

The benefits of district heating in the Netherlands

A research study on main aspects of DH and RE in the Netherlands, based on experiences in Denmark

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"I am convinced that whoever builds a clean energy economy, whoever is at the forefront of that, is going to own the 21st-century global economy."

-Barack Obama-

President of USA (state of the Union, 27-01-2010)

PREFACE

This thesis is made to finish my master education Construction, Management and Engineering (CME) course, taught at the Eindhoven University of Technology. With a bilateral cooperation of the Danish Technical University in Copenhagen and the TU/e, I had the possibility to learn from the Danish approach. This thesis is made in the time period of February 2011 – July 2011.

During the master course CME, the (re)development of district(s) or brown fields were taught in the University. In my opinion DH has a great opportunity in the (re)development of such areas. While I was living and enjoying Denmark, I also had the possibility to see, to learn and to know more about DH.

I would like to thank the persons who gave me access to the information I used. First of all, the supervisor Svend Svendsen of the DTU, which gave me directly the possibility to attend the DTU research group at DTU. Second, I would like to thank my supervisors from the Netherlands, Erik Blokhuis and Wim Schaefer. During the Skype meetings I got inspiration for another way of implementing the data I gathered. Finally the DH institutions, DH company VEKS and the DTU of supplying me information about the way of heating DTU.

Jelte Glas
Eindhoven, July 2011

LIST OF ABBREVIATIONS

DH:	District Heating
CHP:	Combined Heat Power
RES:	Renewable Energy Sources
IEA:	International Energy Agency
UN:	United Nations
EU:	European Union
ECN:	Energy research Center of the Netherlands
SWOT:	Strengths, Weaknesses, Opportunities and Threats
EJ:	Exajoule 10^{18} J
PJ:	Petajoule 10^{15} J
TJ:	Terajoule: 10^{12} J
USSR:	Union of Soviet Socialist Republics
IAEA:	International Atomic Energy Agency
B.C.:	Before Christ
OPEC:	Organization of the Petroleum Exporting Countries
LNG:	Liquefied Natural Gas
EZ:	Ministry of Economic Affairs of the Netherlands
CDM:	The Clean Development Mechanism
ETS:	Emission Trade Scheme
Jl:	Joint Implementations
WWF:	World Wide Fund
GHG:	Green House Gas
PV:	Photo Voltaic
GDP:	Gross Domestic Product
DTU:	Danish Technical University
HE:	Heat Exchanger
ELENA:	European Local ENergy Assistance
DEA:	Danish Energy Agency
TSO:	Transmission System Operator
CFL:	Compact Fluorescent Lamp
DEA:	Danish Energy Agency
NAM:	Nederlandse Aardolie Maatschappij
SDE:	Stimulering Duurzame Energieproductie

1 RESEARCH DESIGN

The worldwide energy sector will change in the future. Some fundamental changes will arise in this sector. High class renewable energy projects will be arise, the transport sector has to deal with other energy sources and the normal life of an inhabitant will change due to the low energy houses, while we still want to heat our spaces and tap water, and probably electric cars. In other words, an exponential economic growth, associated with increasingly consumption, could not be sustained on the long run on a planet with the current resources.

1.1 Problem definition

This section explains the area of research in which the proposal was formulated. Understanding this section will be helpful to finalize into clear research questions and expected goals from macro level to district heating in the Netherlands.

The worldwide primary energy demand will grow within 47% in the upcoming 25 years (IEA, 2010), assuming the current energy policy. Many economies of different countries depend on energy, in the past and in the future. In addition, the world population is assumed to expand from a 7 billion in 2010 up to 9 billion in 2035 (UN, 2011). These grow will lead to a higher energy demand. A sustainable worldwide policy is essential for a long term future prospective.

The energy use in Europe is, in according to the world energy use, a smaller amount, but even an alarming factor. Our current energy sources in Europe are not sufficient for the future. For an energy policy, a mutual EU energy strategy for Europe is made up for the time period until 2020. In March 2007, the European Council presented their targets: 20% renewable energy, 20% reduction of CO₂ emissions and 20% energy reduction in 2020. Although in these days, many countries are still lagging behind in reaching these targets. Many possibilities are launched in renewable energy solutions. Different pilot projects have been initiated, implemented and evaluated; nevertheless, due to the economic crisis starting from 2007, more and more countries refuse to put more effort in reaching these targets in 2020. In order to limit the energy losses, countries with cold climates, such as the Scandinavian countries, Poland and Estonia, the district heating technology in urban areas has been used for many years and its use is widespread (Froning, 2003), while the investments in sustainability in other countries, where mild climates prevail, are lagging behind.

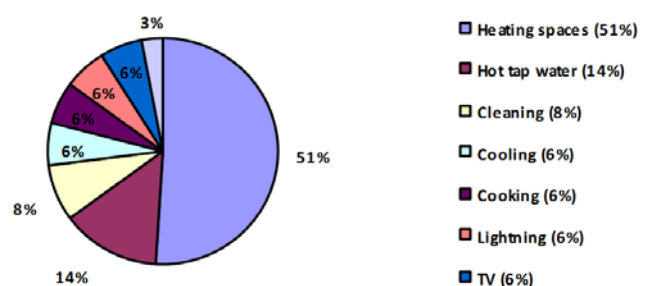


Figure 1: Energy use of a Dutch household
(translated from www.milieucentraal.nl)

Apart from that, some projects are successful, especially in Denmark. Wind power, solar power, water power and smart distribution methods are widely used. An important amount of the Danish export market is related to renewable energy.

In the Netherlands, the policy is mainly based on electrical developments, while roughly two-third of the total energy use in households is applied for heating spaces and/or water (fig 1). This represents an enormous amount of energy, if we endeavor a sustainable approach on energy in our houses, space and water heating will definitely be a good start. Many possibilities are introduced: heat pumps, local systems, district systems, but even applying good insulation in the existing and new building materials.

District heating is a centralized system for distributing heat to consumers, for and by consumers. The heat can be obtained by different sources, such as fossil fuels, biomass, geothermal heating, central solar heating, heat-only boiler systems and even nuclear power stations. Centralized district heating plants in high density area have higher efficiencies than smaller localized boilers (scaling). District heating systems are often owned by the consumers, so they make direct profit out of it.

Apart from that, an advantage of centralized energy distribution is, that it will reduce heat losses (fig 2). District heating has a big potential in the European countries, but the use of DH systems is at the moment not balanced between the different countries (fig 3). Denmark is one of the key-players in the district heating and the systems seem to be fruitful after a long term period of implementation district heating as a cornerstone of the Danish

Energy Policy. Currently, the system is introduced in 60% of all the Danish households, and in the Copenhagen area in almost 98% of the households (DBDH, 2010). The companies in this system, district heating companies, are owned by the consumers. Thus, all the benefit will go to the consumers and this will lead to a lower energy price. A strong support from the municipalities and authorities is required. Nowadays, in most research the technical or financial aspect are most highlighted in applications of district heating. Apart from that we can see some developments in DH system for low energy buildings. More passive energy houses can be expected and the implementation can be adapted in the new DH systems in Europe. In theory it is possible to obtain a low network heat loss although all houses connected to the DH system have a very low heat demand (Olsen et al., 2008).

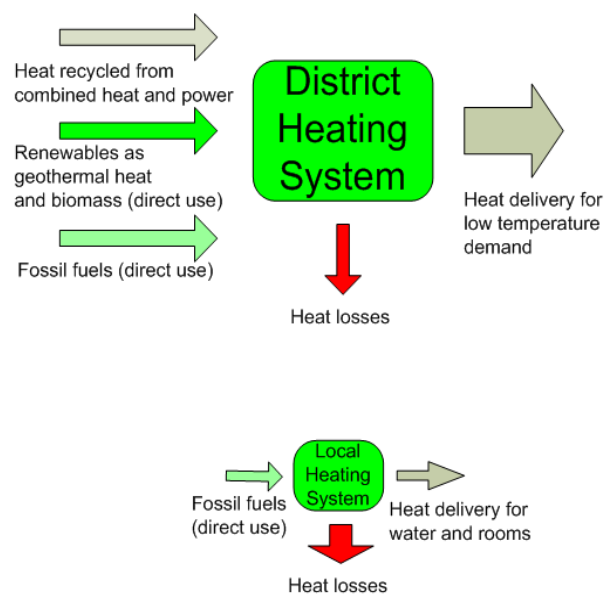


Figure 2: Fundamental idea of District Heating and Local Heating, less heat loss and better pollution control. (Adapted figure from Euroheat and power, 2009)

During the years, the relatively simple principle of district heating has shown large benefits. However, the implementation of DH systems in European countries is diverse; some countries employ district heating, others not. The Netherlands lies quite far behind others in distribution networks, because the policy is mainly focusing on electrical energy, not on heating (Stichting Warmtenetwerk, 2010). However, if we compare the Netherlands with for instance Denmark, we can see large similarities, especially in the density of the population, and the high scale of urbanization. Therefore, I think that district heating can be an interesting system in the future in the Netherlands. However, a successful implementation of this system will require insight in several important challenges that can be expected.

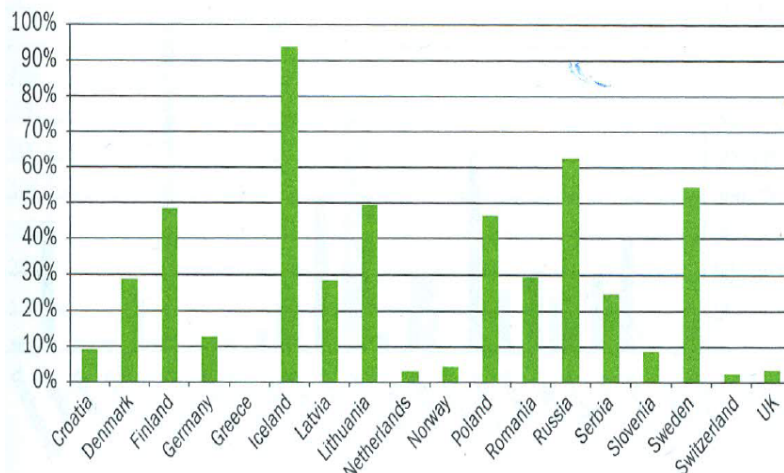


Figure 3: Shares of DH used to heat buildings (residential and other sectors) (Euroheat and power, 2009)

The successful implementation of district heating systems in the Netherlands requires a stable political and organizational approach, in which governmental agencies are responsible for improving the attractiveness of the system through policy, and in which the organizational structure should provide for the right stimuli for consumers. What kind of stakeholders, suppliers and constructors are required? Such a justified approach is missing in the current Dutch energy policy. Therefore, I am interested in the main learning points from Denmark, from an organizational perspective. How can we create in a political and organizational way (by and for consumers) an approach where inhabitants and society will cooperate in district heating systems, in order to move towards a responsible future social society?

Apart from that, in a macro scale, a future scenario for the prospected renewable energy use in the Netherlands can be outlined. Short term and long term solutions can be gathered in scenarios for 2020 and 2050. At this moment, the Netherlands has a transition commission for prospective on energy. This will show the short term solutions in 6 years, and a prospective in 12 years. In which way can we create sustainable future and a spread risk between the relatively new renewable energy solutions?

In the Netherlands in 2011 a high tech gas power plant was opened in Lelystad, so new investments in the current gas market. Nevertheless our gas nation should be transferred to a high tech renewable energy nation in the future. Can we sketch a roughly prospective for 2020 and 2050 for the Netherlands? What are the major targets for 2050? The evaluation of the current Clean and Economical program as part of the energy research center of the Netherlands (ECN) show a scenario which we will not able to reach the goals of 2020. On the other hand, the Netherlands has the potential as well as the responsibility to reach a global top 10 position in the clean tech market (Van den Berg, 2009). How do we have to deal with our future in the Netherlands?

1.2 Research objectives

Denmark is advanced in renewable energy applications. Especially the wind energy, but even the DH of Denmark is remarkable. This has a rich history and a potential rich future. I would like to mention the aspects and factors which are responsible for the current situation in Denmark. DH has a future, even in the low temperature houses in the future. The objective is to generate an insight in the future prospective of DH in the Netherlands. This will be reached by a solid SWOT analysis.

The product of this research will be an overview of the different historical milestones in the Danish energy history which is leading to the current policy and status. If possible, an extrapolate picture can be drawn for the future. This knowledge can be translated in a SWOT analysis for an implementing phase in the Netherlands. Which aspects are interesting for the Netherlands? Apart from that I hope to generate scenarios for the future in the Netherlands, in which way we try to have 100% renewable energy on a macro scale in 2050?

1.3 Research questions

The influence of Political and Organizational aspects on the implementation of District Heating is underexposed in literature; these aspects seem to be important in explaining the successful implementation of DH systems. The future of DH systems has to deal with small, well insulated, low temperature houses. The future of renewable energy will be outlined in a rough way for some general solutions and scenarios into the future into 2020 and 2050. These aspects will lead to two main research questions:

RQ1: How became District Heating* a success in Denmark and what kind of new developments can we expect in the future?

RQ2: What changes in an organizational way should be made for implementing district heating in an effective way in the Netherlands and how can we see DH in Europe in the future?**

*District Heating will be noticed as DH.

**Organizational will even focus on the different renewable energy sources in future prospective 2050 the Netherlands

Different sub research questions are involved:

1. **How the Danish Heating sector is currently organized?**
2. **How can we see DH in past and future in Denmark?**
3. **What are historical milestones in development of DH systems in Denmark?**
4. **Which new developments can we expect in the future?**
5. **What is/can be the role of the inhabitants, government and municipality in stimulating the implementation of DH systems in urban areas?**
6. **What is the benefit of District Heating companies?**

Sub questions mainly on the Netherlands:

7. **How is the Dutch heating industry organized, from a historic point of view?**
8. **What are the best conditions (technical, political and organizational) for implementing the system?**
9. **Which factors can contribute to a successful implementation of DH in the Netherlands, regarding the successful DH implementation in Denmark?**
10. **What kind of stakeholders is required for a justified implementation of the system in the Netherlands.**

The following sub questions can generate an answer on the renewable energy in the future in the Netherlands:

11. **What is the current energy policy in the Netherlands?**
12. **Which renewable energy sources can have a high potential in 2020 and 2050?**

1.4 Research approach

My stay in Denmark has the possibility to see the implementation of District Heating in Denmark. The history and future in District heating will be analyzed and translated in a SWOT analysis for the future prospective in the Netherlands. The current systems as well the future systems are essential to see.

Quality function deployment (QFD) tools will be used for a competition analysis. The possible RE sources for the future will be examined in a 5 point ranking system. The different aspects will be compared and given a ranking. Through this tool, the close countries will be examined for their RE approach and their possibilities in the future in RE.

Apart from this, the approach in the share of renewable energy sources is interesting for 2020 and 2050. The potential scenarios will be sketched. All the gathered information can be used for a realistic scenario for the future in the Netherlands.

1.5 Research scope

The research will mainly focus on DH, and the link to the Netherlands. Five key figures will be explained for a successful implementation in the Netherlands:

- Technical
- Political
- Financial
- Organizational
- Sociological

These aspects will be explained in a general way while the organizational aspect will be outlined in further detail. In which way do we have to make changes in an organizational way to have a successful implementation of DH in the Netherlands? Which way is justified to enlarge the possibilities?

The renewable energy sources in future can be expected, but in which time schedule. Again, this will be outlined and prospected in a macro scale for the Netherlands in 2020 and 2050.

1.6 Personal motivation

When I look around me in the winter, lot of windows are still open, holes or chinks can be seen, and a lot of heat is lost which is an unknown phenomenon for most consumers. I wonder how we can use this heat in a more efficient way.

Apart from that, Denmark has a leading character in renewable energy; this was a reasonable factor to go abroad for a short time for me. What can happen in the future, of course this will have an incredible change in the current state of our country. Not one institute or one person/company is able to solve the energy problem; we all have to participate in creating a sustainable stable future, which is an interesting factor for me.

2 ENERGY

We have been using energy in the past and we will continue to do so in the future. Which consequences are expected for the worldwide energy problems? Global warming, carbon dioxide (CO₂) pollution and melting ice caps; these are raising problems nowadays without a solid and clear solution. How did we use energy in history, how much energy are we using in ratio to the continents? Which part of the world uses the most? This paragraph will present the worldwide energy aspects in a nutshell.

2.1 Energy worldwide

We, the people in this world, are using in one year approximately 460 EJ. This is equivalent to the amount of solar energy reaching Earth in only one hour (Crabtree and Lewis, 2007). Therefore the sun is a powerful source of energy, which we can use a lot.

The stock of the primary energy worldwide is changing. While our grandparents used less than 1000 · 10⁶ tons coal equivalent, the energy use grew with a factor 20 between the year 1900 and 2000 as we can see in figure 4. We still need to use energy in the future, because of heating our houses and using an increasing amount of (electrical) apparatus. We will need energy for the economical values, and for a sustainable living climate, but we should consider our society for the very far future. Although the world primary energy consumption consists mostly in oil, coal, natural gas, nuclear power and hydro energy even more green energy sources has been introduced. Contrarily to fossil fuels, which give us a completely controllable energy flow, renewable energy sources are more uncertain, they are often unavailable at the time of demand and incompilant with the specification of demand.

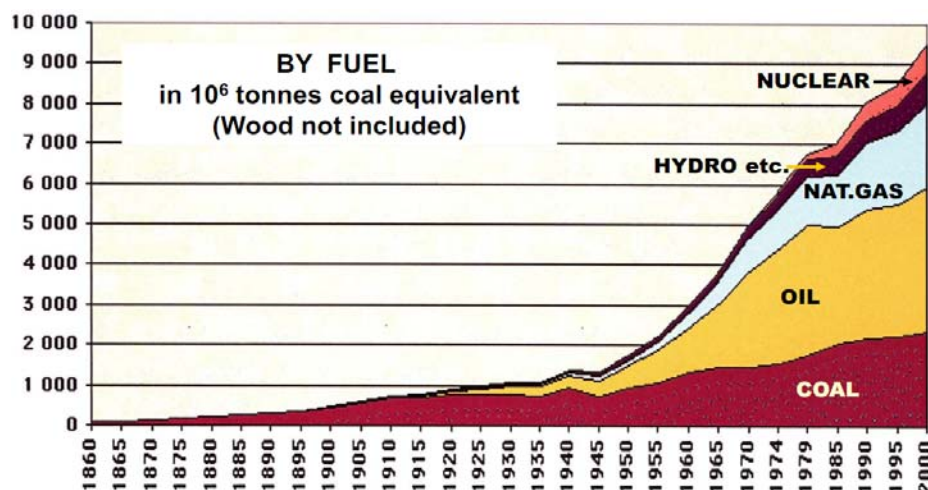


Figure 4: Historic primary energy consumption dev. Source: www.BP.com

Figure 4 shows us the primary energy consumption over the past 140 years. A considerable growth is noticeable after the Second World War.

