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Investigating fossil fuel utilization and the potential of reducing fossil fuels for heating in companies

The case of Gävleborg County

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Preface

This thesis marks the end of my two years of master studies at the University of Gävle in the field of energy systems. Looking back at the course of the six or more months that this thesis has taken to complete, my hope is that I can remember the good and bad actions that I have taken and learn from them.

I first want to think my supervisor Ulf Larsson, who answered my questions and read the report several times and gave his comments on what could be improved. I also want to thank both my external supervisors at Länsstyrelsen, Mats Selin and Åsa Eklund Öberg for helping define the objectives and method of the thesis.

I also want to thank the energy advisors at the municipalities in Gävleborg for answering my questions and helping me with my research. To the companies that answered the survey, thank you for taking the time to answer my questions! Finishing this thesis would not have been possible without your responses.

Abstract

Fossil fuels constitute roughly 80 % of the world's energy supply and of this amount oil makes up almost one third. The combustion of these fossil fuels leads to increasing levels of greenhouse gases, causing a warming of the earth through the so called greenhouse effect. Because of this, several environmental and energy goals have been established by both the European Union and Sweden.

The purpose of this thesis was to investigate how the use of fossil fuels can be reduced in companies that use oil for heating, in Gävleborg County. The thesis was divided into four problems to be solved. First, the companies that fit this description was identified by contacting energy advisors at municipalities. The second task was to investigate how willing these companies were to change to some other form of heating, which meant creating and sending a survey to them.

It was also investigated what other aspects can affect a companies' decision making, both technical and behavioural. The technical aspects meant listing and discussing some of the technical difficulties that can hinder a company from changing heating technology. Behavioural aspects were investigated using the comments left on the survey as well as research on the topic of barriers and driving forces that can affect companies.

The final task was to estimate the reduction in CO_2 emissions that could be achieved. This was done with data for the companies that answered that they wanted to change to some other form of heating and assumption regarding to the amount of emissions from different fuels.

It was found that 95 companies use oil in Gävleborg County and 26 of these companies answered the survey to some extent, although results were only based on 24 of these answers. On the question of whether companies could consider changing to a different heating system, the same number (nine) that said "yes" also said "no". There were many reasons for a company not wanting to change. Technical difficulties might be proximity to district heating net, not being able to install heat pumps, lacking infrastructure for biomass supply or being too close to a densely populated area to use biomass. Even so, it was concluded that for every company there is a possible technical solution.

Behavioural aspects were also found to be numerous. Some companies answered that their reason for not changing was not owning their working facility and seeing the heating need as being too low to justify an investment. The research collected stated that lack of time, lack of money and having other priorities are important barriers. Meaning that to help companies change heating system, financial aid should be given, for example in the form of subsidies and soft loans. It can also be important to provide consulting assistance and informing companies of energy related issues and the benefits of dealing with them.

The other answers to the survey varied a lot. The amount of oil used varied from 5 MWh to over 125000 MWh. The companies could also consider changing to all the optional heating systems, though district heating and heat pump were the most chosen with eight each. Ten companies said that they needed consultation and the same number

said that they didn’t need it. Ten companies also said that they needed investment support and eight said that they did not need it.

It was estimated that greenhouse gas emissions could be lowered by approximately 28900 tons, for the companies that took part in the survey. Two companies could also consider installing solar heating and assuming that this replaces 20 % of the total heating demand, a further reduction of roughly 1030 tons of greenhouse gas emissions is achieved.

Based on past research, it was concluded that it is possible to reduce the consumption of fossil fuels in a region or company. This might come in the form of lowering overall energy use or replacing oil with biofuels. The responses to the survey also show that there is some interest in the companies asked. Even though they might have answered that they did not want to change heating, they did at least answer the survey.

Contents

1 Introduction

1.1 Background

Fossil fuels have been formed when plants and animals sunk to the bottom of seas and lakes, the remains of these plants and animals have then been covered by more and more sediment. Over millions of years they are subjected to high pressures and temperatures, and have been transformed in to carbon and hydrogen compounds; oil, coal and natural gas. (Swedish Energy Agency, 2014)

According to US Department of energy (2013) coal has been used for heating for thousands of years. Coal was also the first fossil fuel used on a wide scale in England in the 1700's. (Areskoug & Eliasson, 2007). Coal was used more and more in the 18t^{h}, 19th and 20th centuries due to an increasing demand for energy. Improvements in steam engines, powered by coal, meant that more water could be pumped out of coal mines and the mines could become deeper, producing more coal. The increased supply of coal could also be used for other purposes, such as clothing factories, transportation and production of steel. (Matthew White, n.d.)

Oil, commonly called petroleum, was made available in the middle of the 19th century. Its first use was for lighting, where the fuel was refined and used in paraffin lamps. At the end of the century, the internal combustion engine was invented which marked the beginning of the automobile and since then the use of oil has only increased. (Areskoug & Eliasson, 2007). Swedish Energy Agency (2016a) states that 80 % of the current world wide supply of energy is by fossil fuels, and of this amount oil makes up almost one third of the supply.

Adverse effects of using fossil fuels are numerous, and exist on both local and global scales. Emissions with local effects include carbon monoxide (CO) and nitrous oxides (NO_x). Carbon monoxide is formed during incomplete combustion and inhaling it can cause, among other things, headaches, nausea, dizziness and even death (US Consumer product safety commission, n.d.). Nitrous oxides (NO_x) can form with high combustion temperatures and generate ground level ozone, which is harmful to respiratory systems and crops. (Areskoug & Eliasson, 2007)

Coal and oil also contains sulphur, which forms sulphuric acid in contact with moisture in the air. This is called acid rain and it caused many forests and lakes to die in Europe in the 1960's and 70's. Several measures can be taken to reduce acid rain, and a great effort has been made which has caused an 80 % decrease of the amount of sulphur in Sweden, from 1990 to 2013 (Swedish Environmental Protection agency, 2016a). It should also be noted that fossil fuels are not the only energy carrier that can have adverse environmental effects. (Areskoug & Eliasson, 2007)

Arguably the most important emission from fossil fuels are greenhouse gases. These gases stop heat from leaving to space and instead redirect it towards the earth. Their contribution to warming the earth is called the greenhouse effect and without it, the surface temperature would be too low to sustain all life. This effect is sometimes referred to as a blanket around the earth, keeping it warm. (Swedish Society for Nature Conservation, 2016)

Out of all greenhouse gases, the most important is carbon dioxide (CO_2), which is formed from combustion of fuels containing carbon. Other examples of greenhouses gases include methane (NH_4), laughing gas (N_2O) and many refrigerants. When used for comparison, the effect of other gases is commonly calculated as the equivalent of the greenhouse effect of CO_2, which is called their carbon dioxide equivalents. (Swedish Society for Nature Conservation, 2016)

According to Höök and Xu (2013) the first mention of the impact of greenhouse gases on climate was in the late 1800's, but the subject fell into obscurity until after the 1950's. Today, most (90-100 %) of climate scientists agree that human emissions are the main cause of rising greenhouse gas levels and the environmental impacts that come with it (Cook et al. 2016). This fact and more research on the subject eventually led to the formation of the intergovernmental panel on climate change (IPCC) in 1988 (IPCC, n.d.).

The fact that it takes millions of years for fossil fuels to form means that, on a human scale, practically no new formation of these fuels occur. Any fuel that is extracted and used now will not be renewed, thus fossil fuels can theoretically be completely depleted (non-renewable). Although any resource can be depleted if it's extracted at a faster rate than it is replenished, Höök, Bardi, Feng and Pang (2010) used 19th century whaling as an example of this. This have made it important to determine what the future reserve of fossil fuels are and how much can be extracted. For example, Shafiee and Topal (2009) calculated that the current reserves of oil, coal and gas will last for 35, 207 and 37 years respectively. According to Kjärstad and Johnsson (2009) more than half of the world's ultimately recoverable oil and two thirds of current estimates of proven reserves will have been used up by 2030.

Many human activities during the last two centuries have led to a sudden increase of greenhouse gases in the atmosphere, which raises the average temperature of the earth (Swedish Society for Nature Conservation, 2016). These activities include combustion of fossil fuels, burning biofuels such as wood without planting new trees and emissions from agriculture (ibid.). In 2010, the activity with the largest share of greenhouse gas emissions (~70 %) was from the energy sector (IEA, 2015, ss. 7). In this sector, 90 % of the emissions was in the form of CO_2 (IEA, 2015).

As a consequence of the negative impacts of human emissions and activities, several energy and environmental targets have been made. The European Union has climate and energy goals for 2020, 2030 and 2050. For 2020, these include a 20 % reduction in greenhouse gas emissions compared to 1990 levels, having 20 % renewable energy and using energy 20 % more efficiently. For 2030, these same levels are 40, 27 and 27 percent respectively. By 2050, the goal is to have a low-carbon-economy, which means that greenhouse gas emissions should be 80 % lower than they were in 1990. (European Commission, 2016)

The European Union Emissions Trading System (EU ETS) is designed to lower emissions of carbon dioxide from power and heat generation, energy-intensive industries and civil aviation. This system works on a "cap and trade" principle, where allowances, worth one ton of CO_2 emissions, are bought and sold among companies. (European Commission, 2013)

Other documents and agreements worth mentioning include the Kyoto protocol, which is an international agreement, signed in 1997. Its purpose was to set goals and commitments for reductions in greenhouse gas emissions. (UN framework convention on climate change, 2014)

Another is the Report of the World commission on environment and development: “Our common future” (often called the Bruntland report). This report outlined the concept of sustainable development and states that the needs of the current generations should not compromise the needs of future generations. (UN Economic commission for Europe, n.d.)

