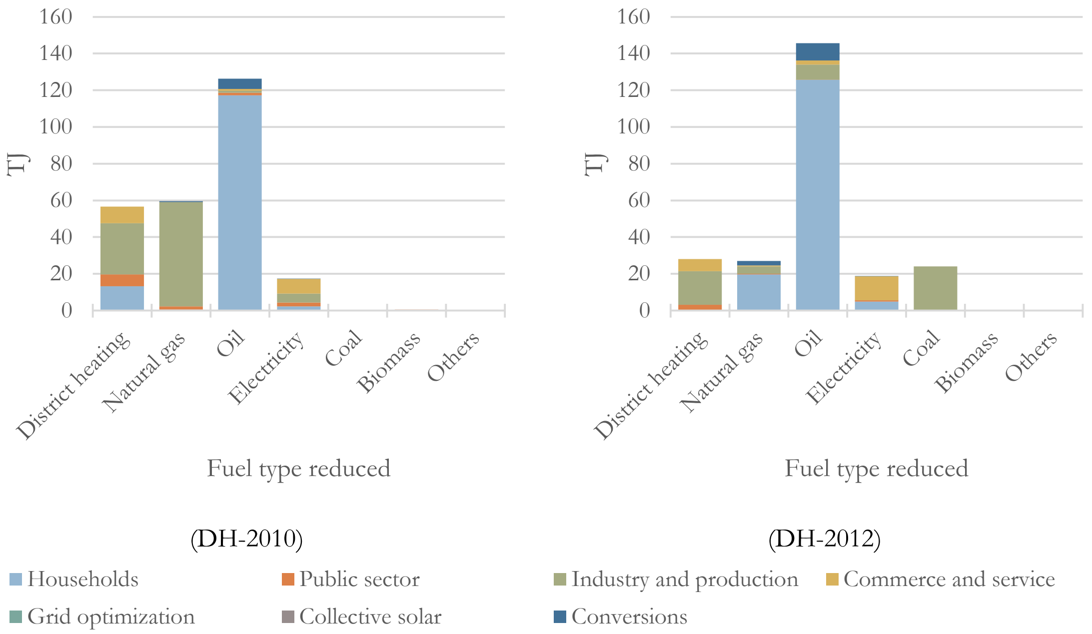

Figure 6.6 Reported savings by the oil companies in 2010 and 2012 (Danish Energy Agency 2011, Danish Energy Agency 2013)

In terms of conversions, the oil companies make almost none with 2 % of the savings coming from conversions in 2010 and 5 % in 2012. Those made are interestingly away from oil and converts to electricity.

The strategy of the oil companies has historically been, according to the Danish Oil Industry Association (see Appendix I), to perform savings within oil and the oil sector. This is based on that they have natural access to customers and savings, with a focus on service and replacing old boilers. This strategy has to been in light of how the oil companies have organized around the savings. (Jensen 2013b)

From an organization point of view, the oil companies have two components to their saving strategies. The organization of oil savings are local agreements with collaborates who report the savings. The savings found outside the oil sector are organized through an energy savings trust, which have the responsibility of buying savings, organizing the reporting of the savings and gathering the sufficient funds for these. (Jensen 2013b) In that relation, it is important to note that because the oil companies do not have the same legal framework as the other three companies, who are operating on a "self-balancing principle" meaning that income has to match expenses, they have to gather the money needed from somewhere else. The oil companies have historically been doing the local savings for a long time, so from an organization point of view, they have not changed, but the energy savings trust is a new organizational measure to tackle the Energy Savings Agreement.

The oil companies are satisfied with the agreement, and have the main standpoint that free choice of method and cost efficiency are key elements of the agreement (Jensen 2013b). One of the important attitudes towards the future of the agreement is that no energy type must not be favored compared to others. No fuel type should get an unfair treatment. They agree on the targets of a 100 % renewable energy society in 2050, but they argue that this is still far out in the future, thus oil should currently still be an option in cases where it creates the most savings and most efficient solutions (Jensen 2013b). Not before 2050 is closer should other suboptimal solutions be considered.

> *"There has to be a neutrality between the different energy types, which means that there should not be any favoritism on one type at the expense of others types because of some narrow political goals or other agendas." (Jensen 2013b)*

6.6 Summary

The overall conclusions from this chapter are that the performance of the utility companies primarily focuses on industries, especially when accounting for the lack of additionality in household savings. The companies especially target industries when they are doing savings outside of their own supply area, where there are more variety in the type of savings made when it is within their own energy sector. All, besides the oil sector, have a large amount of savings in industry within their own sector. Else, it is important to note that the reported savings are not equal to the Energy Savings Agreement effect on the energy system. Households are the second biggest group of reported savings, but when accounting for additionality they drop. Furthermore, savings in households are small savings meaning they are accounted based on the standard value chart. As such, there are uncertainties whether the reported savings are actually the performed since these are not measured.

When looking at the strategies of the individual utility companies it is seen that every sector, besides the power grid companies, target their own sector primarily, even though some say that there are no specific strategy towards this. All the companies with a primary focus on delivering energy for industry and heat have easy available savings in improving the energy equipment at the end-user, and in the case of district heating also the distribution grid. Therefore, the oil companies logically target oil boilers and the same for the natural gas companies who target the boilers and energy units at their end users. The district heating companies target the distribution grid and heating units. The power grid companies do not have these easily available savings, and as such have a need to seek more widely. This also helps explaining that they have the most varied types of savings in terms of different energy sectors.

Chapter 7, discusses and compares the elements of this chapter with each other and Chapters 4 and 5 with a focus on whether the Energy Savings Agreement is in line with the strategies for saving but also to identify the longevity of the savings agreement towards the goal of a 100 % renewable energy system in 2050.

7 A Future Plan for Promoting Energy Savings

The goal of this chapter is to identify whether the current performance of the utility companies are sufficient compared with the strategies defined in Chapter 5, and towards 2050. This discussion covers two sections, one that compares the defined strategy with the performance of the utility companies and the Energy Savings Agreement, and one that discusses this performance towards reaching the 2050 goal. Including in this are suggestions to possible changes and alternatives, which is important in light of the elements in Choice Awareness.

7.1 Comparing the Defined Strategy with the Performance and Agreement

The first strategy defined in Chapter 5 was that heat savings in form of energy renovating buildings should be a focus early in the process, and have the right targets from the beginning because of the long lifetime of insulations. Industrial and electricity savings have shorter lifetimes and therefore require more changes towards 2050, and making the implementation of these more flexible in terms of when and how.

The Energy Savings Agreement included in 2006 a sentence indicating that savings should be equally focused between all types of energy savings and, as such target heat savings in houses. This is not present in the current agreement. Instead, prioritization parameters have the responsibility of creating an incentive for energy renovation of houses and other buildings. The first set of parameters that has the possibility of influencing the utility companies to perform in line with this is strategy is those that prioritize projects with longer lifetimes. They do however mostly focus on limiting projects with lifetimes below 4 years than promoting projects with lifetimes over 15 years. Only in projects done in end-users who use non-quota fuels can projects with lifetimes over 15 years be multiplied with a factor 1.5, else all projects with lifetimes over 4 years are not separated in prioritization. When increasing insulation, installing new windows in oil and gas heated buildings there is also a prioritizing parameter of 1.5, but this is not applicable to savings done in district heating. As such, only house with individual heating are prioritized in terms energy renovation, but even then, because of the high costs of energy renovation (Risø DTU, Ea Energianalyse 2010b), these parameters are not enough to secure an early and correct completion of these projects, thus there is a rick for a need of further refurbishments later.

In terms of the electricity savings, there are no specific parameters focusing on these besides conversions away from electricity and to other energy types. Industrial savings seem to be cost-efficient, and there are no direct parameters targeting industrial savings, besides the ones creating incentive for energy renovating the buildings they are using.

When looking at the results from Chapter 6, they show that the primary targets of savings are industry. The utility companies report many savings in households, but when including the additionality of the projects the amount drops. In total, reported savings tied to energy renovations were 1,469 TJ, which equals 22 % of the total reported renovations in 2012. Of these reported savings, 71 % are however from households, which apply the standard value chart. As Section 5.2 points to, there is a tendency to over evaluation in these, and the additionality is generally low in households.

Therefore, there is an effect on energy renovations of buildings and households, and the agreement have a focus on prioritizing these savings, however the focus is somewhat limited, which Energitjenesten that is an organization who helps promote energy renovations also argues for (Bender 2013) (see Appendix J). Therefore, it is hard to make some overall conclusions on whether the utility companies are performing as desired, but better incentives toward renovating buildings earlier and the right way is most likely still desired.

The second strategy was that conversions should be with the focus of moving away from electrical heating and the use of fossil fuels, which in terms of industry and individual heating are primarily from oil and natural gas. The target of these conversions is district heating and heat pumps, and to a lesser extent biomass.

Again, the Energy Savings Agreement has parameters that lies within the overall thought of this strategy but also conflicts with this strategy. The first parameters showing this is when converting from electricity to district heating and fuels within the CO_2 quota system. A conversion from electrical heating to district heating is very desirable towards the 2050 goal, but converting from electricity to oil, natural gas and coal is not. The agreement also punishes the opposite conversion. The system does not reward conversions from quota fuels to district heating, which is not in line with the strategy, but in line with the strategy, it rewards conversions from fuels outside the CO_2 quota system to district heating. The Agreement regards biomass as a non-quota fuel and therefore there are no parameters incentivizing conversions to biomass. Another indicator of elements operating against the defined strategy are that installations of new oil and natural gas boilers outside the quota system are prioritized with parameter 1.5, but on the other hand so is heat pumps that replaces oil and natural gas boilers.

Chapter 6 shows that most conversions are from oil to the other energy sectors. The companies, besides the oil companies, target conversions to their own sector, which results in the conversions not being in line with the overall strategy defined in this report. The savings are primarily from non-quota fuels to electricity, district heating and other non-quota fuels. These are either not affected by the parameters or only gives a slight prioritizing of converting from non-quota fuels to district heating. In terms of electricity and non-quota fuel conversions it is hard to determine how much are conversions to respectively heat pumps and biomass, with heat pumps being the only one with a significant parameter.

Overall, the current prioritizing parameters give the companies opportunity to make conversions to their own sector, even though this might be undesired on a long-term perspective. This indicate that the institutionalizing and organization of savings and conversions through the Energy Savings Agreement and utility companies might not have been sufficient in terms promoting the needed technological change.

The third strategy targets that when converting from individual heating or industry to district heating this has to be coordinated with balancing the electricity demand. The goal is to lower the electricity demand, and currently CHP plants are the primary responsible for the power production. The conversion to district heating however increases the demand for heat production and as such, the CHP operates more inefficient.

Within the framework of the Energy Savings Agreement, heat pumps can balance out this discrepancy. By coordinating conversions to district heating with individual heat pumps, the CHP plants can operate more evenly. The Energy Savings Agreement only has the one parameter focusing on heat pumps and do not look at the possible synergies between these two different types of conversions.

This also results in that the activity described in Chapter 6, which shows no indicators of the combinations of electricity savings, and conversions to district heating and individual heat pumps due to this strategy. The key point here is that the amount of conversions to heat pumps is not clear, but there are reductions of the electricity consumption and conversions to district heating.

Overall, there is very little promoting this strategy in the current agreement and it is unclear whether the companies perform in this way. However, this might also become rather complex to include in an Energy Savings Agreement.

The fourth strategy defined in Chapter 5 states that the reduction of heat demand in district heating should be alongside the reduction of electricity demand. The explanation for this strategy is the same as strategy 3, it creates better relation between heat demand and electricity demand resulting it better CHP performance, thus reducing the overall PES and CO_2 emissions. Therefore, savings in both sectors are important.

There is no indication of such coordination taken into account in the Energy Savings Agreement through parameters. Nevertheless, it does include the option of individual measurement in large-scale projects. In these, it is possible to include the increased savings caused by coordinating electricity savings with heat savings. This is however not possible in projects that uses the standard value chart, which results in the different relations between the activities not being taken into account.

The results in Chapter 6 show that the savings target both district heating and electricity, which is important on the overall system perspective. In both 2010 and 2012, and in scenarios I-III, the utility companies perform more savings in district heating than in electricity. Depending on the scenario and the effect of grid and network optimizations, the companies should still strive towards a better balance. For the EnergyPLAN calculations, it is not important whether the coordination of electricity and heat savings happens in the same activity, but because decentralized district heating plants operate based on heat demand, coordination has to happen within the same district heating area.

Overall, on a whole system level there is a focus on both electricity and heat savings, with the possibility of slightly better coordination. It is however not possible to say whether there are coordination between electricity savings and district heating savings in the same district heating areas. Because of the Energy Savings Agreement lack of promoting this strategy, projects based on the standard value chart probably do not focus on coordinating heat and electricity savings, where projects with individual accounting have the possibility of considering such coordination.