The effects of using these fuels are becoming apparent: Global warming and melting ice caps are the main subjects of discussion. The greenhouse gases (GHG) emissions are raising, and we all have to reduce our pollutant consumption. In figure 5 we can see the parts of the world which have the most CO₂ emissions at the moment. CO₂ is the most common

greenhouse gas. The European Council has agreed to focus on reducing CO₂ emissions with 20% and to reach this target in 2020. Different industrial countries have agreed on the Kyoto-protocol to reduce the CO₂ emissions. These targets can be reached by compensations to invest in projects, or to trade in emissions. Three possibilities are launched:

- The Clean Development Mechanism (CDM)
- CO₂ compensations: Emission Trade Scheme (ETS)
- Joint Implementations (JI)

CDM is launched to provide different countries with investments in possibilities to reduce the CO₂ emissions. Carbon projects in developing countries are the most popular. CDM should be additional projects, next to the existing projects in these countries. In practice this is quite difficult to measure, and CDM projects seem not to be additional to the CO₂ emissions in the current approach.

The ETS is a trading scheme for central authorities to set a limit on the amount of a pollutant that can be emitted. Firms are required to hold a specified amount of carbon credits. When increasing their limit, they have to buy permits. This system was very difficult to establish, but it is a first good step forward.

The last one, JI projects, might involve a change in coal fired plants. These can be transformed or replaced by more efficient CHP plants. Most JI projects will take place in the 'economies in transition', described in Annex B of the Kyoto protocol. Russia and Ukraine are the most popular places for establishing JI projects .

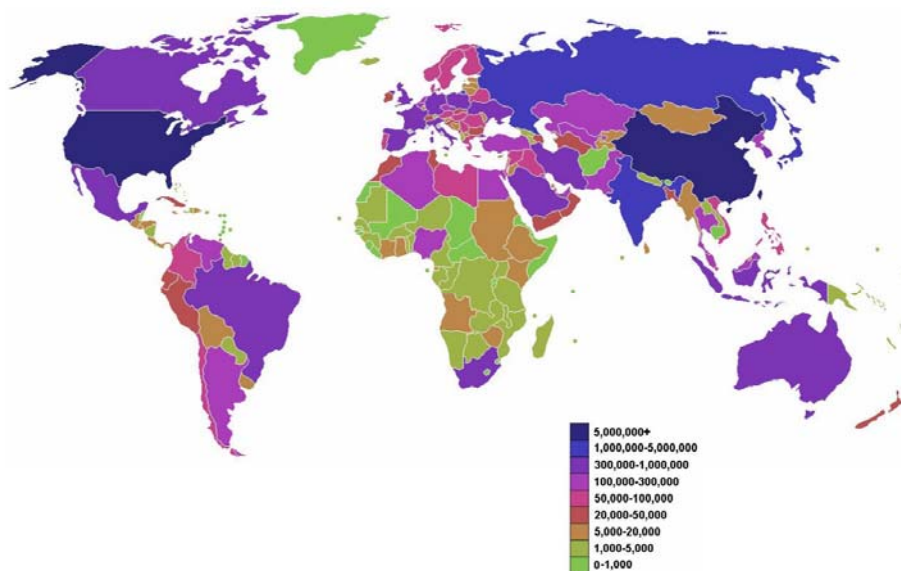


Figure 5: World CO₂ emission (Baletic, B., 2009)

Future

Various research is done to predict the energy use in the world, because the future depends on a lot of different and difficult to predict factors. This is why a lot of institutions or companies have totally different expectations about the future energy mix. Predictions differ from one company to another. Figure 6 and 7 illustrate the world energy supply developed by WWF and Shell.

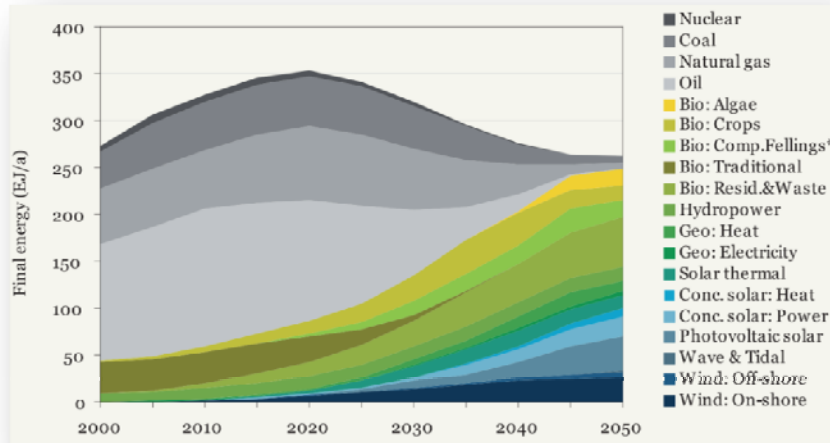


Figure 6: World energy supply by source.
(WWF Ecofys today, 2011)

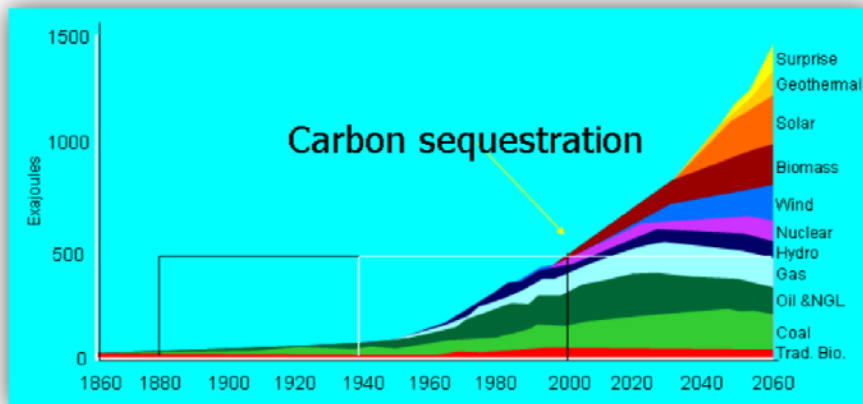


Figure 7: Shell Oil's "sustainable" growth scenario.
(www.shell.com)

In the nearby future, energy, water and food will be scarce in many countries. We are running out of fossil fuels, this meaning for transport sector a possible change into electrical transport. Electric transport will lead to a high demand of electricity and therefore difficulty in supplying it from the grid. The base load of electricity will be huge, and probably not sufficient with only RE sources. In the future, not only the way we use energy will change, but also the way to generate it. The fact that the energy prices are raising should make us aware of a need to reduce energy demand.

2.1.1 Nuclear Power

Nuclear power was used for the first time for a commercial purpose on June 27, 1954. The USSR's Obninsk nuclear power plant in Russia became the world's first nuclear power plant to contribute with energy on the grid. This power plant produced around 5 MW at that time. From that year on, the use of nuclear power started to grow. Even after a development of more than 50 years, still only 6.3 % of the total energy demand comes from nuclear power these days. The biggest production of nuclear power is in USA, France and Japan, which covered together 57% of the world nuclear power share in 2009 (BP report, 2010). Nuclear energy policy differs between EU countries, some having no active nuclear power stations at the moment. Belgium is the only country who has an active phase-out law of nuclear power, and since years Austria is the only country where nuclear power is illegal by law. Due to the 1973 oil crisis, France and Japan made a big investment in nuclear power. Nowadays 80% of the electricity demand of France is supplied by nuclear power, apart from their export of (nuclear) electricity.

Future

Due to three important nuclear power accidents in 1979 (Three Mile Island), 1986 (Chernobyl) and 2011 (Fukushima), the debate on nuclear power has peaked in these years and gained attention in 2011 due to the nuclear power accident in Fukushima, Japan. Many countries reconsider their investment in nuclear power, the debate being critical in some countries. However, interest in starting new nuclear power programs remains high all over the world. Over 60 Member States of the IAEA have expressed their interest in considering the introduction of nuclear power (IAEA, 2010). Potentially, nuclear power can grow, especially because it is an important way to generate a carbon-free world. Nevertheless, the environmental effects of nuclear power cannot be controlled or estimated for a sustainable future, which is a big disadvantage.

2.1.2 Gas

The use of gas was established in the 19th century and it was obtained as a byproduct of producing oil. This gas was usually flared. Later on, gas was found to be a useful product to sell. Gas is in comparison to coal and oil the cleanest fossil fuel if we measure the CO₂ emissions. The unused gas by producing oil can be used, or otherwise brought back to the earth, which is environmentally more friendly than flaring. Of course this extra effort is more expensive. Unfortunately, in poor countries governmental organizations or oil companies refuse to pay extra for these expenses. Nowadays, gas has a third place in most used energy resource, after oil and coal products (BP, 2010).

Future

Even the current gas stock is increasing. Biogas, which is made out of anaerobic materials, has a big potential for the future. A big advantage of gas is the transportation form; gas can easily be used in the transport sector. Natural gas is ending in the upcoming years, but use of gas will be important due to the fact that gas is cleaner in CO₂ emissions than coal or oil products and is useful in the transport sector.

2.1.3 Coal

Coal is the most common fuel for the huge energy demand in the world. Coal can be used in different ways, but is mainly used for generating electricity; coal is usually pulverized and then burned in stoves with a boiler. The heat is converted to steam. This steam can be used for generating turbines for electricity. This long way to generate electricity will lead to an efficiency of around 33% for most coal plants. New, high tech coal plants can reach 50% of the energy level, because of the use of CHP. Combining other buildings with their heating demand can lead to benefits: producing electricity and heat for the consumer. The biggest problem of coal plant is the global warming. Burning coal is contributing a lot of CO₂, in comparison to other fuels. Brown coal emits 3 times as much CO₂ as natural gas, for instance.

Future

Coal is still the most used source in electricity generation, but the future of using coal is quite vulnerable. The demand will rise and the consequences for the global warming will expand. Within the current policy, the world primary coal demand will follow an increasing line up to 2035.

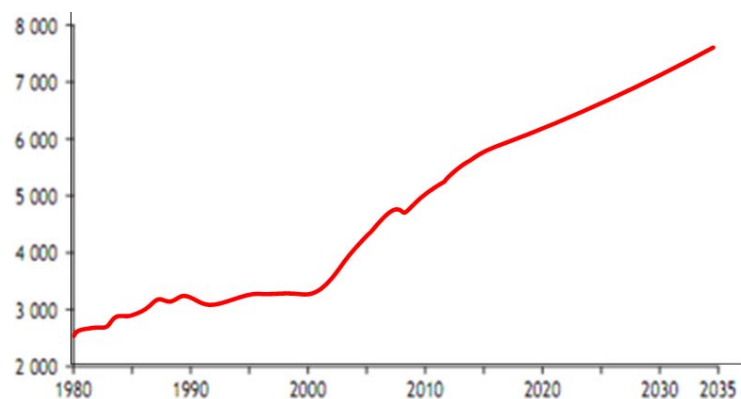


Figure 8: World primary energy demand up to 2035 scenario based on current policy. (million tonnes of oil equivalent) Source: WORLD ENERGY OUTLOOK, 2010

2.1.4 Oil

Crude oil is a liquid from hydrocarbons. This oil is not useful in the original way, which is usually called petroleum, but through several processes this will transform into a large number of consumer products, from gasoline and kerosene to asphalt and chemical products to make plastics. Oil is enormously important for the transport sector, while petroleum is transformed into gasoil and petrol. Apart from that, kerosene is used as a fuel for planes, almost all having their engine running on it. Due to the high density of energy per kilogram, oil became our most important energy source for transport since the 1950s. Oil consists for a percentage of 83 to 87 out of carbon, which is contributing a lot to the worldwide CO₂ amount. Crude oil varies greatly in its composition. Black coal is the most common one and is usually found together with natural gas.

Future

Oil will be important also in the future. The political instabilities in the northern African countries of February 2011 showed us the demand of oil, especially Libya, which is serving 2% of the worldwide oil. Some EU and American journalists proposed arguments for reforming these countries, based on their oil stocks. A new energy source in the transport sector is not upcoming very vast in the near future, so the gasoil and petrol will still have a critical role in transport industry.

2.1.5 Hydrology

Last of the five most important sources at the moment is hydrology. Hydrology consists of moving waters. The first elements of engineering on the way of hydrology were found in the Mesopotamian towns, dating from 4000 B.C. Nowadays, it is still used, and gives us a significant amount of energy in our daily life. Hydrology is a clean way to generate energy. Water has the big advantage of storing energy. Big basins can be stored, and be used in case of a high demand somewhere. The biggest hydrology projects are based in parts of the world with mountains.

Future

Not every geographical area is suitable for a justified use of hydrology for energy use, while in most cases a huge decay is needed to generate energy. For a growing use of hydrology that could ensure socio-economic and environmental sustainability, we should focus on integrated, renewable resource management of energy production and use. Within this framework, water and, so, hydrology has a new integrative and regulating role to play (Koutsoyiannes et al., 2009).

2.2 Primary energy use

The primary energy use in the world differs a lot. Some countries have big industries which are using a lot of energy, others have geographical reasons and the use of energy is also linked to the gross domestic product (GDP). Energy consumption per capita differs a lot; figure 9 shows us the consumption in the world. The Middle East has a lot of oil, Russia has a lot of gas, and Canada is a big spender. Norway, with a small population of less than 5 million has a lot of oil, and uses it as an important export product.

We can consider the five different sources described in paragraph 2.1 as the most important ones. The year 2009 was the first year since 1982, in which the world consumption of energy decreased. It fell down by 1.1%. Still, in 2009, oil is the most used form of primary energy source since 1970. In 2009 it had a share of 34.8% of all resources.

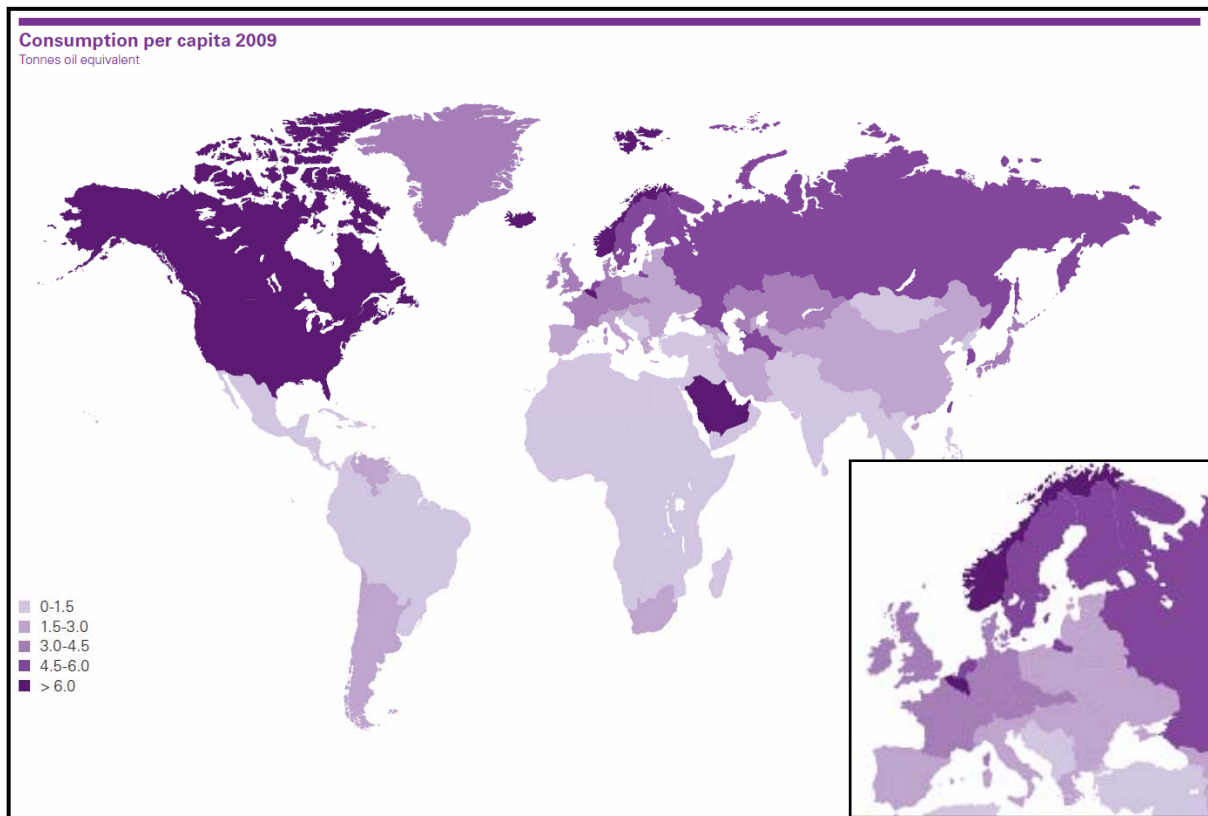


Figure 9: Consumption of primary energy per capita in 2009

Source: BP, 2010

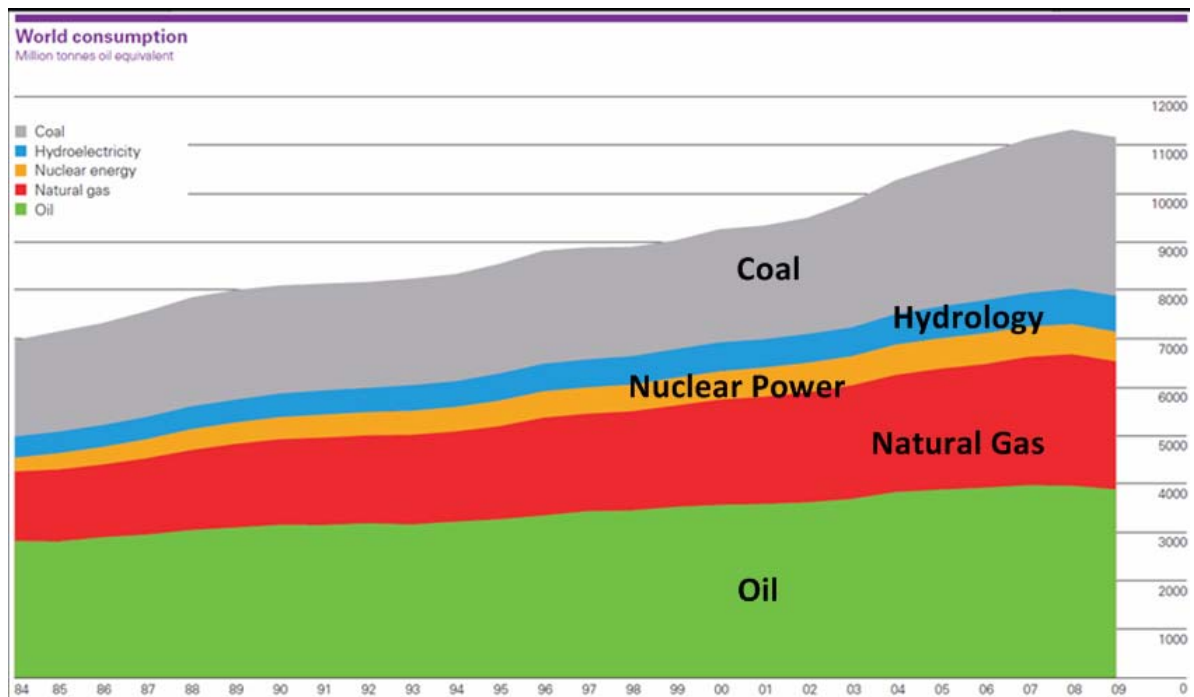


Figure 10: World primary energy consumption per million tonnes of equivalent from 1984 to 2009. Source: BP, 2010

Most economies are based on fossil fuels; in 2010 the amount of fossil fuels worldwide was more than 90% according to the BP report. Still, the share of RE has a potential growth in the next years.