1.2 Energy and CO_2 emissions in Sweden

Sweden has been no stranger to fossil fuel use, for example oil was the primary energy source in the 1950’s and supplied 80 % of the energy in the early 1970’s (Nilsson, et al. 2004). They are still a large part of the energy used, but a decline has been evident. From 1970 to 2013, the supply of fossil fuels has been more than halved, from 354 to 164 TWh. Figure 1 shows how the use of petroleum products has changed from 1983 to 2013, in TWh. In addition to these petroleum products, 12 TWh of coal and coke was also used in 2013. (Swedish Energy Agency, 2016a)

The primary cause of this decrease has been a shift in the oil for heating buildings, which in large part has been replaced by electricity and district heating. Today the main use of oil products in Sweden is petrol and diesel for transportation as well as coal and coke for industries. Natural gas represents only about 2 % of fossil fuel use, and it is mostly concentrated in the south west of Sweden. (Swedish Energy Agency, 2016a)

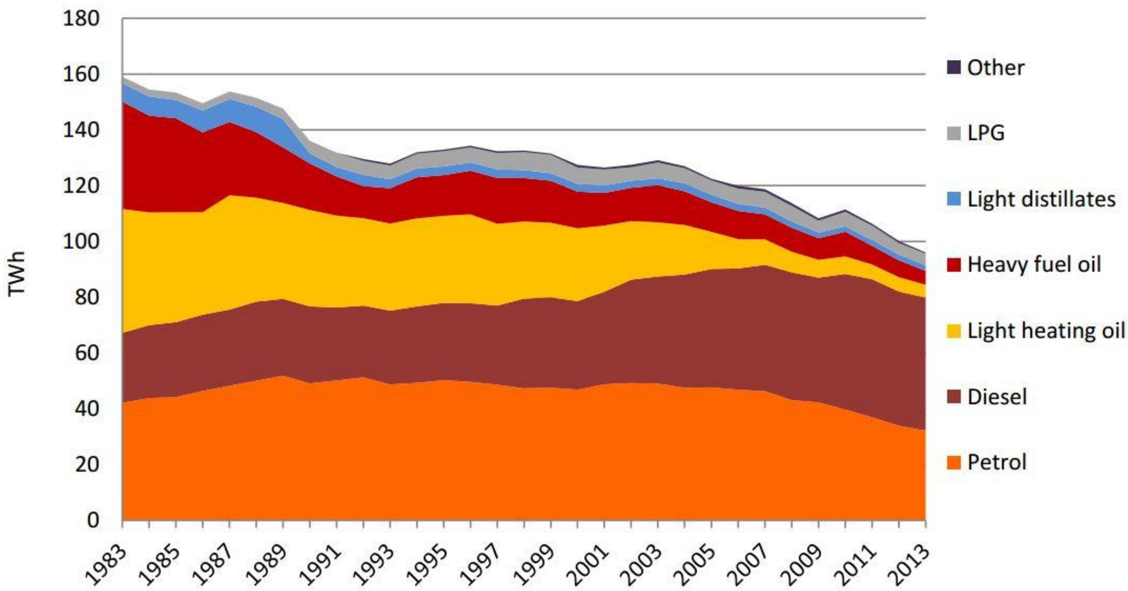

Figure 1: Fossil fuel use in Sweden from 1983 to 2013 (Swedish Energy Agency, 2016a)

The emissions of greenhouse gases from burning fossil fuels, refrigerants, methane emissions from ruminants and more lead to a total of 54.4 million tons equivalent CO_2 emissions in Sweden in 2014, compared to 71.9 million in 1990. The largest contributors to this was transportation at 33 %, industries at 27 % and agriculture at 13 %. (Swedish Environmental Protection agency, 2015a)

In Sweden, there are several goals for energy use and environment. Several resources are also available, with the purpose of making businesses reduce their energy use. A few of the goals and resources are listed below.

Swedish goals include reducing emissions of greenhouse gases by 40 % from 1990 to 2020, having at least 50 % renewable energy by 2020 and to use 20 % less energy by 2020 compared to 2008. (Government Offices of Sweden, 2015)

EEF (Energy Efficiency Companies) is a collection of companies that have energy efficient products and delivers technical solutions and services (EEF, n.d.). The "Network for energy efficiencies" is a similar concept, where several companies have entered a network (Swedish Energy Agency, 2015a). These companies can help and support each other with energy issues, and have an energy expert devoted to them (ibid.).

In 2014, a law came in to force where all large companies in Sweden have to perform energy audits every four years (Swedish Energy Agency, 2016b). Swedish Energy Agency (2016c) provides financial support for small and medium-sized companies that want to make an energy audit. These companies can also get support for additional studies after the energy audit has been conducted (Swedish Energy Agency, 2016d). This can help companies study their energy use more thoroughly (ibid.). The investment program "Klimatklivet" (Roughly translates to "Climate stride"), gives support for climate investments on a local level (Swedish Environmental Protection agency, 2016b).

1.2.1 Energy and fossil fuels in Gävleborg County

The total amount of energy used in Gävleborg in 2014 was approximately 19.7 TWh (Statistics Sweden, 2016). Energy use per person is higher in Gävleborg compared to the national average. According to Gävleborg County administration board (2012) this is because of several energy intensive industries, such as steel and pulp and paper and because the county is sparsely populated with a lot commuting between small towns. Figure 2 shows how energy is used in Gävleborg, where others include companies that are not manufacturing or in mining and quarrying.

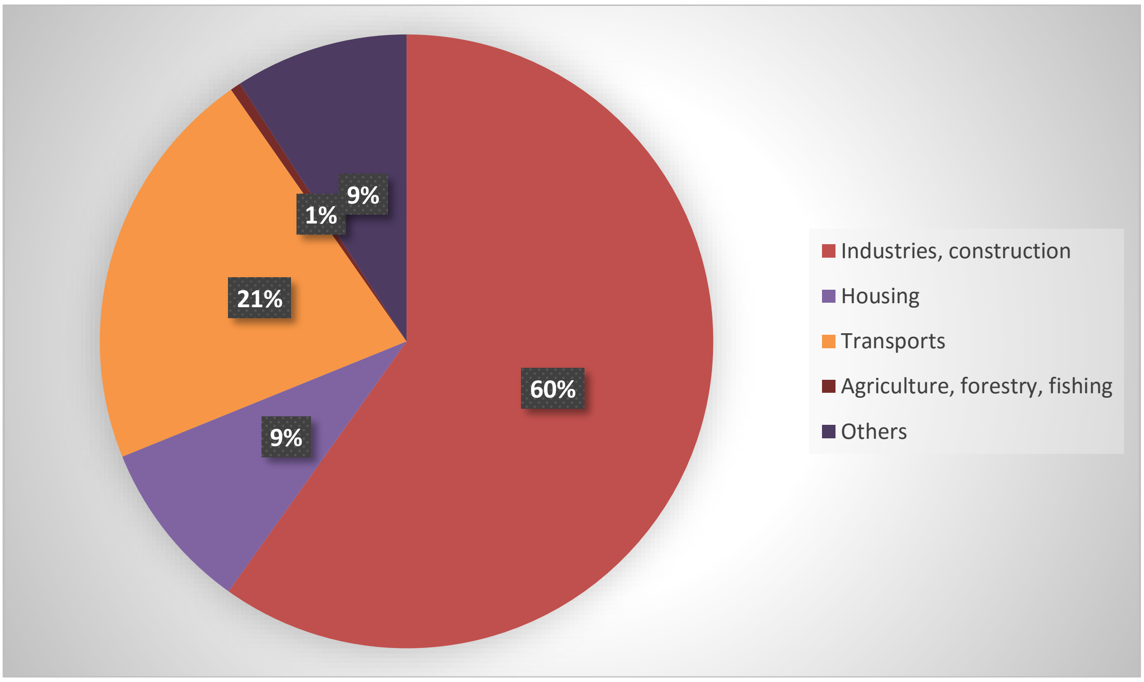

Figure 2: Energy use in Gävleborg in 2014 (Statistics Sweden, 2016)

The use of fossil fuels has decreased in Gävleborg, from 6 TWh in 1990 to 4.5 TWh in 2014. In the same time period the housing sector has decreased its use of fossil fuels from approximately 1.8 TWh to just a few GWh. Figure 3 shows the distribution of fossil fuel use in 2014. (Statistics Sweden, 2016)

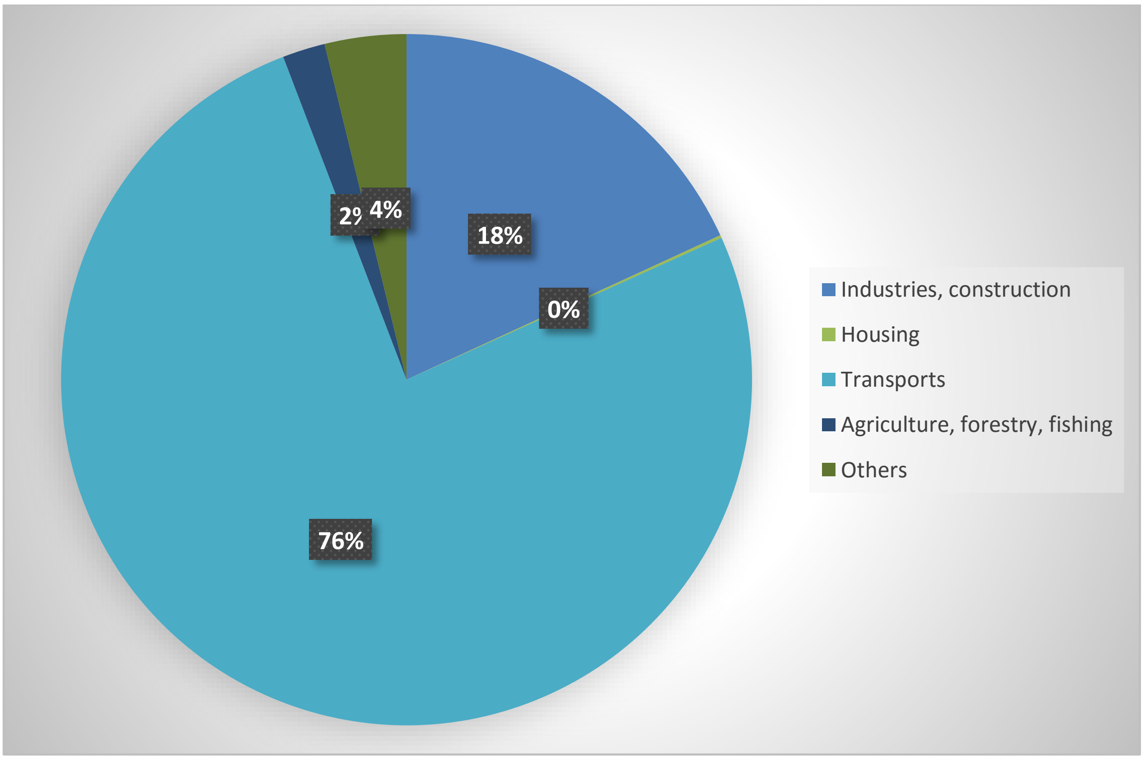

Figure 3: Fossil fuel use in Gävleborg in 2014 (Statistics Sweden, 2016)

If Gävleborg County wants to contribute to meeting the energy and environmental goals of Sweden and the European Union, reductions should occur in transportation, manufacturing industries, construction firms and other businesses. As previously mentioned, Gävleborg has several energy intensive companies that contribute to a high energy use and CO_2 emissions in the county. However, in 2015 the vast majority (99.9 %) of companies had less than 200 employees and more than 80 % had less than four employees (Statistics Sweden, 2015).

According to Backlund and Thollander (2015), these sizes of companies have a large untapped energy efficiency potential in the entire European Union. They also state that small and medium-sized companies constitute a large part of the energy use in Europe, are often not energy intensive and since energy costs are relatively small for each company, energy efficiency investments are not a priority. In Sweden, about 30 % of energy used in industries is by non energy-intensive industries. These facts about small and medium-sized companies has made them the subject of many studies (Trianni & Cagno, 2012; Cagno & Trianni, 2014; Schleich & Gruber 2008; Fleiter, Scheich & Ravivanpong, 2012; Meath, Linnenluecke & Griffiths, 2016; Thollander, Danestig & Rohdin, 2007).

This thesis was conducted in cooperation with Gävleborg county administration board (“Länsstyrelsen Gävleborg”), who also have several goals for the environment and energy. One goal is that the use of fossil fuels should decrease by 3.5 TWh and be replaced by renewable energy sources, increasing the use of renewable energy to 85 % of the total energy used by 2020. A further goal is that the county should use its energy 25 % more efficiently. (Gävleborg County administration board, 2012)

One way to help Gävleborg County administration board reach these goals is to investigate the small and medium-sized companies in the county, which are numerous (~34000) and have the possibility of having a large energy efficiency potential and fossil fuel reduction.