The final and fifth strategy based on the analyses in Chapter 5, is that individual heat savings and industry savings are unrelated to other reductions and as such do not have to be coordinated in the same way as other savings. They however still have to live up to the goals of 100 % renewable energy in 2050.

As mentioned earlier, the Energy Savings Agreement promotes savings in individual heating areas by parameters if they are done in buildings heated by natural gas or oil. This also includes buildings in industry. The agreement does however not include parameters that improve efficiencies in industrial equipment. Another tool, also mentioned earlier in this section is that the Agreement prioritizes the installation of new oil and natural gas boilers.

Chapter 6 shows that the primary savings are within industry and most of them are improvements of the production units. Because the lifetime of industrial projects are around 7 years according to Danish Energy, the quick performance of many industrial savings have to be maintained over the years so the energy demands in industry are not increased when new equipment have to be installed. The industrial savings are predominantly by reducing natural gas. Regarding individual heating savings, it is important to note that many of these are through installing new boilers. The natural gas and oil companies focus on these savings.

Even though these savings does not relate to other types of demand reductions, there are still some important points. Industrial savings primarily reduces fossil fuel use, although 7 % of the savings were in biomass. It is important to maintain a low energy demand in industry. In terms of individual heating savings, many of the savings are because of replacement of boilers. Thereby the oil and natural gas companies maintains there position in the energy market by renewing oil and natural gas boilers instead of switching to district heating, biomass or heat pumps. Again, the utility companies might not be able to perform the technology change needed, because of the Energy Savings Agreement do not create the right organization when it comes to what energy types should be included in the future energy system.

7.2 Towards the 2050 Goal

Section 7.1 discusses each suggested strategy with the performance of the utility companies. This leads to that some of the elements functions well and others need changes in order to reach a 100 % renewable energy system in 2050. The suggestions for changes include perspectives from the utility companies.

The Energy Savings Agreement results in savings and secures savings distributed to all energy sectors. The analyses show that this most likely is because of the involvement of all the utility companies because of the local focus tree of them have. If some of them were to leave the agreement, the variety of savings might change. Because of this, the Energy Savings Agreement results in savings that target the current Danish energy system well in terms of having savings in both electricity and district heating which gives an overall better performance of the savings.

The Energy Savings Agreement also succeeds in reporting savings in all types of end-users although with a primary focus on industrial savings. The Energy Savings Agreement also focus on conversions and the included parameters help towards connecting more end-users to district heating. As such, cost efficiency and free choice of method can lead to some of the needed savings.

Although the utility companies report a large amount of savings in households, when including the additionality of the savings and the notion from Energitjenesten the indication is that the Energy Savings Agreement does not perform as well as the reporting indicate (Bender 2013). The Energy Savings can therefore have a better focus in performing savings in households and promoting energy renovations to reach the 2050 goal. First, there should not be an incentive to replace boilers with fossil fuels and instead the parameter of 1.5 should be reduced, maybe to 0.5. Furthermore, the incentive for energy renovations could increase by increasing the parameter for long lifetime projects. The suggestion is first to raise the parameter of projects with lifetimes over 15 years in all energy sectors so households within district heating have incentives to do energy renovations, and second increase the parameter to more than 1.5, which it is today. This increase should be on projects lowering the energy use of the building, and not the energy use of the unit heating the building. DONG Energy suggests to increase the parameter to 5.0 (Pedersen, Fuglsang & Broberg 2013).

The lowering of the parameter of replacing oil and natural gas boilers with new more efficient ones has to be combined with changing the prioritizing parameters for conversions. Right now, the conversions are primarily from a fossil fuel to a utility companies' own energy type. Therefore, the new parameters have to challenge both the replacement of boilers and conversions to an undesired energy type in regards of the 2050 goal. The suggestions become to introduce a parameter that incentivizes conversions to heat pumps and improves on the one to district heating. Finally, conversions to fossil fuels should always have a low prioritization parameter. By doing this, incentives are created without removing the free choice of method, which all the utility companies claim to be very important to keep since this strives towards cost efficiency. The issue is that such parameters make the reported savings even less comparable to the actual effect of the savings. Therefore, these have to be precisely determined, so the companies perform the desired type of energy savings.

Even though the Energy Savings Agreement results in savings in all energy sectors, the synergy between different savings should still be in focus. This is important because district heating demand and electricity demand has to be coordinated on a local level. The standard value chart does not consider such things, whether the synergies in savings create better or worse overall results. Therefore, the standard value chart could include such elements instead of being a simple addition. This would create an incentive to do savings with a total focus in households and not only on heat savings, which Danish Energy also points to as a possible change to the current agreement (Thingvad 2013). This might however create higher workloads for the small utility companies.

The Energy Savings Agreement primarily focuses efficiency increases and do not target elements that helps towards energy conservation through monitoring programs and advices. The reason might be that they are harder to register, but they might secure higher saving rates. The Danish District Heating Association suggests an increased focus on such elements because they have registered houses, which have already been energy renovated, sometimes have an increased energy consumption (Jensen 2013a). Therefore, there is a need for energy advice and monitoring which creates better behavior. Also, Energitjenesten suggests that more focus are put on improving counselling because the small money that the utility companies can give are not what currently creates the big savings in households. It might only serves as a kick-starter (Bender 2013).

8 Discussion

While Chapter 7 focused on discussing the results of the analyses between each other, the Energy Savings Agreement and the theoretical framework regarding technological change, this chapter seeks to discuss the results in relation to the methodology and theories. Included in this is elements of uncertainties tied the results. First of is the theoretical framework discussed, and secondly the methods and the uncertainties related to these.

8.1 Discussion of the Theoretical Framework

The theoretical framework has two primary elements. It defined the holistic approach in terms of identifying energy savings, and defined increased energy savings as a technological change.

The holistic approach focuses on that instead of analyzing savings on a micro level, the whole energy system has to be the focus. The argument is that this understanding creates a better strategy for how to integrate energy savings on a societal scale. The alternative to this approach is to determine potentials for each type of saving on a micro level.

By using the holistic approach, it becomes hard to reach clear numbers for total reduction targets because of the many possible elements to include in the analysis. The goal of the analyses was however not to do this but instead to understand how different energy savings operated together, which the thesis from Section 2.1 also states. In addition, by looking at the results of the report it managed to define where the system affected the savings and from that define strategies towards future savings activities. Therefore, the calculations are seen as successful even without the use of specific numbers.

The thesis and the defined approach to identifying suitable energy savings strategies can still be expanded on, partly due to the holistic approach that opens for the analyses of many more effects and synergies.

The second primary part of the theoretical framework is technological change. The purpose of this element is in relation to understanding whether current organizations can handle technological change in form of energy savings. The Energy Savings Agreement defines the framework for the utility companies and within that the organization of energy savings. The results show that savings are being reported and in relation with the study from Ea Energy Analyses also being done. However, the interviews and results also show that certain approaches by the companies hinder the right development. This leads to a situation of status quo in terms of changing from natural gas and oil. This is also because of the definitions in the Energy Savings Agreement.

Therefore, when looking at the identified hypotheses in Section 2.2, the Energy Savings Agreement creates a product of energy savings and implements new techniques in terms of identifying savings. The organization also follows to a certain extent with the utility companies creating new divisions and such. But even though the organizations are changing, and they claim that the predominant goal is to do cost efficient savings, all companies besides the power grid companies focus on mostly on their own type of energy. This is partly due to the companies having more knowledge in this field making it a logical and easy place to do savings, but the activity also helps maintaining the status quo, and therefore keep their role in the energy system. This is partly in line with hypotheses three, but there is also a will to perform savings in form of efficiency increases, so the goal is not only to maintain a status quo.

When looking at the elements in the Energy Savings Agreement it also appears that some of them help in maintaining the status quo as hypothesis 4 states, for example, the factor 1.5 when installing a new natural gas or oil boiler.

These elements indicate that the theory explains some of the activities by the utility companies, but it is important to remember that they do perform savings. Therefore, the analyses cannot finally conclude whether the Energy Savings Agreement leads to the needed energy savings and conversions to reach the goal of 100 % renewable energy in 2050. Although, without performing the suggested changes in Chapter 7, the organizational change probably will not be enough and there is a greater chance of the technological change failing.

8.2 Discussion of the Methodology and Uncertainties

This section describes the methodologies and uncertainties relating to the two primary analyses in this thesis. The first section focuses on the definition of an approach towards analyzing the integration of suitable energy savings and the energy system analysis relating to this approach. The second section focuses on the interviews and calculations in relation to the assessment of the current activities by the utility companies.

The approach defined in Section 3.2 regarding how to analyze the integration of suitable energy savings shows that because of the holistic approach the three steps require many considerations and all of them are an analysis in itself. In relation to this project, not all were necessary from the perspective of energy system analysis, thus the focus only was on analyzing step 1, which focuses on identifying how the system works in relation reducing demands and converting between energy types. This step will not produce specific numbers for the further analyses, but can describe the tendencies of the system that are equally important. The next steps in determining the integration of suitable energy savings are assessing the potential for savings, combining these with the relations identified in step 1 and finally introducing renewable energy. This thesis does include information related to the second step but only convers it qualitatively. The third step is only included peripherally.

Because the analysis did not focus on specific estimates of potentials for energy savings, as step 2 focus on, the uncertainty of the analysis id not relate to the sensitivity of these potentials. Instead, the uncertainty in step 1 focus on the model applied, and how well it represents the system that it seeks to emulate.

The analysis focused on the current Danish energy system, but to make sure the identification of relations in this system were correct the analysis applied two models of the current Danish system. The first model was the 2010 CEESA model, already modeled in EnergyPLAN and the second was the 2008 Climate Commission model, which was modeled in EnergyPLAN in relation to this thesis. There are some differences in these two models such as the heat demand in district heating compared to the individual heat demand, and demand for energy in industry. Therefore, there were slight differences in the outputs, but all the results showed the same tendencies for relations in the current Danish energy system. Although some of the numbers in the Climate Commission model came from the CEESA model, the assessment is that these had only a slight effect on the results, and the differences in demand had greater effects. Overall, because the two systems showed the same behavior in terms of relations and synergies between different savings the uncertainty is rather small, and the assessment is that the results show how the Danish energy system reacts to different savings.

The assessment of the performance of the utility companies consists of analyzing the reported savings and interviewing the utility companies.

The calculations consisted of representing the reported savings as registered by the Danish Energy Agency and by taking into account the additionality of the reported savings and the use of prioritization factors when the companies converted from one fuel type to another. In regards of the additionality, Ea Energy Analyses mentions that the methodology used by them is uncertain. Therefore, the numbers presented in Chapter 6 also have uncertainty to them. Therefore, the specific numbers as a result is not of much use but the tendencies the results show are of great importance, since they help showing a more likely distribution of savings caused by the Energy Savings Agreement. Because of the uncertainties, the calculations used two ways of multiplying additionality to the reported savings, which lowers the uncertainties in relation to understanding the estimated actual performance of the utility companies.

The calculations also corrected for prioritization parameters that focus on conversions between different fuels. The Energy Savings Agreement includes many parameters, but not all of them were possible to correct for, which together with the relevance of the conversions in terms of the 2050 goal are reasons why the thesis focused on conversions between different fuel types. There were also uncertainties tied to this estimation, since the calculations had three assumptions. One, the conversions are all to the utility companies own fuel; two, conversions from fossil fuels were outside the CO_2-quota system; and three, the conversion factor used was based on the standard value chart. In real life, there is greater variance to these, but based on Ea Energy Analyses and the results from the utility companies reported savings, the conversions do primarily target their own fuels and most of the fossil fuels conversions are non-quota. The final assumption was necessary since all given savings available includes the parameters and therefore makes it impossible to identify the specific before and after reductions. Therefore, the standard value chart becomes the one to base these on.

Overall, the primary findings from the calculations in Chapter 6 are the overall tendencies of the utility companies' performance, and in addition, how the reported savings can be different from the effect of the Energy Savings Agreement.

The analysis in Chapter 6 uses interviews with the involved interest organizations to reflect on the tendencies and strategies identified in the data. The interviews thereby confirm or give other information in relation to the data. The use of interest organizations have the benefit of getting the official opinion of the utility companies as one and an overview of all the energy sectors by only having a few interviews. However, on the other hand these companies might not have a great deal of experience actually finding the savings, which is why interviews with DONG energy and information from an older report helps identifying the more local activities and the opinion when performing these. There were no scientific assessment involved in selecting these local companies, and therefore should not be seen as representative, but instead they provide a perspective to the overall strategies. Thereby, the interviews succeed in identifying current strategies and what organizational changes the companies have experienced due to the Energy Savings Agreement. The interviews also managed to gather suggestions for changes, but it was not possible to get reflections on all changes suggested in this section, partly due to the answers given by some of the companies.