2.3 Energy Europe

The EU, which contains almost all the European countries, has set up some rules for the energy use in Europe. Especially the 20/20/20 rule, which is made up for 2020 is important:

- 20% renewable energy,
- 20% reduction of greenhouse gas emissions (GHG)
- 20% energy reduction

The OPEC countries, an intergovernmental group of 12 developed countries, are important in the energy supply. Unfortunately, none of the EU countries are part of the OPEC. Only one country in the EU has more export in comparison to import: Denmark. At the moment, all 27 states of the EU are on track to meet the RE and GHG targets. Only the energy efficiency is stuck by only 9%. We should increase a lot, and especially, this is a good way to create jobs on the spot, especially in a time where the construction sector has a big crisis.

In Europe we do not have a lot of oil or coal production, but a lot of gas, and, thanks to France, a particular amount of nuclear power. Europe has taken leadership in starting up targets for reducing the problem

of global warming by starting the ETS program and, finally, other countries in the world seem to follow in making plans for a sustainable future.

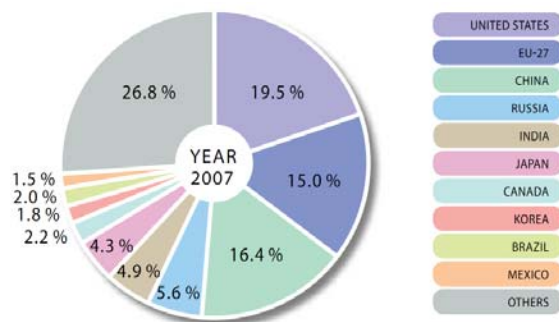


Figure 11: Gross inland energy consumption by country in 2007. (Statistical pocket book, 2010)

Energy use

The energy consumption in Europe is, in comparison to the USA and China, just a small proportion. Europe was using in 2007 only 15% of the total energy demand. This is quite similar when comparing the population:

Europe represents roughly 11% of the world population at this time (730 million in EU out of 6,5 billion worldwide). Note that in the African countries and in South America this energy consumption is less because of the low national GDP.

Electricity consumption is probably a

better way to measure the energy consumption, while electricity

demand rises. Nowadays Europe's electricity consumption represents 18% of the world ratio. This is a relatively high demand.

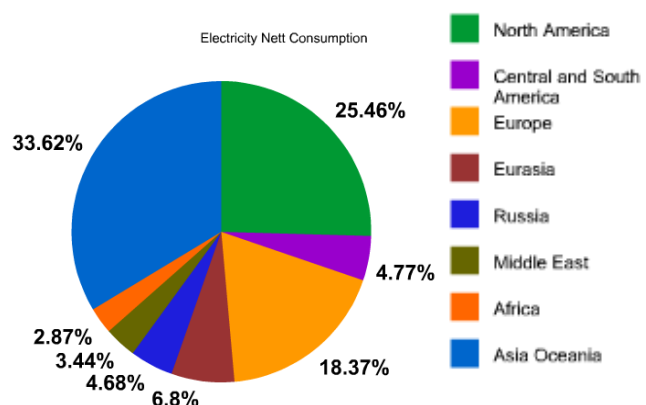


Figure 12: Electricity Nett. Consumption (IEA)

3 DENMARK AND DISTRICT HEATING

During the last half century, energy became an important economy in Denmark. During the 1970s, Denmark changed their policy radically and was gradually transformed into an energy exporting country; energy is currently a major part of the Danish economy. Today, Denmark is still the only country in the EU that produces more energy than it uses. How was Denmark able to transform in this short period? How is Denmark organized when it comes to energy and when was DH introduced? This paragraph gives an overview of the energy sector, DH in general and the key factors of DH.

3.1 The Energy sector

The Danish energy sector has transformed after the first oil crisis. During the 1973, Yom Kippur War between Israel, Syria and Egypt, most of the Western world was subjected to an Arab-led oil embargo. The crisis, based on an increasing oil price of 70%, and a decreasing oil production of 5% per month, was, for most Western European countries and the USA, a serious setback. This crisis forced Denmark, which was almost 100 percent dependent on foreign oil at the time, to develop an alternative-energy policy. As a nation with few energy resources of its own, Denmark had to consider its needs and rethink its policies in the face of an almost complete withdrawal of its oil and energy supply.

In the years since the oil crisis, Denmark has worked tirelessly to develop new technology and new policies. The Danish Energy Agency (DEA), which is part of the Danish government, formulated three focus points (www.ens.dk) :

1. Security of supply
2. Climate impact
3. Cost effectiveness

The DEA was established in 1976 as part of the ministry of climate and energy. Strong legislation and policy led to a strong institute with international respect and power. Heat also became a focus point in these years. The government presented their first heat supply law in 1979. This law was mainly made for local authorities and split up into 3 phases:

1. Heat consumption, methods and heat requirements (Data collection)
2. A future draft design for heating (Possible solutions)
3. Overall heat planning for the future (Detailed planning)

After the 1970s different projects were started around energy, in which wind power was the most important one. More research was done on renewable energy and the possibilities to expand its share. During the same period, investments were done in co-generation of heat and electricity to exploit surplus heat from electricity generation. In 1986 the co-generated heat and electricity agreement became a major energy policy priority. The ban on installing electric heat in new buildings dates back to 1988. And in 1994 this ban was extended to electric heat installation in existing buildings with water based central heating systems. The ban on electric heat remains in effect (DEA, 2005).

In the 1990s, the heat supply law was improved by a new planning system to meet heat supply requirements. Mainly it was aimed to gain a better expansion of decentralized CHP. A driven force was the CO₂ pollution and a growing economy in energy through the expansion of the natural gas grid. The successful approach ensured to one of the most effective co-generation of heat and electricity in Europe. Another phenomenon was introduced in the 1990s: Open field plants. These field plants are small, public heat installations. They are usual environmental friendly producers of heat with low CO₂ pollution. Today, approximately 80 open field plants are based in Denmark. Most of them are natural gas based.

The last years

Denmark used in 2009 almost 809 PJ direct energy (Energy statistics, 2009). 81% of all the energy was established by fossil fuels, as we can see in figure 13.

In comparison to other countries, it is a big share of RE, but, unfortunately, still depending for a big share on fossil fuels. The share in wind power and other RE sources is growing.

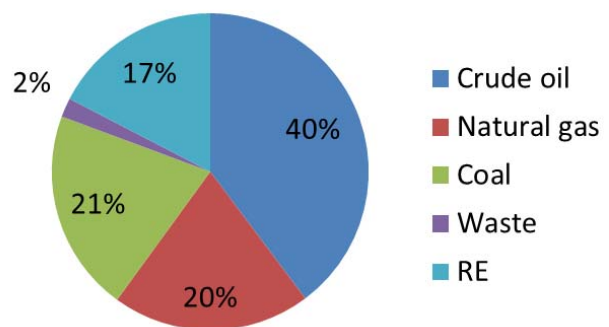


Figure 13: Total energy consumption in 2009
Source: ens.dk

Today, twenty percent of Denmark's energy need is met by electricity generated by wind turbines, and the proportion is steadily increasing. Thanks to advances in technology and turbine design, the cost of wind power has been reduced by 75 percent since 1970, when the programs began. Wind power is also important for Denmark, because they export technology. Around 40% of the world's supply of wind turbines comes from Denmark, due to their high tech research program. Wind power is not the only energy source in Denmark; biomass, CHP efficiencies, high tech coal power plants, PV panels, solar energy and geothermal turbines are widely installed in Denmark. Denmark has the world's most efficient clean coal technology and the highest proportion of the total electricity generated by RE.

Denmark's other sources are the North Sea oil fields, but these fields are expected to run out within twenty years. Investments in other RE sources are necessary for the energy supply in the near future. The costs of renewable energy resources have decreased dramatically over the past thirty years and a higher efficiency was established. Denmark's transformation from almost 100% foreign oil dependency to an autonomous RE stimulated country is an example to the world. The people of Denmark are aware of the need to ensure a sustainable society for future generations. Their effort in reducing energy consumption and producing it in a more environmental friendly way, came to a milestone in 1997, the year in which Denmark became self-sufficient in energy. Denmark has seen substantial developments in DH, which are described in paragraph 3.2.

The last ten years, more focus was put on the electricity network. The connection to other countries is important to the adaptation of large volumes of wind power into the electricity grid. Converting to different types of biomass fuel and other investments in CHP are important for the current share of RE. The electricity market and supply is extremely green, about 28% is made from a RE source due to the large wind farms (Energy statistics, 2009). Another reason for the impressive status of Denmark is the cooperation with customers. Back to 1979, the Danish energy policy presented initiatives to enable consumers to save energy. In these days, initiatives were undertaken to improve the buildings insulation and to decrease the energy use. Nowadays, we can see the energy labeling, which contains strict rules. The energy labeling in Denmark is strict. A complete energy certificate will be made if you want to sell your house, for example. The energy state of the house and recommendations/investments on improving the energy state are essential. The labeling schemes of electrical apparatus and campaigns for energy savings in households or energy savings agreements with the industry are leading to an even more energy efficiency.

The production of electricity is mainly based on the nine coal based power plants. The export of electricity is mainly to Norway and Sweden, thanks to the electricity network. Energinet.dk provides an on line monitoring system to show the actual export and import of electricity on the whole country. According to the Sankey diagram in figure 14, the most important sources for electricity are the coal based power plants.

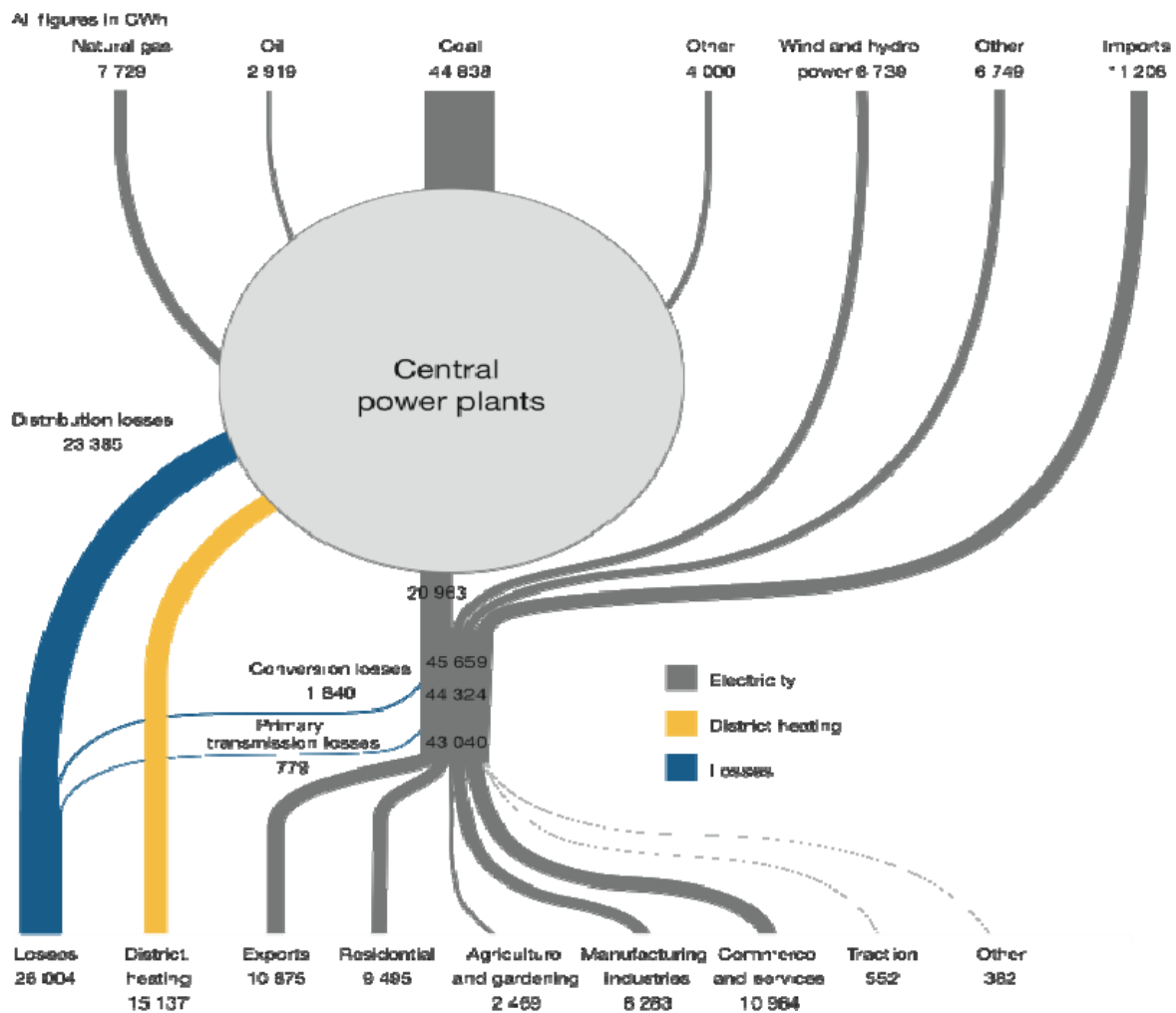


Figure 14: Danish Energy balance for the electricity sector 2009 (all numbers in GWh).
Source: energinet.dk

Energy structure

Two main energy companies deliver gas and electricity: DONG Energy and Vattenfall. They own all nine coal power plants in Denmark. In short, both companies:

DONG energy was found in 2006 as part of a cooperation of six small energy companies. This merger was accomplished by the EU in March 2006. The majority (73%) of DONG Energy is owned by the government according to Wikipedia. DONG Energy owns a few important gas pipes; from Danish part of the North Sea to Sweden, the F3 pipeline (50%) to the Netherlands, the DEUDAN pipeline from Jutland to Hamburg and has a share in the Norwegian gas pipe system. They are involved in the off shore wind farm of the Danish island of Anholt in the Kattegat.

Internationally DONG Energy has shares in central power plants in Norway, Great Britain and the Netherlands. In RE share, projects are initiated in many EU countries. DONG has 6,000 employees in seven countries.

Vattenfall is a Swedish energy company established more than a century ago. During the restructuring of Trollhätte kanal they tried to exploit the national fall to produce electricity. The first hydropower stations were built for railways and industries. Up to 1970, hydropower was the main activity of Vattenfall, and had, at that time, one of the first 400 kV cable links in the world. In the beginning of the nineties, the EU tried to stimulate an international business, and, from 1997, Vattenfall became international in Germany, Finland, Poland and other countries. Today it transformed into a European company with 40,000 employees in eight countries.

Next to these companies, several other companies supply heat or own a network. Important institutions in this case are VEKS, CTR, Københavns E and many municipalities. A transmission company supplies heat to local DH companies. The local DH companies then, resell the heat to private consumers, business customers and institutions. VEKS, for example, one of the biggest transmission companies has close cooperating with their 11 municipalities. VEKS buys most of its heat from Avedørevarket, which generates heat and electricity. They resell it to others, with this profit, they can maintain their network.

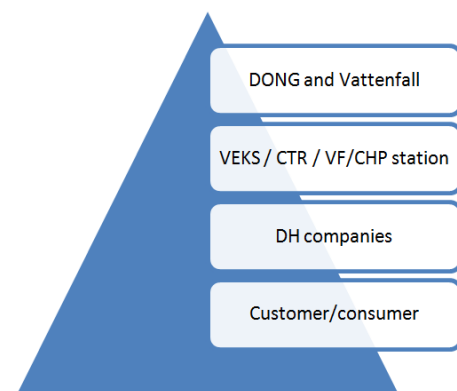


Figure 15: General structure of companies in the Danish energy flow.

Denmark-import-export

Denmark is a net exporter of energy, and they have a share in important gas infrastructure in the nearby countries. They are electrically well connected to Scandinavia and are exporting usually to Scandinavia. In 'wet years', Norway and Sweden have sufficient electrical power, due to the hydrology plants in these countries.

Their biggest growing export product is energy technology. Their peak was in 2008 with an increase of 19 per cent from 2007 to 2008. That is four times as much as the growth of any other Danish export sector export. Their most important markets are UK, USA and Germany.

