Innovation& Business - 2011 – Develop and Market (E11) – SPRO 3

Implementing Solar Energy "Sustainable rural districts through common technical and social solutions"

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Preface

The purpose of this report is to present the result from our semester project on how to decrease the CO_2 output in a rural district near Sønderborg with a focus on the energy consumption in households. In addition to that the aim will be how and whether it is possible to implement solar power in a village like Smøl as their main energy provider.

The report also contains descriptions for different Scenarios and basic calculations in the business cases, some of them will show how much it would cost the village.

Further on there are listed and explained environmental and financial benefits by having a solar plant as the main energy supplier.

The barriers given by the Danish energy law-situation concerning the implementation of a solar power plant as main power supplier for village as Smøl, and the intern supply of the energy are discussed and suggestions listed.

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Executive Summary

In this report we tried to implement green renewable energy in a small village outside of Sønderborg called Smøl. Through meetings with citizens of Smøl we found what the villagers wanted, and started discussing internally what would be the best possible solution for them, followed by research and analysis of data received from them.

To find the best solution we created different scenarios, which we discussed with Project Zero and other experts, and calculated the approximated costs on the best scenarios.

Finally we concluded on Smøls' request, and what we found was the best green solution.

This report was created with help from:

Syddansk Universitet (University of Southern Denmark)

Smøl and its citizens

Project Zero

Sønderborg Kommune

Kasper M. Paasch

Esbensen Consulting Engineer Aps

Project Formulation

Problem Background

The world is nowadays focusing on renewable energy, in first order to reduce the environmental pollution, which causes climate warming. But also raising costs for fossil fuels and high-energy prices are important factors for that new focus. Due to those aspects and the aim of becoming CO_2 neutral until the year 2029 the commune of Sønderborg is trying to implement renewable energy technologies, starting as early as possible. In addition to fulfill the aim everyone has to participate to succeed and lower the CO_2 output.
Smøl, a small village near Sønderborg, is one of those participants who is willing to reduce their energy consumption by renewable energy. Our task in this case is to look into how the households are heated and how they use and receive their electricity. With this data and other information just as the location and circumstances et cetera we are able to see which renewable energy technology or technologies is or are the best for the population of Smøl.
So all in all this report deals with the questions whether there is one or more renewable energy technologies to reduce the energy consumption in Smøl, and if there are more "Which one is the best?"

Problem Formulation

In the final report we expect coming up with more than one solution for reducing the energy consumption in Smøl, so we will develop many different Scenarios. From a meeting we had with the population of Smøl we already know that they are interested in solar energy. Due to that the Scenarios will mostly deal with solar panels and will describe how they could be used and where they could be installed. There will also be different factors affecting these Scenarios.
During developing Scenarios in the project there are some milestones we are confronted with. First there is the question about the Danish law situation in the production of renewable energy in the case of solar energy. We will try to develop Scenarios, which stick to the laws and which neglect them. One reason

therefore is because the law situation in Denmark might change in the beginning of the year 2012.
The next milestone is the technical feasibility. There are two alternatives in the production of solar energy - photovoltaic and solar thermal power plants, where one of them is responsible for the electricity, and the other one for heating. Both of them work in a different way. Since Smøl is interested in the electricity supply we are responsible making Scenarios with photovoltaic plants.

So in order to optimize the Scenarios all the milestones have to be passed and as much data as possible has to be collected.
Afterwards we will create a few business cases and concepts depending on the different Scenarios to find out how solar power could be implemented in Smøl. Furthermore it will be possible to analyse whether the project- realization is economic or not, and a flowchart will be created to ease the whole process for upcoming projects.

Problem Delimitation

During the project we will create business cases and concepts focusing on the best possible solution for Smøl. We will do basic calculations on the cost for implementing the systems and calculate the annual savings along with payoff rates.
We will neither draw up any technical solutions nor build or invent something physical. To get the biggest amount of possible solutions the law situation and the associated conflicts will be neglected in some Scenarios.

Methodology

In the chart to the left it can be seen the basic guideline of our progress during the project.
We began with gathering basic information due to internet researches and a first meeting with a group of interested citizens from Smøl.
With this information we have been able to create a basic project plan and a presentation for all citizens from Smøl.
During the presentation and while the question & answer time with the citizens we have been able to get more detailed information on their needs and wishes for the project. Based on this information different scenarios were developed to prove how the best solution for the village would be like.
Firms and independent professionals as well as detailed internet research provided us with the needed knowledge to form the scenarios and write the report.
More information on how we worked is given as an introduction in each chapter.

Chapter 1) Research and Analysis

In this chapter the focus will be on how the research and analysis is done for this report and how the data is collected both from the citizens of Smøl and the Internet. It will also show how it is analysed and used inside the report.

1.1 Town Analysis

This analysis is based on data collected from the citizens of Smøl through a meeting with the citizens asking for their data on power consumption and the data was received through e-mail. The analysis in the following part of this chapter is also used as a reference in other chapters and sub points through the whole report.

1.1.1 Smøl Analysis[1]

In the tables below we have divided the households in Smøl into three groups concerning their electricity use over one year.
So in each table you can see the energy use, persons in each house, house nr: and energy source.

Group 1: (2000 kW/h to 5000 kW/h):

House nr: / Energy:	Electricity use: (pr.year)	Persons in the household:
23 (Gas)	3355 kW/h	2
28 (Gas)	4990 kW/h	3
16 (Gas)	4350 kw/h	2
15 (Gas)	4050 kW/h	2
22 (Gas)	3100 kW/h	2
34 (Gas)	2968 kW/h	1
25 (Gas)	2979 kW/h	2
Total: 7		**Total: 14**

[1] See appendix B data table from Smøl.