In total, the interviews is seen as an success, and because of the use of both overall organization and perspectives from local companies, the interviews in relation to the calculations create a good understandings of the strategies of the utility companies. They also show how the Energy Savings Agreement has influenced the organization of the companies, and how the Energy Savings Agreement creates a framework that defines certain types of energy savings.

9 Conclusion

The introduction to this report framed a problem that circled around two elements, there is a need for energy savings towards creating a 100 % renewable energy scenario and this needs political guidance to ensure that the right types of savings are made. The Energy Savings Agreement creates this foundation by making the utility companies responsible for demand reductions. The research question was:

How does the Danish energy system effect the integration of large-scale energy savings and what are the consequences in terms of defining suitable integration strategies of savings towards the goal of 100 % renewable energy in 2050. Is the current Energy Savings Agreement helpful towards implementing such strategies?

The first conclusion relates to the identification of savings in relation to defining suitable integration strategies. From the analyses in chapter 5, the conclusion becomes that the Danish energy system, because of combined heat and power production requires coordination when combining reductions in district heating demand and electricity demand, and when converting from individual heating and industrial energy to district heating in relation to reducing electricity demand. These are, in combination with the other information obtained through this analysis, summarized into five strategies:

- Heat savings have to be done correctly from the beginning because of their long lifetimes. Industrial and electricity savings have shorter lifetimes so they are more flexible.
- In both individual heating and industry, electrical heating, oil and natural gas should preferably be converted to heat pumps and district heating, and to a lesser extent biomass.
- When converting to district heating it has to be coordinated with balancing the electricity demand by using heat pumps.
- Reduce heat demand in district heating and electricity demand combined as this generates better coordination between the two demands resulting in better operation in the combined heat and power plants.
- Industrial savings and savings in individual heating demand can largely be made without attention to reduction in other energy sectors.

In terms of whether the Energy Savings Agreement is helpful towards implementing these strategies, the first conclusion is that the utility companies do perform energy savings. The calculations in this report do not determine whether the amounts of savings performed are sufficient towards the total demand reductions required in 2050, but they indicate whether the

Energy Savings Agreement and utility companies operate towards this goal. In terms of savings, the activities are predominantly industrial savings and the demand reductions performed in households are uncertain both in terms over evaluation and additionality. The savings in households also includes a large amount of replacing old natural gas and oil boilers with new ones. In terms of conversion, the utility companies focus on converting to their own energy sector, with the primary conversions being from oil. The conversions however target natural gas, electricity and district heating and probably also some biomass and heat pumps.

Therefore, some of this activity is in line with the strategies, while other elements are not. Overall, the Energy Savings Agreement will not work on a long run towards 2050 without changing the prioritizing elements towards displacing fossil fuels. The current agreement instead maintains the fossil fuel companies' role in the energy system.

These adjustments do not rule out the use of the free choice of method or having cost efficiency as an overall goal, but some of the utility companies might no longer be a part of the agreement. By not having all utility companies involved the analyses indicate that it will influence the savings made and therefore, might reduce the variety in savings. If this is to be the case, the Energy Savings Agreement might not the right way of organizing savings towards a 2050 scenario. However, if the companies are willing to change the way savings and conversions are prioritized, nothing in the analyses show that the Energy Savings Agreement cannot be a part of converting the Danish energy system to 100 % renewable energy in 2050.

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List of Appendices

Appendix A

EnergyPLAN output for CEESA 2010

Input CEESAnalyses.txt

The EnergyPLAN model 10.1

Electricity demand (TWh/year):		Flexible demand	0,00
Fixed demand	33,28	Fixed imp/exp.	0,00
Electric heating	1,94	Transportation	0,40
Electric cooling	0,00	Total	35,62

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	2,78	10,42	22,67	35,87
Solar Thermal	0,01	0,00	0,00	0,01
Industrial CHP (CSHP)	0,00	0,00	0,96	0,96
Demand after solar and CSHP	2,77	10,42	21,71	34,90

Wind	2934 MW	6,28 TWh/year	0,00	Grid
Offshore Wind	868 MW	2,95 TWh/year	0,00	stabili-
River Hydro	0 MW	0 TWh/year	0,00	sation
Photo Voltaic	0 MW	0 TWh/year	0,00	share
Hydro Power	0 MW	0 TWh/year		
Geothermal/Nuclear	0 MW	0 TWh/year		

	Capacities MW-e	Capacities MJ/s	Efficiencies elec.	Efficiencies Ther	COP
Group 2:					
CHP	1945	2407	0,37	0,46	
Heat Pump	50	98			1,95
Boiler		3667		0,93	
Group 3:					
CHP	2500	4188	0,31	0,53	
Heat Pump	0	0			3,50
Boiler		7978		0,93	
Condensing	7522		0,40		

Heatstorage: gr.2: 40 GWh gr.3: 10 GWh
Fixed Boiler: gr.2: 2,5 Per cent gr.3: 1,0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0,00	0,00
Gr.2:	0,00	0,62
Gr.3:	1,01	1,14

Regulation Strategy:	Technical regulation no. 3	
KEOL regulation	23450000	
Minimum Stabilisation share	0,30	
Stabilisation share of CHP	0,00	
Minimum CHP gr 3 load	450	MW
Minimum PP	0	MW
Heat Pump maximum share	0,50	
Maximum import/export	0	MW
Distr. Name :	Price_DKV_2008.txt	
Addition factor	80,00	DKK/MWh
Multiplication factor	0,75	
Dependency factor	0,02	DKK/MWh pr. MW
Average Market Price	395	DKK/MWh
Gas Storage	0	GWh
Syngas capacity	0	MW
Biogas max to grid	0	MW

Fuel Price level:

	Capacities MW-e	Storage GWh	Efficiencies elec.	Efficiencies Ther.
Hydro Pump:	0	0	0,85	
Hydro Turbine:	0		0,85	
Electrol. Gr.2:	0	0	0,73	0,07
Electrol. Gr.3:	0	0	0,73	0,07
Electrol. trans.:	0	0	0,73	
Ely. MicroCHP:	0	0	0,73	
CAES fuel ratio:	0,000			

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0,00	69,63	0,00	0,00
Household	0,00	5,89	7,73	12,04
Industry	2,88	16,04	14,03	3,08
Various	0,00	8,39	7,89	0,00

Output WARNING!!: (1) Critical Excess;

	District Heating										Electricity																		Exchange	
	Demand	Production									Consumption						Production							Balance					Payment	
	Distr. heating MW	Solar MW	Waste+ CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Ba-lance MW	Elec. demand MW	Flex.& Transp. MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste+ CSHP MW	CHP MW	PP MW	Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Imp Million DKK	Exp Million DKK
January	6571	0	898	503	4584	60	0	559	0	-34	4143	45	132	0	389	0	0	946	0	0	315	3044	442	160	0	37	37	0	0	0
February	6723	0	898	514	4216	71	0	968	0	55	4084	46	145	0	399	0	0	1376	0	0	315	2792	289	141	0	99	99	0	0	0
March	5728	1	898	437	4090	57	0	257	0	-13	3983	46	106	0	332	0	0	1101	0	0	315	2715	385	151	0	50	50	0	0	0
April	4590	2	898	348	3230	52	0	93	0	-33	3548	45	81	0	255	0	0	911	0	0	315	2141	566	160	0	4	4	0	0	0
May	3601	2	898	271	2293	45	0	69	0	23	3522	46	63	0	188	0	0	921	0	0	315	1516	1160	178	0	95	95	0	0	0
June	1632	3	898	118	927	37	0	29	0	-380	3551	46	31	0	55	0	0	966	0	0	315	589	1869	205	0	56	56	0	0	0
July	1632	2	898	118	913	36	0	29	0	-365	3233	45	30	0	55	0	0	653	0	0	315	579	1848	225	0	31	31	0	0	0
August	1632	2	898	118	912	36	0	28	0	-363	3728	46	30	0	55	0	0	920	0	0	315	578	2110	217	0	66	66	0	0	0
September	2505	1	898	187	1413	38	0	29	0	-61	3768	46	43	0	114	0	0	906	0	0	315	933	1863	200	0	47	47	0	0	0
October	3731	1	898	282	2261	52	0	185	0	53	3830	45	68	0	197	0	0	1500	0	0	315	1490	997	150	0	162	162	0	0	0
November	4895	0	898	373	3304	58	0	294	0	-31	4076	46	89	0	276	0	0	1441	0	0	315	2193	655	144	0	118	118	0	0	0
December	5845	0	898	447	3897	58	0	528	0	17	4013	46	112	0	340	0	0	982	0	0	315	2580	711	166	0	77	77	0	0	0
Average	4084	1	898	309	2667	50	0	253	0	-95	3789	46	77	0	221	0	0	1050	0	0	315	1760	1077	175	0	70	70	0	Average price	
Maximum	11476	14	898	883	6595	98	0	5107	0	3928	5875	93	368	0	721	0	0	3802	0	0	315	4445	4165	302	0	2855	2855	0	(DKK/MWh)	
Minimum	1429	0	898	104	754	30	0	26	0	-3263	1959	1	24	0	41	0	0	0	0	0	315	450	0	100	0	0	0	0	145	0
TWh/year	35,87	0,01	7,89	2,71	23,42	0,44	0,00	2,23	0,00	-0,83	33,28	0,40	0,68	0,00	1,94	0,00	0,00	9,22	0,00	0,00	2,77	15,46	9,46		0,00	0,62	0,62	0,00	0	0

FUEL BALANCE (TWh/year):

	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste	CAES Elc.ly.	BioCon-version	Synthetic Fuel	Wind	Offsh.	Hydro	PV	Solar.Th.	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Imp/Exp Corrected Netto	CO2 emission (Mt): Total	CO2 emission (Mt): Netto
Coal	0,00	0,27	23,33	-	-	17,14	-	-	-	-	-	-	-	-	-	-	-	-	-	2,88	43,63	-1,18	42,45	14,92	14,52
Oil	0,71	0,03	1,03	-	0,22	0,69	-	-	-	-	-	-	-	-	-	-	-	69,63	5,89	24,43	102,63	-0,05	102,59	27,34	27,33
N.Gas	0,90	13,45	3,77	-	0,28	2,29	-	-	-	-	-	-	-	-	-	-	-	-	7,73	21,92	50,35	-0,16	50,19	10,33	10,30
Biomass	1,31	1,42	2,99	0,58	1,31	3,42	-	-	9,19	-	0,33	-	-	-	-	-	-	-	11,89	3,08	35,52	-0,15	35,37	1,08	0,00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	6,28	2,95	-	-	0,13	-	-	-	9,35	0,00	9,35	0,00	0,00
H2 etc.	-	0,00	0,00	0,00	0,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	0,00	-	-	-	-	-	-	-	-0,25	-	-	-	-	-	-	0,25	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	2,93	15,17	31,13	0,58	1,82	23,54	-	-	9,19	-	0,08	-	6,28	2,95	-	-	0,13	69,88	25,51	52,31	241,49	-1,53	239,95	53,67	52,15

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Appendix B
Modeling Climate Commission 2008

The Climate Commission defines the demand for energy based on the 2008 energy system. Table C1 show these demands divided into groups needed for inputting the numbers in EnergyPLAN. The numbers from the Climate Commission does not divide the district heating demand into the different types of district heating systems present in the Danish energy system, district heating without electricity production, decentralized CHP and centralized CHP. Therefore, to split out the district heating demand, the shares from CEESA are used. These are 8 % for group 1, 29 % for group 2 and 63 % for group 3 (Lund et al. 2011b).

The second important notion is that the Climate Commission defines industry by the demand whereas EnergyPLAN calculates based on fuel use. This means that number is rather low which is why tweaking the industry numbers might become necessary.

Demand type	Energy [TWh]
Electricity	33.06
District heating	28.61
- *DH group 1*	*2.22*
- *DH group 2*	*8.31*
- *DH group 3*	*18.09*
Individual heating	32.49
- Oil	6.94
- Natural gas	10.56
- Biomass	11.94
- Coal	0
- Electricity	1.94
- Heat pump	1.11
Industry	23.33
- Oil	8.61
- Natural gas	9.44
- Biomass	2.50
- Coal	2.78
Transport	
- Petrol	21.67
- Diesel	33.89

Table C1 Demand inputs in EnergyPLAN, italics indicate numbers based on CEESA (Lund et al. 2011a, Risø DTU, Ea Energianalyse 2010a)

The next step in converting the Climate Commissions base model to EnergyPLAN is the definition of the installed capacities and efficiencies of the various production units. More specifically this covers the installed capacities of district heating, power production, boilers, stoves, waste incineration and renewable energy. Here the Climate Commission's reports become somewhat unclear on the capacities installed in the current system. Therefore, when the numbers have not been available in the reports associated with the Climate Commission, the baseline for installed capacities and fuels the thesis adopts numbers from the CEESA report; these numbers are marked in italics in the table. CEESA also defines the base number for the efficiency of the installed energy production units in cases where the Climate Commission does not define the numbers. If the Climate Commission defines both installed capacity and yearly production, the goal is to calculate the efficiency.