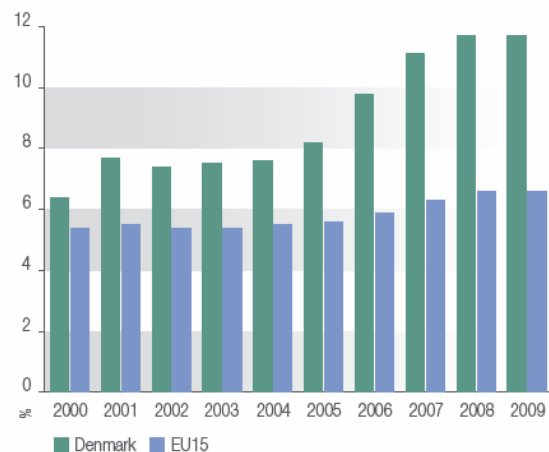


Figure 16: Energy technology share of total goods exports in 2009.

Source: Danish Energy Agency

“Impressing, this is a strong position to have, which further supports Denmark’s international brand for energy efficient solutions” according to Connie Hedegaard, European Commissioner for climate action, and former minister for climate and energy strategy in Denmark. With this energy technology Denmark can prove an end of the Danish oil and gas self-sufficiency within a decade at most (Höök et al., 2009).

Future

From coal, oil and gas to green energy is the title of the new energy strategy 2050 of the Danish government. This report was launched in February 2011 and explains the new strategy up to 2050, describing in detail how to reach a green energy nation in 2050. This strategy is the first of its kind, in Denmark and in the rest of the world. It is important to emphasize that Denmark is not able to be sufficient by itself, and should cooperate with others, especially EU countries, to move in the same direction. The government’s target arises from the EU climate and energy package:

- Share of 30% RE in 2020 (EU is 20%)
- Share of 10% RE in transport sector by 2020
- Reduced overall emissions of greenhouse gases by 30% by 2020 relative to the 1990 level.

High efficiency is one of the key elements for the future. Within DH a lot of heat and energy can be saved. In 2050, the Danish energy consumption could be more than 50% more overall efficient, according to the report. The electrification of the transport sector is important for the future. Electric cars, plug-in hybrids or fuel-cell cars should be possible in 2050, although more research should be done.

Nuclear power is not part of the Danish energy planning, due to the decision in 1985 by the Danish Parliament. Due to the accidents of the tsunami in 2011 in Japan, more arguments

against Nuclear power are arising. DH heating will play a role in the energy reduction. The reliability, flexibility and simplicity of DH are aspects which are essential to adapt on future energy resources.

3.2 DH in Denmark

The origin of DH in Denmark was found in Frederiksberg, where the Danes copied the example of Germany. Frederiksberg was growing rapidly, and in the end of the 19th century, Frederiksberg developed from a village towards a growing city. In Hamburg, a plant was developed to burn waste with a facility to generate heat for the city. In this way, Denmark decided to send some samples of waste to Hamburg to investigate the possibilities. In 1902, this test was positive and the municipality of Frederiksberg decided to build Denmark's first waste incineration plant. Both, heat and electricity were produced in the same plant. In this plant waste was brought by horse carriages to a higher floor to put the waste in a silo. From this silo, the waste was burned, and the steam was blown in a tunnel which provides heat for the new build hospital, children's home and a poorhouse.

In the 20's and 30's more developing in DH with diesel was established. During the time until WW II, these plants or systems were quite modest and only limited to a small area, and still running on diesel. These plants created a basis for expanding the heating supply networks. After the world war, large central power plants were introduced for the electricity. The smaller heat plants were still used for the heating systems. We can see the steam based DH system as the first generation DH.

Actually, just in 1973 the Danes realized their vulnerability of energy supply, and the energy consumption per inhabitant was extremely high. Energy savings were important, while the energy at this time was almost 100% imported from fossil fuels to generate heat. The second DH generation can be seen in the form of heating water in tubes. This water will have at least a T_{supply} of 100° C, up to around 120 °C. Today, this way of DH is used in the big pipes from the primary heat to the secondary heat generation, in the transmission network in city level.

The third generation is most common nowadays in the build environment and supplies the houses of heat on a lower temperature. A T_{supply} of 80-90 °C with a T_{return} of 40-50 °C is normally used with a ΔT of 30-50 °C. This is more efficient than the previous one and well connected to the radiators in our houses.

The fourth generation is based on a much lower temperature. This generation is not yet implemented on a wide scale. It has a great opportunity to save energy in the build

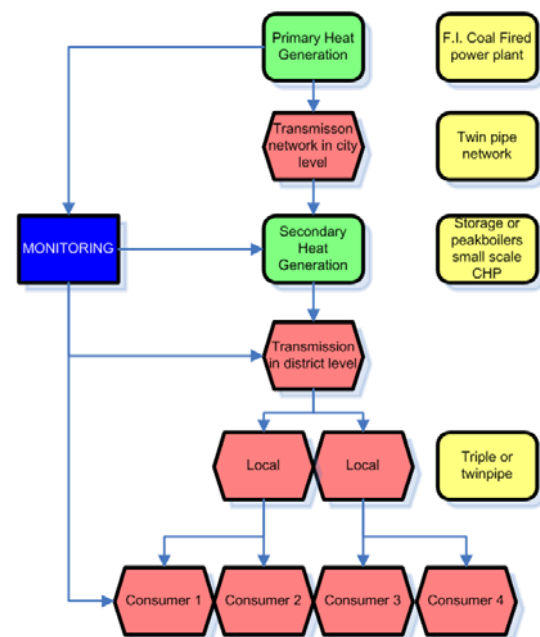


Figure 17: Hierarchy in heat transmission

environment. Different possibilities can be used, but the main idea is a T_{supply} of 55 °C and a T_{return} of 20-30 °C. The supply has a limit, due to the existence of the bacteria legionella. Research is going on in Dresden University to find solutions to use water of a lower supply temperature without or a lower risk of legionella.

Most of the networks are mixed networks of the second and third generation. The fourth generation is based on the new low energy houses and future houses with a very low energy use.

VEKS

VEKS, also known as Vestegnens Kraftvarmeselskab I/S, is a transmission company supplying heat to local DH companies at Vestegnen. VEKS was established in 1984 with the aim of to use CHP in a more efficient way. Today, VEKS supplies 150,000 families with heat and hot water. VEKS buys most of the heat from Avedøreværket, which generate heat and electricity. Unit 1 at Avedøreværket is a coal fired facility; Unit 2 is a multi-fuel facility using gas, fuel or wood pellets. Onother energy source is the heat from waste incineration plants: VEGA in Høje taastrup, KARA in Roskilde and Vestforbrænding in Glostrup.

Before VEKS was established, the local district heating companies generated heat themselves by oil and coal-fired boilers. Within VEKS, these boilers could be used in a more effective way, for example by a peak load. The monitoring of the heat is easily done by computers. The sister company CTR is connected to the network of VEKS. This system in its entirety is one of Europe's largest district heating transmission systems (VEKS, 2003).

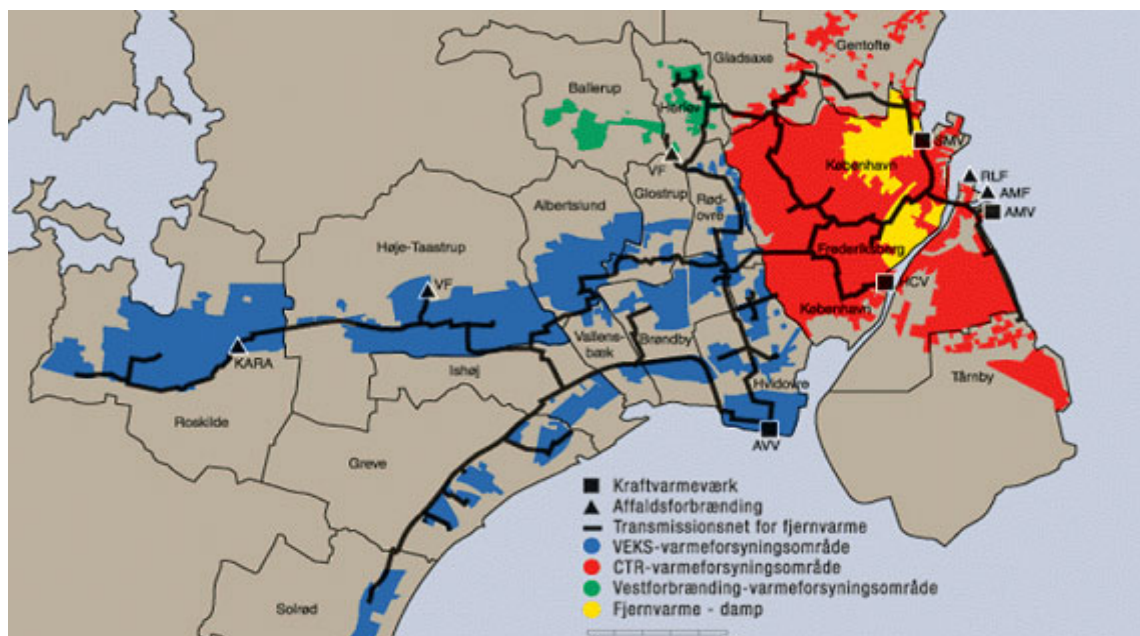


Figure 18: The Copenhagen Area and their transmission network owners

3.3 Key factors DH

For justified implementations, different key factors will be overviewed. Not only governmental support on a national scale, but also strong support by the local municipalities is essential for a successful cooperation. Technical issues and financial reasons are important for a long term successful implementation. The main factors will be described in the following section.

3.3.1 Organizational

For an implementation of the fourth generation DH in the existing build environment, an excellent organization is needed. Not only the ongoing infrastructure of the city hampered the construction works, but even the existing heat supply of the buildings should be kept intact. DH networks are useful in the city due to the fact that the pipelines are relatively short. To reach a reasonable efficiency level of the network, the life time, the heat demand, the status of the buildings and the possibility to situate new pipelines in the ground/buildings should be examined carefully.

Perfect for the 4th generation DH networks are developing brown fields; usually these large scale projects will be transformed in new buildings with a totally new infrastructure. The buildings on brown fields are old and should be demolished; this gives new plans a great opportunity to build a new part of the district or city to build a new network. The buildings are built for at least 50 years, and the payback period is long enough to make profit out of the network, even with the new low temperature buildings. The energy source on this network can differ, depending on the large scale heat facilities in the environment (CPH or waste incineration plants). Due to the experiences in DH networks and their specialized institutions, a change to this new generation can be made. Danish DH manufactures produce over half of the world total pre insulated pipes, which gave Denmark a big source of income.

3.3.1.1 Governmental

The government of Denmark has power in the energy industry but its influence is steering, not decisive. We have seen the strong energy laws in Denmark during the past decades in paragraph 3.1. The Copenhagen area is covered almost entirely by a DH network. In the future, more RE in form of geothermal, wind power, biogas and other solutions can be researched for more applications. The national long term support of networks provides a stable economy in this DH sector.

3.3.1.2 Regional/Local

The success of DH in Denmark is based on a strong municipality policy. A strong contribution of effort by municipality is needed for a successful implementation. One such example is VEKS, which is a transmission company, supplying heat to 19 local district heating companies at Vestegnen (western suburban area of Copenhagen). These local district heating companies then resell the heat to private consumers or business customers. VEKS was established for a better supplying of heat from the CHP and waste incineration plants. Nowadays they consist of a partnership made up of 11 partnering municipalities in Vestegnen, with a total servicing area of 370,000 inhabitants. The municipalities are jointly

and severally liable for any debts incurred by the company. The municipalities also have separate district heating companies. This strong cooperation between energy suppliers, governmental institutions and consumers/customers is characteristic for the regional/local approach.

3.3.1.3 Consumers and the district heating companies

The consumers are usually part of the DH companies, due to the nonprofit aspect of these companies. Maintenance and other investments can be done by contribution of the consumers/customers. The consumers elect members for the board of directors directly or indirectly through public elections. The energy prices and budgets for the consumers are public and transparent, and the consumers make profit from the heat supply. District heating companies are, by law, non-profit organizations. Within the district, all the consumers/customers have an installation in common, so from sociological point of view, the inhabitants should cooperate to make more profit out of it.

3.3.2 Policy

Denmark has a well-defined target to reduce energy. To reach this target, DH, more insulation and more efficiency in the primary side of energy generation should be adapted. DH in combination with new low temperature houses can be perfect for reducing energy use. Like other EU countries, Denmark has a strong legislation for new buildings. Strict energy rules are given for different energy levels of houses: In 2006 the energy frame was reduced significantly compared to the 1995 energy frames and the low-energy class energy frames were introduced (Bygningsreglementet BR-95/08):

Klasse 1: 35+(1100/heated floor area) kWh/m² per year.

Klasse 2: 50+(1600/heated floor area) kWh/m² per year.

3.3.3 Technical

To expand the energy saving possibilities, the 4th generation of DH should be a standard for new building plans. This generation is based on a low temperature heating with a very low energy use. A T_{supply} of 55 °C and a T_{return} of 20-30 °C will be standard. To have a constant heating loop for DHW and SH in bathrooms during summer different technical solutions were found. One of the solutions is the triple pipe solution with different modes:

- Mode 1: DHW demand: Pipe 1 and 3 supplies, pipe 2 returns. (Max. heat demand)
- Mode 2: No SH demand, DHW preparation: Idle water flow is supplied by pipe 1, pipe 3 act as a recirculation line, the return line 3 is not active. This will keep pipe 1 keep hot. Line 2 return is needed.
- Mode 3: Summer: no tapping DHW, 1 supply, 2 returns. Only demand for SH.

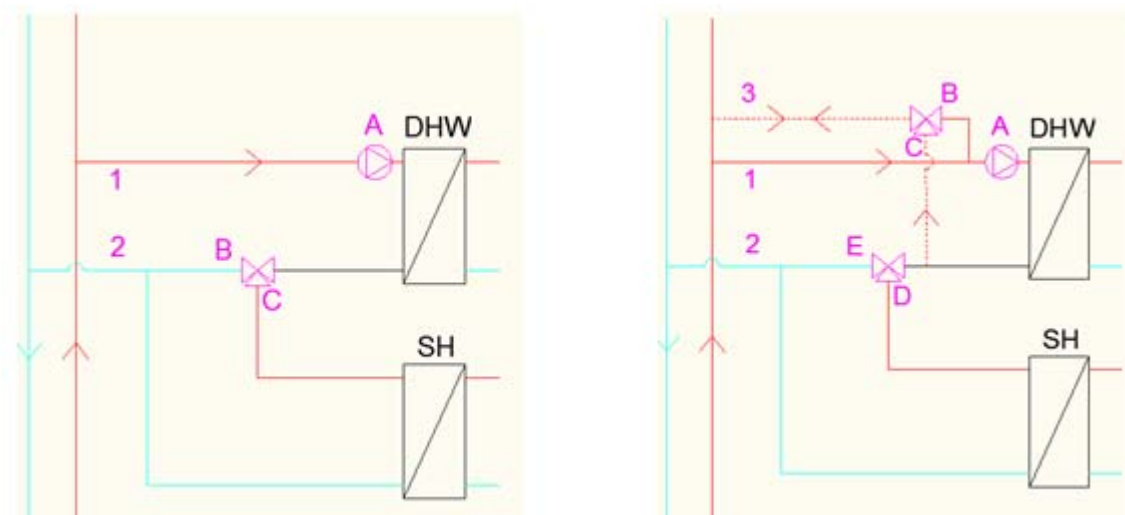


Figure 19: Branch pipe configurations for twin pipe connection left, and a triple pipe connection right. Source: DTU DH research group.

The supply has a limit due to the existing of the bacteria Legionella. In this field, some extra research can be done, due to the fact that SH in a floor, needs a low temperature to heat.

3.3.4 Financial

Fossil fuels are cheaper than renewable, in general. DH has the disadvantage of needing a high investment, with a long-term payback. Both are negative for an investor in short term. For the existing buildings, the technical solutions are difficult and the payback period is probably not in line with the life time of the buildings. A third generation DH system can be combined with CHP and has a different payback period compared to a high tech DH system based on biogas. This will probably hold true for some time. Maintenances are difficult to predict for new systems, thus making it vulnerable.

DH has a big advantage for reducing energy use. In Europe, the target of reducing energy consumption by 20% by 2020 is difficult to reach. However, DH has a big potential to contribute to achieving it. The payback period differs a lot because of the many different factors with significant influence. Payback period for capital costs differs a lot: with governmental support it can be short but in rural areas without governmental support it can take more than 40 years. Experienced payback periods by VEKS were 12 to 13 years.

3.4 Heating DTU

The Technical University of Denmark, also referred to as DTU, was established in 1994. Before this period, it was called Technical College of Denmark. Their complex is located in Lyngby and was built in the period from 1962 to 1974. Now the buildings occupy approximately 375,000 square meters. Around eighty percent of the buildings were built before 1974; these buildings are called 100- and 50-meters buildings, with a relatively high energy use of 200W/m². The buildings on the DTU campus are relatively old and not well isolated. In the near future, more departments of DTU, which are located outside DTU, will move to Lyngby. This development will lead to more new offices and an increase in heat demand.

The DTU buildings are normally heated by the gas power plant of DONG energy. This gas running power plant is located on the DTU campus and supplies also the neighborhoods in Lyngby. During

winter time, the peak demand of the environment can become quite high and can reach the maximum power of the plant. In this

case, DTU has 3 boilers and two HEs, which can produce 9.3 MW of heat each. On average, around 25 days per year, these boilers are running for heating. The supply of hot water is around 90 to 93 °C and a return around 70 °C. The boilers reach almost the maximum level of heating. When more buildings are attached to the grid, extra boilers or extra reduce of heat will be necessary.

The supply pipes are situated underneath the buildings, in tunnels. Huge tunnels are connecting all these buildings. These tunnels are quite big and there is a possibility to cycle through them. Maintenance in pipes or electrical systems is possible without lot of construction work. An overview of the tunnels can be found in the appendixes.