Group 2: (5000 kW/h to 7000 kW/h):

House nr: / Energy:	Electricity use: (pr.year)	Persons in the household:
13 (Gas)	5165 kW/h	2
19 (Brænderfyr)	5400 kW/h	2
7 (Gas)	5570 kW/h	5
Total: 3		**Total: 9**

Group 3: (7000 kW/h to 10000 kW/h (including the farm)):

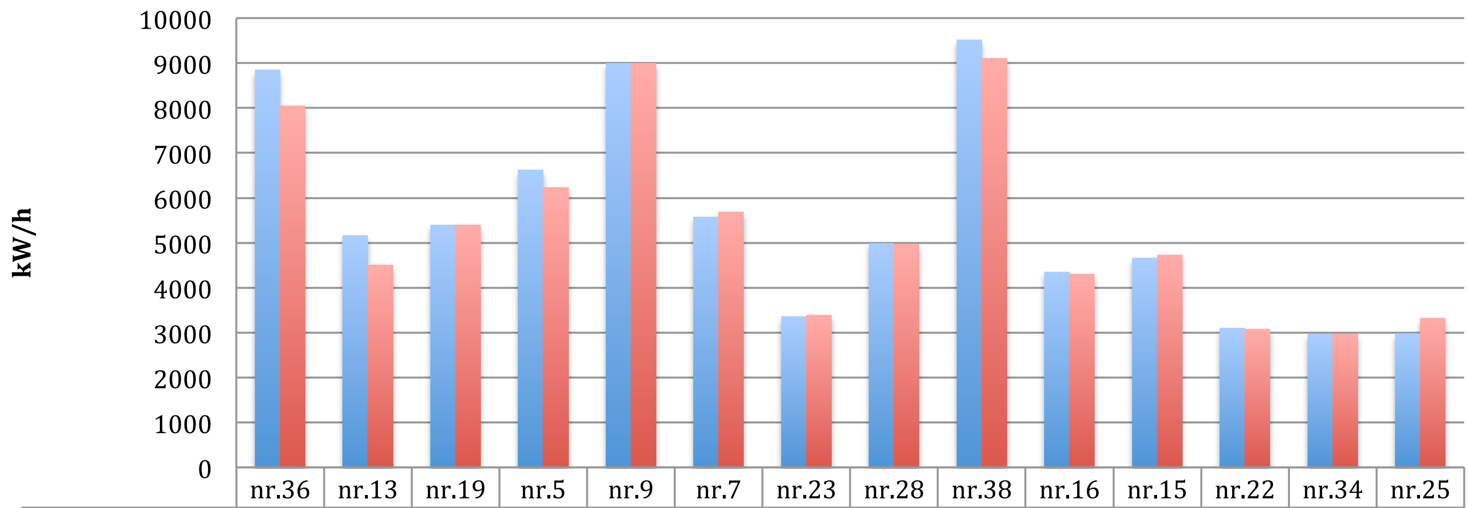
House nr: / Energy:	Electricity use: (pr.year)	Persons in the household:
36 (El.varme)	8847 kW/h	2
5 (Strokerfyr)	7091 kW/h	6
9 (Water pump/Gas)	9000 kW/h	4
38 (Water pump)	9523 kW/h	4
Total: 4		**Total: 16**
Farm	25000 kW/h	4
Total: 5		**Total: 20**

The average electricity consumption[2] for a household in Denmark:

Persons per Household:	1	2	3	4	>4
Electricity Consumption per year in kWh:	2.954	3.752	4.520	5.181	5.695

In the graph 1 below you can see the usage of each household in 2010 and the average use of each household over a 3-year period, but there are some households that didn't provide us enough data but are still included in this graph. Below the graph, you can see the house number of the household that did not provide enough data.

[2] http://www.dongenergy.dk/privat/energiforum/tjekditforbrug/typiskelforbrug/Pages/hus.aspx (08.12.2011)