This methodology of course create lesser variance between the two energy systems, but because of the timeframe given for the thesis it was the most sound way of doing it. Especially because the CEESA 2010 system represents the current energy system and as such, the assumption is that the numbers are close. In addition, it should be possible to see differences in the behavior of the systems because of the differences in demands. Finally, the hourly distribution files are also from CEESA. Tables C2 to C7 show the installed capacities and efficiencies of the various energy production units.

	Group 1 DH	Group 2 DH	Group 3 DH
CHP capacity	-	*1945 MW-e*	*2500 MW-e*
Boiler	-	*3667 MJ/s*	*7978 MJ/s*
Condensing capacity	-	-	*7522 MW-e*
Electrical efficiency	-	*0.3732*	*0.3148*
Thermal efficiency	*0.9271*	*0.4618*	*0.5274*
Boiler efficiency	-	*0.9271*	*0.9271*
Condensing efficiency	-	-	*0.4020*

Table C2 Installed capacities and efficiencies in district heating and CHP. Italics indicate number from CEESA. (Lund et al. 2011a)

	Coal [TWh]	Oil [TWh]	Natural gas [TWh]	Biomass [TWh]
DH	-	*2.23*	*2.83*	*1.31*
CHP2	*0.2*	*0.02*	*9.8*	*1.42*
CHP3	*19.41*	*0.86*	*3.14*	*2.99*
Boiler2	-	*2.23*	*2.83*	*1.31*
Boiler3	-	*2.23*	*2.83*	*1.31*
Condensing/PP	*26.75*	*1.07*	*3.57*	*3.42*
PP2	-	-	-	-

Table C3 Distribution of fuels in district heating and CHP plants. Italics indicate number from CEESA.(Lund et al. 2011a)

	Wind	Off-shore wind
Capacity	2500 MW	800 MW

Correction factor	0.08	0.22

Table C4 Installed capacities and correction factors for renewable energy.(Risø DTU, Ea Energianalyse 2010a)

	Thermal efficiency	COP heat pump
Coal boiler	*0.7*	-
Oil boiler	*0.85*	-
Natural gas boiler	*0.90*	-
Biomass boiler	*0.80*	-
Heat pump	-	*3*
Electrical heating	-	-

Table C5 Efficiencies and COP in individual heating. Italics indicate number from CEESA.(Lund et al. 2011a)

	DH group 1	DH group 2	DH group 3
Waste input	*0.07*	*3.21*	*5.91*
DH efficiency	*0.8*	*0.75*	*0.75*
Electricity efficiency	-	*0.19*	*0.19*
DH production from industry	*0*	*0*	*0.96*
Electricity production from industry	*0*	*0*	*1.01*

Table C6 Waste incineration and industry parameter. Italics indicate number from CEESA.(Lund et al. 2011a)

	Bio-diesel plant	Bio-petrol plant
Electricity share	*0*	*0.011*
Bio-diesel share	*0.96*	-
Output bio-diesel	*0.19*	-
Steam share	-	*0.13*
Steam efficiency	-	*1.25*
Bio-petrol efficiency	-	*0.50*
DH3 group share	-	*0.10*
TWh/year bio-petrol	-	*0.06*

Table C7 Parameters for biofuel plants. Italics indicate number from CEESA.(Lund et al. 2011a)

By applying these tables, the thesis creates an overall system. Tweaking is however necessary to make the inputs fit the outputs defined by the Climate Commission. Appendix C show the final system with inputs and outputs.

Appendix C
EnergyPLAN output for Climate Commission 2008

Input ClimateCommissionAnalyses.txt **The EnergyPLAN model 10.1**

Electricity demand (TWh/year):		Flexible demand	0,00
Fixed demand	33,12	Fixed imp/exp.	0,00
Electric heating	1,94	Transportation	0,40
Electric cooling	0,00	Total	35,46

District heating (TWh/year)	Gr.1	Gr.2	Gr.3	Sum
District heating demand	2,22	8,31	20,09	30,62
Solar Thermal	0,01	0,00	0,00	0,01
Industrial CHP (CSHP)	0,00	0,00	0,96	0,96
Demand after solar and CSHP	2,21	8,31	19,13	29,65

Wind	2500 MW	5,14 TWh/year	0,00	Grid
Photo Voltaic	0 MW	0 TWh/year	0,00	stabili-
Wave Power	0 MW	0 TWh/year	0,00	sation
Offshore Wind	800 MW	1,8 TWh/year	0,00	share
Hydro Power	0 MW	0 TWh/year		
Geothermal/Nuclear	0 MW	0 TWh/year		

	Capacities MW-e	MJ/s	Efficiencies elec.	Ther	COP
Group 2:					
CHP	1945	2418	0,37	0,46	
Heat Pump	50	98			1,95
Boiler		3667		0,93	
Group 3:					
CHP	2500	4185	0,31	0,53	
Heat Pump	0	0			3,50
Boiler		7978		0,93	
Condensing	7522		0,40		

Heatstorage: gr.2: 40 GWh gr.3: 10 GWh
Fixed Boiler: gr.2: 2,5 Per cent gr.3: 1,0 Per cent

Electricity prod. from	CSHP	Waste (TWh/year)
Gr.1:	0,00	0,00
Gr.2:	0,00	0,61
Gr.3:	1,01	1,12

Regulation Strategy:	Technical regulation no. 3	
KEOL regulation	23450000	
Minimum Stabilisation share	0,30	
Stabilisation share of CHP	0,00	
Minimum CHP gr 3 load	450	MW
Minimum PP	0	MW
Heat Pump maximum share	0,50	
Maximum import/export	0	MW
Distr. Name :	Price_DKV_2008.txt	
Addition factor	80,00	DKK/MWh
Multiplication factor	0,75	
Dependency factor	0,02	DKK/MWh pr. MW
Average Market Price	395	DKK/MWh
Gas Storage	0	GWh
Syngas capacity	0	MW
Biogas max to grid	0	MW

Fuel Price level:

	Capacities MW-e	Storage GWh	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.:	0	0	0,80	
Ely. MicroCHP:	0	0	0,80	
CAES fuel ratio:		0,000		

(TWh/year)	Coal	Oil	Ngas	Biomass
Transport	0,00	55,46	0,00	0,00
Household	0,00	9,62	11,73	13,33
Industry	4,90	13,00	10,00	2,20
Various	0,00	4,00	2,00	0,00

Output WARNING!!: (1) Critical Excess;

	District Heating										Electricity																			Exchange	
	Demand	Production									Consumption						Production							Balance					Payment	
	Distr. heating MW	Solar MW	Waste+ CSHP MW	DHP MW	CHP MW	HP MW	ELT MW	Boiler MW	EH MW	Ba-lance MW	Elec. demand MW	Flex.& Transp. MW	HP MW	Elec-trolyser MW	EH MW	Hydro Pump MW	Tur-bine MW	RES MW	Hy-dro MW	Geo-thermal MW	Waste+ CSHP MW	CHP MW	PP MW	Stab-Load %	Imp MW	Exp MW	CEEP MW	EEP MW	Imp Million DKK	Exp Million DKK
January	5903	0	894	422	4375	45	0	188	12	-32	4137	45	94	0	386	0	0	707	0	0	312	2878	766	184	0	0	0	0	0	0
February	5579	0	894	398	3953	50	0	254	30	0	4109	46	93	0	383	0	0	1065	0	0	312	2599	659	166	0	5	5	0	0	1
March	4807	1	894	341	3455	37	0	48	5	25	3991	46	77	0	310	0	0	828	0	0	312	2266	1025	186	0	8	8	0	0	1
April	3591	2	894	252	2409	27	0	24	0	-17	3558	45	57	0	228	0	0	668	0	0	312	1580	1327	201	0	0	0	0	0	0
May	2354	2	894	162	1352	29	0	22	2	-110	3544	46	43	0	151	0	0	684	0	0	312	876	1953	221	0	40	40	0	0	10
June	1721	3	894	116	918	27	0	23	2	-261	3481	46	35	0	111	0	0	704	0	0	312	582	2088	226	0	15	15	0	0	5
July	1397	2	894	93	832	26	0	23	1	-473	3185	45	30	0	89	0	0	472	0	0	312	513	2056	247	0	5	5	0	0	1
August	1448	2	894	97	843	27	0	22	2	-438	3674	46	31	0	93	0	0	686	0	0	312	522	2348	240	0	24	24	0	0	8
September	2040	1	894	140	1024	28	0	23	2	-71	3735	46	39	0	131	0	0	665	0	0	312	664	2316	230	0	7	7	0	0	3
October	3172	1	894	223	1920	37	0	32	27	37	3808	45	58	0	228	0	0	1157	0	0	312	1253	1459	181	0	43	43	0	0	12
November	4475	0	894	318	3170	43	0	49	27	-26	4048	46	76	0	311	0	0	1114	0	0	312	2082	991	170	0	19	19	0	0	4
December	5409	0	894	386	3956	43	0	100	24	5	3990	46	88	0	367	0	0	744	0	0	312	2598	846	185	0	9	9	0	0	2
Average	3486	1	894	245	2347	35	0	67	11	-114	3771	46	60	0	232	0	0	790	0	0	312	1532	1489	203	0	15	15	0	Average price	
Maximum	6199	14	894	443	5977	98	0	3148	1582	3382	5797	93	125	0	1935	0	0	3300	0	0	312	3952	4293	308	0	1682	1682	0	(DKK/MWh)	
Minimum	1256	0	894	72	753	24	0	0	0	-1423	1915	1	27	0	80	0	0	0	0	0	312	450	0	100	0	0	0	0	441	366
TWh/year	30,62	0,01	7,86	2,15	20,62	0,31	0,00	0,59	0,10	-1,00	33,12	0,40	0,53	0,00	2,04	0,00	0,00	6,94	0,00	0,00	2,74	13,46	13,08		0,00	0,13	0,13	0,00	0	47

FUEL BALANCE (TWh/year):	DHP	CHP2	CHP3	Boiler2	Boiler3	PP	Geo/Nu.	Hydro	Waste	CAES Elc.ly.	BioCon-version	Synthetic Fuel	Wind	PV	Wave	Offsh.	Solar.Th.	Transp.	househ.	Industry Various	Total	Imp/Exp Corrected Imp/Exp	Netto	CO2 emission (Mt): Total	Netto
Coal	-	0,23	21,38	-	-	24,90	-	-	-	-	-	-	-	-	-	-	-	-	-	4,90	51,41	-0,25	51,16	17,58	17,50
Oil	0,52	0,02	0,92	-	-	0,99	-	-	-	-	-	-	-	-	-	-	-	55,46	9,62	17,00	84,53	-0,01	84,52	22,52	22,52
N.Gas	0,49	10,33	3,36	-	-	3,22	-	-	-	-	-	-	-	-	-	-	-	-	11,09	12,00	40,48	-0,03	40,45	8,26	8,26
Biomass	1,31	1,42	2,99	0,06	0,57	3,42	-	-	9,19	-	0,33	-	-	-	-	-	-	-	13,33	2,20	34,82	-0,03	34,79	1,08	0,00
Renewable	-	-	-	-	-	-	-	-	-	-	-	-	5,14	-	-	1,80	0,59	-	-	-	7,52	0,00	7,52	0,00	0,00
H2 etc.	-	0,00	0,00	0,00	0,00	0,00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Biofuel	-	-	0,00	-	-	-	-	-	-	-	-0,25	-	-	-	-	-	-	0,25	-	-	0,00	0,00	0,00	0,00	0,00
Nuclear	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0,00	0,00	0,00	0,00	0,00
Total	2,32	12,00	28,64	0,06	0,57	32,53	-	-	9,19	-	0,08	-	5,14	-	-	1,80	0,59	55,71	34,04	36,10	218,77	-0,32	218,45	49,44	48,27

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Appendix D
Interview guide

Questions regarding the handling of the energy savings agreement

a) How much are your target savings?
b) How do you reach the target savings?
c) How do you divide the target savings onto your member organizations
d) How does the individual company perform these savings
    a. Between local and external savings?
    b. Differences between the types of plants?
e) How have the prices for savings developed?
f) Have the energy savings agreement had an effect on your production activities?

Questions regarding the current involvment in the energy savings agreement

a) Why did you choose to participate in the energy savings agreement?
b) How do you see your role in this agreement?
c) What are the consequences, if any, of you being responsible of delivering energy and reducing energy demands?
d) Have the responsibility regarding savings had a effect on you as an organization? Have there been a need for change?
e) Do you have certain strategies and goals in regarding what type of savings should be made, and where should they be made?