What	Amount
Number of students	7.000
M2 heated floor	300.000 m ²
M2 building	400.000 m ²
M3 building	1.600.000 m ³

Table 1:
Main characteristics of DTU, 2011

Year	Electricity (kWh)	Price* (DKK)	Heating (kWh)	Price* (DKK/kWh)	Water (m ³)	Price of Water* (DKK/m ³)
2007	32.837.751	1,75	53.322.804	0,65	113.337	49
2008	33.592.767	1,75	52.516.877	0,65	118.841	49
2009	34.343.269	1,75	50.312.110	0,65	125.310	49
2010	36.348.524	1,75	66.753.556	0,65	112.278	49

Table 2: Energy statistics of DTU. Source: DTU campus service.
***based on average price (including all taxes and fees).**

3.5 Conclusion

The Danish energy sector sets an example for other countries due to its rapid change from a 100% energy importing country to a net exporter of energy. The power of the government in this transition was vital. Therefore, the share of main energy institutions in Denmark is still powered by the government or regards it as a major shareholder. The energy sector has targets which are exceed the European rules. Another main aspect is the export of energy related products and knowledge. The energy sector of Denmark is important for neighbor countries, since, through this cooperation, the expectation of changes in the energy sector will be easier to estimate.

The existing DH projects have proven their success. The new generation of DH networks within a T_{supply} of 55 °C is developed with a very low energy use. At the moment, the limit is the bacteria. Large-scale building projects have a preference for these networks, for it is the easiest way to implement the pipes. The organization behind one of the biggest heat transmission networks in Europe is complex, but has proven its success. In conclusion, DH projects require, in the beginning, high financial investments and, apart from this, have a long payback period. Nevertheless, one should not underestimate the need for sustainability nowadays and, hence, should think more of long-term benefits rather than fast, but environmentally destructive profits. In future DH will be a main energy focus point, next to the increasing share of RE sources for a future of 100% RE in 2050.

4 ENERGY IN THE NETHERLANDS

We have seen the energy use in the world and the amount of energy we are using. Besides noticing the transition of Denmark into an energy exporting country with big wind farms, DH solutions and a strong energy policy, we also noticed the success of using heat. DH has been and continues to be a focus point and has proven its success.

However, the Netherlands has a totally different way of supplying their energy needs. This paragraph will explain the history and future of the energy sector and will go into further detail regarding the organizational aspects of the heating and warm water supply in the Netherlands. Apart from these, some innovative pilot projects in the Netherlands will also be described and the possibilities for DH in the Netherlands will be outlined.

4.1 The energy sector

The Netherlands developed themselves as a gas nation. Gas trade was and is responsible for the growth of prosperity and contributes for five billion euro every year on profit to the government. The year 2010 was a great year for gas selling. A new record of getting gas from the gas fields was achieved: 51 billion cubic meters gas was pumped from Slochteren (NL) and 16 billion cubic meters from other fields in the Netherlands, with a total of 67 billion cubic meter of gas (NAM, 2011). On one hand, an enormous amount of money was earned in selling this gas, but on the other hand, the storage of our gas will be emptied earlier. Most of the households in the Netherlands have a gas boiler and the trends in replacing this boiler to more efficient one is growing due to the increasing price of gas. In 2004, the average gas price per m³ in the Netherlands was 0,27 eurocent and in 2009 0,72 eurocent; almost 3 times higher (Milieucentraal, 2011). The use of this gas will end around 2030, according to the ministry of economic affairs. More import of foreign gas, more coal, wind and nuclear power will be urgent. Today, roughly half of our used energy is found by gas, oil has a third, coal has around 10% and the small RE and nuclear power supplies around 6% of our energy. Our energy sector is important for the country since we have a big share in trading energy: the amount of import and export is significant more than our own production (Fig. 20).

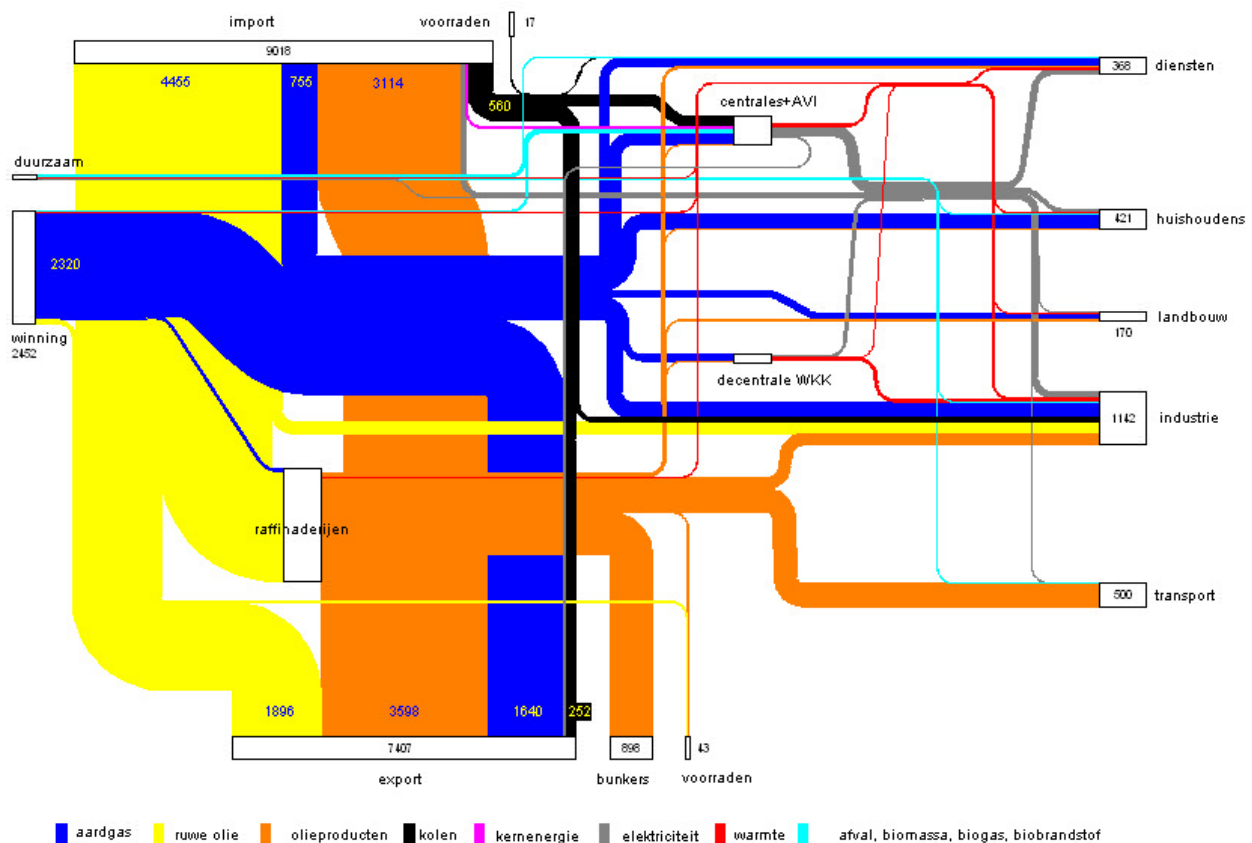


Figure 20: Energy in the Netherlands: Sankey diagram based on data 2006

Source: CBS 2006, www.energie.nl

4.1.1 Heating in history

Heating period 1930 till 1940

In the thirties people used to heat their houses mainly by home based coal fired heating systems or gas heated systems. Possibilities for heating on petroleum were introduced, but at that time, it was not popular, due to the high pollution and unhealthy way of heating on petroleum. Nonetheless, heating on electricity was possible, but this was expensive in comparison to the other solutions. Only the high class was able to afford this way of heating. DH systems require a large scale approach on high investments; this was done in Utrecht in 1923. More common was the so called street or quarter heating, which was initiated by corporations and building companies. Customers were not able to choose, but the opinions afterwards were positive and the much higher price for energy was able to compensate the comfort of living in such houses. This trend was initiated before the second world but afterwards, it only expanded on a small scale.

Heating Period 1940-1960

Gas was introduced for the customers who could afford it, for it was a quite new and expensive way of heating. Heating was still most commonly done by coal based heating systems. Many households were forced to heat on coal, because of financial reasons. In the fifties, another phenomenon was added to the heating market: oil based heating. This possibility was more expensive than the coal based heating, but less expensive in comparison to the gas heating. The price of coal was rising and oil based heating became more and more popular due to the better regulating possibility of this system. Still, the majority of the houses till 1960 were heated by coal.

In 1950, minister Joris in 't Veld of the Ministry of Social Housing decided to go for quantity rather than quality. *'DH was probably desirable, but not necessary'*. No financial support was established for social housing. Another aspect was the freedom of choice, which was important. The government was not giving priority to more comfort in heating, but in more houses shortage. In other EU countries more initiatives were set up for collective heating in houses.

Warm tap water was used only for 1 third of the population in 1960 and was seen as a luxury. Fifteen years later, almost 95% of the households had warm tap water. This luxury product changed quite fast in a very common one.

Heating period 1960-1980

This period is characterized by the increasing of gas use, due to the discovery of gas fields in the North Sea, in 1959, by the Nederlandse Aardolie Maatschappij (NAM). In a very short time, plans were made for a distribution network for this gas, which transformed the coal and oil based heated houses in the next ten years. Roughly 75% of the houses became connected to this gas. Even the rural areas were supplied with a gas network.

Four main reasons for this rapid transformation can be mentioned:

- Gas was a 'cleaner' method to heat
- Gas was cheaper than coal or oil
- Gas to everyone means a stable market, non-dependent on fluctuating prices of oil and coal
- Comfort for everyone

From 1960, pressure on the government for implementing central heating was made by architects, corporations and municipalities. Due to this development, more and more houses were built with a central heating system. The low price of gas results in a higher energy use. The discovery of the amount of gas in the Netherlands contributed to the increase of gas use. In the sixties and seventies several initiatives for DH or quarter heating were common, but gathered less attention due to the huge gas amount discovered in Slochteren. The government feared the upcoming nuclear power and, for this reason, huge amounts of gas were sold to foreign countries for a particular low price.

Heating period 1980-2010

In the early eighties, some district heated areas were established in the Netherlands, but, still, not on a wide scale. The huge gas amount was still the driven factor for heating our houses. In the nineties, the energy market (gas and electricity) was liberalized; more competition, both at national and international level, for suppliers was expected, resulting in lower prices for the consumer. The price for gas was increasing, thus the need of saving energy became more interesting and so more efficient gas boilers were installed. On average, two thirds of the energy in the house was used for space heating. Business in reducing energy by insulating, installing double glass or other saving method was expanding. Still the use of gas was important and in 2010 roughly 95% of the houses were heated by gas (Propaan.eu, 2011). Some initiatives such as heat pumps and sun boilers were established, especially in the new build housing industry.

In the beginning of the 1980 cooking on electricity became more popular. In 1985, almost 20% of the households were cooking on electricity. The others were cooking on gas and in 2010 most households were cooking on gas.

From 2010

Het Dutch new law on heat, 'Warmtewet' was established by the government on 10 February 2009. This law was supposed to contribute for a better implementation of heat in the calculations. Today, this law is still not yet implemented and the government would like to adapt it for a better measuring of heat. The 'Warmtewet' will probably launch in the first of January 2012.

Next to this, the development in SDE+ (Stimulerend Duurzame Energieproductie) policy, the Dutch governmental support for RE projects, is currently unclear. In the end of May 2012, the Ministry of Economical Affairs published the provisional payback data about the heat. According to the energy reduction targets of the Netherlands, heat will be more interesting to invest in. The government should make use of heat in a more efficient way. The future of heat will expand by this policy, within a plan up to 2020.

4.1.2 Stakeholders

The electricity and gas sector are sectors in which societal interests meet financial interests. This makes the sectors complex. A lot of stakeholders are involved and they often have conflicting interests. This makes a cooperating view on electricity and gas' future supply more difficult. On a national level, the sector is liberalized but some general interests are still protected by public ownership and law.

The consumers are the most passive stakeholder. Their need is only safety, quality, availability and a reasonable price for their electricity and gas. Except from the price, these needs are surely covered, because the Dutch networks are among the best in the world. Although this stability in quality, the opinion of the consumer is changing to a more active one, because of the raising prices. Most users are small users and see the network as the public utility it always was.

The government has to prepare new laws and maintaining rules on energy. They have an important force to steer the national energy sector. They have to guide the sector from a (cheap) gas sector to an (expensive) RE sector. Economic grow and free market might go well together, but will be disturbed by legislation on RE. The governmental institutions have the power to confine the liberal parts of the sector and stimulate new RE programs. Surely, the sector will change in the future.

The production and supply companies are in large amount and they trade electricity/gas for selling it to the end users. Most of these private companies are part of the European energy market. The biggest Dutch energy companies tried to merge a few years ago, but they failed. Recently, the biggest energy companies in the Netherlands were sold: NUON was bought by the German RWE and Essent by the Swedish company Vattenfall. The biggest producers of energy are now owned by foreign companies. The interest for more development in electricity, which is a focus point of the Dutch government depend now on the (foreign) companies. Some opportunities for electrical cars can be taken. On the other hand, reduction in energy consumption and increase of micro generation energy supply is a threat for their business.

The network operators have a public character and have the responsibility to provide, maintain and transport energy to consumers on the most efficient and safe way. These operators are publicly owned private entities. Some are fully owned by public organizations. The current developments on international smart grids in electricity are important for the network operators. The future of smart grid seems to be important, due to the possible transformation of the transport sector from oil based engines to electrical based engines in the future; their network should be adapted for this development.

Legislation

The current system of regulation of electricity and gas networks has been implemented at the end of the twentieth century. Nowadays, European legislation is made for the internal market on electricity and gas. This is made for an open concurrent market and the trade of CO₂ emissions can be coordinated easier. Initiatives on micro or small RE have a better way to survive within these rules.

The Electricity Act 1998 and the Gas Act regulate operational activities relevant to a better use of the electricity and gas networks. Separate companies are charged with operating these networks. They are referred to as regional network operators. The Energy Chamber of the Netherlands Competition Authority (NMa) guards general access to electricity and gas networks. Tariffs and conditions concerning access and transport, as set out by electricity network operators, should not discriminate against anyone. NMa monitors the transport tariffs employed by gas network operators. Unlike electricity network operators, gas network operators are not legally bound to access and transport. However, their transport conditions and tariffs should not discriminate against consumers who are dependent on their supply. NMa annually fixes transport tariffs for regional gas network operators.

Labelling houses

Since 2008, sellers and renters of houses have to show the energy label of the house to the new owner/renter. The houses are labeled from A++ to G. Among the persistent critique of the system, the adapted energy labeling method is introduced in 2010. This label or report shows the energy use per m², but also the possible energy reducing methods for the specified house.

Label	EI (Energy Index) in MJ/m ² /Year
A++	<0,51
A+	0,51 – 0,70
A	0,71 – 1,05
B	1,06 – 1,30
C	1,31 – 1,60
D	1,61 – 2,00
E	2,01 – 2,40
F	2,41 – 2,90
G	>2,90

Table 3: Energy labels for houses in the Netherlands.

4.1.3 Future

The near future will be positive for heat. The new law gives opportunities for new projects and a financial support will be established for heat generated by RE. This is forced by EU pressure to reach the EU targets, which should imply increasing sustainable district heating. The target in 2020 is at least 14% RE for the Netherlands. The Netherlands stuck by on 4% in 2010 (Eurostat, 2010). The current policy on increasing renewable energy by wind power cannot be sufficient for the formulated targets. Research is done on heat, geothermal heat and other applications in heat. Potential heat and heat demand maps will be developed in the nearby future.

Discussion on nuclear power is still going on. Delta (Dutch energy company) would like to build a second nuclear power plant. They have already advanced plans to build it in the nearby future in Zeeland. They would like to increase the nuclear power share from 2% now, to 10% in the next 10 years (VARA, 2011). One of their targets is the CO₂ free society in 2050.

2050:

The contours will be given for 2050 (Energierapport, 2008):

The Netherlands will have lots of gas power plants, not only natural gas, but even biogas will play an important role. The heat demand will be reduced individually, but even in the industry by cooperating. The personal cars will use electricity, bio fuel or fuel cell powered by hydrogen. The Energy research Centre of the Netherlands (ECN) made programs for 2020 to reach the goals in renewable energy and energy reduction.

Of course these contours are not defined in a detailed way. At the moment, the decisional power regarding policies in the Netherlands is shared by four different ministries; this is undesirable and does not fit with consistency and strength (Burgerininitief, 2010). An independent energy transition commission should inform the government for terms of 6 years, according to this law. A lack on long term vision is mentioned in this law.

Nowadays, the policy is vulnerable because of a lack of long term vision. In the end of 2010, a new gas power plant opened, while the government is still debating over the nuclear power programs. At the same time a huge wind park called Noordoostpolder is planned. Fortunately, energy and climate is one of the seven focus points, according to the Miljoenennota.

The expectations from different institutions vary. The research on RE is important for a sustainable future, but some predictions about gas supplying are also satisfying regarding to 2050. The exact future is difficult to predict. For sure, the energy sector will change the next decades and an active role in this is important to maintain a major key player in the energy sector.

4.2 Innovative projects in the Netherlands

In history, the Netherlands is famous for the original wind mills. They were an innovation and very important for our economy during the golden century. Wind mills were very important for the reclamation of flooded land. In the Netherlands, we still have several innovative projects; this section describes the most interesting projects on heat (distribution) in the Netherlands

Purmerend: District Heating 2.0

The District Heating network in Purmerend is running on RE: geothermal heat and biomass. This network should be operational in 2014 and will reduce CO₂ emissions of 100.000 ton Equivalent per year. The existing buildings will get profit out of this: the use of only RE with a high efficiency on heat supply. Nowadays 24.000 households and 1000 companies are connected to the grid. The system is running 80% on RE and in 2014 this will be expanded to 100%.

The European Commission supports this new initiative of district heating, and gave a support of 1.8 million Euros, as part of the subsidizing program European Local ENergy Assistance (ELENA). This is the second project which receives money from ELENA in Europe (EIB, 2010).

Citizen initiative

Every year, many inhabitants apply for the grant for local solar panels, but unfortunately, this grant is finished usually in one day. That was the reason for launching the foundation wijwillenzon.nl. This initiative of several fanatic RE citizens allows customers to install their own solar panels for a reasonable price. The foundation tries to get an order of 10MW of solar panels in China for a cheap price. These panels can be bought in several possibilities. The payback time of these panels is between 12 and 15 years, based on the current energy price. This project proved a success and many potential customers were set on a waiting list.