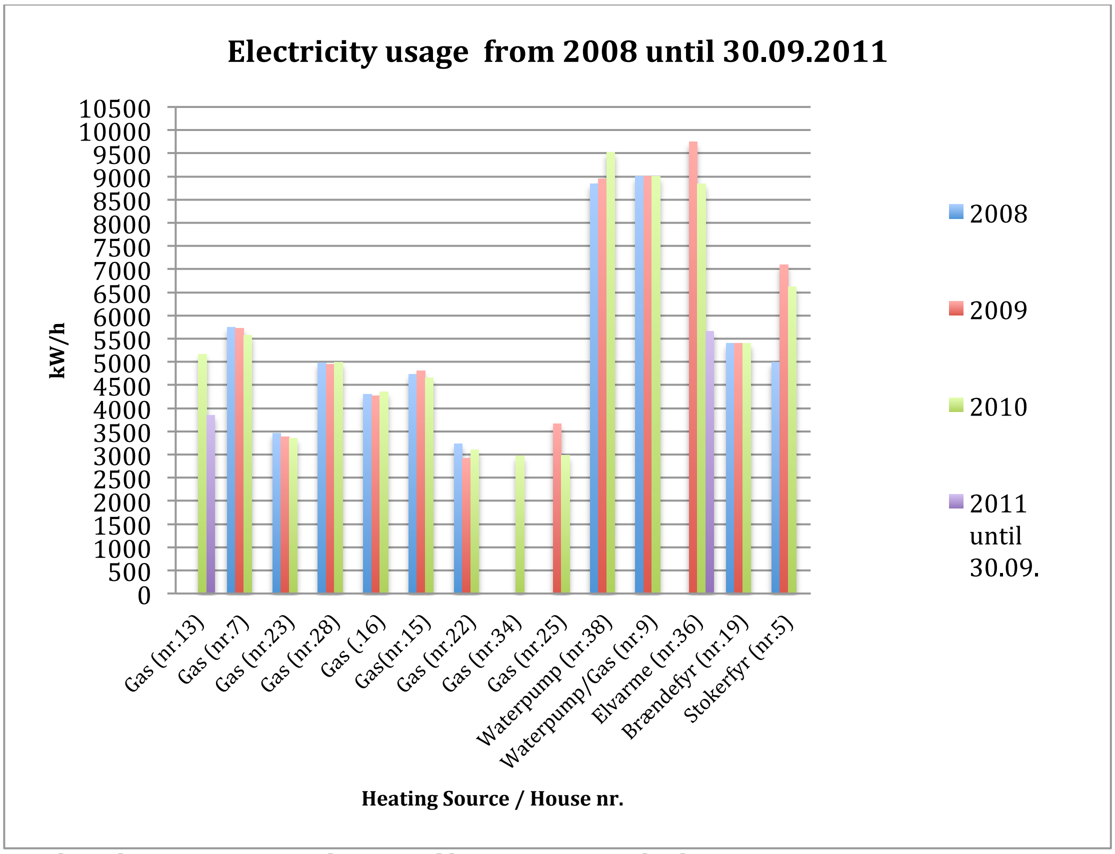


	nr.36	nr.13	nr.19	nr.5	nr.9	nr.7	nr.23	nr.28	nr.38	nr.16	nr.15	nr.22	nr.34	nr.25
2010 usage	8847	5165	5400	6617	9000	5576	3355	4990	9523	4350	4660	3100	2968	2979
Average usages	8051	4505.5	5400	6234.6	9000	5683.3	3396.3	4974	9105.6	4306.5	4733.3	3081.6	2968	3322

Graph 1: Electricity usages in 2010 and average use

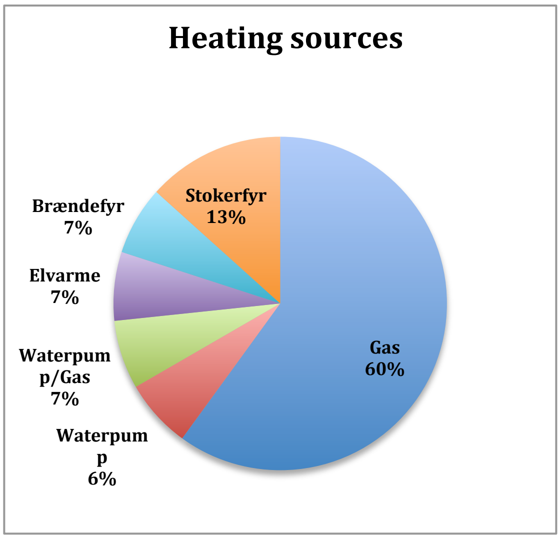
19 and 9 provided us with their estimated usage over this three-year period,
36 provided us with their usage for 2009, 2010 and until end of September 2011,
25 provided us with their usage for 2009 and 2010,
13 provided us with their usage for 2010 and until end of September 2011,
34 provided us with their usage for only 2010.

By looking at the graph we can see that the average usage of each household is very similar to their normal usage over a one-year period. We can also see that their usage over this three-year period is very stable or similar in each year. That tells us there is no significant increase or decrease in the electricity usage in these houses .In graph 1, the Farm or house number 24 as it is called in the data tables above is not included. The reason for neglecting the farm in this graph is that by including the farm the scale on this graph would be way to high and the graphs would lose their accuracy.



Graph 2: Electricity usage each year and heating sources plus house nr.

The graph 2 above shows that gas is the most used heating source at present in Smøl. 9 out of 15 houses that we collected data from use gas, which is around 60% of the households in Smøl as is shown on the pie chart below. In the graph above there are only included 14 out of 15 houses that we collected data from. The reason is that, house nr. 24 is a farm and has higher-electricity usage or consumption than other houses in Smøl. If it was included in the graph it would lose its focus and therefore it was neglected. The graph on the following page includes the farm and shows the energy usage from 2008 until 30.09.2011.Graph 2 shows that the households using gas as a heating source have more stable electricity use over these years compared to the other heating sources. Water pump users have an increased usage each year, so does Biomass boilers (Stokerfyr) users. The ones using electricity heating have a decreasing electricity usage. Due to the human behaviour and weather changes, the electricity consumption can change every year and in all directions.

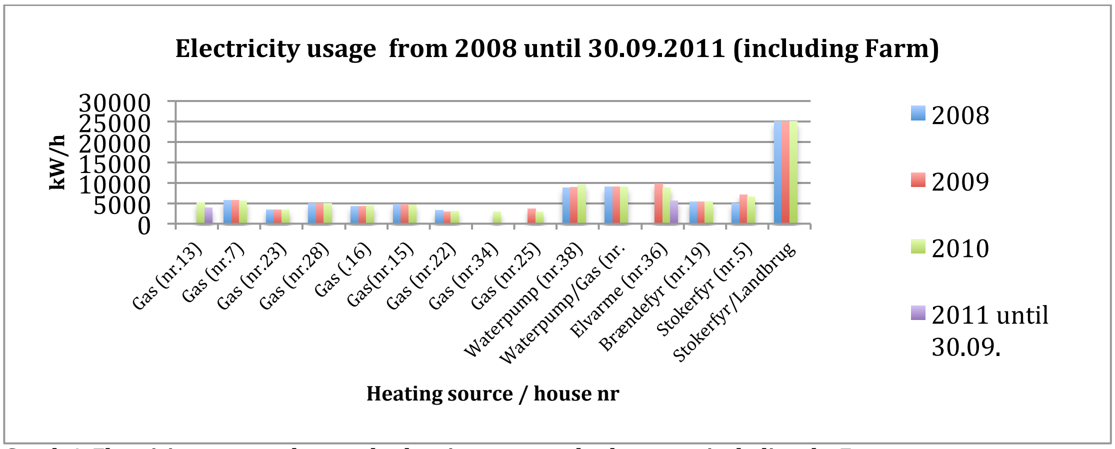


Graph 3: Different types of energy sources.