2 Purpose

The purpose of this thesis has been to investigate how the use of fossil fuels can be reduced in Gävleborg County. The case made was small and medium-sized companies in. Small and medium-sized are companies that have less than 250 employees and a maximum annual turnover of 50 million euros (European Commission, 2003).

The thesis was divided into these four problems to be solved:

1. Identify which companies in Gävleborg use fossil fuels.
2. Investigate how willing these companies are to change to some other technology.
3. Investigate what aspects influence a company to change to another heating technology or engage in energy related issues.
4. Estimate the reduction in CO_2 emissions from the measures proposed.

2.1 Delimitations

This thesis was done in cooperation with, and for, Gävleborg County administration board, and thus only considered fossil fuels that are used in Gävleborg County and the municipalities in it. The only considered use of fossil fuels was for heating, i.e. not for transportation or other processes. Finding new ways to generate heat or electricity was also not a part of this thesis, only which existing technologies can be used.

Some assumptions were also made on the technical viability of the proposed heating technologies. No economical suggestions or calculations were made, since the individual companies' circumstances will determine profitability.

The only environmental impact, originating from the different heating systems, chosen to be calculated was CO_2 and CO_2 equivalents.

3 Method

To identify the companies that use fossil fuels in Gävleborg, energy advisors at all municipalities in the county were contacted[1]. An exception was Gävle municipality, where Eva Jackson[2] (Environmental manager at Gävle municipality) was contacted, after advice from external supervisor at Gävleborg County administration board.

A survey (Appendix A) was created and sent to these companies, to find how willing these companies were to change heating technology. This survey included questions about the amount of oil used, if the company wanted to change to something else and what other technology they could consider changing to.

Investigating the aspects that cause companies to engage in energy related issues was done in several fashions. One was from a purely technical point of view. This meant listing and discussing some of the technical difficulties that might hinder a company from changing heating technology. In addition, presenting the alternative technologies that were available besides oil.

The other aspects are from what could be considered more related to behavioural point of views. The companies could leave additional comments on the survey, but it was assumed that the majority of them would not do this, or explain their choices in detail. To give an explanation of their choices, research on the barriers and driving forces that affects companies' decision making was collected.

Reductions in CO_2 emissions was calculated using data for the companies that answered "yes", to the question asking if they wanted to change to something other than oil. Calculations were done using the amounts of oil these companies reported that they used and what kind of technology they could consider switching to. If one or more companies responded that they could consider changing to more than one alternative technology, all cases were calculated.

The emissions from different energy sources was the same as the ones used in the investment program "Klimatklivet", which is handled by the Swedish Environmental Protection agency (2015b). The only exception for this was regarding calculations on district heating. If data was available for the emissions of a specific district heating net that a company was situated in, that data was used instead of the average.

Companies could answer their oil consumption in different units, e.g. cubic metres, litres or ton. When calculating CO_2 emissions these answers were converted to MWh, where the energy content of heating oil was assumed to be 10 kWh/litre (Svenska petroleum & biodrivmedel institutet, 2016). If companies answered their consumption in a range (e.g. 20-25 m^3), the average was used. For heat pumps it was assumed that the yearly average coefficient of performance was 2.5.

[1] Bollnäs, 2016; Hofors, 2013; Hudiksvall, 2016; Ljusdal, n.d.; Ovanåker, 2016; Nordanstig, 2016; Sandviken, 2016 and Söderhamn municipality, 2016 as well as Energikontor, Gävleborg, n.d.
[2] Eva Jackson, Environmental manager Gävle municipality, mail 3 March 2016.

4 Literature review

This chapter is intended to explain how fossil fuel consumption can be reduced and the complexities around it. Achieving this goal can be accomplished in several ways. One way is to directly replace the current technology using fossil fuels for something else. Another way is to lower overall energy use, which indirectly lowers the use of fossil fuels as well as other kinds of energy.

The first part of this chapter lists some of the research on how fossil fuel use can be reduced or replaced, on small and large scales. The second part lists the heating technologies that can be used to replace fossil fuels for heating and what other fuels or technologies should be used for this purpose. The last part shows some of the barriers and drivers that affects companies that want to reduce their oil consumption or overall energy use.

4.1 Reducing fossil fuel use

As mentioned earlier, fossil fuels make up a huge part of the world's energy supply, meaning that it is used in all sectors. This means that there should be a possibility of reducing the use and consumption in all sectors.

This part will cover some of what can be done and what has been done to lower fossil fuel usage, in Sweden and elsewhere. Much of it is regarding energy efficiency measures in general, while the purpose of this thesis was to only consider fossil fuels for heating. It is however probable that a company or building owner that changes their heating system also performs energy audits and efficiencies at the same time, or is at least more positive towards it in the future. Changing heating system is in itself not an energy efficiency measure, unless the overall thermal efficiency of the new heating system is superior to the old one. If this is true, less fuel will be needed.

According to Boverket (2008) changing the envelope of a building is an important measure to do when changing the heating system, since it lowers the maximum power need of the building. Meaning that the investment for the heating system is lowered and there is less chance of having a wrongly dimensioned system in the event of future retrofits to the envelope.

Agriculture is a small sector in Sweden, but is very dependent on fossil fuels (Swedish institute of Agricultural and Environmental Engineering, 2014). To help achieve the energy and environmental goals, it can be relevant to see if and how fossil fuels in the agricultural sector in Sweden and Gävleborg can be reduced.

Kimming et al. (2015) investigated how a dairy farm could become energy self-sufficient and fossil free. They found that it was possible to achieve energy self-sufficiency by using residual resources available at the farm and that greenhouse gases could be reduced by at least 36 %. They also point to several articles on energy use and emissions from farming (Fredriksson et al. 2006; Hansson et al. 2007; Ahlgren et al. 2008; Kimming et al. 2011).

Making entire regions or countries more energy efficient and use less fossil fuels have been shown to be possible by several researchers. Dahlquist, Yan and Thorin (2013) studied how the area around Lake Mälaren in Sweden could become independent of fossil fuels. They say this can be done by lowering energy demands, using electric vehicles, eating less meat, using other fuels besides electricity for heating, showering, washing etc. and an increase in wind energy, biomass from land and energy forests (ibid.). Richardson and Harvey (2015) concluded that it could be possible to replace the use of conventional fuel in Ontario, Canada. The electrical and transportation system could become fossil fuel-free using nuclear, wind, solar, hydro power, energy from storage, demand response, biomass and finally electricity (ibid.). Joelsson and Gustavsson (2012) found that, in Sweden, the sectors: space heating for buildings, road transport and off-road mobile machines and chemical pulp production could become almost fossil fuel free.

Gustavsson et al. (2007) investigated how an increased use of biomass could help Sweden reduce its carbon dioxide emissions and oil use. They assume that 400 PJ/year more biomass (almost twice as much as was used when the article was written) could be produced and studied four scenarios with this increase: prioritizing CO_2 reductions, prioritizing reduction of oil use, combined scenario where CO_2 emissions and oil are reduced at the same time or producing ethanol with the purpose of replacing petrol.

To get the maximum CO_2 reduction, the additional biomass should be used for district heating, replacing electric space heating with heat pumps, construction of wood buildings and producing electricity from black liquor. To reduce fossil fuel utilization as much as possible, oil boilers for heat and electricity production should be replaced (both industrial processes and space heating) and methanol should be procured from black liquor. The most efficient way to reduce both CO_2 emissions and oil use was found to be replacing electric and oil-based heating, increase wood in construction, black liquor gasification for electricity generation or motor fuels and replacing oil in stand-alone heat and power-production. (Gustavsson el al., 2007)

It is stated that increasing the use of biomass provides an important potential for reducing carbon emissions and oil use. What the increase in biomass should be used for depends on what the goal is, reducing CO_2 emissions versus reducing oil dependence. Optimising the increase for CO_2 reductions leads to much greater reductions in emissions compared to if the biomass is used to reduce the use of oil. The reverse is true for the case of oil reductions, where the use of oil of is greatly reduced, but emissions less so. The combined scenario was found to give less CO_2 and oil use reduction, but had the benefit of saving money. Using the biomass for ethanol production gave less reductions in both categories, and at a higher cost. (Gustavsson el al., 2007)

An increase in biomass production could provide a decrease in fossil fuel consumption and/or CO_2 emissions. However, Lior (2010) states that planning a renewable energy system is nearly impossible when oil and gas prices are highly fluctuating. Also says that energy costs of buildings are a very small fraction of the resident's/owner's income, which means they have very little incentive to improve it (ibid.). This could also be true for industries and other businesses that have some kind of production process or service businesses.

Zhang, Lundgren and Zhou (2016) assessed energy inefficiencies in 14 different industry sectors, in Sweden, and found that they all had some inefficiencies, though the amounts differed. They say that firms that use fossil fuels had a tendency to use energy more efficiently to lower the costs of additional taxes placed on these fuels. The energy tax, that is present in Sweden, was also shown to have had a positive effect to promote energy efficiency. Consistent with other research, this article also found that there are large energy efficiency potentials in firms that are not energy-intensive, meaning that they should receive particular attention. (Zhang, Lundgren and Zhou, 2016)

All companies have a building to conduct their business in or to produce a product. Depending on the type of company, the buildings' energy use can differ, but there is still often an energy efficiency potential available in it. Backlund and Thollander (2015) studied 241 companies and found that for both manufacturing and non-manufacturing companies, the largest energy efficiency was found in building related energy uses, space heating and ventilation. Fleiter, Schleich and Ravivanpong (2012) also found that, for 542 small and medium-sized companies, most of the adopted energy efficiency measures were building related, such as in heating and hot water.

Performing energy efficiencies that are building related can be different for each building. For example, the envelope can be improved to reduce the heating demand or the ventilation air flow can be changed to work optimally. There are too many examples of case studies on buildings to mention here, especially theses by students, and by companies and other literature. What can be mentioned is that one energy efficiency measure can affect others, for example if more efficient lighting is installed, any heat that they used to give off is reduced possibly increasing the heating demand.

4.2 Heating technologies

The main purpose of this thesis was to investigate how fossil fuel consumption can be lowered in Gävleborg County, with the case of companies that use oil for their heating needs. For this reason, a few of the heating technologies that are available is described below and some of the advantages and disadvantages listed for each of them.

4.2.1 Electricity and electrical heating

Regardless of heating system, electricity is used to some extent. In electrical heating and heat pumps it is the main source of heating, but electricity is also used in other heating systems, such as district heating and domestic boilers. Most heating systems have an electrically driven pump as well as computers or other control systems. This electricity is most often produced in large power plants that are far away from the place where it's used, where the fuel for these power plants can be wind, running water, nuclear, coal, gas, biomass or solar power (US department of energy, 2014). This means that emissions from electricity consumption is directly linked to what fuel is used to produce the electricity, which is also true for heating systems such as electrical heating and heat pumps.