Packet	Panels	Price (incl. VAT and transport)
A	6 Panels 1410 Wp	€ 3304,65 (incl. VAT and transport)
B	12 Panels 2760 Wp	€ 6071,40 (incl. VAT and transport)
C	16 Panels 2960 Wp	€ 6439,11 (incl. VAT and transport)
D	3 Panels 555 Wp	€ 1359,00 (incl. VAT and transport)

Table 4: Different possibilities (A-D) of wijwillenzon.nl
Source: www.wijwillenzon.nl

Drilling (heat) pipes

The drilling of pipes has been used for many years, with, usually, gas and oil pipes being drilled in places nearby infrastructure like water, highways or rails. The use of (flexible) heat pipes is an innovation from the recent years. The new pipes for the waste incineration plant in Amsterdam were built under water, rails and highways. This was a relatively difficult and expensive job. In this way, a horizontal directional drilling (HDD) method was used. This

allowed for the position of the chuck to be measured with a remote control. In this way, a distance of approximately 1000 meter could be drilled without digging. In Amsterdam a pipe with a dimension of 700 mm was drilled over a distance of 700 m.

4.3 Possibilities for DH

As mentioned before, the first district heating networks were established in 1923 in Utrecht. In the seventies, more initiatives were introduced, but due to the cheap gas and the need for more buildings, the priority was given to build more and fast. The quality and reducing aspects came later.

Still now, some initiatives for DH networks are established. The government changed their policy in the 'Warmtewet' but this will become reality in January 2012. Until then, heat will be lower on the list of priorities. The possibilities for DH in the Netherlands are explained in 5 aspects: Technical, Political, Financial, Organizational and Sociological.

Technical

The technical aspects are important. 'Technically we are ready' is an often used sentence. We already have electric cars, RE solutions, solar panels etc. Most of these innovations are not yet widely installed. Still, more research is usually leading to a much better and evaluated product. The technical aspects on DH are mainly done by the Scandinavian countries and have a long history in this. We should implement this in our economy. Thermaflex is a company in the Netherlands who deliver pre insulated pipes for DH. These pipes are now mostly used for CHP.

Political

The Netherlands is not able to be stable in political long term situation. Within the last decades, many formations were not able to finish their mandate of four years. The problem is that the government has been, for many years, focused on gas and transforming from a gas nation into a sustainable renewable energy nation requires stable law. The 'Warmtewet' is essential for DH and should be implemented, adapted and maintained by the current developments in the heating and energy sector. The potential heat sources in the ground for geothermal heat should be reached and used more. Many municipalities have launched their heat storage maps. A strong focus and policy on the long term is important for a changing period to a RE society with DH.

Financial

The financial aspects are the most difficult aspects. A lot of companies and institutions want and are able to build DH networks. From a cheap gas heated society to an expensive RE sources country... we all want to be CO2 free and renewable, but we do not want to pay for it. This will be a challenge for the financial sector. High investments are needed for a long term approach. Cooperation between housings associations, private companies, government and customers are essential. A linkage to export of this sector can be helpful for the implementation.

Organizational

Transforming from a private gas boiler to a common district heating network is difficult to manage. Customers should have an energy supply in 'common'. Shared risks are difficult. Apart from that, DH networks requires a high financial invest and this should be covered by many partners. A good, clear and fair approach will be necessary for the future and implementing DH. Different partners for implementing the systems should be operating in the Netherlands, for the economy to be supported. Thermaflex is a Dutch company supplying pipes in forty countries. Their core product range over thirty years is developing and marketing insulation foams. The pre-insulated pipes were introduced in 2001 and Thermaflex is a true leader in technology (thermaflex.com). Research at the headquarters in the Netherlands is triggered by both customer demand and new insights from scientific research and processing technology development.

Sociological

The implementing factor of DH has also a sociological impact. During the last decades, people became more aware of their energy use. A green approach for a company is important and has an impact on the employees' lifestyle. Compact fluorescent lamps (CFL) are normal in houses and also, for example, 'het nieuwe rijden' was introduced to contribute for a milieu friendly drive style and many energy saving instruments can be used. Personal attitude is important in our individualizing society.

The discourse on climate politics so far is an expert and elitist discourse in which peoples, societies, citizen, workers, views and voices are very much neglected. There is an important background assumption which shares in the general ignorance concerning environmental issues and, paradoxically, this is incorporated in the specialism of environmental sociology itself – this is the category of 'the environment'. If 'the environment' only includes everything which is not human, not social, then the concept is sociologically empty. If the concept includes human action and society, then it is scientifically mistaken and politically suicidal (Beck, 2010).

This asked for more sociological approach for a climate/energy change. More cooperation or at least the feeling is needed between societies to implement DH and other RE solutions in the current energy system.

4.4 Conclusion

The Netherlands is a gas nation. Their heating and energy use history consists of natural gas. Unfortunately, within 20 to 30 years, gas can no longer be attracted from their fields and so, new ways of energy supplying and heating the houses should be found. New initiatives and RE sources have big possibilities in the close future. The Netherlands is lagging behind in the European targets, but there are many possibilities for new projects. DH is one of these possible future investments. The 'Warmtewet' is a step forward to the implementation of DH.

Undoubtedly, the next years will be focused on changing or a transition in the energy supply sector. Technically, we have enough experience. Political and organizational aspects are mainly controlled by the government. From the new possibilities for heat, DH would be an interesting market in the future. The financial aspect is the most problematic, because high investments should be done, which would be earned back years later. The consumer and the inhabitants of the Netherlands will play a more active role in the next years.

Next to these unclear plans for 2050, the discussion of nuclear power is still going on. The next years will be crucial for the plans to build a second nuclear power plant. Delta wants to expand their business from a 2% share of nuclear power, to a 10% nuclear power share of it in the future (VARA, 2011).

The decision of this reign period can be crucial for the next decades and for the approach toward an CO₂ free, environmental friendly way of generating our energy.

5 ANALYSIS

This paragraph gives us an analysis of the gained information. A SWOT analysis of implementing DH in the Netherlands will be given, followed by an overview of general focus points in Germany, Belgium, United Kingdom, Denmark and France. After that, there will be a presentation of the situation in the Netherlands, in comparison to these (brother) countries. At last, an energy scenario of 2050 in the Netherlands will be drawn and the possible ways of energy supply will be outlined.

5.1 SWOT analysis of DH in the Netherlands

The gathered information about implementation of DH in the Netherlands can be shown in a SWOT analysis. This figure plots the most important strengths, weaknesses, opportunities and threats from the Netherlands for implementing DH in a wide scale.

Intern	Extern
Strengths	Opportunities
National <ul style="list-style-type: none"> • High density of inhabitants • High demand of new buildings • Existing related (international) companies in DH • Reducing energy use District <ul style="list-style-type: none"> • Regional support. Cooperation with social housing industry and CHP plants are launching • In addition to the plans for geothermal heat • District plans for brown fields Local <ul style="list-style-type: none"> • Municipalities have already some central heating systems 	National <ul style="list-style-type: none"> • Experiences in Denmark • Overall implementation of the system by big projects such as Blauwe Stad, Leidsche Rijn. • New heat law for better economic values District <ul style="list-style-type: none"> • DH in combination with existing RE projects. High flexibility factor. • New housing projects are planned (wide scale) Local <ul style="list-style-type: none"> • Strong benefit products for the inhabitants
Weaknesses	Threats
National <ul style="list-style-type: none"> • Strong existing energy supply by private heat boilers. • Strong support and plans for nuclear power • Just opened a new gas power plant • No strong support for heat until now District <ul style="list-style-type: none"> • Local government is usual inactive, and an active attitude is needed for implementing DH Local <ul style="list-style-type: none"> • We can distinguish different local institutions. Strong support with the end customer is advisable. The local cooperation should be established. 	National <ul style="list-style-type: none"> • An inactive role in heat and focus on the current stocks of gas. New laws on heat should be introduced in a short time period. • Decisions in the next 10 years are crucial District <ul style="list-style-type: none"> • A crucial link between local and national is necessary through a good organized district institute. Local <ul style="list-style-type: none"> • The energy companies are structures on a new gas boiler. • People who bought a new gas boiler invest in their heating, how to deal with a different system?

Figure 21: SWOT analysis of DH in the Netherlands

5.2 Competition analysis

The countries around the Netherlands all have to deal with the same EU legislation. What are their prospects for a RE future in 2050? Which aspects are most important for the countries? Figure 26 shows us a QFD analysis of the different countries. A 5 points scale based on different data gives us an overview of the current status.

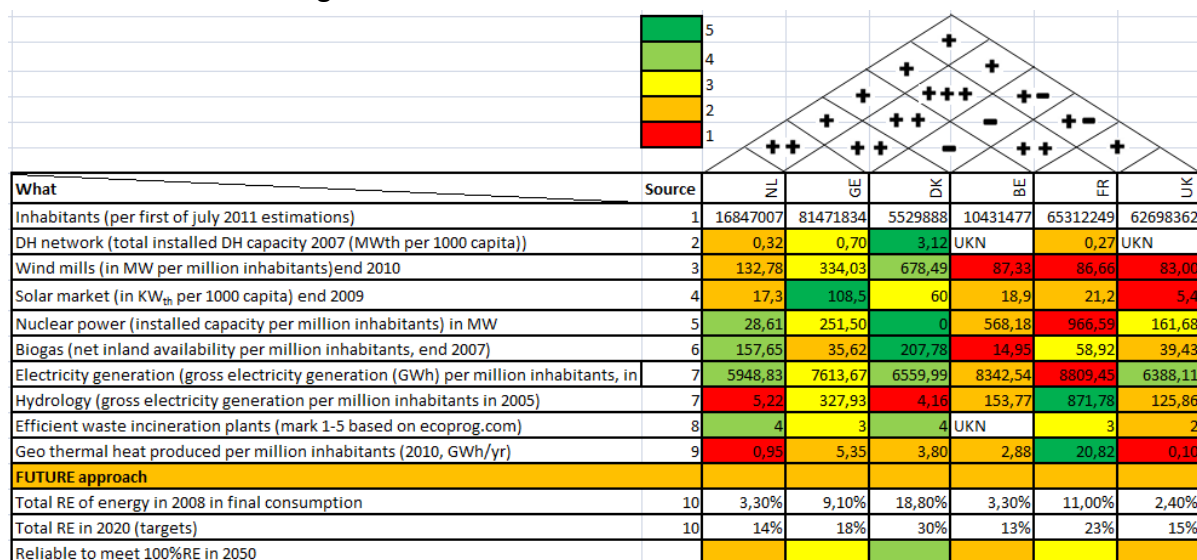


Figure 22: Competition analysis between different EU countries

Aspects to improve

District heating is not yet widely implemented in the Netherlands, whereas Germany and Denmark are doing much better in this. The new heat law in the Netherlands should improve the status of DH. Next to DH, also the share of wind power should be enlarged. Our country has a relatively big coastline and the government has approved plans for wind mill farm in the North Sea. However, if we look to our neighbor countries, we are lagging behind.

Apart from this, solar energy also deserves much of our attention. Solar panels are difficult to expand in the Netherlands, because of the lack of financial support by the government. Nonetheless, this will probably be improved in the next years.

Furthermore, geothermal heat announces to be important in the future. According to the figure, the Netherlands and UK are not yet accomplished in this way of generating heat, but the prognosis is quite good. Many municipalities have their own plans on geothermal heat, hence we can improve a lot at this point, especially in combination with DH.

Besides these, the government is highly considerate of using biogas as a RE source. We are doing well in comparison to the other countries. CHP is well introduced in the Netherlands, based on ecosprog.com, we can receive a 4 on the scale of 5. Perhaps, it is worth mentioning that Denmark has a bigger share, scoring a 5 on the same ratings.

Moving on to nuclear power, the current plans are vulnerable, due to the crisis in Japan, in 2011, more and more people are scared. The plans are advanced and can be increased a lot, this will lead to a higher share, which is not a positive development to the other RE sources. Lastly, the government should become more aware, that the energy saving methods should be improved to achieve the energy saving targets of the EU. These targets subscribe a 20% reduction in 2020 compared to the statistics of 1990. Although the amount of electricity used by inhabitants in the Netherlands is relatively low, but even so, we should decrease our energy demand in the next decades.

European trade

The trade between the 6 countries is difficult to measure. Based on the export and import between the countries, a linkage between the countries is established. In short a quick description about the countries:

Germany is the biggest in population and largest national economy in Europe. The economy of Germany can be mentioned by their innovative character. Cars, machinery, metals, chemical goods are important. Solar power technology and wind turbines are also important for their economy. Their trade to and from France is important for both of the countries. Agriculture is an important sector for France, but even the technological export in cars, machines, planes and tourism are considerable. The UK is importing a lot more than the export of products. Beverages, tobacco, manufactured goods and fuels are the most important export products. Belgium has a strong relation with France and the Netherlands, their neighbor countries. Their turnover of import/export is quite big for such a small country.

Denmark has a more export products with RE, Germany and the Netherlands are important export countries for it. At last the Netherlands, which has a strategic place. Many goods for Germany are based in one of the biggest harbors, the infrastructure toward Germany is very important.

If we look to the amount of import and export of the different countries, only Germany and the Netherlands have more export than import.

Country	Import (Billion dollar)	Export (Billion dollar)
Belgium	387.7	371.5
Denmark	116.4	114.9
France	692.0	601.9
Germany	1232.0	1498.0
The Netherlands	475.9	533.2
UK	636.0	464.9

Table 5: Import/export goods during 2008
Source: CIA world Factbook

5.3 Future energy scenario NL 2050

Scenario up to 2050, what is going to happen?

Many municipalities have targets to be CO₂ free or green targets. Still, these plans should be worked out and nobody knows the exact way to 2050 on the energy sector. Even so, we can say something about the nearby future.

Much of the legislation should be changed in order to have a strong and stable energy market in the Netherlands. The current plans consist of building huge wind farms. Unfortunately, they have many opponents, mainly from the municipality where the farms should be build. Some critical professors from the technical university are skeptical, as well.

Gas will most probably play an important role in the future. It is and will be the most important energy source for the next decades. Within the existing power plants, the new Maxima gas power plant, in Lelystad, stands out, because it was completed recently and promises to be one of the most efficient gas power plants in Europe.

Apart from these, the next 5 years will give us an answer in the Nuclear power plants of the nearby future. Oil and Coal fired power plants will gain less attention, due to the high CO₂ pollution.

The Netherlands can be transformed into a country with a much more environmentally friendly way of generating energy. Heat will also play an important role. DH networks will be more widely introduced and so will the local solutions on energy, such as heat pumps, private solar installations and thermal storage solutions.

Our countries next to us have a major influence on our transformation. In Germany, for example, the zero energy buildings are more standard than in the Netherlands, thus we can and should learn from our neighbor countries in order to achieve the international goal of reduction CO₂.

6 EINDHOVEN CHARACTERISTICS

All the gathered information can be translated to Eindhoven. The municipality of Eindhoven has ambitions, mainly on the Brainport concept, a business area with an innovative character. The RE ambitions are high of the municipality. What is established in Eindhoven in the last years? A short summary:

- 1 windmill
- 13 TS installations, within the TU/e (Biggest of Benelux)
- 31 Solar installations
- 2 Biogas installations

This paragraph will describe the possibilities of heat in Eindhoven. The big spenders will indicated and finally in a heat supply possible locations for Eindhoven.

6.1 Industrial areas

Eindhoven was actually established by Philips. Nowadays it has several industrial areas. The Eindhoven university of technology is official not part of the industrial areas, but business areas. These are important for the employment and economy of Eindhoven. Ekkersrijt also has an important value for Eindhoven, but is not part of the Eindhoven industrial areas.

The industrial areas can be divided into 3 different categories:

- Category 1: Development of the area's are under construction or not defined aim
- Category 2: Industrial area's with an important role for the SME.
- Category 3: Small industrial area's within a big influence of small social/economical values

Code	Category	GAS USE (M3)	Big spenders
DA	Manufacturing Food + Drink	796919	0
DB	Manufacturing Textile	90491	0
DC	Manufacturing Leather	1242	0
DD	Wood industry	189202	1
DE	Manufaturing Paperindustry	1133395	9
DG	Chemical industry	58311	0
DH	Manufacturing rubber	60555	0
DI	Manufacturing glas/cement	125922	0
DJ	Manufacturing Metals	1134180	6
DK	Manufacturing Apparatus (big)	567972	4
DL	Manufacturing Apparatus (small)	248118	0
DM	Manufacturing cars/combinations	20024	0
DN	Preparation for recycling	770731	1
Total		5197060	21

Table 6: Gas use, and the amount of big spenders in Eindhoven by category D of SBI 93.

Table 6 represents the gas use of the industry under category D. Category D of the Standaard Bedrijfsindeling '93 (SBI 93) contains the biggest energy using companies. The amount of big spenders is shown by the subcategory. Big spenders are companies with a yearly gas use of >50.000 m³ gas. The paper industry and steel industry has the biggest spenders, respectively 9 and 6.

6.2 Heat possibilities

The heat possibilities of Brabant are potential high. Although, Eindhoven has a high demand, but not enough companies who are giving heat. Moerdijk, in the north of Brabant has the opposite. The possibility to use this heat in Eindhoven is low due to the long distance.