By looking at the graph3 and the data table 1[3], it's possible to see some missing columns that are due to a lack of data from some households in Smøl. Even though here is some lack of data from the citizens of Smøl, we got an understanding of the needs and energy usage.

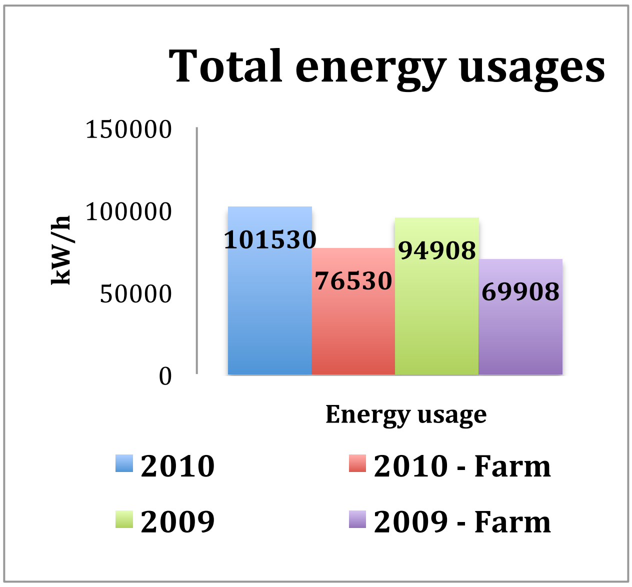
There are some factors that can be taken into account when looking at these graphs above, which are for example: how was the winter these years, cold or relatively warm. It also has to be taken into account how many people are living in the house during this time. The information about how many are living in the house can be found in the tables on pages 9 and 10.

Graph 4 below shows the energy usage for year 2008, 2009 and 2010 until end of September 2011, each house is shown including house number 24 or the farm, also included in the graph are the heating sources of each house.



Graph 4: Electricity usage each year plus heating sources plus house nr: including the Farm.

[3] See Appendix B (data table 1)



Graph 5: Total energy usages.

By using the data from Smøl we could calculate the total usage of the town in the years 2009 and 2010 both without the farm and by including the farm. The results are shown on the graph beside the text. In the year 2009 we are missing data from houses nr. 13 and 34, in that case we decided to neglect the results from 2009 in the calculation below.

The total usage in 2010:

With the farm the total usage was; **101530 kW/h**
Without the farm the total usage was: **76530 kW/h**

The calculations below show how much solar panels (in m^2) would be needed to produce the estimated electricity usage of Smøl. The calculations are done on the base that every household is allowed to set up a 6 kWp solar system with an estimated output of 5300 kW/h per year and with an estimated size of 40 m^2. The amount of electricity to be covered in this case is taken as 101530 kW/h.

Calculation 1: (With the farm)

$$\boldsymbol{6\ kW = 40\ m^2}$$

$$\boldsymbol{Output = 5300 \frac{kW}{h}\ per.year}$$

$$\boldsymbol{\frac{5300\ kW/h}{40\ m^2} = 132.5\ \frac{kW/h}{m^2}}$$

$$\boldsymbol{101530 \frac{kW}{h} total\ usage\ in\ 2010:}$$

$$\boldsymbol{\frac{101530\ kW/h}{132.5 \frac{kW/h}{m^2}} = 766,264\ m^2\ \approx 767\ m^2}$$

$$\boldsymbol{767\ m^2\ needed\ space\ for\ total\ output}$$

$$\boldsymbol{\frac{767\ m^2}{15\ households} = 51,084\ m^2\ needed\ plane\ size\ of\ each\ of\ the\ 15\ houses}$$

$$\boldsymbol{\frac{6\ kWp}{40\ \ m^2} = 0.150\ \frac{kWp}{m^2}}$$

$$\boldsymbol{51.084\ m^2 *\ 0.150\ \frac{kWp}{m^2} = 7,663\ kWp}$$

Calculation 2: (Farm neglected)

$$\boldsymbol{6\ kW = 40\ m^2}$$

$$\boldsymbol{Output = 5300 \frac{kW}{h}\ per.year}$$

$$\boldsymbol{\frac{5300\ kW/h}{40\ m^2} = 132.5\ \frac{kW/h}{m^2}}$$

$$\boldsymbol{76530 \frac{kW}{h} total\ usage\ in\ 2010:}$$

$$\boldsymbol{\frac{76530\ kW/h}{132.5 \frac{kW/h}{m^2}} = 577,585\ m^2\ \approx 578\ m^2}$$

$$\boldsymbol{578\ \ m^2\ needed\ space\ for\ total\ output}$$

$$\boldsymbol{\frac{578\ m^2}{14\ households} = 38.533\ m^2\ needed\ plane\ size\ of\ each\ of\ the\ 15\ houses}$$

$$\boldsymbol{\frac{6\ kWp}{40\ \ m^2} = 0.150\ \frac{kWp}{m^2}}$$

$$\boldsymbol{38,533\ m^2 *\ 0.150\ \frac{kWp}{m^2} = 5,780\ kWp}$$

Authors: Bjarnhéðinn Guðlaugsson, Bo Jessen, Ufuk Ören& Felix Haakon Lenz

In the calculations above we have calculated the total system size which would be needed to cover the total electricity consumption of the year 2010 for two cases, the first one including the farm (which is using about ¼ of the total consumption) and the second one without the farm. We calculated these two cases to be able to see how big the difference in needed capacity is.
Both calculated cases are containing the same mathematical ways of solving but with different numbers.
As the first step we set our system specs according to our information about solar systems for private use. As the output of a system like the named with 6 kW_p at a size of 40 m^2we took 5300 kW/h as the total output per year. We calculated the output per m^2 to be able to calculate the total size of the common system needed for the annual electricity consumption.
After we got the size for the total system we divided the size with the number of households (we got the data from) and compared it to the legal limit which in this case would be 40m^2. The last thing that was done was to convert the result from m^2 to kWp.
The results showed, that in the first case we would be over the legal limit of 6kWp per private household. For the second case (without the farmer) the needed capacity would be inside the legal restrictions as they are today (26.10.2011).