Questions regarding the future of the energy savings agreement

a) How do you see the future of the energy savings agreement?
b) What consequences will increasing prices have?
c) What does the free choice of method in the energy savings agreement mean to you and your involvement? What are the consequences on limiting the options here?
d) Are there any possible changes and improvements to the agreement you would like to see?
e) How easy will it be in the future to perform the required savings?

Appendix E
Summary of Interview and Mail from DONG Energy

An interview with Knud Pedersen and answers via email from Charlotte Naja Fuglsang and Morten Broberg create the foundation for this summary.

Questions regarding the handling of the energy savings agreement

DONG energy had to reduce 326 GWh in year 2013. They reach their target savings by focusing on savings from their suppliers. This means that normally the savings done within these suppliers, but they do not have a goal in terms of this. DONG energy savings are determined based on what they sell, so the savings are related to natural gas and electricity. Today the pay 0.42 DKK/kWh saved.

The energy savings agreement have had an influence on the delivering of energy but not a 1:1 influence. It is mostly on overall demand level they feel a difference

Questions regarding the current involvment in the energy savings agreement

DONG energy was required to enter the agreement so they have targeted to define how to split the burden between the companies and getting some useful tools.

The agreement have made it easier for the operation of DONG energy with the increased focus on both savings and reduction of energy. The Energy Savings Agreement have led to certain units being created which focus on energy saving both at their supplier and at themself.

DONG do not have a specific set of strategies besides performing the most cost efficient savings. DONG energy however also thinks this is in line with them being a national energy company who operates within all fields of energy, thus they should not limit their focus in terms of energy savings. They perform savings at both small and large customers and do it by providing subsidies, energy counseling and finding external savings.

Questions regarding the future of the energy savings agreement

Because of DONG operating on the “self-balancing principle”, they see that the increase in prices on savings will affect the energy prices at the customers.

The free choice of method is crucial for DONG energy in securing the cost efficiency of the savings, and therefore they do not regard changes to this as a very good strategy since it will also increase the bureaucracy and increased costs.

Improvements suggested by DONG energy could be to put the responsibility of the savings to the suppliers instead of the energy companies who cannot perform the savings. Other suggestions goes towards increasing the parameters of desired activities and lowering the parameters related to undesired activity.

Appendix F
Summary of Interview with Danish Energy

The interview with Kamilla Thingvad creates the foundation for this summary.

Questions regarding the handling of the energy savings agreement

Danish Energy have the responsibility of accounting the energy savings from the power grid companies. This amounts to 4.5 PJ in 2013-2014. The savings are reached at the individual plant and are divided between them according to their productions.

The companies perform savings both outside and inside their own energy sector and as such primarily targets cost efficient savings. A few plants have strategies towards local savings.

The prices that the power grid companies have experiences a small drop in prices for savings, but with the current agreement the prices are expected to rise since it is no longer possible to perform the cheapest savings.

The Energy Savings Agreement have had an effect but it is very complex to identify how big of an effect it had had because of all the other tendencies in the energy system and society.

Key quote:

"The savings are probably lower than the reported savings since there are overlaps in the Agreement"

Questions regarding the current involvement in the energy savings agreement

Danish Energy have an important role as an interest organization in how the agreement looks since it is a voluntarily agreement. The key for them is that there are balance between the different energy types in terms of the different energy sectors demand equals the reduction targets. Therefore, Danish Energy have taken a lesser target compared to the other energy companies in this agreement. They also pay great attention to the free choice of method and the cost efficiency and that the savings made are actual savings.

The energy savings agreement have not led to conflicts between production and reduction of energy demand. Danish Energy think it is natural for them to both focus on having greener energy production and reducing the energy demand to have better use of the energy. The companies have moreover been responsible of savings since the 90's.

Because of them being historically responsible the energy savings agreement have not had the great effect on the way they organize savings, but it has created a more focused and precise performance. The energy companies are performing the task differently than before the agreement with the possibility of involving outside partners and perform savings in all energy sectors. The number of employees working with energy savings have also increased.

The primary strategy for Danish Energy is to perform the savings the most cost efficient way. The individual companies might have other strategies but it always have to in consideration of cost efficiency. Many companies have local savings because they think they have to give back to the local end users. Danish Energy relates that the reason why their performance is spread out to the fact that they have done savings since the 90's and that they have the customer in focus who might need other types of savings than electricity as well. Furthermore, the oil companies have natural savings in replacing oil boilers and the district heating companies in increasing the efficiency of the grid.

Key quote:

"The reason why we do not only focus on our own sector is partly due to historical reasons in that we have made energy counseling since the 90ies. Until 2006 we were only allowed to make electricity savings, but we could see that it did not make any sense to only focus on one type of energy."

Questions regarding the future of the energy savings agreement

In the future, it is important to maintain the free choice of method and focus on cost efficiency. Changes on these are not in the interest of Danish Energy. If the free choice of method were to be limited the society will experience greater costs of energy savings, and the strength of this agreement is its focus on cost efficient savings on a broad palette of savings.

If the prices increase, the focus should be on whether the savings is cheaper than producing more renewable energy. When this happens, it makes more sense to install a wind turbine. Before savings under the current agreement are still possible.

Danish Energy agrees with the overall structure of the savings agreement but points that improvements could be made in terms of buildings who report their savings based on the standard value chart. The savings made here do not take synergies into account and therefore are not thought through in terms potentially higher savings and possible overlaps. There might be reasons for applying a different methodology on buildings. They also want to open up for more savings in transportation, and keep maintaining the reporting procedures, which becomes increasingly important with the growth of the agreement.

Key quote:

" If a certain subsidiary aim is applied to the savings agreement, and thereby breaking with the principals of cost efficiency and free choice method, we probably will not take part in a voluntarily agreement."

Appendix G
Summary of Interview with Danish District Heating Association

The interview with Louise Overvad Jensen creates the foundation for this summary.

Questions regarding the handling of the energy savings agreement

The Danish District Heating Association (DDHA) is responsible for reporting all savings done in district heating companies. These are divided based on how much each company is producing. The DDHA assume that prices for the individual heating company have gone up during the agreement with the increased targets. There has been a development where the district heating companies have broaden the search for energy savings from having more local savings towards having savings outside district heating and also in terms of more household savings.

Questions regarding the current involvement in the energy savings agreement

The district heating companies did not participate in the first agreement, but entered in the second one with the rationale of that they most likely would be forced otherwise. Thereby they could influence the content of the agreement. Thereby elements such as improvements in the distribution grid and solar panels are included. The Danish District Heating Association has the attitude that the current agreement is good, but also know that some plants think it hinders their production of cheap energy and only serves as a tax. The overall strategy is cost efficiency but the plants can adopt other strategies towards having targets for local savings, but the DDHA do not care about such strategies. Therefore, the free choice of method is important for the DDHA because it creates the foundation for cost efficient savings.

Key quote:

"We don't have an opinion on how the individual plant reaches their given target. But there are great difference in the individual people's opinion on where to make the savings, and some thinks that they should be done locally."

Questions regarding the future of the energy savings agreement

In terms of the future, the DDHA argues that maintaining the free choice of method is essential since it keeps the cost low. If other elements were introduced that would limit the free choice of method it would create more markets and overall increase the costs of savings, which also would be against the intention of cost efficiency.

Overall, there is a satisfaction with the current agreement, but the DDHA suggests that a change could be to make it easier to report savings in households that currently requires individual measurements. A specific example is that lowering the return temperature of district heating increases efficiency, but measures towards this are very hard to report. Another change could be to include increased importance of energy monitoring that can lead to energy conservation. This can go hand in hand with energy renovation that does not guarantee that the end-users have the right behavior. These do not count today. The goal of DDHA is to start counting these savings as well.

The DDHA sees that savings become harder to perform in the future with increases to today's standard and other elements that increases the price.

Appendix H
Summary of Interview with HMN Natural Gas

The interview with Per Jensen creates the foundation for this summary.

Questions regarding the handling of the energy savings agreement

HMN Natural Gas have the responsibility of saving 336,000 MWh in 2013, and the savings they have the intention of being on their own playing field but in the last years it has become harder and harder so the savings have broaden to other areas. HMN Natural Gas always offer the same price for savings 0.38 DKK/kWh.

Questions regarding the current involvment in the energy savings agreement

The reason for HMN Natural Gas' participation in the energy savings agreement is that has been natural to focus on savings, which they have done since the 90's. Therefore, it is good that the Energy Savings Agreement formalizes the requirements and creates an even playing field for all companies. A great incentive for them is that they believe the best energy is the one that is never produced.

HMN Natural Gas focuses on that the savings are actually performed due to the requirements and therefore wants to prioritize savings that have longer payback times and therefore benefits more from the Energy Savings Agreement. They do not see a conflict between production and savings, but instead see the Energy Savings Agreement as a possible way of establishing a better performance of natural gas.

The organization have not changed greatly internally but there are better collaboration with outside partners in terms of crafts and counseling firms.

The strategy of HMN Natural Gas is to perform the savings as cost efficient as possible, and have the intention that the savings come to them, and they do not have to look for the savings. They do however prefer to do savings within natural gas when this is possible, but do also seek to perform savings in other places if that makes more sense. There is a natural focus on replacing inefficient gas boilers.

Key quote:
"The best energy we have is the one that was never produced"

Questions regarding the future of the energy savings agreement

HMN Natural Gas sees the lacking supply of energy savings as the biggest challenge in the future, which will lead to increased prices. Therefore, they seek to keep a good amount of extra savings so their customers will not be affected too much. Right now they assess that reasonable savings can be found until 2017-2018.

They do think that maintaining the free choice of method is important since this maintain the cost efficiency of the savings. Overall, HMN Natural Gas sees the Energy Savings Agreement as a good one.

Appendix I
Summary of Interview with
Danish Oil Industry Association

The interview with Michael Mücke Jensen creates the foundation for this summary.

Questions regarding the handling of the energy savings agreement

Because of the late timing, the interview skipped this part.

Questions regarding the current involvement in the energy savings agreement

The oil companies perform savings through an energy savings trust operated by Danish Oil Industry Association, and local savings done by the local oil companies and installation companies. The energy savings trust maintains the reporting of the savings and finding savings outside the oil companies, with the strategy of cost efficiency. Therefore, the free choice of method is very crucial. The local companies find savings within their current supply areas.

The oil companies have historically targeted local savings in the oil sector, with the consideration of them being oil companies and therefore have natural access to these end-users.

The oil companies are in the agreement on a voluntarily basis that is more free than the other companies are, since they do not have the same legal binding as the other utility companies. They however think it is very natural to register savings they have always done under the Energy Savings Agreement.

They have not experienced a conflict between savings and production since the oil companies have always been responsible of savings. The only consequences for them as an organization have therefore been the establishing of the energy savings trust.

Questions regarding the future of the energy savings agreement

The current agreement is overall very good, but in terms of the future, it is very important to maintain that no energy types are favored over others in terms of the possible types of savings in the agreement. Danish Oil Industry Association acknowledges the 2050 goal but thinks that it cannot be in the way of what is the most efficient solution current, also if that is a new oil boiler, especially if it is combined with energy renovation. The agreement should not limit savings in certain sectors because of political goals.

Key quote:

"There has to be a neutrality between the different energy types, which means that there should not be any favoritism on one type at the expense of others types because of some narrow political goals or other agendas."

Appendix J
Summary of Interview with Energitjenesten

The interview with Marianne Bender creates the foundation for this summary. The questions asked were:

- Do you inform your clients about the Energy Savings Agreement?
- How many uses the possibility of funding?
- How much is the energy consumption in a household lowered when performing savings?
- How could energy savings be improved?

Energitjenesten is a counseling company supported by the Danish Government, which seeks to improve energy efficiency in households, offices, shops and other buildings.

They do tell their clients that the Energy Savings Agreement offers the possibility of subsidizing their project, but they have to contact their local utility company. Energitjenesten does not think that many households take advantage of this opportunity, but this might be due to that the utility companies already have agreements with local craft firms who report the savings for them. Therefore, Energitjenesten do not hear about it.

Energy renovations can lead to various decreases in consumption, but based on Energitjenesten's assessment of their own activities, the households typically save from 10,000 kWhs and up.

To improve savings in households, a better awareness is key. This is important both in terms of informing people of the possible subsidies in the Energy Savings Agreement, which can act as kickstarter, but also deducting the cost for energy renovations. The greatest effect is however, through creating awareness of the possible counseling the consumers can get. There are many options in the energy savings market, but not all are the right ones for the given consumers. Therefore, this becomes important. This also includes informing the house owners of what is the advantage of energy renovations, which also includes better indoor climate. To inform the house owners of this local cases become important.

Appendix K
Inputs in the energy system analysis

CEESA Inputs

These tables show the inputs in the CEESA model for all calculations in Chapter 5.