Electricity used for heating can have several different configurations; one is to install radiators that use electrical resistance to produce heat. The other is to use an electric furnace that heats water, which is then distributed throughout a piping system in a building in the same way as other boiler systems. (Swedish Energy Agency, 2015b)

The advantages of electrical heating are that it is cheap to install, have no local emissions and maintenance is low (Swedish Energy Agency, 2015b; omboende, 2013).

A major disadvantage is that the price of electricity can fluctuate dramatically, depending on season and year. It is also very difficult to know where the electricity originates from and what emissions are associated with it.

Emissions can be hard to determine partly because there is joint electricity system among the Nordic countries as well as some transfer to the rest of Europe. Customers can also choose their provider freely in Sweden and, to some extent, the source of the electricity. Emissions from different sources varies greatly, e.g. greenhouses gas emissions can be from 10 kg/MWh for wind and hydropower, up to 1000 kg/MWh for coal condensing power plants. (Gode, Byman, Persson & Trygg, 2009)

According to Areskoug & Eliasson (2007), electricity is an energy source with high quality (100 %). This means that it can be converted to any other form of energy. The heating system in a building is most often at a temperature of 70 °C or lower. This kind of energy only has an energy quality of 20 %. Using electricity to heat buildings thus means taking a high quality energy source and converting it to one with much lower quality, which can be seen as wasteful. (Areskoug & Eliasson, 2007)

4.2.2 District heating

District heating system works by providing heat from a central production facility through distribution lines to local substations, the substations then distribute the heat to a buildings' heating system Typical temperatures in district heating net are 70-120 °C in the feed line and 40-65 °C in the return line. (Frederiksen & Werner, 2011)

Similar to electricity, the emissions from the use of district heating will depend on the fuel that is used in the central production facility. In general, any primary energy source that is used for producing electricity or heating can be used, for example wood, pellets, wood chips, branches and tree tops and municipal solid waste. Waste heat from industrial processes can also be used, and is done in several Swedish cities. (Frederiksen & Werner, 2011) Only about 9 % of fuels supplied to district heating were fossil fuels in 2013, which are used for peak load, back-up and in some cases during low load periods (Swedish Energy Agency, 2016a; Swedish District Heating Association, 2006).

Some advantages of district heating include that low-quality fuel can be used, the efficiency of larger facilities is usually better than smaller ones, the equipment takes less total space and there are less local health effects due to better combustion and high chimneys. The most important advantage might be that low-quality fuel can be used, e.g. municipal solid waste, which is very difficult in small scale systems. Of course there are also disadvantages, such as individuals having less control over their heating system and that any disturbance will have greater consequences, compared to if each house had a separate heating system.

The facility that produces the heat in a district heating network can be anywhere from a few hundred meters to more than ten kilometres from the consumer. The profitability of district heating is dependent on the distance from the heating plant to the consumers that need the plant's heat and the total heating demand in that consumers' area. Because of these factors, new pipes will only be laid so far, unless the customer has a sufficient need that is economically viable. (Frederiksen & Werner, 2011)

4.2.3 Heat pumps

Heat pumps work in four stages: vaporization, compression, condensation and expansion. Inside a heat pump, a refrigerant circulates and transfers energy from one place to another. A heat pump is normally used to transfer heat from a surrounding to a building or other object that need heat, although the same process can be used for cooling. The surrounding can be bedrock (borehole), ground source, outside air, a lake or other water sources as well as return ventilation air. (Granryd et al. 2011)

Heat pumps use electricity as their "fuel", implying that the amount of fossil fuels and CO_2 emissions from them depend on what the electricity is produced with (Granryd et al. 2011). The performance of a heat pump is called its coefficient of performance (COP). The COP can be anywhere from 2.5 to 4.5, meaning that a heat pump uses 1 kWh of electricity to produce 2.5 to 4.5 kWh of heat. This is also the major advantage of heat pumps. (Areskoug & Eliasson, 2007)

Another downside with heat pumps is that the refrigerant they use can have strong effects on the environment. Some refrigerant affects the global warming of the earth several thousand times more than carbon dioxide and some can also have an adverse effect on the ozone layer. Refrigerants can exit the closed circuit of the heat pump from leakages, breakdown, when the heat pump is being dismantled and during general handling of the refrigerant. (Nilsson, 2001)

4.2.4 Small scale boilers

A boiler uses some kind of fuel to convert chemically stored energy into heat, in the form of hot water. The fuel for a boiler can be fossil fuels, biomass, electricity or some combination of these. The type of fuel of course affects the cost, emissions and other environmental impacts from the system.

The main types of biomass used in small-scale boilers are wood logs, wood chips and pellets. These biomass fuels (biofuels) can have very differing characteristics when it comes to energy content and the amount and kinds of emissions (Obernberger, 1998).

Wood logs can be a very cheap fuel for heating, especially if a local supply is available (Energi & klimatrådgivningen, n.d.a). A wood boiler is usually accompanied by an accumulation tank, which stores hot water. With this tank, less fires have to be started each day and the efficiency of the system is increased, leading to less wood being used (Energi & klimatrådgivningen, n.d.b). One possible disadvantage (or discomfort) is that the wood has to be cut and split, and the boiler filled, every day (Swedish Energy Agency, 2010a).

Pellets is made by compressing residual biomass to small cylinders, which means that it has higher energy content than its source and does not contribute to increasing greenhouse gas levels. (Svebio, n.d). Some disadvantages of using pellets for heating include that more maintenance is needed than for other heating systems, there is a risk for disturbance in its operation and the fuel has to be stored in large spaces close to the burner (Boverket, 2008). Wood chips can also be used for heating, but requires a more advanced system compared to other fuels and the chips have to be dried before it can be used (Bioenergiportalen, 2013). Both pellets and wood chips are resources that, if not used for heating, might not be used at all.

Possibly the greatest disadvantage with all the biomass fuels mentioned above are their local emissions. These emissions include carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and particles of varying sizes (Buczynski, Weber & Szlek, 2015). The emissions from these boilers are also present on ground level, since the chimneys are often at the top of houses. The age of a boiler also has a significant impact on the amount of emissions. For instance, Johansson et al. (2004) found that the methane emissions of a new boiler connected to a storage tank was between eight and 9000 times lower than an old wood boiler.

4.2.5 Solar heating

This sort of heating system uses solar energy to heat a fluid, which is usually transferred to an accumulation tank where the heat is stored. Solar heating is most often paired with a supplementary heat source, which can be wood, district heating, a heat pump or electricity. In those cases, the heat from the solar heating system is always used first, since the heat is essentially free. (Svesol, n.d.) Solar heating can also be used for more than heating of buildings, for instance drying crops and grain in agriculture (Chel & Kaushik, 2011).

The reduction in heating that can be achieved from installing solar heating depends on several factors. Such as what type of solar heating system is used and how much available space is available (e.g. roof area). Another important factor is geographical location, which country or which part of a country a solar system is placed in will affect its performance.

Advantages of solar heating include that it’s environmentally friendly, much more energy is produced compared to what is needed to produce the devices, solar energy is present all around the world and the “fuel” is completely free. This also means that compared to other forms of heating, there are no fluctuations in fuel costs, when the system is paid for the heat is practically free. (Solar Energy Association of Sweden, 2015)

The main disadvantage of solar heating is that when it is most needed, the insolation is at its lowest point. The system cannot just be “turned on” when there is a need for heating, which requires that it is complemented by another heat source. (Solar Energy Association of Sweden, 2015)

4.3 Choice of energy source for heating

For some of the heating system described in section 4.2 there are different kinds of fuel available, not in the least for district heating. Choosing which fuel or energy type should be used is in many cases based on financial decisions. Other factors can of course be important, such as the energy source´s total cost to society, how much it contributes to global warming and other environmental impacts. Fuel availability can also determine what type of fuel is used in different circumstances. For example, Sweden has no domestic extraction of oil, but a lot of biomass is used and there is a large potential for increased biomass production (IEA, 2012; Hagström, 2006).

Larsson and Persson (2009) has proposed using a “heating hierarchy”, which shows the order of fuels that have the least amount of impact on the environment and climate and that uses the least amount of resources. This hierarchy can be used real estate owners and others that need to change heating system. The hierarchy is shown in table 1, with the source with the least impact at the top.

Table 1: The heating hierarchy proposed by Larsson and Persson (2009)

Surplus energy
Waste fuels
Residual biomass
Primary biofuels
Electricity
Fossil fuels

This hierarchy has been made according to the primary energy used by each energy source, a practice that the Energy efficiency committee (2008) says give a better view on the actual environmental impact an energy source has.

Using residual or surplus energy is possibly the best practice in many cases, not only for heating. Lior (2010) said that it takes significantly more than 1 J (Joule) of energy to generate 1 J of power and that the same logic is true for the resources and environmental impacts from energy generation. In Sweden, residual heat from industries provides almost five TWh to the district heating nets and more is available (Arnell et al., 2013). Residual heat can also originate from sources other than industry, for example indoor air for exhaust air heat pump systems or residual heat from bakeries (Nibe, n.d.; Freisinger et al. 2015). Meaning that heat at virtually any temperature can be used for some purpose.

The heating choice can also depend on the local conditions at the building in question. Joelsson and Gustavsson (2012) approximated that in Sweden, 95 % of buildings in densely populated areas are covered by a district heating net and that the same figure for sparsely populated areas is 5 %. Additionally, 60 % of all buildings could use heat pumps and for the rest, domestic boiler is a viable option. They also state that this order: district heating, heat pumps followed by boilers, is the most efficient. However, this article deals with the whole of Sweden, while there might be regional differences. (Joelsson and Gustavsson 2012).

As previously mentioned, small-scale boilers using biofuels have a lot of emissions that are harmful and present on ground level. This might make them less suitable for densely populated areas.

4.4 Barriers and driving forces

This part presents some of the barriers and drivers that hinders or helps companies engage in energy related issues, such as changing heating technology or perform energy audits and energy efficiency measures.

The first research worth mentioning is Swedish Energy Agency's (2010b) report on the attitude of small and medium-sized companies when it comes to energy and environmental issues. This was done by performing 1015 telephone interviews and 20 in-depth complementing interviews. They found that the mind-set "We'll deal with it later" represented the average companies' view on energy issues. The focus is usually on the business side, "problems" are solved when and where they occur and environmental and energy costs have low priority.

The study showed that most companies (69 %) try to reduce their energy usage with the main purpose of saving money and that a very small percentage (4 %) do not try this at all. It was stated that the size and type of business did not determine the companies' view on their energy usage. Also stated that the larger companies among small and medium-sized companies have better conditions (resources) to analyse, plan and act on these issues. When communicating with the companies it is important to put oneself in their situation and to understand what their priorities are. Focus should be on proposing solutions that are economically sound as opposed to benefitting society as a whole. (Swedish Energy Agency, 2010b)

It is also important to remember that companies are not the same as the general population, decisions are made on different basis where the focus is on efficiency (time and money). When contact has been established with an interested company, it is important to be informative, interested and to have concrete advice, as well as a promise that the performance of the company can be improved. Only arguing that changes should be made to benefit society will have a very small or no effect. It is also good to be able to show previous examples on how energy efficiencies have been made and that it had a positive effect on other companies. (Swedish Energy Agency, 2010b)

4.4.1 Barriers for companies

This part is intended to shed some light on the barriers that stand in the way for companies that want to engage in energy efficiency measures and similar efforts. Much research has been conducted on what the major barriers are for small and medium-sized companies that wish to engage in energy efficiency measures. Table 2 shows some of the barriers that can hinder companies from conducting energy efficiency measures. Table 2 is based on the conclusion of Thollander (2008).