1.1.2 Analysis conclusion

This analysis gives out some good information on the effect of the size of households and the energy sources used to heat up the household have on the electricity behaviour and consumption. Furthermore the analysis increases the understanding of electricity consumption in the village of Smøl. Therefore, the calculations in the analysis show how much electricity the power plant needs to produce and how big it needs to be in m^2, to be able to meet the required electricity consumption of Smøl over a one year period.

1.2 Solar Cells

In this chapter the focus will be on solar cells and solar energy.

1.2.1 General and Technical Information

In this sub point we are going to talk about general and technical information of solar energy. Starting by a short definition of solar energy in general, it will be continued by describing the differences in the two types of solar plants – to generate an overview.

1.2.1.1What is Solar Energy?

When we nowadays hear the words ”solar energy” and “solar power” the first things we associate with those words are solar plants, renewable energy, reduction of environmental pollution and many other expressions – but as it can be seen, all the associations we have are positive. Now the word that we are mostly interested in is “solar plants”, because it is currently the most efficient way to take benefit out of solar power. So solar energy is nothing else but the energy radiated by the sun, already harnessed by us humans since a long time.

1.2.1.2 Are there different in Solar Plants.

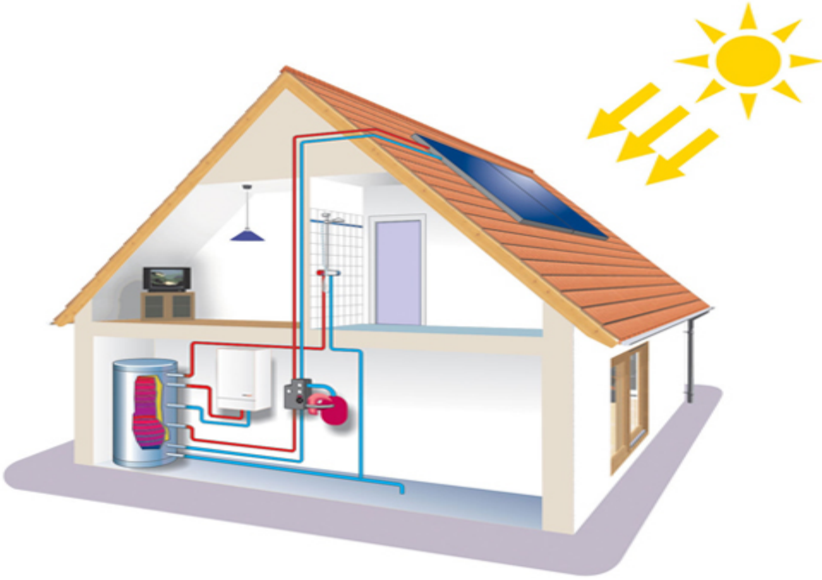
There are two different types of solar plants – photovoltaic (short PV) and solar thermal plants. As similar they might look like there is a big difference in the gain of both of them. Whereat photovoltaic solar plants produce energy, thermal plants are responsible for heating. Since there is a difference in the gain of the plants there is also a difference in the construction of them.
Abstract: Many people associate solar energy directly with PVs and not with solar thermal power generation.

1.2.1.3How do these two Different Types of Plants work?

Due to the fact that our semester project is about reducing the energy consumption of Smøl, a small village near Sønderborg, the solar plant, which is more significant, is the PV – so the description of the thermal plant will be kept as simple as possible.

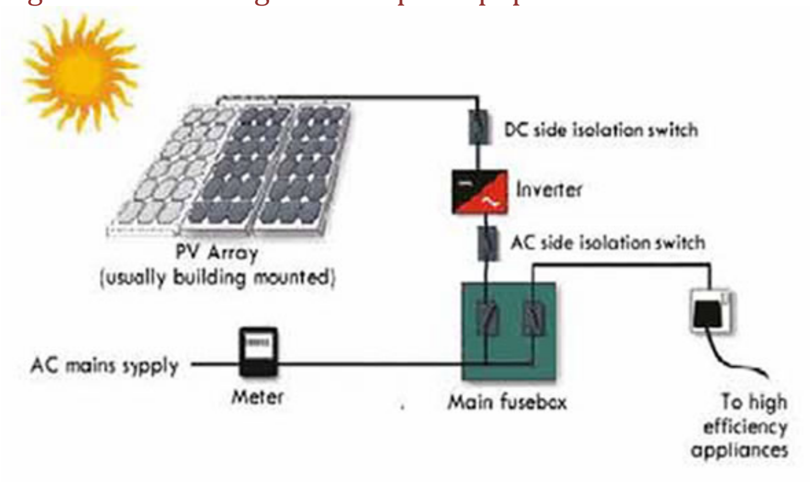
1.2.1.3.1 Thermal Solar Plant

Figure 1.1: Showing the set-up of a solar thermal plant



A special collector, which is coated and also insulated on the rear side, is heated by solar energy. Through pipes that are implemented in the collectors streams a liquid consisting of water and propylene-glycol – and absorbs the heat radiated by the sun. By the use of a pump this liquid mixture is then circulated to a hot water tank, which then heats the service water by a heat exchanger – when a post heating is necessary there is also a heating installation that ensures hot water.