% reduction	0%	5%	10%	14%	19%	23%	26%	30%	34%	46%	54%
TWh recution	0.00	1.76	3.43	5.02	6.53	7.97	9.33	10.62	11.85	16.19	18.90
El demand input [TWh]	35.22	33.46	31.79	30.20	28.69	27.25	25.89	24.60	23.37	19.03	16.32

Table L1 Inputs for electricity savings

% reduction	0%	5%	10%	14%	19%	23%	26%	30%	34%	46%	54%
DH1 demand input [TWh]	2.78	2.64	2.51	2.38	2.26	2.15	2.04	1.94	1.84	1.50	1.29
DH1 TWh reduction	0.00	0.14	0.27	0.40	0.52	0.63	0.74	0.84	0.94	1.28	1.49
DH2 demand input [TWh]	10.42	9.90	9.40	8.93	8.49	8.06	7.66	7.28	6.91	5.63	4.83
DH2 TWh reduction	0.00	0.52	1.02	1.49	1.93	2.36	2.76	3.14	3.51	4.79	5.59
DH3 demand input [TWh]	22.67	21.54	20.46	19.44	18.46	17.54	16.66	15.83	15.04	12.25	10.50
DH3 TWh reduction	0.00	1.13	2.21	3.23	4.21	5.13	6.01	6.84	7.63	10.42	12.17

Table L2 Inputs for district heating savings

% reduction	0%	5%	10%	14%	34%	43%	54%
Coal input [TWh]	0	0	0	0	0	0	0
Oil input [TWh]	5.89	5.60	5.32	5.05	3.91	3.35	2.73
Natural gas input [TWh]	7.73	7.34	6.98	6.63	5.13	4.40	3.58
Heat pump input [TWh]	1.31	1.24	1.18	1.12	0.87	0.74	0.60
Electrical heating input [TWh]	1.94	1.24	1.18	1.12	0.87	0.74	0.60

Table L3 Inputs for individual heat savings

% reduction	0%	5%	10%	14%	34%	43%	54%
Coal input [TWh]	2.88	2.74	2.60	2.47	1.91	1.64	1.33
Oil input [TWh]	16.04	15.24	14.48	13.75	10.64	9.12	7.43
Natural gas input [TWh]	14.03	13.33	12.66	12.03	9.31	7.98	6.50

Table L4 Inputs for industrial savings

% converted	0%	5%	10%	14%	34%	43%	54%
Input electricity [TWh]	1.94	1.84	1.75	1.66	1.29	1.10	0.90
Input natural gas [TWh]	7.73	7.84	7.94	8.04	8.46	8.66	8.89
Input biomass [TWh]	12.04	12.16	12.27	12.38	12.85	13.08	13.34
Input DH gr. 1 [TWh]	2.78	2.88	2.97	3.06	3.43	3.62	3.82

Input DH gr. 2 [TWh]	10.42	10.52	10.61	10.70	11.07	11.26	11.46
Input DH gr. 3 [TWh]	22.67	22.77	22.86	22.95	23.32	23.51	23.71

Table L5 Inputs for conversions from electricity to other fuel types. The fuel types converted to are all analyzed separately

% converted	0%	5%	10%	14%	34%	43%	54%
Input oil [TWh]	5.89	5.60	5.32	5.05	3.91	3.35	2.73
Input natural gas [TWh]	7.73	8.01	8.28	8.53	9.61	10.13	10.72
Input biomass [TWh]	12.04	12.35	12.65	12.93	14.15	14.74	15.40
Input DH gr. 1 [TWh]	2.78	3.03	3.27	3.49	4.47	4.94	5.47
Input DH gr. 2 [TWh]	10.42	10.67	10.91	11.13	12.11	12.58	13.11
Input DH gr. 3 [TWh]	22.67	22.92	23.16	23.38	24.36	24.83	25.36

Table L6 Inputs for conversions from oil to other fuel types. The fuel types converted to are all analyzed separately

% converted	0%	5%	10%	14%	34%	43%	54%
Input natural gas [TWh]	7.73	7.35	6.98	6.63	5.13	4.40	3.58
Input biomass [TWh]	12.04	12.47	12.89	13.28	14.97	15.79	16.71
Input DH gr. 1 [TWh]	2.78	3.13	3.46	3.77	5.12	5.78	6.52
Input DH gr. 2 [TWh]	10.42	10.77	11.10	11.41	12.76	13.42	14.16
Input DH gr. 3 [TWh]	22.67	23.02	23.35	23.66	25.01	25.67	26.41

Table L7 Inputs for conversions from natural gas to other fuel types. The fuel types converted to are all analyzed separately

% converted	0%	5%	10%	14%	34%	54%
Input natural gas [TWh]	7.73	7.35	6.98	6.63	5.13	3.58
Input Heat pumps [TWh]	1.305	1.48	1.64	1.80	2.48	3.17
Input DH gr. 2 [TWh]	10.42	10.59	10.76	10.92	11.59	12.29

Table L8 Inputs for conversions from natural gas to heat pumps and DH group 2

% converted	0%	5%	10%	14%	34%	54%
Input natural gas [TWh]	7.73	7.35	6.98	6.63	5.13	3.58
Input Heat pumps [TWh]	1.305	1.65	1.98	2.30	3.65	5.04

Table L9 Inputs for conversions from natural gas to heat pumps

Climate Commission Inputs

These tables show the inputs in the Climate Commission model for all calculations in Chapter 5.

% reduction	0%	5%	10%	14%	19%	23%	26%	30%	34%	46%	53%
TWh reduction	0.00	1.75	3.42	5.00	6.50	7.93	9.29	10.58	11.80	16.11	18.82
El demand input [TWh]	35.06	33.31	31.64	30.06	28.56	27.13	25.77	24.48	23.26	18.95	16.24

Table L10 Inputs for electricity savings

% reduction	0%	5%	10%	14%	19%	23%	26%	30%	34%	46%	54%
DH1 demand input [TWh]	2.22	2.11	2.00	1.90	1.81	1.72	1.63	1.55	1.47	1.20	1.03
DH1 TWh reduction	0.00	0.11	0.22	0.32	0.41	0.50	0.59	0.67	0.75	1.02	1.19
DH2 demand input [TWh]	8.31	7.89	7.50	7.12	6.77	6.43	6.11	5.80	5.51	4.49	3.85
DH2 TWh reduction	0.00	0.42	0.81	1.19	1.54	1.88	2.20	2.51	2.80	3.82	4.46
DH3 demand input [TWh]	20.09	19.09	18.13	17.22	16.36	15.55	14.77	14.03	13.33	10.86	9.31
DH3 TWh reduction	0.00	1.00	1.96	2.87	3.73	4.54	5.32	6.06	6.76	9.23	10.78

Table L11 Inputs for district heating savings

% reduction	0%	5%	10%	14%	34%	43%	54%
Coal input [TWh]	0	0	0	0	0	0	0
Oil input [TWh]	9.62	9.14	8.68	8.25	6.38	5.47	4.46
Natural gas input [TWh]	11.73	11.14	10.59	10.06	7.78	6.67	5.43
Heat pump input [TWh]	1.11	1.05	1.00	0.95	0.74	0.63	0.51
Electrical heating input [TWh]	1.94	1.84	1.75	1.66	1.29	1.10	0.90

Table L12 Inputs for individual heat savings

% reduction	0%	5%	10%	14%	34%	43%	54%
Coal input [TWh]	4.9	4.66	4.42	4.20	3.25	2.79	2.27
Oil input [TWh]	13	12.35	11.73	11.15	8.62	7.39	6.02
Natural gas input [TWh]	10	9.50	9.03	8.57	6.63	5.69	4.63

Table L13 Inputs for industrial savings

% converted	0%	5%	10%	14%	34%	43%	54%
Input electricity [TWh]	1.94	1.84	1.75	1.66	1.29	1.10	0.90
Input natural gas [TWh]	11.73	11.84	11.94	12.04	12.46	12.66	12.89
Input biomass [TWh]	13.33	13.45	13.56	13.67	14.14	14.37	14.63
Input DH gr. 1 [TWh]	2.22	2.32	2.41	2.50	2.87	3.06	3.26
Input DH gr. 2 [TWh]	8.31	8.41	8.50	8.59	8.96	9.15	9.35
Input DH gr. 3 [TWh]	20.09	20.19	20.28	20.37	20.74	20.93	21.13

Table L14 Inputs for conversions from electricity to other fuel types. The fuel types converted to are all analyzed separately

% converted	0%	5%	10%	14%	34%	43%	54%
Input electricity [TWh]	9.62	9.14	8.69	8.25	6.38	5.47	4.46
Input natural gas [TWh]	11.73	12.19	12.62	13.03	14.79	15.65	16.61
Input biomass [TWh]	13.33	13.84	14.32	14.78	16.77	17.73	18.81
Input DH gr. 1 [TWh]	2.22	2.63	3.02	3.39	4.97	5.75	6.61
Input DH gr. 2 [TWh]	8.31	8.72	9.11	9.48	11.06	11.84	12.70
Input DH gr. 3 [TWh]	20.09	20.50	20.89	21.26	22.84	23.62	24.48

Table L15 Inputs for conversions from oil to other fuel types. The fuel types converted to are all analyzed separately

% converted	0%	5%	10%	14%	34%	43%	54%
Input natural gas [TWh]	11.73	11.15	10.59	10.06	7.78	6.67	5.44
Input biomass [TWh]	13.33	13.99	14.61	15.21	17.77	19.02	20.41
Input DH gr. 1 [TWh]	2.22	2.75	3.25	3.73	5.77	6.77	7.89
Input DH gr. 2 [TWh]	8.31	8.84	9.34	9.82	11.86	12.86	13.98
Input DH gr. 3 [TWh]	20.09	20.62	21.12	21.60	23.64	24.64	25.76

Table L16 Inputs for conversions from natural gas to other fuel types. The fuel types converted to are all analyzed separately

% converted	0%	5%	10%	14%	34%	54%
Input natural gas [TWh]	11.73	11.15	10.59	10.06	7.78	5.44
Input Heat pumps [TWh]	1.11	1.37	1.62	1.86	2.89	3.94
Input DH gr. 2 [TWh]	8.31	8.57	8.82	9.06	10.09	11.14

Table L17 Inputs for conversions from natural gas to heat pumps and DH group 2

% converted	0%	5%	10%	14%	34%	54%
Input natural gas [TWh]	11.73	11.15	10.59	10.06	7.78	5.44
Input Heat pumps [TWh]	1.11	1.64	2.14	2.62	4.66	6.78

Table L18 Inputs for conversions from natural gas to heat pumps

Appendix L
Results from Energy Savings Calculations

These tables show the results from the analysis of electricity savings, heat savings and industrial savings, both in the CEESA 2010 model and the Climate Commission 2010 model.

CEESA results

% reduction	0%	5%	10%	14%	19%	23%	26%	30%	34%	46%	54%
CO2	0	1.186	2.273	3.228	4.047	4.792	5.468	6.073	6.609	8.302	9.22
PES	0	3.51	6.68	9.54	12.12	14.45	16.56	18.45	20.14	25.46	28.34
RES	0	0.4	0.8	1.1	1.3	1.5	1.7	1.8	2	2.5	2.8

Table M1 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when reducing electricity demand

% reduction	0%	5%	10%	14%	19%	23%	26%	30%	34%	46%	54%
CO2	0.00	0.15	0.24	0.29	0.34	0.39	0.44	0.48	0.52	0.65	0.72
PES	0.00	1.07	2.00	2.82	3.55	4.20	4.79	5.33	5.83	7.44	8.33
RES	0.00	0.00	0.10	0.10	0.20	0.20	0.20	0.20	0.20	0.20	0.10

Table M2 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when reducing demand in district heating

% reduction	0%	5%	10%	14%	34%	54%
PES	0	0.91	1.75	2.58	6.06	9.67
CO2	0	0.236	0.456	0.672	1.577	2.516
RES	0	0	0	0.2	0.4	0.7

Table M3 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when reducing individual heating demand in oil, natural gas, electricity and heat pumps

% reduction	0%	5%	10%	14%	34%	54%
CO2	0	0.405	0.793	1.161	2.74	4.369
RES	0	0	0.2	0.3	0.9	1.4
PES	0	1.64	3.21	4.7	11.09	17.69

Table M4 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when reducing industry energy supplied by oil, natural gas and coal

Electricity and DH Savings separately added together - CEESA											
% reduction	0%	5%	10%	14%	19%	23%	26%	30%	34%	46%	54%
CO2	0	1.339	2.51	3.517	4.389	5.181	5.904	6.551	7.127	8.955	9.941
RES	0	0.4	0.7	1	1.1	1.3	1.5	1.6	1.8	2.3	2.7
PES	0	4.58	8.68	12.36	15.67	18.65	21.35	23.78	25.97	32.9	36.67
Electricity and DH savings in the same system - CEESA											
Reduction	0%	5%	10%	14%	19%	23%	26%	30%	34%	46%	54%
CO2	0	1.358	2.622	3.805	4.909	5.937	6.887	7.766	8.569	11.181	12.626
RES	0	0.4	0.7	1.1	1.4	1.7	2	2.3	2.6	3.3	3.7
PES	0	4.67	9.03	13.11	16.93	20.5	23.81	26.88	29.75	39.32	44.77