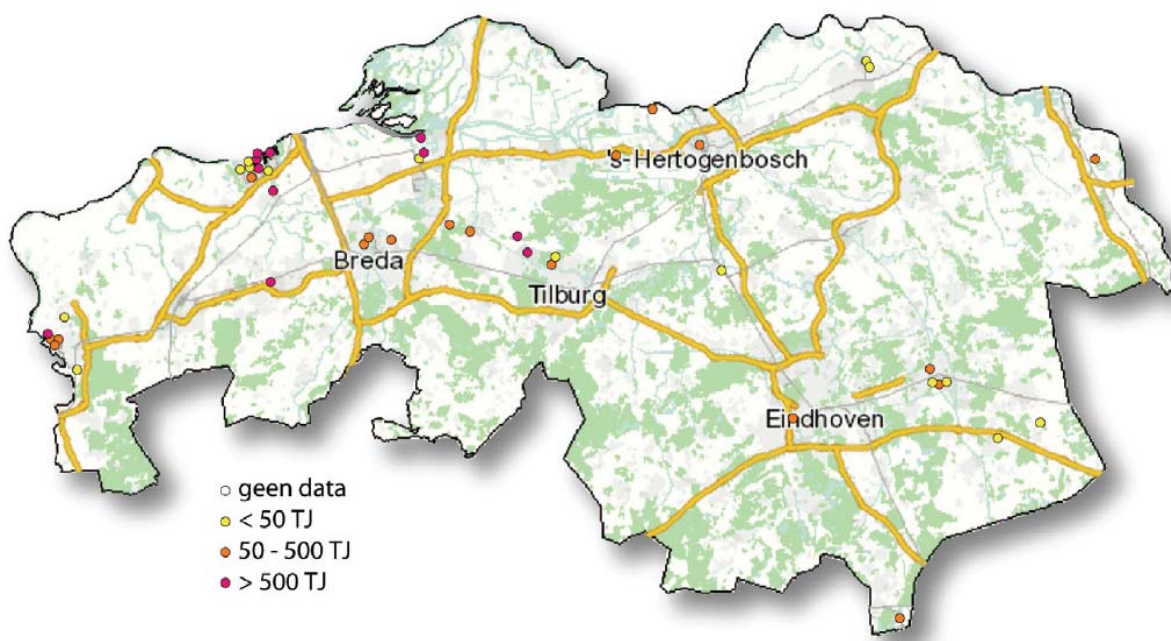


Figure 23: Current heat sources in Brabant
Source: Agentschap, 2011

The use of surplus heat at this moment can be found in the 'big spenders' on a low scale, and on the TS system of the TU/e.

6.3 DH implementation

We have seen the high demand of Eindhoven, but a low offer of heat. What are the final solutions? Figure 24 shows the final results with the industrial areas and the location of the big spenders in Eindhoven. Further research can be done for the final use of this heat.

Possible DH areas

Only one location, Meerhoven, is actually working with heat supply, but this is not part of the municipality Eindhoven. This district is already working with DH. The other possible area is Oud Woensel, next to the TU/e. This district can probably use the surplus heat of the University.

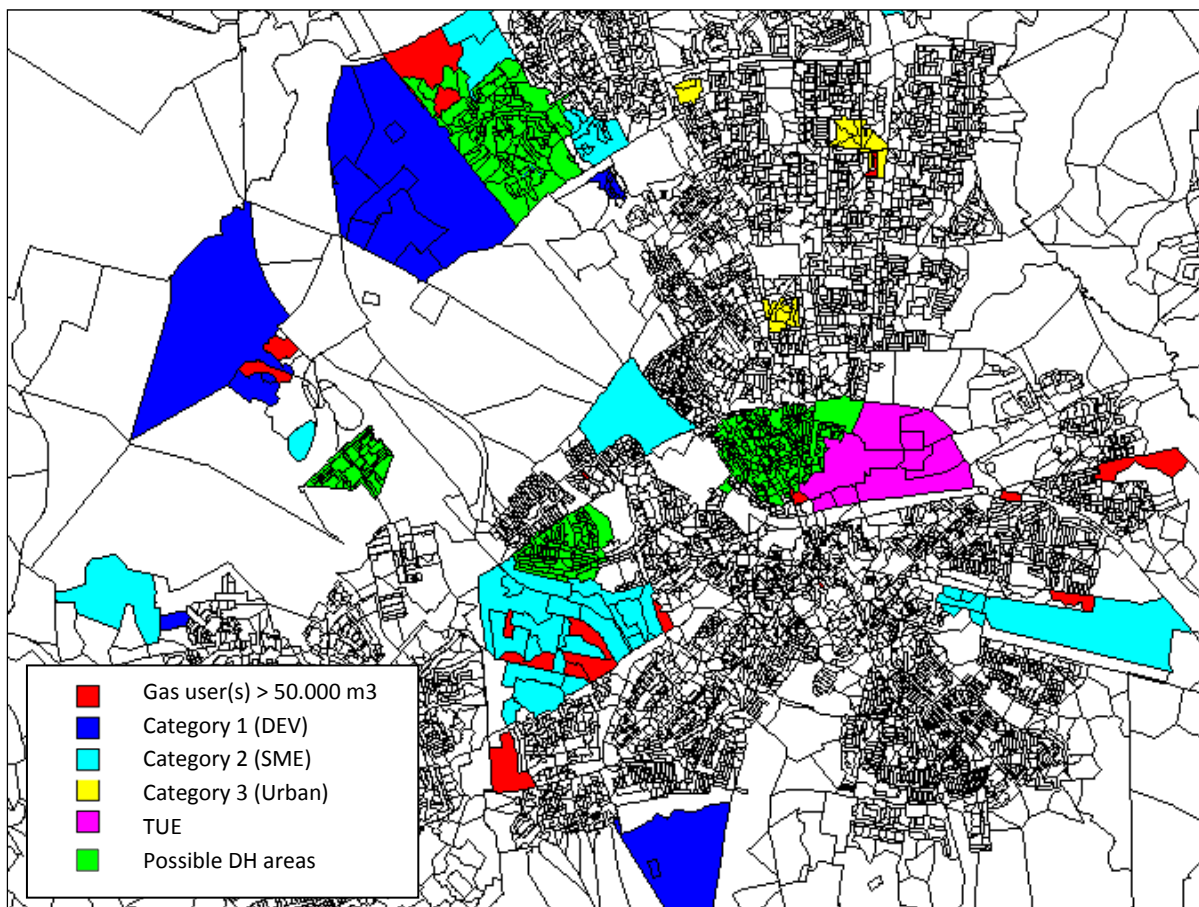


Figure 24: Industrial areas of Eindhoven, within the big spenders and the possible DH areas

6.4 Eindhoven University of Technology

The Eindhoven University of Technology, TU/e, was established in September 1986. The university is the only university in Eindhoven. The campus is in the city centre and is surrounded by green parks.

The university was heated by private installations. In 2002 the University decided to install a big TS installation, currently the biggest in the Benelux. This was done by the fact that the University was not allowed anymore to use water source to cool down.

The current main characteristics are roughly the same as the DTU in Denmark as we can see in table 7.

What	Amount
Number of students	7.118
M2 heated floor	332.071 m2
M2 building	400.000 m2
M3 building	1.400.000 m3

Table 7: Main characteristics TU/e

Year	Electricity (kWh)	Price (€)	Heating (kWh)	Price TS (kWh)	Gas	Price of gas (€/m3)	Water (m3)	Price of Water (€/m3)
2007	41.072.720	0,11	7.041.000	-	4.566.070	0,390	224.911	1,807
2008	37.440.981	0,11	6.700.000	-	4.922.026	0,418	173.502	2,25
2009	41.105.411	0,11	8.256.569	0,008	4.634.848	0,409	176.466	2,12
2010								

Table 8: Energy statistics of TU/e. Source: Energiejaarverslagen TU/e.

The TU/e has many agreements on energy, which are leading to a lower energy price. The electricity prices are set until the end of 2014, with a price of €0,11 per kWh. Solar panels cannot be economical attractive for the TU/e by this price level.

7 CONCLUSIONS, DISCUSSIONS AND RECOMMENDATIONS

Heat is and was important to generate high comfort in houses. We want to have hot water and a warm place in the future. This chapter will present the results and conclusions which can be drawn out of the gathered information.

7.1 Conclusions

Research question 1:

RQ1: How became District Heating a success in Denmark and what kind of new developments can we expect in the future?

The key factors of DH, and the history of DH are described in paragraph 4. It is and was one of the important ways to reduce energy consumption in Denmark. During the last 40 years, policy, consumers and governmental institutions made effort to reach important goals on energy. Their results can be seen in the years, in increasing the share of RE and reducing energy use. Strong effort from the government was important, but also the international attention contributes to a high RE supply of Denmark.

The DTU research group of DH is continuing developing DH networks for the future, mainly the future housing concept, low energy houses. These future prospective shows results for a low energy house district, where houses use less energy, but the network can be still build with profit. During my stay at DTU, I was introduced in the DTU research group on DH. I became aware of the future in DH. The passive houses will be build more and more in the future. A strong basis can be established by a heating network before the construction phase of these houses. A triple pipe system together with a high insulated house is attractive for the future.

Research question 2.

RQ2: What changes in an organizational* way should be made for implementing district heating in an effective way in the Netherlands and how can we see DH in Europe in the future?

*Organizational will even focus on the different renewable energy sources in future prospective in 2050 the Netherlands

The Netherlands seems to be a good location for implementing DH, since the density of the inhabitants is high, which will lead to shorter heat supply pipes. Although we have already some DH networks in the Netherlands, more networks and in a widely scale can be possible to reach the 20% reducing energy targets. Important for a good implementation is the organization of this product. Important aspects are described in paragraph four. The most important aspects are the support from and by the several institutions. End consumers,

governmental institutions as well the energy supply companies should put effort to generate a public heating network of the future.

DH can be one of the elements for a RE approach towards 2050. For an approach towards 2050, a look into the energy supply of the countries around the Netherlands is important. Denmark profiles themselves with their export of RE technology. Nuclear power is still important for France and Germany put effort in solar technology.

For sure, the decisions in the next years should have a strong basis for the future. The decision about implementing new nuclear power is important as well the new legislation about using heat and their financial consequences. New legislation, steering policy, security of supply, safety and a strong (financial) approach are important for the future.

7.2 Discussion

This research study shows general findings about renewable energy. It is always useful to zoom out into a general level to see the basic elements and focus points of others. In this study this is done in a very general way. More detailed information could be more useful, but was unrealistic to reach in the time limit of this study.

Many institutions or companies which has an interest in the development of energy supply, such as oil companies, but also companies working in the RE sectors. They would like to steer the future, for this reason, they made approaches and reports towards the future on energy supply. Their reports differ a lot and should be nuanced. A view without an interest in these reports and companies are important to reach the final goal with the best national and public interest. Already different foundations without financial profit are established to prospect the future aspects.

Although this shows the most general points, an insight in the DTU research group of DTU gathers the newest information about DH in the future. Denmark looks like the Netherlands in many ways. This will help to make more use of heat in the Netherlands.

7.3 Recommendations

Although these results are focused on general findings, more detailed research can be followed up.

For a good implementation of DH inside a municipality the process inside a municipality should be investigated so a detailed manual for municipalities can be made.

Large self-sufficient communities are more and more popular. The energy supply of such a district is usual interesting, and some developments have proven their success. District Vauban, in Freiburg (Germany), for example, which has its own solar panels to fulfill their energy demands. But also EVA Lanxmeer in the Netherlands has wall heated solutions in combination with solar collectors. A manual can be written within the DH possibilities for a specific urban area within a driven force from the inhabitants.

We noticed the need of a strong legislation for using heat. A study about the impact of legislation on energy should be interesting within different scenarios for the next years.

The most passive stakeholder in energy, the consumer is changing to a more active one. What is the range of effort of this group? To answer this question, more research should be done on the willingness of consumers/customers to invest in their own energy supply.

Last, financial structures are important for construction DH network. More research can be done on this subject in order to gather shorter payback period.

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Steen Hansen (CAS head of installations DTU)

Bjarke Nonbøl (Energymanager BMS, DTU)

Svend Svendsen (Professor DTU)

PHD District Heating (Research Group, DTU)

Odd brusgaard (VEKS Operation Center)

Thijs Meulen (Energieadviseur TU/e)

Note figure 22:

Different sources/websites were used:

International trade

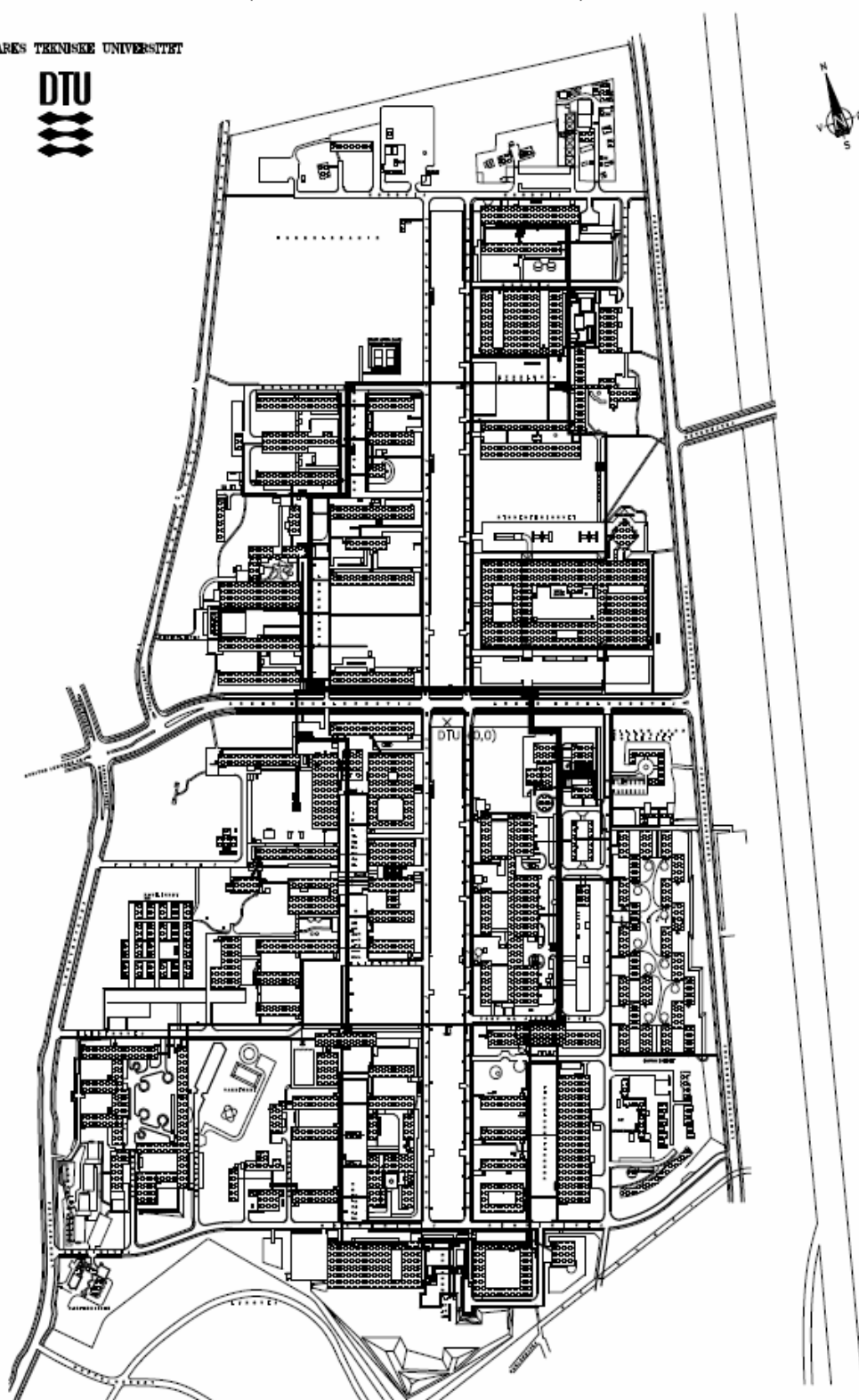
Country	Document
DK	http://www.danishexporters.dk/scripts/danishexporters/export.asp
BE	http://www.abh-ace.be/nl/binaries/Buit%20Hand%20-12m%202010_tcm448-128148.pdf
UK	http://www.bis.gov.uk/assets/biscore/international-trade-investment-and-development/docs/u/11-719-uk-and-single-market.pdf
FR	http://www.ambafrance-nl.org/spip.php?article135
GE	http://www.dnhk.org/nl/niederlande/fakten/handel-met-nederland/
UK	https://www.uktradeinfo.com/index.cfm?task=Data

For the different energy sources:

Source number	Document
1	https://www.cia.gov/library/publications/the-world-factbook/fields/2119.html
2	http://www.euroheat.org/Statistics-69.aspx
3	http://www.ewea.org/fileadmin/ewea_documents/documents/statistics/EWEA_Annual_Statistics_2010.pdf
4	http://www.estif.org/fileadmin/estif/content/market_data/downloads/2009%20solar_thermal_markets.pdf
5	http://www.nei.org/resourcesandstats/documentlibrary/reliableandaffordableenergy/graphicsandcharts/worldnucleargenerationandcapacity/
6	http://data.un.org/Data.aspx?d=EDATA&f=cmID:BI;trID:0914#EDATA
7	http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-GB-07-001/EN/KS-GB-07-001-EN.PDF
8	http://www.ecoprog.com/en/pdf/studies/studie_waste_incineration.pdf
9	http://www.nationmaster.com/graph/ene_geo_pow_use-energy-geothermal-power-use
10	http://www.decc.gov.uk/assets/decc/statistics/publications/trends/articles_issue/1102-renewable-energy-eu-2020-trends-art.pdf

APPENDIX

DANMARKS TEKNISKE UNIVERSITET



DTU map of the Tunnels

SUMMARY

THE BENEFITS OF DH IN THE NETHERLANDS

A research study on main aspects of DH and RE in the Netherlands, based on experiences in Denmark

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ABSTRACT

The energy sector will change radically in the next years. The implementation of renewable energy sources will be fundamental. The implementation will ask for changes in political, organizational and in financial ways. The oil/gas based energy supply will change to a renewable one. What are the main characteristics of the Netherlands? How are other countries doing? Most of our daily energy use is ending in heat, how are we dealing with heat and what are the prospective for the Netherlands?

Keywords: District Heating, Renewable Energy, Environmental science, Heat supply system

INTRODUCTION

The worldwide energy sector will change in the future. Some fundamental changes will arise in this sector. High class renewable energy projects will be arise, the transport sector has to deal with other energy sources and the normal life of an inhabitant will change due to the low energy houses, while we still want to heat our spaces and tap water, and probably electric cars. In other words, an exponential economic growth, associated with increasingly consumption, could not be sustained on the long run on a planet with the current resources.

Energy in the world

We have been using energy in the past and we will continue to do so in the future. Which consequences are expected for the worldwide energy problems? Global warming, carbon dioxide (CO₂) pollution and melting ice caps; these are raising problems nowadays without a solid and clear solution. How did we use energy in history, how much energy are we using in ratio to the continents? Which part of the world uses the most?