Figure 2.1: showing the set-up of a pvp[4]



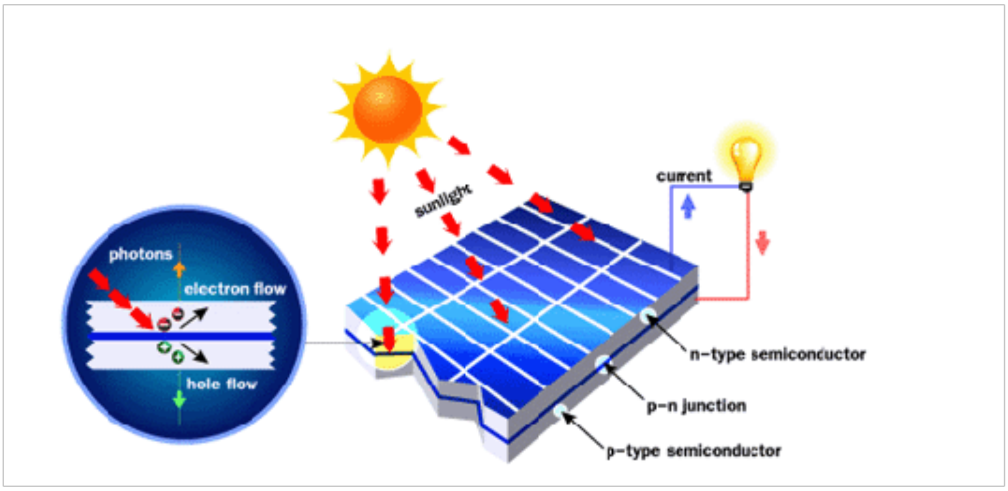
[4]http://vrgblog.wordpress.com/2011/04/18/exploring-views-on-a-community-benefit-co-operative-photovoltaic-panels-for-cherwell-school/ (date: 03.11.2011)

1.2.1.3.2 Photovoltaic Plants (PV Plants)

The word "photovoltaic" is build-up by the Greek word "photo" which means "light" and by the word "volt" that is coming from a physician called Alessandro Volta, who was a pioneer in electro-technics. The PV solar plants convert the radiated solar energy into electricity by an effect called photo effect – hereby negative and positive charge carriers are discharged by the supply of light or heat. By this way the solar cells, mostly consisting of silicon plates, produce a concurrent flow that can either drive a motor or charge a storage battery. If the produced energy should be used with a 230 V AC voltage or should be connected to the grid there is an oscillator needed. This oscillator converts concurrent flow into AC voltage.

Pros: PV solar plants bring many positive aspects with themselves, starting with green and environmental friendly energy production. In addition to that it shows the opportunity for the consumer to produce their energy independent from the grid – isolated application.

Figure 2.2: Showing how sunlight is turned into electricity



Description of Figure 2.2:

The figure above shows the process how sunlight is transformed into electricity. First it can be seen a simple structure of a photovoltaic solar plant consisting of two silicon layers. Whereat one of the layers is a n-type semiconductor, the other one is a p-type – in different words: one of the layers is negative charged and the

other one is positive charged. To understand how to get the semiconductor charged either negative or positive, there is a need of a periodic table of the elements. Looking at the periodic table silicon has six valence electrons. When there is a silicon-silicon compound there is no charge at all because the need of electrons in this compound is fulfilled, due to two of the electrons will be shared. For a negative or a positive charge of the electrons there is a process called doping needed. ”Doping is the addition of impurities to a semiconductor to control the electrical resistivity.”[5]So it can be said that in order to get the semiconductors either n- or p-type there is a need of an impurity to the silicon, which has six valence electrons as mentioned before. For having an n-type semiconductor the impurity must have seven valence electrons so when the two elements, silicon and the impurity, compound with each other there is a surplus of one electron. For a p-type it is the complete opposite which means the impurity must have five valence electrons, so there is a shortfall of one electron. When then sunlight hits the solar panel the surplus electrons from the n-type move to the shortfall in the p-type semiconductor. This movement deduces a flow of electrons, which generates electricity.
The element used for the n-type is phosphor and for the p-type is boron.

1.2.1.4 Benefits:

In this sub-point general information about environmental benefits, as well as economic benefits are listed.
Since the sun is the environmentally friendliest energy source – within just 5 seconds there's radiated energy in the amount of what the whole world population uses in one year – there is a great advantage for the environment, when using this solar energy. The usage also affects the economy of the owner in a positive way.

[5]http://www.chemicool.com/definition/doping.html (03.11.2011)

1.2.1.4.1 Environmental benefits:[6]

- Electricity gained from solar panels is electricity with zero emissions, what means that solar energy is CO_2 free.
- As long as the solar system exists and we assume that it will stay forever, it can be said that solar energy is an infinite resource. Fact is that many other resources as oil, gas and coal just to mention a few examples are not infinite.
- Alternative energy technologies, for example nuclear reactors have serious environmental issues. Nuclear reactors create radioactive waste with a long radioactive half-life, which is harmful for its environment.

1.2.1.4.2 Economic benefits:[7]

Even when there is a high start-up cost for purchasing solar panels, looking at it in the long run term it will be cheaper generating their own electricity than buying it from companies. This pay-off rate is determined as approximately 15 years, whereat the lifetime of a solar panel is 30+ years.

- In addition to that it has to be mentioned that energy prices are rising so it might be a positive change in the pay-off time towards the owner of the panel.
- If a common solar panel is becoming legal in the upcoming year(s) the economic benefit of the solar energy can be maximized due to there is a limit of 6 kWp in the production of solar energy. But since some people don't use the maximum output of a 6kWp system other could benefit from their loss.

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[6] http://www.cleansolarliving.com/webpage.php?page=19 (21.12.2011)
[7] http://www.ehow.com/about_5479923_economic-advantages-solar-energy.html(21.12.2011)

1.3 Heat Pumps with Earth Collectors[8]

In this chapter the focus will be on earth collectors with heat pumps. We are going to go briefly into how this technology is used and how it operates.