Table 2: Barriers that affect companies (Thollander, 2008)

Technical risks such as risk of production disruptions
Lack of time or other priorities
Lack of access to capital
Cost of production disruption/hassle/inconvenience
Other priorities for capital investments
Technology is inappropriate at the site
Difficulty/cost of obtaining information about the energy use of purchased equipment
Lack of budget funding

Many other researchers have found similar barriers, but in different orders and magnitudes, some of them include (Cagno and Trianni, 2014; Fleiter, Schleich and Ravivanpong, 2012; Thollander, Danestig and Rohdin, 2007; Trianni, Cagno and Farné, 2016; Meath, Linnenluecke and Griffiths, 2016; Schleich and Gruber, 2008).

Trianni, Cagno and Farné (2016) found that barriers are of different importance depending on what stage of the decisions making process companies are in. The most significant barriers were found in the starting phases of this process, when lack of awareness and behavioural barriers are the most important. Barriers were found to diminish the further a company gets in the process.

Rohdin and Thollander (2006) interviewed companies that had short pay-back time criteria, one to three years, which made energy investments a lower priority. They also found that for companies not owning their working facility, this was a major barrier. The company that owns the facility did not have the same incentives to perform energy efficiencies.

Schleich and Gruber (2008) states that many companies might not have sufficient knowledge about the magnitude of their energy use and where the energy is used. They also found that for companies that rents their facilities, this was a major barrier to energy efficiency. Unlike large and energy-intensive, small and medium-sized companies don’t normally have the expertise required to assess their energy flows. External consultants are said to often be considered too costly compared to the expected energy costs savings, which means that subsidy programmes that offer energy audits at a low cost can be effective at promoting energy efficiency.

4.4.2 Driving forces for companies

This part lists some of the drivers that have been found to encourage companies. The drivers that cause companies to engage in energy related issues don’t necessarily have to directly address the barriers that exists, although they might to this indirectly.

According to Dahlquist, Yan and Thorin (2008) the most significant effect a Swedish policy has had is the introduction a CO_2 tax in 1992, which increased the utilization of biofuels from 50 to 120 TWh/year. Cansino, Pablo-Romero, Román and Yñiguez (2011) states that subsidies are a good way to promote the use of renewable energy sources for heating and cooling. They say that subsidies are a good way to reduce the high investment costs that are associated with heating and cooling, providing a direct encouragement that is easy to implement (ibid.).

To tackle the barrier of making companies aware of the benefits and cost savings of energy efficiency, Trianni, Cagno and Farné (2016) says that stakeholders such as manufacturers, technology suppliers, installers and energy service companies should provide vocational training (e.g. technical support). Cagno and Trianni (2014) also said that support of external stakeholders is an important driver, since small and medium-sized companies might not have sufficient technical skills to manage energy related issues.

Meath, Linnenluencke and Griffiths (2016) found that the most important motivators were financial interests (saving money) and meeting industry environmental requirements. The authors also included a framework that they think can be used to encourage adoption of energy efficiency measures in small and medium-sized companies. The framework consists of: investigating motivators and barriers (1), tailoring programs/assistances to multiple motivators and barriers (2), implementing the program/assistance (3) and lastly measuring and recognising successes (4). The last step also includes investigating new barriers and motivators that may have appeared and the process may start again from step 2. (Meath, Linnenluencke and Griffiths, 2016)

Fleiter, Schleich and Ravivanpong (2012) found that investment subsidies and soft loans are effective tools to promote energy efficiency measures in small and medium-sized companies.

Thollander, Backlund, Trianni and Cagno (2013) found that the most important drivers in foundry industries in several European countries were financially related followed by organizational ones. The most important financial drivers were the threat of rising energy prices and cost reductions as a result of lowered energy use. Other important drivers were commitment from top management and people that have real ambition

Thollander and Tyrberg (2008) found that important driving forces were reduced costs, people with enthusiasm and the threat of rising energy prices. The authors also say that to promote interest among companies they should receive external support to establish an energy strategy and support from energy experts or other consultants.

5 Results

This chapter is divided into two parts. The first one shows the responses that were given to the survey and the second part calculations on CO_2 emissions that have been made on some of these responses.

5.1 Responses to the survey

After contacting all the energy and climate advisors at the municipalities, it was found that 104 companies use fossil fuels in Gävleborg County. Nine of these 104 companies answered that they had already switched to some other form of heating or had never used it, making the real sample 95 companies. Out of these 95, two companies did not want to answer the survey and two more companies stated that they did not have time to answer the survey.

In total, 26 companies answered the survey fully or to some extent. Two answers were chosen not to be used for calculation or discussion. One of if these companies responded that they use HVO (hydrogenated vegetable oil) as energy for its production processes and a heat pump for heating. The other company used diesel to power lorries and electricity for heating. This means that the results were based on 24 responses.

Table 3 shows the number of companies that answered yes, no or maybe to the question "Would you like to switch to a different fuel?".

Table 3: Companies' responses to the question on if they wanted to change.

Yes	9
No	9
Maybe	6

23 of the 24 companies used heating oil as their energy source and one used diesel to power a steam boiler, which was used for the production processes as well as heating of premises.

Two of the 24 companies responded that the fuel was used for both production processes and heating. Two more said that the oil was only used for production purposes and one company did not answer what they used it for. This means that 19 companies used oil for heating purposes.

The amount of oil used differed a lot between companies. Four companies had oil use that exceeded 125000 MWh (~12500 m^3). For the other 20 companies, oil use varied between 5 and approximately 1700 MWh, with an average annual use of roughly 256 MWh.

Table 4 shows what other heating source the companies could consider, which was a multiple choice question. The numbers have no affiliation to the size, location or what kind of company it was, it is completely random. Others include answers that could not clearly be sorted. Company 1 could consider using residual heat from their processes and switching their use of liquefied petroleum gas to natural gas. Company 15 answered "do not know". Company 21 said that they use heating oil for production purposes and could consider changing that to liquefied petroleum gas. They did not specify if they are currently using a heat pump or if they could consider it, only that their heating need is "a small piece of the pie" (original Swedish: "liten del av kakan"). Company 22 stated that they could consider switching to "environmental fuel" (original Swedish: "Miljöbränsle"), though it is unknown what fuel this means specifically.

Table 4: The kinds of heating technologies the companies could consider.

Company	District heating	Heat pump	Biofuel	Solar heating	Rental system	Others	Did not answer
1	X		X			X	
2		X		X			
3		X					
4			X				
5							X
6							X
7							X
8			X				
9	X			X			
10	X		X	X			
11							X
12		X					
13	X	X	X				
14		X					
15						X	
16	X						
17	X		X				
18	X	X					
19							X
20			X				
21		X				X	
22						X	
23							X
24	X	X			X		
Sum	8	8	7	3	1	4	6

On the question of how long it would take to change to some other form of heating the responses varied from a few months to 15 years. Five of the companies said that it would take less than a year, two to six months. Four companies responded that it could take anywhere from one to 5 years. Possibly the largest company asked responded that it could take anywhere from five to 15 years, depending on decisions at the leadership level, costs and more.

Table 5 and 6 shows responses to question 9 (if consultation is needed) and question 10 (if investment support is needed), respectively.

Table 5:The number of companies that needed consultation.

Yes	10
No	10
Did not answer	4

Table 6: The number of companies that needed investment support.

Yes	10
No	8
Did not answer	6

5.2 Reductions in CO_2 emissions

As stated previously, the calculations for reductions in CO_2 are based on the Swedish Environmental Protection agency's (2015b) emission data for different fuels. The values that have been used are shown in table 7. The district heating value seen in table 7 is a national average that can be used if local values are unknown. The only unique district heating value used was for a company situated in Ljusdal municipality, where the emissions were 46.93 g CO_2e/kWh (Ljusdal Energi, n.d.). For biofuels, an average value was calculated from the values of all biofuels listed: wood chips, pellets, bark, recycled wood, biofuels from energy crops, sawmill residues and wood briquettes.

Table 7: Emissions from different fuels. (Swedish Environmental Protection agency, 2015b)

Heating technology	Emissions [g CO_2e/kWh]
Solar heating	19
Heating oil	288
Electricity	125
Biofuels, average	13
District heating, average	60

Nine companies answered that they wanted to switch to some other heating technology, but one of these answers is not used for calculations. The reason is that this company only answered the question on the amount used with a number ("46"), not the actual unit. On the question of what fuel this company could consider changing to, the answer was "environmental fuel" (original Swedish: "Miljöbränsle"). This means that calculations have been based on the answers from eight companies.

Of the eight companies used for calculation, seven had consumption of oil ranging from 30 to 300 MWh per year. The last one had an annual energy use of approximately 125500 MWh. This means that any calculation results will be dominated by the answer from this last company, which could only consider switching to district heating or solar heating. In table 4, these eight companies have the numbers 2, 4, 6, 9, 12, 13, 17 and 20.

CO_2 emissions were calculated using equation [1], shown below. Reductions in emissions were calculated depending on the heating technology the companies said that they could consider changing to. The eight companies for which calculations were made could consider switching to district heating, biofuel or heat pump and all these cases were calculated. One of them did not give an answer to what they could change to and for this company all cases were calculated. As said in the method chapter, the seasonal (yearly) COP for heat pump was assumed to be 2.5 and the energy content of heating oil was assumed to be 10 kWh/litre (Svenska petroleum & biodrivmedel institutet, 2016).

$$CO_2\ emissions = Energy\ use\ in\ kWh * \ grams\ CO_2\ emissions\ /kWh \quad [1]$$

Table 8 shows the results of the calculations, where the numbers are the total emissions for all heating systems in tons CO_2 equivalents.

Table 8: Emissions for different heating systems.

Sum of emissions before changes	36544 [tons CO_2]
With district heating	7590 [tons CO_2]
With biofuel	7564 [tons CO_2]
With heat pump	7588 [tons CO_2]

Table 8 shows that whatever heating system is prioritized, there is very little difference between the results. Reduction in tons of equivalent CO_2 emissions is approximately 28900 tons in all cases.

Two of the companies that wanted to switch heating system said that they could consider solar heating. Assuming that this replaces 20 % of the total heating demand, CO_2 emissions are reduced to approximately 6560 in all cases and a further reduction of 1030 tons of equivalent CO_2 emissions is achieved.

6 Discussion

The first and possibly most important task concerning this thesis was finding out how many companies use oil in Gävleborg County, and which companies they were. Adjusting for the number of companies that had already changed heating system, the total number found was 95 and 26 if these answered. This, I think, is an acceptable amount, about 27 %. It is of course entirely possible that the total number of companies is more or less.

The method of finding the companies that use oil for heating was contacting energy advisors at all municipalities. This method was also suggested by my external supervisors at Gävleborg County administration board. It is unknown if there is a better method for this task.