Table M5 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when coordinating savings in the same system between district heat savings and electricity savings

Electricity and Individual savings separately added together - CEESA						
% reduction	0%	5%	10%	14%	34%	54%
CO2	0.00	1.34	2.58	3.68	7.67	10.91

RES	0	0.4	0.8	1.3	2.4	3.4
PES	0	4.19	8	11.48	24.72	35.65
Electricity and Individual savings in the same system - CEESA						
% reduction	0%	5%	10%	14%	34%	54%
CO2	0.00	1.34	2.58	3.68	7.67	10.91
RES	0	0.4	0.8	1.3	2.4	3.4
PES	0	4.19	8	11.48	24.72	35.65

Table M6 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when coordinating savings in the same system between individual heat savings and electricity savings

Electricity and Industrial savings separately added together - CEESA						
% reduction	0%	5%	10%	14%	34%	54%
CO2	0	1.591	3.066	4.389	9.349	13.589
RES	0	0.4	0.8	1.3	2.4	3.4
PES	0	5.15	9.89	14.24	31.23	46.03
Electricity and Industrial savings in the same system - CEESA						
% reduction	0%	5%	10%	14%	34%	54%
CO2	0	1.591	3.066	4.389	9.349	13.589
RES	0	0.4	0.8	1.3	2.4	3.4
PES	0	5.15	9.89	14.24	31.23	46.03

Table M7 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when coordinating savings in the same system between industrial savings and electricity savings

Climate Commission results

% reduction	0%	5%	10%	14%	19%	23%	26%	30%	34%	46%	54%
CO2	0.00	1.35	2.63	3.82	4.93	5.93	6.83	7.63	8.35	10.65	11.92
PES	0.00	4.07	7.89	11.37	14.60	17.60	20.33	22.76	24.91	32.00	36.07
RES	0.00	0.40	0.80	1.30	1.80	2.20	2.50	2.90	3.30	4.30	4.90

Table M8 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when reducing electricity demand

% reduction	0%	5%	10%	14%	19%	23%	26%	30%	34%	46%	54%
CO2	0.00	0.06	0.11	0.16	0.21	0.25	0.29	0.33	0.37	0.48	0.50
PES	0.00	0.64	1.23	1.77	2.26	2.72	3.15	3.55	3.93	5.16	5.85
RES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10

Table M9 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when reducing demand in district heating

% reduction	0%	5%	10%	34%	54%
PES	0	1.34	2.59	8.94	14.26
CO2	0	0.338	0.653	2.249	3.581
RES	0	0	0.1	0.6	1.1

Table M10 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when reducing individual heating demand in oil, natural gas, electricity and heat pumps

% reduction	0%	5%	10%	14%	34%	54%
CO2	0	0.357	0.7	1.024	2.419	3.854
RES	0	0	0.1	0.2	0.8	1.2
PES	0	1.39	2.72	3.98	9.4	14.98

Table M11 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when reducing industry energy supplied by oil, natural gas and coal

Electricity and DH Savings separately added together – Climate Commission										
% reduction	0%	5%	10%	14%	19%	23%	26%	30%	34%	46%	54%
CO2	0	1.409	2.744	3.982	5.14	6.176	7.119	7.959	8.718	11.129	12.42
RES	0	0.4	0.8	1.3	1.8	2.2	2.5	3	3.4	4.4	5
PES	0	4.71	9.12	13.14	16.86	20.32	23.48	26.31	28.84	37.16	41.92
Electricity and DH savings in the same system – Climate Commission											
Reduction	0%	5%	10%	14%	19%	23%	26%	30%	34%	46%	54%
CO2	0	1.408	2.74	3.981	5.142	6.227	7.246	8.197	9.079	11.999	13.627
RES	0	0.4	0.8	1.2	1.6	1.9	2.3	2.6	3	4.1	4.7
PES	0	4.74	9.23	13.43	17.36	21.04	24.51	27.75	30.76	40.79	46.49

Table M12 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when coordinating savings in the same system between district heat savings and electricity savings

Electricity and Individual savings separately added together – Climate Commission						
% reduction	0%	5%	10%	14%	34%	54%
CO2	0	1.60	3.11	4.52	10.00	14.55
RES	0	0.4	0.9	1.3	1.8	2.4
PES	0	5.14	9.97	14.41	32.09	47.51
Electricity and Individual savings in the same system – Climate Commission						
% reduction	0%	5%	10%	14%	34%	54%
CO2	0.00	1.60	3.11	4.52	10.00	14.55
RES	0.00	0.40	0.80	1.30	2.40	3.40
PES	0.00	5.14	9.97	14.41	32.09	47.51

Table M13 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when coordinating savings in the same system between individual heat savings and electricity savings

Electricity and Industrial savings separately added together – Climate Commission						
% reduction	0%	5%	10%	14%	34%	54%
CO2	0	1.709	3.33	4.843	10.765	15.774
RES	0	0.4	0.7	1.1	2.5	3.7
PES	0	5.46	10.61	15.35	34.31	51.05
Electricity and Industrial savings in the same system – Climate Commission						
% reduction	0%	5%	10%	14%	34%	54%
CO2	0	1.709	3.33	4.843	10.765	15.774
RES	0	0.4	0.7	1.1	2.5	3.7
PES	0	5.46	10.61	15.35	34.31	51.05

Table M14 Reduction of CO_2 emissions and primary energy supply, and percentage point increase of renewable energy share when coordinating savings in the same system between industrial savings and electricity savings

Appendix M
Results from Calculating Conversions

These tables show the results from the analysis of conversions, both in the CEESA 2010 model and the Climate Commission 2010 model.

CEESA results

	% converted	0%	5%	10%	14%	34%	54%
Biomass	CO2	53.669	53.591	53.515	53.443	53.135	52.817
	RES	18.6	18.8	18.9	19.1	19.8	20.5
	PES	241.49	241.54	241.59	241.63	241.82	242.01
DH group 1	CO2	53.669	53.679	53.685	53.591	53.721	53.754
	RES	18.6	18.6	18.6	18.6	18.6	18.6
	PES	241.49	241.48	241.47	241.46	241.41	241.37
DH group 2	CO2	53.669	53.556	53.447	53.344	52.964	52.719
	RES	18.6	18.6	18.7	18.8	19	19
	PES	241.49	241.31	241.13	240.96	240.34	239.82
DH group 3	CO2	53.669	53.649	53.628	53.608	53.535	53.471
	RES	18.6	18.6	18.6	18.6	18.7	18.8
	PES	241.49	241.33	241.17	241.01	240.41	239.86

Table N1 Outputs from conversions from natural gas

	% converted	0%	5%	10%	14%	34%	54%
Natural gas	CO2	53.669	53.627	53.59	53.552	53.402	53.322
	RES	18.6	18.6	18.6	18.6	18.7	18.7
	PES	241.49	241.41	241.35	241.28	241.02	240.87
Biomass	CO2	53.669	53.605	53.547	53.489	53.252	53.141
	RES	18.6	18.6	18.7	18.8	19	19.1
	PES	241.49	241.42	241.37	241.31	241.1	240.98
DH group 1	CO2	53.669	53.63	53.594	53.559	53.415	53.342
	RES	18.6	18.6	18.6	18.6	18.7	18.7
	PES	241.49	241.41	241.34	241.27	240.99	240.85
DH group 2	CO2	53.669	53.594	53.528	53.461	53.188	53.051
	RES	18.6	18.6	18.6	18.7	18.8	18.9
	PES	241.49	241.36	241.25	241.13	240.67	240.45
DH group 3	CO2	53.669	53.621	53.578	53.535	53.361	53.273
	RES	18.6	18.6	18.6	18.6	18.7	18.8
	PES	241.49	241.36	241.25	241.15	240.7	240.49

Table N2 Outputs from conversions from electricity

	% converted	0%	5%	10%	14%	34%	54%
Natural gas	CO2	53.669	53.639	53.63	53.609	53.527	53.485
	RES	18.6	18.6	18.6	18.6	18.6	18.6

	PES	241.49	241.48	241.47	241.45	241.39	241.35
Biomass	CO2	53.669	53.592	53.517	53.445	53.141	52.992
	RES	18.6	18.7	18.8	18.9	19.4	19.7
	PES	241.49	241.51	241.53	241.54	241.62	241.65
DH group 1	CO2	53.669	53.654	53.64	53.623	53.565	53.533
	RES	18.6	18.6	18.6	18.6	18.6	18.6
	PES	241.49	241.47	241.45	241.41	241.33	241.28
DH group 2	CO2	53.669	53.567	53.469	53.374	52.979	52.814
	RES	18.6	18.6	18.7	18.7	18.9	19
	PES	241.49	241.34	241.2	241.06	240.51	240.27
DH group 3	CO2	53.669	53.633	53.599	53.563	53.427	53.36
	RES	18.6	18.6	18.6	18.6	18.7	18.7
	PES	241.49	241.35	241.23	241.09	240.59	240.35

Table N3 Outputs from conversions from oil

% converted	0%	5%	10%	14%	34%	54%
Conversion from natural gas to DH group 2 - added together - CEESA						
CO2	0.00	1.30	2.49	3.55	7.31	10.17
RES	0.00	0.40	0.90	1.30	2.40	3.20
PES	0.00	3.69	7.04	10.07	21.29	30.01
Conversion from natural gas to DH group 3 - added together - CEESA						
CO2	0.00	1.21	2.31	3.29	6.74	9.42
RES	0.00	0.40	0.90	1.30	2.40	3.20
PES	0.00	3.67	7.00	10.02	21.22	29.97
Conversion from natural gas to DH group 2 - same system - CEESA						
CO2	0.00	1.30	2.45	3.40	6.82	9.39
RES	0.00	0.40	0.80	1.10	2.00	2.80
PES	0.00	3.68	6.96	9.89	20.54	28.77
Conversion from natural gas to DH group 3- same system - CEESA						
CO2	0.00	1.20	2.30	3.25	6.57	9.18
RES	0.00	0.40	0.80	1.10	2.00	2.90
PES	0.00	3.66	6.95	9.90	20.63	28.91

Table N4 Reductions in CO_2 emissions and primary energy supply, and percentage point increase in renewable energy share when and when not conversions from natural gas are coordinated with electricity savings

% converted	0%	5%	10%	14%	34%	54%
Conversion from oil to DH group 2 - added together - CEESA						
CO2	0.00	1.29	2.47	3.52	7.30	10.22
RES	0.00	0.40	0.90	1.20	2.30	3.20
PES	0.00	3.66	6.97	9.97	21.12	29.80
Conversion from oil to DH group 3 - added together - CEESA						
CO2	0.00	1.22	2.34	3.33	6.85	9.60
RES	0.00	0.40	0.90	1.20	2.30	3.20
PES	0.00	3.65	6.94	9.94	21.04	29.73
Conversion from oil to DH group 2 - same system - CEESA						
CO2	0.00	1.29	2.46	3.42	6.91	9.58
RES	0.00	0.40	0.80	1.10	2.00	2.80
PES	0.00	3.65	6.92	9.85	20.54	28.84
Conversion from oil to DH group 3- same system - CEESA						
CO2	0.00	1.22	2.34	3.30	6.72	9.42
RES	0.00	0.40	0.80	1.10	2.00	2.90

PES	0.00	3.64	6.91	9.85	20.66	28.94

Table N5 Reductions in CO_2 emissions and primary energy supply, and percentage point increase in renewable energy share when and when not conversions from oil are coordinated with electricity savings

Climate Commission results

	% converted	0%	5%	10%	14%	34%	54%
Biomass	CO2	49.44	49.323	49.21	49.103	48.646	48.205
	RES	19.4	19.6	19.9	20.2	21.3	22.4
	PES	218.77	218.85	218.91	219.98	219.27	219.69
DH group 1	CO2	49.44	49.458	49.473	49.488	49.551	49.628
	RES	19.4	19.4	19.4	19.4	19.3	19.3
	PES	218.77	218.76	218.74	218.73	218.66	218.61
DH group 2	CO2	49.44	49.231	49.031	48.842	48.067	47.336
	RES	19.4	19.4	19.5	19.5	19.9	20.4
	PES	218.77	218.35	217.93	217.55	216.1	214.93
DH group 3	CO2	49.44	49.377	49.315	49.257	49.001	48.821
	RES	19.4	19.4	19.5	19.5	19.8	20
	PES	218.77	218.42	218.08	217.77	216.48	215.36