1.3.1 General Information

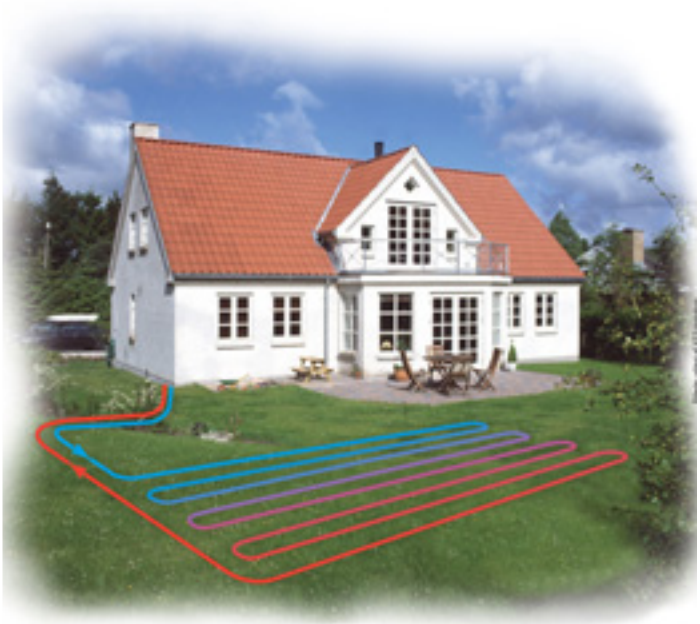
Throughout the summer the top layer of the soil is collecting a vast amount of energy thanks to the sunrays. The soil is storing this heat or energy at a low temperature, 8 to 10 degrees Celsius, but this energy doesn't disappear during the winter.

The top layer of soil is therefore storing a vast amount of energy that is replenished every summer.

This energy can then be harvested the entire year through a heat pump and plastic pipes in the ground to provide warm water and heating. By installing earth collectors each household would save up to approximately 66% of their total heating bill.

1.3.2 Technical Information:

To harvest this energy, pipes of 40 mm in diameter (Ø) are placed 1 meter below the surface. A low temperature heat pump is installed in the house and when needed, the heat pump pumps the cold water out into the system, while it draws warmed water back into the house.



[8]http://www.jordvarme.dk/ (12.12.2011)

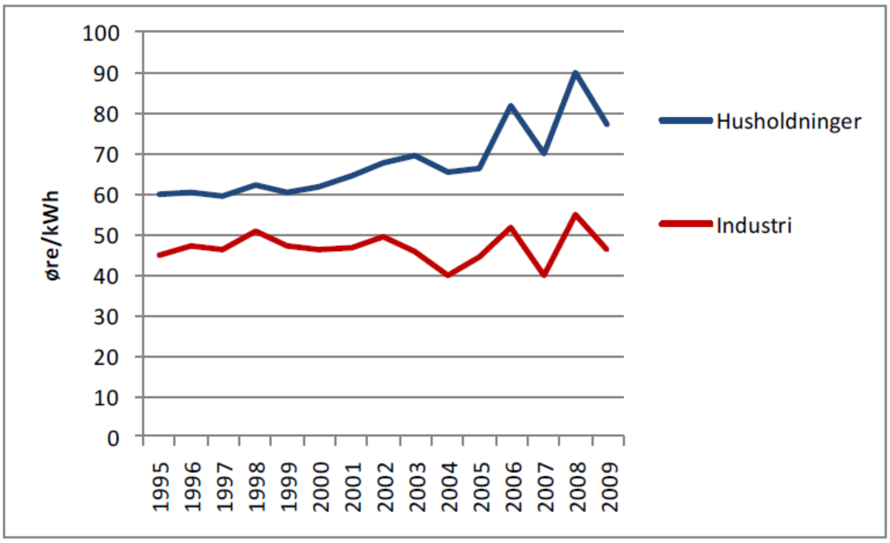
Depending on the size and insulation of the house the system can vary from 200 to 600 meters of 40 mm Ø pipes. Compared to wind- or solar energy, earth heating is an endless supply of energy that can be used when it is needed, and not when nature allows us to use it.
The only negative side to earth heating is that once the pipes are placed it takes approximately a year for the soil to settle around the pipes, therefore there might be a slight shortage in the first winter, but afterwards the energy is sufficient enough to heat the water and the house. The picture on the page before shows how this technology works.

1.4 Price

This chapter will focus on electricity price, it will go briefly into the price and changes that have been affecting the electricity price over the last few years.

1.4.1 Electricity Price

The electricity prices have risen consequently in the past years. To give an overview of the price development we have done a research about the electricity price development in Denmark. The results can be seen in the following sub-chapter.
The electricity price has increased rapidly for private households during the last years.



Figur 1. Elpriser for husholdninger og industri. Der er tale om faste priser (2009-priser), ekskl. PSO, moms og afgifter. Se kapitel 5 for de anvendte kilder. Bemærk at der er nogen usikkerhed knyttet til data, særligt for perioden 2001-2005.

The graph[9] on the page before shows the development of the electricity price from 1995 - 2009 for private households and firms. The price is in Danish øre per kWh without taxes, Public Service Obligations (PSO) and other charges. We will not go in detail why the electricity price for private households raised significantly more than for firms.
The electricity price rose from about 60øre/kWh (in 2005) to about 85 øre/kWh (in 2008/2009) this corresponds to 42%[10].
In appendix G can you see an analysis of the electricity prices. The estimated electricity price for 2017 is regarding to appendix G 2,4 DKK.

1.5 Electric Storage Technology[11]

In this chapter the focus will be on electricity storage facilities. We are going to go briefly into how they operate, what the requirements are for these facilities, describe some technology used to store electricity today, the benefits and the cost.

1.5.1 General and Technical Information

Storage facilities that are used to store unused or over produced electricity use other type of energy to store the electricity like chemical, kinetic, thermal and potential energy and when there is need for the stored electricity it converts the stored energy into electricity again. These storage facilities can provide different types of basic service to different scenarios: supplying electricity where there is a danger of electricity shortage by using the stored electricity which was produced during the lower demand season of electricity, makes it easier to control the supply and demand of electricity, helps balancing out the electricity consumption in general and delays expansions of electricity grid capacity.