We, the people in this world, are using in one year approximately 460 EJ. This is equivalent to the amount of solar energy reaching Earth in only one hour (Crabtree and Lewis, 2007). Therefore the sun is a powerful source of energy, which we can use a lot.

The stock of the primary energy worldwide is changing. While our grandparents used less than 1000 · 10⁶ tons coal equivalent, the energy use grew with a factor 20 between the year 1900 and 2000. We still need to use energy in the future, because of heating our houses and using an increasing amount of (electrical) apparatus. We will need energy for the economical values, and for a sustainable living climate, but we should consider our society for the very far future. Although the world primary energy consumption consists mostly in oil, coal, natural gas, nuclear power and hydro energy even more green energy sources has been introduced. Contrarily to fossil fuels, which give us a completely controllable energy flow, renewable energy sources are more uncertain, they are often unavailable at the time of demand and in compliant with the specification of demand.

The energy use in Europe is, in according to the world energy use, a smaller amount, but even an alarming factor. Our current energy sources in Europe are not sufficient for the future. For an energy policy, a mutual EU energy strategy for Europe is made up for the time period until 2020. In March 2007, the European Council presented their targets: 20% renewable energy, 20% reduction of CO₂ emissions and 20% energy reduction in 2020.

Although in these days, many countries are still lagging behind in reaching these targets. Many possibilities are launched in renewable energy solutions. Different pilot projects have been initiated, implemented and evaluated; nevertheless, due to the economic crisis starting from 2007, more and more countries refuse to put more effort in reaching these targets in 2020. In order to limit the energy losses, countries with cold climates, such as the Scandinavian countries, Poland and Estonia, the district heating technology in urban areas has been used for many years and its use is widespread (Froning, 2003), while the investments in sustainability in other countries, where mild climates prevail, are lagging behind.

Apart from that, some projects are successful, especially in Denmark. Wind power, solar power, water power and smart distribution methods are widely used. An important amount of the Danish export market is related to renewable energy.

DISTRICT HEATING

District heating is a centralized system for distributing heat to consumers, for and by consumers. The heat can be obtained by different sources, such as fossil fuels, biomass, geothermal heating, central solar heating, heat-only boiler systems and even nuclear power stations. Centralized district heating plants in high density area have higher efficiencies than smaller localized boilers (scaling). District heating systems are often owned by the consumers, so they make direct profit out of it.

Apart from that, an advantage of centralized energy distribution is, that it will reduce heat losses (fig 1). District heating has a big potential in the European countries, but the use of DH systems is at the moment not balanced between the different countries. Denmark is one of the key-players in the district heating and the systems seem to be fruitful after a long term period of implementation district heating as a cornerstone of the Danish

Energy Policy. Currently, the system is introduced in 60% of all the Danish households, and in the Copenhagen area in almost 98% of the households (DBDH, 2010). The companies in this system, district heating companies, are owned by the consumers. Thus, all the benefit will go to the consumers and this will lead to a lower energy price. A strong support from the municipalities and authorities is required. Nowadays, in most research the technical or financial aspect are most highlighted in applications of district heating. Apart from that we can see some developments in DH system for low energy buildings. More passive energy houses can be expected and the implementation can be adapted in the new DH systems in Europe. In theory it is possible to obtain a low network heat loss although all houses connected to the DH system have a very low heat demand (Olsen et al., 2008).

During the years, the relatively simple principle of district heating has shown large benefits. However, the implementation of DH systems in European countries is diverse; some countries employ district heating, others not. The Netherlands lies quite far behind others in distribution networks, because the policy is mainly focusing on electrical energy, not on heating (Stichting Warmtenetwerk, 2010). However, if we compare the Netherlands with for instance Denmark, we can see large similarities, especially in the density of the population, and the high scale of urbanization. DH can be an interesting system in the future in the Netherlands. However, a successful implementation of this system will require insight in several important challenges that can be expected.

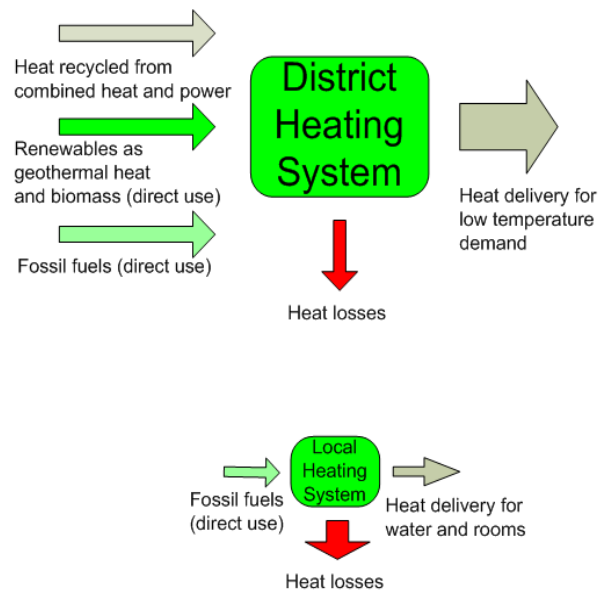


Figure 1: Fundamental idea of District Heating and Local Heating, less heat loss and better pollution control. (Adapted figure from Euroheat and power, 2009)

The successful implementation of district heating systems in the Netherlands requires a stable political and organizational approach, in which governmental agencies are responsible for improving the attractiveness of the system through policy, and in which the organizational structure should provide for the right stimuli for consumers. What kind of stakeholders, suppliers and constructors are required? Such a justified approach is missing in the current Dutch energy policy. Therefore the research design is about DH in the future and about RE in the future.

RESEARCH DESIGN

Research Questions:

In order to give an answer on the problems mentioned, two research questions were set up.

Research question 1

RQ1: How became District Heating a success in Denmark and what kind of new developments can we expect in the future?

Research question 2

RQ2: What changes in an organizational* way should be made for implementing district heating in an effective way in the Netherlands and how can we see DH in Europe in the future?

*Organizational will even focus on the different renewable energy sources in future perspective in 2050 the Netherlands

Goals

We can expect several 'sub-solutions' for our energy problem, one of the potential solutions is District Heating. DH can be found in Denmark, and is widely installed in the country. I would like to gather information about the future of DH in Europe, even in combination with the low energy houses. What is the future.

And if there is a future, how can we implement DH systems in the Netherlands. Which problems do we have to deal with? What are the companies/partners who will be interested?

Next to this, how is the Netherlands in RE resources at the moment, if we compare our neighbor countries? Last of all, how can we see our future scenario?

Method

Through the fact that I had the opportunity to take part in the DTU research group, I was able to gather information about the current research of the professors on DH.

Next to this, a QFD method is used to compare the implementation of RE in the countries like Germany, England, Belgium, France, the Netherlands and Denmark. Within this scheme a stable insight can be generated. Last, some future lines can be drawn for the energy future

of the Netherlands. What can we expect in the future about fossil fuels, taxes and energy developments?

A case study is done to find the best DH system or heat use in the municipality of Eindhoven, the Netherlands. Gas data will be converted to big spenders with MAPinfo.

DENMARK AND THE NETHERLANDS

Denmark

The Danish energy sector sets an example for other countries due to its rapid change from a 100% energy importing country to a net exporter of energy. The power of the government in this transition was vital. Therefore, the share of main energy institutions in Denmark is still powered by the government or regards it as a major shareholder. The energy sector has targets which are exceeding the European rules. Another main aspect is the export of energy related products and knowledge. The energy sector of Denmark is important for neighbor countries, since, through this cooperation, the expectation of changes in the energy sector will be easier to estimate.

From the 20's and 30's DH solutions with diesel was established. During the time until WW II, these plants or systems were quite modest and only limited to a small area, and still running on diesel. These plants created a basis for expanding the heating supply networks. After the world war, large central power plants were introduced for the electricity. The smaller heat plants were still used for the heating systems. We can see the steam based DH system as the first generation DH.

Actually, just in 1973 the Danes realized their vulnerability of energy supply, and the energy consumption per inhabitant was extremely high. Energy savings were important, while the energy at this time was almost 100% imported from fossil fuels to generate heat. The second DH generation can be seen in the form of heating water in tubes. This water will have at least a T_{supply} of 100° C, up to around 120 °C. Today, this way of DH is used in the big pipes from the primary heat to the secondary heat generation, in the transmission network in city level.

The third generation is most common nowadays in the build environment and supplies the houses of heat on a lower temperature. A T_{supply} of 80-90 °C with a T_{return} of 40-50 °C is normally used with a ΔT of 30-50 °C. This is more efficient than the previous one and well connected to the radiators in our houses.

The fourth generation is based on a much lower temperature. This generation is not yet implemented on a wide scale. It has a great opportunity to save energy in the build environment. Different possibilities can be used, but the main idea is a T_{supply} of 55 °C and a T_{return} of 20-30 °C. The supply has a limit, due to the existence of the bacteria Legionella. Research is going on in Dresden University to find solutions to use water of a lower supply temperature without or a lower risk of legionella.

Most of the networks are mixed networks of the second and third generation. The fourth generation is based on the new low energy houses and future houses with a very low energy use.

The existing DH projects have proven their success. The new generation of DH networks within a T_{supply} of 55 °C is developed with a very low energy use. At the moment, the limit is the bacteria. Large-scale building projects have a preference for these networks, for it is the easiest way to implement the pipes. The organization behind one of the biggest heat transmission networks in Europe is complex, but has proven its success. In conclusion, DH projects require, in the beginning, high financial investments and, apart from this, have a long payback period. Nevertheless, one should not underestimate the need for sustainability nowadays and, hence, should think more of long-term benefits rather than fast, but environmentally destructive profits. In future DH will be a main energy focus point, next to the increasing share of RE sources for a future of 100% RE in 2050.

The Netherlands

The Netherlands is a gas nation. Their heating and energy use history consists of natural gas. Unfortunately, within 20 to 30 years, gas can no longer be attracted from their fields and so, new ways of energy supplying and heating the houses should be found. New initiatives and RE sources have big possibilities in the close future. The Netherlands is lagging behind in the European targets, but there are many possibilities for new projects. DH is one of these possible future investments. The 'Warmtewet' is a step forward to the implementation of DH.

Undoubtedly, the next years will be focused on changing or a transition in the energy supply sector. Technically, we have enough experience. Political and organizational aspects are mainly controlled by the government. From the new possibilities for heat, DH would be an interesting market in the future. The financial aspect is the most problematic, because high investments should be done, which would be earned back years later. The consumer and the inhabitants of the Netherlands will play a more active role in the next years.

Next to these unclear plans for 2050, the discussion of nuclear power is still going on. The next years will be crucial for the plans to build a second nuclear power plant. Delta wants to expand their business from a 2% share of nuclear power, to a 10% nuclear power share of it in the future (VARA, 2011).

The decision of this reign period can be crucial for the next decades and for the approach toward a CO₂ free, environmental friendly way of generating our energy.

Eindhoven

A case study for the Municipality Eindhoven. The municipality of Eindhoven has ambitions, mainly on the Brainport concept, a business area with an innovative character. The RE ambitions are high of the municipality. What is established in Eindhoven in the last years? A short summary:

- 1 windmill
- 13 TS installations, within the TU/e (Biggest of Benelux)
- 31 Solar installations
- 2 Biogas installations

Eindhoven was actually established by Philips.

Nowadays it has several

industrial areas. The Eindhoven university of technology is official not

part of the industrial areas, but business areas. These are important for the employment and economy of Eindhoven. Ekkersrijt also has an important value for Eindhoven, but is not part of the Eindhoven industrial areas. The table shows the big spenders in the municipality Eindhoven.

Code	Category	GAS USE (M3)	Big spenders
DA	Manufacturing Food + Drink	796919	0
DB	Manufacturing Textile	90491	0
DC	Manufacturing Leather	1242	0
DD	Wood industry	189202	1
DE	Manufacturing Paperindustry	1133395	9
DG	Chemical industry	58311	0
DH	Manufacturing rubber	60555	0
DI	Manufacturing glas/cement	125922	0
DJ	Manufacturing Metals	1134180	6
DK	Manufacturing Apparatus (big)	567972	4
DL	Manufacturing Apparatus (small)	248118	0
DM	Manufacturing cars/combinations	20024	0
DN	Preparation for recycling	770731	1
Total		5197060	21

Table 1: Gas use, and the amount of big spenders in Eindhoven by category D of SBI 93.

CONCLUSIONS

In the nearby future, energy, water and food will be scarce in many countries. We are running out of fossil fuels, this meaning for transport sector a possible change into electrical transport. Electric transport will lead to a high demand of electricity and therefore difficulty in supplying it from the grid. The base load of electricity will be huge, and probably not sufficient with only RE sources. In the future, not only the way we use energy will change, but also the way to generate it. The fact that the energy prices are raising should make us aware of a need to reduce energy demand.

For Eindhoven, the big spenders are located and with making use of them and other heat sources, DH can contribute in the municipality of Eindhoven.

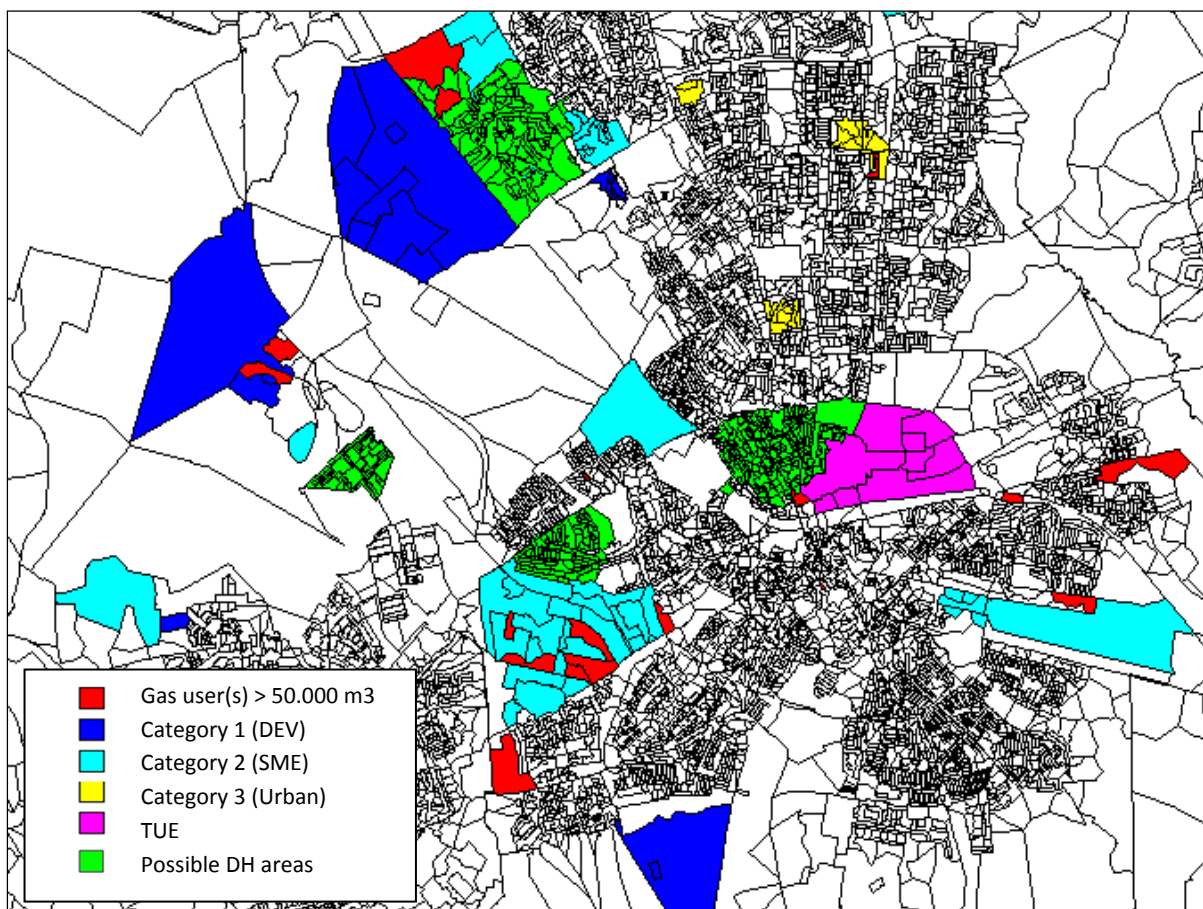


Figure 2: Industrial areas of Eindhoven, within the big spenders and the possible DH areas

Competition

The Netherlands is lagging behind in order to meet the 20% RE sources in 2020. DH can contribute in a national scale. We can see that the Netherlands is lagging not only in heat, but even in wind power and solar power. We should make a future approach up to the future.

The DTU research group of DH is continuing developing DH networks for the future, mainly the future housing concept, low energy houses. These future prospective shows results for a low energy house district, where houses use less energy, but the network can be still build with profit. During my stay at DTU, I was introduced in the DTU research group on DH. I became aware of the future in DH. The passive houses will be build more and more in the future. A strong basis can be established by a heating network before the construction phase of these houses. A triple pipe system together with a high insulated house is attractive for the future.

End consumers, governmental institutions as well the energy supply companies should put effort to generate a public heating network of the future. DH can be one of the elements for a RE approach towards 2050. For an approach towards 2050, a look into the energy supply of the countries around the Netherlands is important. Denmark profiles themselves with their export of RE technology. Nuclear power is still important for France and Germany put effort in solar technology.

For sure, the decisions in the next years should have a strong basis for the future. The decision about implementing new nuclear power is important as well the new legislation about using heat and their financial consequences. New legislation, steering policy, security of supply, safety and a strong (financial) approach are important for the future.

DISCUSSION

We can see the long history of using heat in Denmark. In the Netherlands, this is only used in a small scale basis. Within the new Dutch law, heat will be more important. A trade within heat will be important. The new law is important but maybe a bit too late. The awareness of a 'post gas' period is not noticeable.

Biogas is an interesting method to generate electricity, but without using the heat, this way of creating energy is not comparable with the current energy prices. Even here, heat will deserve more attention. The way of using heat in Denmark is totally different from the way of using heat in the Netherlands. I expect to see a transition in the next 10 years.

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