Additional methods were tried, but turned up nothing so these haven't been mentioned before. These involved searching for a database that (at the time) was thought to have this information as well as contacting chimney sweepers.

The second task was creating a survey and sending it to these companies. The main objective with this survey was that it should give some hint as to if the companies wanted to change to some other heating technology besides oil and that it was to be short and easy to answer with mostly yes and no-questions.

It is unfortunately not possible to know if the companies answered truthfully and who at the company answered the survey. For most of the companies, a general email address was only available, in the form of info@company.com. Since the companies asked were small and medium-sized it is less likely that they have someone dedicated to energy and environmental issues.

Another method that could have been used is interviewing companies instead of, or in addition to, sending out survey. How many of the companies would have wanted to participate in such an interview is difficult to say. What can be said is that Gävleborg County is relatively large, making travel time a major hurdle to this method. The objective was also to get a more general opinion from several companies across the county, which also would have been more difficult with interviews. Performing only interviews could have made the thesis in to a case study on the companies interviewed, which was not the purpose.

The survey could have had more questions included, such as why or why not the companies wanted to change, needed consultation or needed investment support. I don't think that it is likely that the companies would have answered these questions and less companies would have answered the companies because of the burden of these types of questions. It was also possible for the companies to leave comments on the survey sent, but the majority did not do this.

The same number of companies (9) that were willing to change from oil said that they did not want to. I found this hard to understand, since the viewpoint in my studies has always been that fossils fuels are not an alternative. Knowing the damaging effects and non-renewable nature of fossil fuels, why would anyone not want to change to something other than oil? Since the companies were not specifically asked on why, or mostly did not leave a comment on it, the research on barriers and driving forces was collected and summarized as a way to understand this.

Several companies that said “no” to switching still answered what heating technology they could consider switching to and did not say oil again. It is possible that these companies answered what they would change to if something happened to their oil heating system or if they were forced by something, but that they are not willing change it right now.

Much of the research collected has been on energy efficiency measures and not specifically heating, but it should still be applicable. The research described in part 4.4.1 (Barriers for companies) show a similar pattern, companies feel that there is a lack of capital, lack of time and that they have more pressing needs. Production disruptions risks should not be a major barrier for the companies asked, since they were only asked about oil used for heating.

The literature in part 4.4.1 (Table 2) shows a number of barriers affecting companies. Of these, the most important ones are probably lack of access to capital and lack of time or other priorities. Both of these can be due to the small employment size of the companies asked. Larger companies will by their nature have much easier access to these resources. The research displayed in part 4.4.2 (Driving forces for companies) says that subsidies is a good way to promote more energy efficient behaviour, and should also be a good way to lessen the financial impact of investing in a new heating system. Another important barrier is information related ones, meaning that informing companies of the benefits of energy efficiency can be a good driving force and should probably be done by local governments, energy suppliers and consultants.

Some companies did answer why they can or cannot change. One answered that they only rent the facility they work in, which makes energy related investments low priority. It is probable that this is a barrier for many of the companies asked, and for other small and medium-sized companies. Since these are so small it is more likely they rent their facility by another company, which does not have the same incentive. Another company (a realtor) said that the oil consumption is distributed across several real estates and that the oil is only used for peak load.

This thesis only involved fossil fuels for heating, even though they can be used for many more purposes. This did not limit the thesis or the results. First of all, it was unknown what the companies used their fossil fuel for before sending the survey. I did not go through the process of finding out what they used it for, since all companies’ answers could be interesting and they might provide comments on it. Without asking the companies, it is also very difficult to find out what they use fossil fuels for.

Indeed, several companies answered that they use oil for production processes and/or heating. One company used their process heat, which was supplied by a steam boiler, for both production and heating. A further two used steam boilers, powered by heating oil, only for their production. It is difficult to say what options are available for these companies, as they may have specific needs for the temperature and pressure of the steam used. District heating, heat pump or solar heating could technically be used to at least preheat the water used in their processes. Biofuels also have the technical possibility of providing steam at very high temperatures and pressures (e.g. in district heating plants).

Suggesting what other heating technologies companies could use from a purely technical standpoint should be a case-by-case situation, the same goes for financial calculations.

There is a district heating net in many Swedish towns so in many cases that is a real possibility. As mentioned in part 4.2.2, the main limitation for district heating is the distance from the closest district heating pipe and the needed heating in an area. Gävleborg is a sparsely populated county and the district heating net can in some cases be more than ten kilometres away, making it a poor choice.

Several companies that answered the survey are very close to a district heating net, the pipe is basically in the street in front of their facility, which should make this an easy and cheap option. For one company, using district heating had other technical difficulties. It was situated less than 300 metres from the local district heating plant, but there was a train track and river between them. One option for this company could be to use the same biofuel that the district heating plant uses, since there is already an existing infrastructure for it.

Heat pumps and electrical heating is also an option for many of the companies. The electrical grid in Sweden is extensive and electricity is already used for heating in many houses and companies. However, one company answered that they could not switch to heat pump for two reasons, they would need an expensive upgrade to their local electricity system and they could not drill into bedrock and install a geothermal heat pump, since they were directly over a water protection area.

As stated earlier (section 4.3), the best practice is to first save energy, or use surplus energy for other purposes. For some of the companies that answered the survey, it could be possible to use residual heat from their processes. One company commented that they could consider using residual heat. Two of the companies that answered were bakeries, which can be used to heat premises. Though it is likely that the heat is only available for a short period of time.

The calculations that were made on CO_2 emissions are based on a lot of assumptions. Emissions from different fuels have all been taken from a single source, when in reality it could be different for each company. No consideration has been taken to the efficiency of the heating system that is currently used or the system that it was changed to. The exception being heat pumps, where the seasonal coefficient of performance was set to 2.5. These assumptions, and possibly more, makes the calculations only a guideline to the reduction in emissions that is possible.

As stated in section 5.2, one of the companies that was used for calculations had an annual oil consumption of roughly 125500 MWh, or 98 % of the total oil use in these calculations. This company could only consider changing to district heating and solar heating. It was also responsible for most of the CO_2 reductions (~28900 tons) and the reason that there is such a small difference between the different cases made. Without this company, the reduction in tons of CO_2 equivalents is about 330-350 tons, which is still not nothing.

For solar heating, calculating the reduction in energy use and emissions is also difficult and only based on assumptions. Without knowing what the companies' specific circumstances are, this will always be the case. In the calculations it was assumed that solar heating reduces the heating demand by 20 %, which might be right or wrong. With the assumptions made, the relation between the amount that solar heating reduces is linear with the percentage reduction that is assumed. I.e. if the assumption is 40 %, solar heating will reduce emissions by twice as much (~2000 tons CO_2e) and if the assumption is 10 %, emissions are reduced by half as much (~500 tons CO_2e).

The last thing that should be mentioned is the option for rental system in the survey. This was one of the original ideas of the thesis and it is also why this option was available on the survey.

The idea was having a moveable boiler that use renewable fuel, which can be transported between companies that have a heating need during the warm part of the year and companies that need heating during the cold season. The purpose was to investigate if a cooperation could be made between farmers and other companies. Farmers in Gävleborg and other places need heat to dry their grain only in the months of August and September. Since the heating need is for such a short time, it’s less likely and more expensive to change the current oil use for something else, which is why a rental system could be profitable.

7 Conclusions

The main purpose of this thesis was to investigate how the consumption of fossil fuel can be reduced in Gävleborg County. As previous research has shown, it is possible to do this for companies, businesses and even entire regions, though the reduction might come in the form of lowering overall energy use.

In Sweden, it is possible to increase the production and use of biomass, which is an abundant resource that can displace fossil fuel use. Energy efficiency measures are also an important way to decrease overall energy use and fossil fuel consumption, directly or indirectly. A change in heating system can also be seen as an energy efficiency measure, since the efficiency of the new system is likely to be higher than to the old one. It is also probable that a building owner or company is more positive to retrofitting their envelope at the same time as changing heating, or to perform other energy efficiency measures. Other ways to lower fossil fuel use can be to use local resources from agriculture, which is very dependent on fossil fuels, and increasing energy production from renewable energy sources such as wind, solar and hydropower.

The case made in this study was companies in Gävleborg County that use fossil fuels for heating. It was found that 95 companies fit this description and 26 of these answered the survey that was sent to them.

The second purpose problem was to investigate how willing these companies were to change to some other form of heating. Out of these 26 companies, nine answered that they were willing to change to something else. Two companies also said that they are in the process of investigating their energy and that as part of that, their heating fuel should be changed, which means that Gävleborg County should see a decrease in its oil use and CO_2 emissions. Six companies answered that they maybe want to change

Based on these facts, it can be concluded that there is at least some interest for energy related issues in these companies and an opportunity to lower fossil fuel use. It is more difficult to draw conclusions for the companies that answered maybe or no to changing. They did at least answer the survey, which still shows that there might be some interest now or in the future.

As for the question of what aspects influence a company to change to another heating technology or engage in similar energy related issues, it can be concluded that the difficulties facing companies are technical, economical and behavioural.

The technical difficulties can be very different, such as proximity to district heating net, not having the electrical system required for heat pumps, lacking infrastructure for biomass supply or being too close to densely populated areas to use biomass. It can be said there is a technical solution for all companies, but all cases probably require their own case study, proving its technical and economic viability.

The behavioural aspects are as expected numerous and have been listed as barriers and driving forces. Some companies stated their reason for not changing heating, for example not owning the working facility and having too low heating need to see it as a worthwhile investment. Other important barriers that have been reported by research is lack of time, lack of money and having other priorities. This suggests that it is important to help companies financially by e.g. providing subsidies and soft loans. Other important driving forces can be to provide consulting assistance as well as informing companies of energy issues and the benefits of dealing with them.

The last purpose task was to estimate and calculate the reduction in CO_2 emissions that is possible with these changes. Based on the assumptions that have been made, a reduction of approximately 28900 tons is possible. It is difficult to say how accurate this figure is, though it can be said that any change away from oil should lead to a decrease in CO_2 emissions. Unless it is being changed to coal power, which is unlikely since apart from having very high emissions it is also the most expensive energy source.

7.1 Suggestions for future work

As stated earlier, retrofits to companies' heating system or other energy efficiency measures requires case studies at the specific companies. The responses from the survey shows that there is at least some interest in energy related issues from companies. Of course, a case study doesn't have to be in companies that use oil but can be just as relevant and interesting to do in all companies.

My supervisors at Gävleborg County administration board also had an interest in a rental system, which was previously mentioned. The purpose of this was to help farmers use something other than oil to heat their grain, which is only done in August and September. Since the need is on such a short time-frame, investing in a new heating system just for this purpose is unlikely to be profitable. The idea was that enterprises that need heat during the warm half of the year, e.g. farmers, could rent it during that period and companies with heating need can rent it during the cold season. A future study on this could involve designing the details of such a system and investigating if it is profitable.

8 References

Ahlgren, A., Baky, A., Bernesson, S., Nordberg, Å., Norén, O. & Hansson, P-A. (2008). Future fuel supply on Fischer-Tropsch diesel and dimethyl ether from on-farm-grown biomass. *Biosystems engineering*, 99(2008), ss. 145-155.