Table N6 Outputs from conversions from natural gas

	% converted	0%	5%	10%	14%	34%	54%
Natural gas	CO2	49.44	49.386	49.337	49.288	49.09	49.985
	RES	19.4	19.4	19.4	19.4	19.5	19.5
	PES	218.77	218.65	218.55	218.44	218.02	217.79
Biomass	CO2	49.44	49.364	49.295	49.226	48.942	48.797
	RES	19.4	19.4	19.5	19.6	19.8	20
	PES	218.77	218.66	218.57	218.47	218.1	217.9
DH group 1	CO2	49.44	49.389	49.343	49.297	49.108	49.011
	RES	19.4	19.4	19.4	19.4	19.5	19.5
	PES	218.77	218.65	218.54	218.43	217.99	217.77
DH group 2	CO2	49.44	49.346	49.262	49.177	48.829	48.651
	RES	19.4	19.4	19.4	19.4	19.5	19.6
	PES	218.77	218.57	218.39	218.21	217.48	217.11
DH group 3	CO2	49.44	49.374	49.314	49.254	49.007	48.88
	RES	19.4	19.4	19.4	19.4	19.5	19.6
	PES	218.77	218.59	218.42	218.25	217.58	217.24

Table N7 Outputs from conversions from electricity

	% converted	0%	5%	10%	14%	34%	54%
Natural gas	CO2	49.44	49.405	49.373	49.338	49.128	49.13
	RES	19.4	19.4	19.4	19.4	19.4	19.4
	PES	218.77	218.75	218.73	218.7	218.59	218.54
Biomass	CO2	49.44	49.312	49.193	49.075	48.577	48.335
	RES	19.4	19.6	19.8	20	20.9	21.3
	PES	218.77	218.8	218.83	218.85	218.97	219.02

DH group 1	CO2	49.44	49.417	49.396	49.373	49.278	49.234
	RES	19.4	19.4	19.4	19.4	19.4	19.4
	PES	218.77	218.73	218.71	218.66	218.5	218.43
DH group 2	CO2	49.44	49.241	49.053	48.872	48.12	47.759
	RES	19.4	19.4	19.5	19.5	19.8	19.9
	PES	218.77	218.41	218.07	217.74	216.46	215.89
DH group 3	CO2	49.44	49.354	49.274	49.194	48.854	48.687
	RES	19.4	19.4	19.5	19.5	19.7	19.8
	PES	218.77	218.47	218.19	217.91	216.78	216.26

Table N8 Outputs from conversions from oil

% converted	0%	5%	10%	14%	34%	54%
Conversion from natural gas to DH group 2 - added together - Climate Commission						
CO2	0.00	1.56	3.04	4.42	9.72	14.02
RES	0.00	0.40	0.90	1.40	3.80	5.90
PES	0.00	4.49	8.73	12.59	27.58	39.91
Conversion from natural gas to DH group 3 - added together - Climate Commission						
CO2	0.00	1.41	2.76	4.00	8.79	12.54
RES	0.00	0.40	0.90	1.40	3.80	5.90
PES	0.00	4.42	8.58	12.37	27.20	39.48
Conversion from natural gas to DH group 2 - same system - Climate Commission						
CO2	0.00	1.56	3.03	4.39	8.94	12.36
RES	0.00	0.50	1.00	1.60	3.60	5.00
PES	0.00	4.49	8.60	12.35	25.92	37.21
Conversion from natural gas to DH group 3- same system - Climate Commission						
CO2	0.00	1.42	2.76	3.99	8.39	11.89
RES	0.00	0.50	1.00	1.60	3.60	5.00
PES	0.00	4.41	8.52	12.23	26.00	37.41

Table N9 Reductions in CO_2 emissions and primary energy supply, and percentage point increase in renewable energy share when and when not conversions from natural gas are coordinated with electricity savings

% converted	0%	5%	10%	14%	34%	54%
Conversion from oil to DH group 2 - added together - Climate Commission						
CO2	0.00	1.55	3.02	4.39	9.67	14.00
RES	0.00	0.40	0.90	1.40	3.70	5.60
PES	0.00	4.43	8.59	12.40	27.22	39.56
Conversion from oil to DH group 3 - added together - Climate Commission						
CO2	0.00	1.44	2.80	4.06	8.93	12.86
RES	0.00	0.40	0.90	1.40	3.70	5.60
PES	0.00	4.37	8.47	12.23	26.90	39.13
Conversion from oil to DH group 2 - same system - Climate Commission						
CO2	0.00	1.55	3.01	4.37	9.09	12.70
RES	0.00	0.50	1.00	1.60	3.60	5.00
PES	0.00	4.43	8.49	12.21	25.91	37.31
Conversion from oil to DH group 3- same system - Climate Commission						
CO2	0.00	1.44	2.80	4.10	8.64	12.30
RES	0.00	0.40	1.00	1.50	3.60	5.10
PES	0.00	4.37	8.43	12.12	25.95	37.44

Table N10 Reductions in CO_2 emissions and primary energy supply. and percentage point increase in renewable energy share when and when not conversions from oil are coordinated with electricity savings

Appendix N
Performance of Energy Companies in 2010 and 2012

These tables show the total reported savings compared with the two estimates, both for 2010 and 2012.

2010 Savings

TJ	District heating	Natural gas	Oil	Electricity	Coal	Biomass	Other	Total
Households	644.24	382.49	364.09	383.91	7.49	6.03	26.14	1814.38
Public sector	228.72	101.35	11.36	99.42	0.19	2.06	7.22	450.33
Industry and production	652.14	1121.49	404.59	539.51	115.21	159.26	154.23	3146.43
Commerce and service	183.99	30.63	9.17	144.34	0.00	0.49	21.04	389.66
Grid optimization	318.18	1.69	0.90	23.24	0.00	0.36	0.15	344.53
Collective solar	97.88	2.79	3.38	0.74	0.00	0.00	1.44	106.23
Conversions	70.82	52.70	528.33	125.79	0.05	1.08	9.82	788.60
Total	2195.97	1693.13	1321.84	1316.96	122.94	169.29	220.03	7040.15

Table O1 Reported Savings in 2010 (Danish Energy Agency 2011)

TJ	District heating	Natural gas	Oil	Electricity	Coal	Biomass	Other	Total
Households	279.96	185.70	138.69	202.86	4.22	2.57	10.31	824.30
Public sector	97.60	48.59	5.19	46.31	0.00	0.68	2.82	201.19
Industry and production	301.45	529.18	209.20	286.41	55.28	68.65	78.11	1528.27
Commerce and service	75.61	15.09	3.54	70.74	0.00	0.21	7.89	173.09
Grid optimization	121.01	0.64	0.34	10.35	0.00	0.14	0.06	132.53
Collective solar	36.72	1.05	1.27	0.28	0.00	0.00	0.54	39.86
Conversions	66.54	17.48	233.35	37.73	0.01	0.47	3.71	359.30
Total	978.89	797.72	591.57	654.67	59.51	72.72	103.44	3258.53

Table O2 Scenario II estimates in 2010

TJ	District heating	Natural gas	Oil	Electricity	Coal	Biomass	Other	Total
Households	45.97	27.29	25.98	27.39	0.53	0.43	1.86	129.47
Public sector	81.93	36.31	4.07	35.61	0.00	0.74	2.58	161.24
Industry and production	366.24	629.83	227.22	302.99	64.70	89.44	86.62	1767.04
Commerce and service	58.79	9.79	2.93	46.12	0.00	0.16	6.72	124.50
Grid optimization	318.18	1.69	0.90	23.24	0.00	0.36	0.15	344.53
Collective solar	97.88	2.79	3.38	0.74	0.00	0.00	1.44	106.23
Conversions	42.49	10.46	118.80	20.70	0.01	0.26	2.36	195.08

Total	1011.48	718.15	383.28	456.80	65.25	91.39	101.73	2828.08

Table O3 Scenario III estimates in 2010

2012 Savings

TJ	District heating	Natural gas	Oil	Electricity	Coal	Biomass	Other	Total
Households	1265.14	570.55	344.22	459.78	3.00	148.60	7.00	2798.30
Public sector	179.93	99.01	8.71	110.25	66.75	28.41	5.95	499.00
Industry and production	584.90	1270.88	251.19	481.49	598.95	253.13	-6.30	3434.24
Commerce and service	174.57	58.54	14.74	307.99	6.78	4.09	2.69	569.40
Grid optimization	325.18	4.76	0.03	0.19	9.30	0.00	1.89	341.35
Collective solar	96.58	12.08	0.00	0.36	0.00	39.26	8.06	156.34
Conversions	94.09	170.36	344.44	57.02	10.24	14.70	44.48	735.33
Total	2720.40	2186.18	963.34	1417.06	695.02	488.20	63.77	8533.97

Table O4 Reported Savings in 2012 (Danish Energy Agency 2013)

TJ	District heating	Natural gas	Oil	Electricity	Coal	Biomass	Other	Total
Households	640.92	258.29	126.52	240.15	1.43	76.83	2.65	1346.79
Public sector	78.69	48.94	4.21	54.51	25.04	11.73	2.23	225.35
Industry and production	266.54	643.72	122.86	253.62	305.59	132.17	-4.34	1720.15
Commerce and service	82.96	28.48	6.34	150.76	2.54	2.06	1.52	274.66
Grid optimization	123.09	1.79	0.01	0.07	3.49	0.00	0.71	129.16
Collective solar	38.35	4.53	0.00	0.13	0.00	14.73	3.03	60.77
Conversions	51.01	75.94	152.11	10.84	4.22	13.59	18.46	326.19
Total	1281.56	1061.69	412.06	710.07	342.31	251.12	24.26	4083.07

Table O5 Scenario II estimates in 2012

TJ	District heating	Natural gas	Oil	Electricity	Coal	Biomass	Other	Total
Households	90.28	40.71	24.56	32.81	0.21	10.60	0.50	199.68
Public sector	64.45	35.47	3.12	39.49	23.91	10.18	2.13	178.74
Industry and production	328.48	713.73	141.07	270.40	336.37	142.16	-3.54	1928.67
Commerce and service	55.78	18.71	4.71	98.41	2.17	1.31	0.86	181.94
Grid optimization	325.18	4.76	0.03	0.19	9.30	0.00	1.89	341.35
Collective solar	96.58	12.08	0.00	0.36	0.00	39.26	8.06	156.34
Conversions	31.34	37.32	78.31	6.19	2.37	6.14	10.68	172.35
Total	992.10	862.78	251.81	447.84	374.32	209.65	20.58	3159.08

Table O6 Scenario III estimates in 2012

Appendix O
Parameters in the Energy Savings Agreement

Fuel converted from	Fuel converted to	From parameter	To parameter
Electricity	District heating Quota fuels (oil, natural gas, coal)	2.5	1.0
Electricity	Non quota fuels (oil, natural gas, coal) Biomass	1.0	1.0
District heating Quota fuels Biomass	Electricity	1.0	2.5
District heating	Quota fuels	1.0	1.0
District heating	Non quota fuels Biomass	0.8	1.0
Non quota fuels	Electricity	1.0	1.0
Non quota fuels Biomass	District heating	1.0	0.8
Quota fuels	District heating	1.0	1.0
Quota fuels Non quota fuels Biomass	Quota fuels Non quota fuels Biomass	1.0	1.0

Table P1 Conversion parameters from the Energy Savings Agreement (Klima- Energi- og Bygningsministeriet 2012b)

	Less than 4 years	4 to 15 years	More than 15 years
District heating	0.5	1.0	1.0
Electricity and individual biomass	0.5	1.0	1.0
Fuels under the CO_2 quota system (oil, natural gas, coal)	0.5	1.0	1.0
Fuels not under the CO_2 quota system (oil, natural gas and coal)	0.5	1.0	1.5

Table P2 Lifetime parameters from the Energy Savings Agreement (Klima- Energi- og Bygningsministeriet 2012b)

Parameter of 0.5	Parameter of 1.5
• Increasing efficiency of boilers and heating plant on service plans • Efficiency increases of ventilation on service plans • Regulation of heating plant • Systematic maintenance plans for engines and pumps • Energy management	• Increased insulation of floor, walls, ceiling that reduces energy demand in oil and gas heated buildings • New “A” labeled windows and doors in oil and gas heated buildings • Heat recovery to space heating in relation to mechanical ventilation in oil and gas heated buildings • Increased insulation of thermal energy storage and pipes in relation to units for space heating in relation to the use of non-quota fuels • New oil and natural gas boilers in relation to non-quota fuels • Connecting oil or gas heated buildings to district heating • Installation of heat pumps that replaces non-quota oil and natural gas consumption • Solar panels on oil and gas heated buildings.

Table P3 Activity parameters from the Energy Savings Agreement (Klima- Energi- og Bygningsministeriet 2012b)