Areskoug, M., Eliasson, P. (2007). *Energi för hållbar utveckling – Ett historiskt och naturvetenskapligt perspektiv*. Lund: Studentlitteratur AB.

Arnell, J., Bolin, L., Holmgren, K., Staffas, L., Adolfsson, I. and Lindblad, M. (2013). Förutsättningar för ökad nytta av restvärme. (Rapport 2012:14).

Backlund, S. & Thollander, P. (2015). Impact after three years of the Swedish energy audit program. *Energy*, 82(2015), ss. 54-60.

Bollnäs municipality. (2016). Energi- och klimatrådgivning.
http://bollnas.se/index.php/energi-och-klimatradgivning [2016-03-09]

Bioenergiportalen. (2013). *Flis som värmekälla*.
http://www.bioenergiportalen.se/?p=2045 [2016-05-09]

Boverket. (2008). *Alternativa uppvärmningsformer i befintliga permanentbebodda småhus.* Karlskrona: Boverket.
http://www.boverket.se/globalassets/publikationer/dokument/2008/alternativa_uppvarmningsformer.pdf

Buczynski, R., Weber, R. and Szlek, A. (2015). Innovative design solutions for small-scale domestic boilers: Combustion improvement using a CFD-based mathematical model. *Journal of the energy institute*, 88(2015), ss. 53-63.

Cagno, E. and Trianni, A. (2014). Evaluating the barriers to specific industrial energy efficiency measures: an exploratory study in small and medium-sized enterprises. *Journal of cleaner production*, 82(2014), ss. 70-83.

Cansino, J., Pablo-Romere, M., Román, R. and Yñiguez, R. (2011). Promoting renewable energy sources for heating and cooling the EU-27 countries. *Energy policy*, 39(2011), ss. 3803-3812.

Cook, J., Oreskes, N., Doran, P., Anderegg, W., Verheggen, B., Maibach, E., Carlton, S., Lewandowsky, S., Skuce, A., Green, S., Nuccitelli, D., Jabocs, P., Richardsson, M., Winkler, B., Painting, R. and Rice, K. (2016). Consensus on consensus: a synthesis of consensus estimates on human-caused global warming. Environmental Research Letters, 11(2016). DOI: 10.1088/1748-9326/11/4/048002.

Chel, A. and Kaushik, G. (2011). Renewable energy for sustainable agriculture. *Agronomy for Sustainable Development*, 31(2011), ss. 91-118.

Dahlquist, E., Yan, J. & Thorin, E. (2008) How to become independent of fossil fuels in Sweden. *Paper for conference in Shanghai arranged by SJTU and Cornell University*. Dec 6-8, 2008.

EEF. (n.d.). *Det här gör EEF för sina medlemmar*. http://www.eef.se/bli-medlem/det-har-gor-eef-for-medlemmar/ [2016-04-28]

Energikontor Gävleborg. (n.d.). *Ockelbo*. http://energikontorx.se/page/ockelbo.html [2016-03-14]

Energi & klimatrådgivningen. (n.d.a). *Vedpanna.* http://www.energiradgivningen.se/varma-villan/vedpanna [2016-04-06]

Energi & klimatrådgivningen. (n.d.b). *Acumulatortank.* http://www.energiradgivningen.se/varma-villan/ackumulatortank [2016-04-06]

Energy efficiency committee. (2008). *Vägen till ett energieffektivare Sverige*. (SOU 2008:110). Stockholm: Energy efficiency committee.

European Commission (2003). Official Journal of the European Union (EEA) nr C(2003) 1422, L 124, 6.5.2003. ss 36-41. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:124:0036:0041:en:PDF [2016-03-31]

European Comissions. (2013). The EU Emissions Trading system (EU ETS). DOI: 10.2834/55480.

European Commission. (2016). *Climate strategies & targets.* http://ec.europa.eu/clima/policies/strategies/index_en.htm [2016-04-27]

Fleiter, T., Schleich, J. and Ravivanpong, P. (2012). Adoption of energy-efficiency measures in SMEs – An empirical analysis based on energy audit data from Germany.

Frederiksen, S., Werner S. (2011). *Fjärrvärme – Teori, teknik och funktion*. Lund: Studentliteratur AB.

Fredriksson, H., Baky, A., Bernesson, S., Nordberg, Å., Norén, O. & Hansson P-A. (2006). Use of on-farm produced biofuels on organic farms – Evaluation of energy balances and environmental loads for three possible fuels. *Agricultural systems,* 89(2006), ss. 184-203.

Freisinger, U.B., Specht, K., Sawicka, M., Busse, M., Siebert, R., Werner, A., Thomaier, S., Henckel, D., Galda, A., Wurbs, S., Grosse-Heitmeyer, J., Schön, S. & Walk, H. (2015). *There's something growing on the roof*. Idea, Planning, Implementation. Leibniz Cente for Agricultureal Landscape Research (ZALF), Müncheberg.

Gode, J., Byman, K., Persson, A. & Trygg, L. (2009). *Miljövärdering av el ur systemperspektiv.* (Rapport B1882). http://www.svenskfjarrvarme.se/Global/Energieffektivisering/%C3%96vriga%20dokument/Milj%C3%B6v%C3%A4rdering%20av%20el%20IVL%20B1882.pdf

Government Offices of Sweden. (2015). *Övergripande mål och svenska mål för Europa 2020*. http://www.regeringen.se/sverige-i-eu/europa-2020-strategin/overgripande-mal-och-sveriges-nationella-mal/ [2016-04-27]

Granryd, E., Ekroth, I., Lundqvist, P., Melinder, Å., Palm, B. & Rohlin, P. (2011) *Refrigerating engineering.* Stockholm: Royal institute of technology, KTH.

Gustavsson. L., Holmberg, J., Dornburg, V., Sathre, R., Eggers, T., Mahapatra, K. & Marland, G. (2007). Using biomass for climate change mitigation and oil use reduction. *Energy policy*, 35(2007), ss. 5671-5691.

Gävleborg County administration board (2012). *Klimat- och energimål för Gävleborgs län - Beslutade mål samt bakgrundsinformation* (Länsstyrelsens rapporter 2012:6). Gävle: Länsstyrelsen. http://www.lansstyrelsen.se/gavleborg/SiteCollectionDocuments/Sv/miljo-och-klimat/klimat-och-energi/Klimat-och-energimal/Bakgrundsinformation_for_klimat-energimal_.pdf

Hagström, P. (2006). Biomass potential for heat, electricity and vehicle fuel in Sweden. Diss. Uppsala: Swedish University of Agricultural Sciences. http://pub.epsilon.slu.se/1038/1/Hagstrom_thesis_Vol_I_Epsilon.pdf

Hansson, P-A., Baky, A., Ahlgren, S., Bernesson, S., Nordberg, Å., Norén, O. & Petterson, O. (2007). Self-sufficiency of motor fuels on organic farms – Evaluations of systems based on fuels produced in industrial-scale plants. *Agricultural systems*, 94(2007), ss. 704-714.

Hofors municipality. (2013). *Energi och klimatrådgivning*. http://hofors.se/boendemiljo/energiochklimatradgivning.4.4ba46b7012c55b575c88000743.html [2016-03-09]

Hudiksvalls municipality. (2016). *Energi- och klimatrådgivning.* http://www.hudiksvall.se/Bo--leva/Miljo-och-energi/Energiradgivning1/ [2016-03-09]

Höök, M., Bardi, U., Feng, L. and Pang, X. (2010). Development of oil formation theories and their importance for peak oil. *Marine and petroleum geology*, 27(2010), ss. 1995-2004.

Höök, M. & Xu, T. (2013). Depletion of fossil fuels and anthropogenic climate change: a review. *Energy policy*, *52*: 797-809. URL: http://dx.doi.org/10.1016/j.enpol.2012.10.046

IEA. (2012). Oil & gas security – Emergency Response of IEA Countries. https://www.iea.org/publications/freepublications/publication/Sweden2012_OSS.pdf

IEA. (2015). *CO_2 emissions from fuel combustion – highlights*. Paris: IEA Publications. https://www.iea.org/publications/freepublications/publication/CO2EmissionsFromFuelCombustionHighlights2015.pdf

IPCC. (n.d.). *History*. http://www.ipcc.ch/organization/organization_history.shtml [2016-04-29]

Joelsson, J. & Gustavsson, L. (2012). Swedish biomass strategies to reduce CO_2 emissions and oil use in an EU context. *Energy*, 43(2012), ss. 448-468.

Johansson, L., Leckner, B., Gustavsson, L., Cooper, D., Tullin, C. and Potter, A. (2004). Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. *Atmospheric environment*, 38(2004), ss. 4183-4195.

Kimming, M., Sundberg, C., Nordberg, Å., Baky, A., Bernesson, S., Norén, O & Hansson, P-A. (2011). Life cycle assessment of energy self-sufficiency systems based on agricultural residues for organic arable farms. *Bioresource technology*, 102(2011), ss 1425-1432.

Kimming, M., Sundberg, C., Nordberg, Å., Baky, A., Bernesson, S & Hansson, P-A. (2015). Replacing fossil energy for organic milk production – potential biomass resource and greenhouse gas emission reductions. *Journal of cleaner production*, 106(2015), ss. 400-407.

Kjärstad, J. and Johnsson, F. (2009). Resources and future supply of oil. *Energy policy*, 37(2009), ss. 441-464.

Larsson, O. and Persson, A. (2009). Styrmedel för resurseffektiv energianvändning. (Rapport 2009:16). Stockholm: Svensk Fjärrvärme. http://www.svenskfjarrvarme.se/Global/FJ%C3%84RRSYN/Rapporter%20och%20resultatblad/Rapporter%20omv%C3%A4rld/2009/Styrmedel%20f%C3%B6r%20resurseffektiv%20energianv%C3%A4ndning.pdf

Lior, N. (2010). Sustainable energy development: the present (2009) and possible path to the future. *Energy*, 35(2010), ss. 3976-3994.

Ljusdal Energi. (n.d.). Produktion 2009. http://www.ljusdalenergi.se/fjarrvarme/produktion.4.7f9ff366130fe03aa7380003.htm [2016-05-14]

Ljusdals municipality. (n.d.). *Energirådgivning.* http://ljusdal.se/boendemiljo/energiradgivning.4.101ec01914c0da8df65d6.html [2016-03-09]

Meath, C., Linnenluecke, M. and Griffiths, A. (2016). Barriers and motivators to the adoption of energy savings measures for small- and medium-sized enterprises (SMEs): the case of ClimateSmart Business Cluster program. *Journal of cleaner production*, 112(2016), ss. 3597-3604.

Nibe. (n.d.). *Exhaust Air Heat Pumps*. http://www.nibe.co.uk/Products/Exhaust-air-heat-pumps/ [2016-07-29]

Nilsson, L. J., Johansson, B., Åstrand, K., Ericsson, K., Svenningsson, P., Börjesson, P & Neij, L. (2004) Seeing the wood for the trees: 25 years of renewable energy policy in Sweden. *Energy for sustainable development*, VIII(1), ss. 67-81.

Nilsson, P.-E. (2001). *Köldmedier*. (Rapport Effektiv 2001:02). Borås: SP Sveriges Provnings- och Forskningsinstitut. https://www.sp.se/sv/index/research/effektiv/publikationer/Documents/Temarapporter/Rapport%2001-02.pdf

Nordanstigs municipality. (2016). *Energirådgivning*. http://nordanstig.se/Bygga---Bo/Energi--och-varmefragor/Energiradgivning.html [2016-03-09]

Obernberger, I. (1998). Decentrilized biomass combustion: state of the art and future development. *Biomas and bioenergy*, 14(1998), ss. 33-56.

omBoende. (2013). *Direktverkande elvärme och vattenburen elvärme*. http://www.omboende.se/sv/Aga1/Byte-av-uppvarmningsform/Direktverkande-elvarme-och-vattenburen-elvarme/ [2016-03-28]

Ovanåkers municipality. (2016). *Energi- och klimatrådgivning.* http://ovanaker.se/byggabo/energiochklimatradgivning.4.2d8118541343be71ea98000156493.html [2016-03-09]

Richardson, D. B. & Danny Harvey, L.D. (2015). Optimizing renewable energy demand response and energy storage to replace conventional fuels in Ontario, Canada. *Energy*, 93(2015), ss. 1447-1455.

Rohdin, P. and Thollander, P. (2006). Barriers to and driving forces for energy efficiency in the non-energy intensive manufacturing industry in Sweden. *Energy*, 31(2006), ss. 1836-1844.

Sandvikens municipality. (2016). Energi- och klimatrådgivning. http://sandviken.se/byggabomiljo/energiradgivning.4.1ac5f13f94b137c797fff37.html [2016-03-09]

Schleich, J. and Gruber, E. (2008). Beyond case studies: Barriers to energy efficiency in commerce and the service sector. *Energy economics*, 2(2008), ss. 449-464.

Shafiee. S. and Topal, E. (2009). When will fossil fuel reserves be diminished? *Energy policy*, 37(2009), ss. 181-189.

Solar Energy Association of Sweden. (2015). *Frågor och svar om solenergi*. http://www.svensksolenergi.se/fakta-om-solenergi/fragor-och-svar [2016-04-07]

Statistics Sweden. (2015). *Antal arbetsställen fördelat på län, bransch, avdelningsnivå och storleksklass (xls).* Available at: http://www.scb.se/sv_/Vara-tjanster/Foretagsregistret/Aktuell-statistik-ur-Foretagsregistret/

Statistics Sweden. (2016). *Kommunal och regional energistatistik*. http://www.scb.se/en0203 [2016-03-20]

Svebio. (n.d.). *Pellets*. https://www.svebio.se/pellets [2016-05-09]

Svenska petroleum & biodrivmedel institutet. (2016). *Energiinnehåll, densitet och koldioxidemission*. http://spbi.se/blog/faktadatabas/artiklar/berakningsmodeller/ [2016-05-19]

Svesol. (n.d.). *Så fungerar ett solvärmesystem*. http://www.svesol.se/solvaerme/ett-flexibelt-solvaermesystem-med-solfangare [2016-04-07]

Swedish District Heating Association. (2006). *Förnybar ersättning av olja i spetslastproduktion.* (Rapport 2006:5) http://www.svenskfjarrvarme.se/Global/Rapporter%20och%20dokument%20INTE%20Fj%C3%A4rrsyn/Ovriga_rapporter/Energitillforsel_och_Produktion/Fornybar_ersattning_av_olja_i_spetslatsproduktion_2006_5.pdf

Swedish Energy Agency. (2010a). *Värme i villan*. Stockholm: CM Gruppen. https://energimyndigheten.a-w2m.se/Home.mvc?ResourceId=2482

Swedish Energy Agency. (2010b). *Små och medelstora företags syn på energi- och miljöfrågor.* Eskilstuna: Energimyndigheten.

Swedish Energy Agency. (2014). *Fossila energikällor*. http://www.energikunskap.se/sv/FAKTABASEN/Vad-ar-energi/Energibarare/Fossil-energi/ [2016-03-31]

Swedish Energy Agency. (2015a). *Nätverk för energieffektivisering*. http://www.energimyndigheten.se/nrp/natverk-for-energieffektivisering/ [2016-04-28]

Swedish Energy Agency. (2015b). *Elvärme*. http://www.energimyndigheten.se/snabblankar/lattlast/hur-varmer-du-upp-ditt-hus/elvarme/ [2016-04-07]

Swedish Energy Agency. (2016a). *Energiläget – en samlad bild av energisystemet*. http://www.energimyndigheten.se/statistik/energilaget/ [2016-03-04]

Swedish Energy Agency. (2016b) *Lagen om energikartläggning i stora företag*. http://www.energimyndigheten.se/energieffektivisering/lag-och-ratt/energikartlaggning-i-stora-foretag/ [2016-04-28]

Swedish Energy Agency. (2016c). *Stöd för energikartläggning i små och medelstora företag*. http://www.energimyndigheten.se/nrp/stod-for-energikartlaggning-i-sma-och-medelstora-foretag/ [2016-04-28]

Swedish Energy Agency. (2016d). *Stöd till studier inför energieffektiva investeringar*. http://www.energimyndigheten.se/nrp/stod-till-studier-infor-energieffektiva-investeringar/ [2016-04-28]

Swedish Environmental Protection agency. (2015a). *Nationella utsläpp och upptag av växthusgaser*. http://www.naturvardsverket.se/Sa-mar-miljon/Statistik-A-O/Vaxthusgaser--nationella-utslapp/ [2016-03-18]

Swedish Environmental Protection agency. (2015b). *Beskrivning av minskade växthusgasutsläpp för ansökningar i Klimatklivet*. http://www.naturvardsverket.se/klimatklivet

Swedish Environmental Protection agency (2016a). *Det sura regnet avtar.* http://www.naturvardsverket.se/Sa-mar-miljon/Mark/Forsurning/Det-sura-regnet-avtar/# [2016-02-25]

Swedish Environmental Protection agency. (2016b). *Klimatklivet – lokala klimatinvesteringar.* http://www.naturvardsverket.se/Stod-i-miljoarbetet/Bidrag/Klimatklivet/# [2016-04-28]

Swedish institute of Agricultural and Environmental Engineering. (2014). Forskning för ett fossil jordbruk. http://www.jti.se/index.php?page=forskning_pagar_fossilfri_ope [2016-05-29]

Swedish Society for Nature Conservation. (2016). *Faktablad: Växthuseffekten.* http://www.naturskyddsforeningen.se/skola/energifallet/faktablad-vaxthuseffekten [2016-02-25]

Söderhamns municipality. (2016). *Energi- & klimatrådgivning.* http://www.soderhamn.se/byggaboochmiljo/energiochuppvarmning/energiradgivare.4.2cee3a62123ecb921cc800034436.html [2016-03-09]

Thollander, P. and Tyrberg, M. (2008). Drivkrafter for energieffektivisering i små- och medelstora industriföretag. Linköping universitet. https://s3-eu-west-1.amazonaws.com/static.wm3.se/sites/2/media/33700_Rapport_Drivkrafter_for_energieffektivisering_20080131.pdf?1431084036

Thollander, P., Backlund, S., Trianni, A. and Cagno, E. (2013). Beyond barriers – A case study on driving forces in the foundry industries in Finland, France, Germany, Italy, Poland, Spain and Sweden. *Applied Energy*, 111(2013), ss. 636-643.

Thollander, P., Danestig, M. and Rohdin, P. (2007) Energy policies for increased industrial energy efficiency: Evaluation of a local energy programme for manufacturing SMEs. *Energy policy*, 35(2007), ss. 5774-5783.

Thollander, P. (2008). Towards increased energy efficiency in Swedish industry – Barriers, driving forces & policies. Diss. Linköping University of technology, Sweden. Linköping: LiU-Tryck. http://liu.diva-portal.org/smash/get/diva2:25543/fulltext01.pdf

Trianni, A. and Cagno, E. (2012). Dealing with barriers to energy efficiency and SMEs: Some empirical evidences. *Energy*, 37(2012), ss. 494-504.

Trianni, A., Cagno, E. and Farné, S. (2016). Barriers, drivers and decision-making process for industrial energy efficiency: A broad study among manufacturing small and medium-sized enterprises. *Applied energy*, 162(2016), ss. 1537-1551.

UN Economic commission for Europe. (n.d.). Sustainable development – concept and action. http://www.unece.org/oes/nutshell/2004-2005/focus_sustainable_development.html [2016-04-27]

UN framework convention on climate change. (2014). *Kyoto Protocol*. http://unfccc.int/kyoto_protocol/items/2830.php [2016-04-27]

US Department of Energy (2013). *A Brief History of Coal Use*. http://www.fossil.energy.gov/education/energylessons/coal/coal_history.html [2016-03-31]

US department of energy. (2014). *INFOGRAPHIC: Understanding the Grid*. http://www.energy.gov/articles/infographic-understanding-grid [2016-05-05]

US Consumer product safety commission (n.d). *Carbon monoxide questions and answers*. http://www.cpsc.gov/en/Safety-Education/Safety-Education-Centers/Carbon-Monoxide-Information-Center/Carbon-Monoxide-Questions-and-Answers-/ [2016-04-22]

White, M. (n.d.) *The Industrial Revoution*. http://www.bl.uk/georgian-britain/articles/the-industrial-revolution [2016-03-31]

Zhang, S., Lundgren, T. & Zhou, W. (2016). Energy efficiency in Swedish industry – A firm-level data envelopment analysis. *Energy economics*, 55(2016), ss. 42-51.

Appendix A

About oil in Gävleborg

This survey is a part of my master thesis at the master programme in energy systems at the university of Gävle and the Gävleborg County administration board. The purpose is to find out how large the use of oil is in the county, where it is used and how it can be replaced. The survey will help me estimate much the use of oil can be decreased.

The purpose is only to investigate oil for heating and other processes, i.e. not for transports. No question is obligatory, i.e. the survey can be sent without all questions answered.
Your answer is greatly appreciated!

The answers from this survey will be treated completely anonymously.

Regards
Martin Eriksson

1. Company name?

____

2. How much oil or other fossil fuels do you use every year? (m3/litres/ton/MWh)

____

3. What kind of fuel is it?

____

4. Would you like to switch to a different fuel?

Yes ☐
Maybe ☐
No ☐

5. Is the fuel only used for heating purposes? If other, please state what.

Yes ☐
Other ☐

____

6. How much heated area do you have (m2)?

____

7. What other heat source could you consider using instead? (can tick several choices)

Heat pump (air, ground, geothermal, lake) ☐
Biofuel (pellets, wood chips, wood) ☐
District heating ☐
Solar heating ☐
Rental system ☐
(An example of a rental system is a boiler in a container, that is rented by businesses that have heating needs on the warm half of the year, e.g. farmers. This boiler can then be rented by you or other business when there is a need for it)

8. How long time do you think it would take to switch to something else other than oil?

____

9. Do you need consultation to calculate your heating need?

Yes ☐
No ☐

10. Do you feel that an eventual change of heating system is a cost so great that you will seek support for the investment?

Yes ☐
No ☐

11. Other comments/thoughts? (nothing has to be written here)

____
____

Thank you so much for your participation!