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[9]http://www.ens.dk/Documents/Netboghandel%20-%20publikationer/2011/Udviklingen_af_elpriserne.pdf (13.12.11) Page 6
[10]See appendix F
[11]http://www.cpuc.ca.gov/PUC/energy/reports.htmreport from 9th July 2010 Name: Electric Energy Storage: An Assessment of Potential Barriers and Opportunities (09.12.2011)

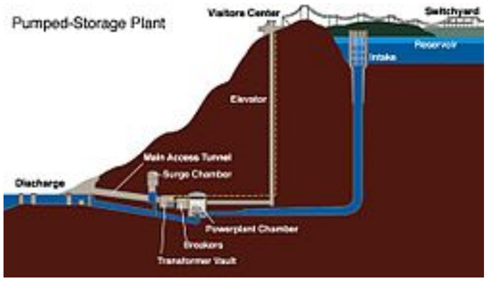
Some of the technology behind storage facilities has existed for decades, technology like batteries, pump hydro and compressed air, therefore the concept of electric energy storage is not that new. Progress in research and developing on materials, electronics, chemistry and also information about technology has resulted in numbers of new and innovative storage technologies. These new technologies have increased the potential of reducing the overall costs in research and developing of new types of storage facilities. Each of these storage technology opportunities has similar types of requirements; a list of requirements can be seen below[12]:

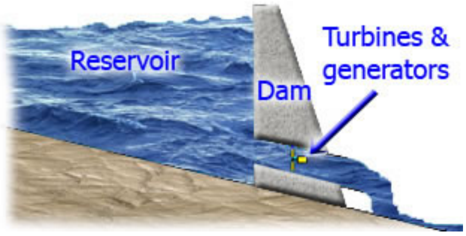
- *Quantity of energy stored (commonly kWh or MWh)*
- *Duration of discharge required (seconds, minutes, hours)*
- *Power level (kW or MW)*
- *Response time (milliseconds to minutes)*
- *Frequency of discharge (number per unit of time, such as per day or year)*
- *Energy density (facility space and total energy storage capacity)*
- *Cycle Efficiency (fraction of energy removed that is returned to the grid)*
- *Cycle life and/or calendar life*
- *Footprint/compatibility with existing infrastructure*
- *Ease of implementation*
- *Transportability*
- *Cost*

Today, there is no storage technology that meets or address all of the requirements stated in the list above. As mention in the text above, there different methods to store electricity. These methods are chemical, biological, and electrochemical, electrical, mechanical, and thermal. The following sub points describe four different types of storage technologies.

[12] www.aps.org/policy/reports/popa-reports/upload/Energy_2007_Report_ElectricityStorageReport.pdf Name: Challenges of Electricity Storage Technologies A Report from the APS Panel on Public Affairs Committee on Energy and Environment (09.12.2011)

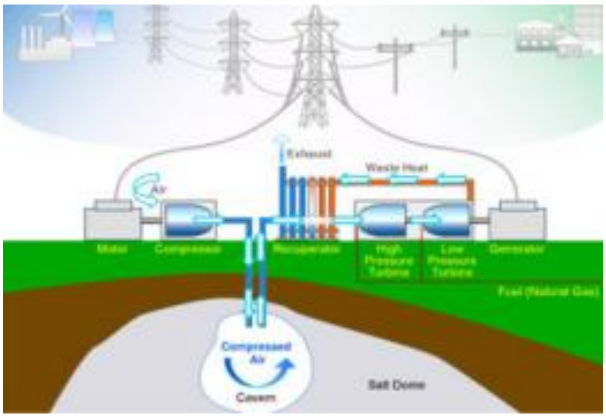
1.5.1.1 Pump Hydro





This method is about storing energy that is later used turn into electricity in the form of water. When there is a high demand of electricity the water is released and pumped down through pipes that lead it through turbines, which are used to convert the energy generated by the water into electricity. The water is stored in high elevation reservoirs that are created by building dams in rivers above the power plant. The pictures to the right show how this method is used today[13].

1.5.1.2 Compressed Air



This method is about storing energy like electricity, which has been generated, during the low demand period and is therefore not used at the point when it was produced. The electricity that is being stored is released during the high demand period of electricity to meet the demand of the users. This method works like following: during the off-peak period the unused electricity is taken of the grid and moved through a motor compressor that uses the electricity to compress air. The compressed air is then lead into a pipe that leads it underground to a storage facility. However, when there is a high demand for the electricity the compressed air is released through a pipe that leads it through a recuperator, turbines and then to a generator that adds the electricity back to the grid. The picture to the right shows how one type of this method is used today[14].

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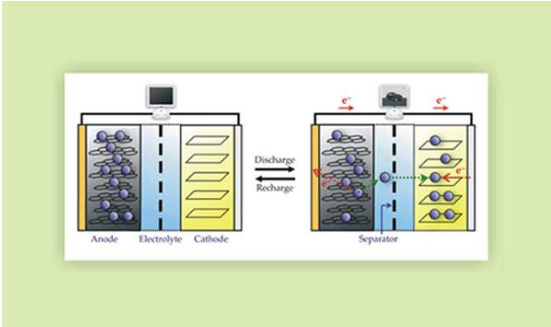
[13] http://www.tva.gov/heritage/mountaintop/index.htm (10.12.2011)
[14] http://www.physorg.com/news188048601.html (10.12.2011)

1.5.1.3 Batteries



This method uses the same principle as the batteries that people use in every day life, like in automobiles, computers and cell phones. However, the batteries used in power grids, are much larger and have higher power configurations. Therefore these batteries need to meet several requirements like; they need to be portable and rechargeable. Furthermore the types of batteries that are usually included in storage systems or facilities are lithium ion or flow batteries. Since the battery technology is already known the utility industry is generally familiar with them. The picture above shows a battery that is used to store energy and also shows how it is recharged[15].

1.5.1.4 Thermal Energy storage

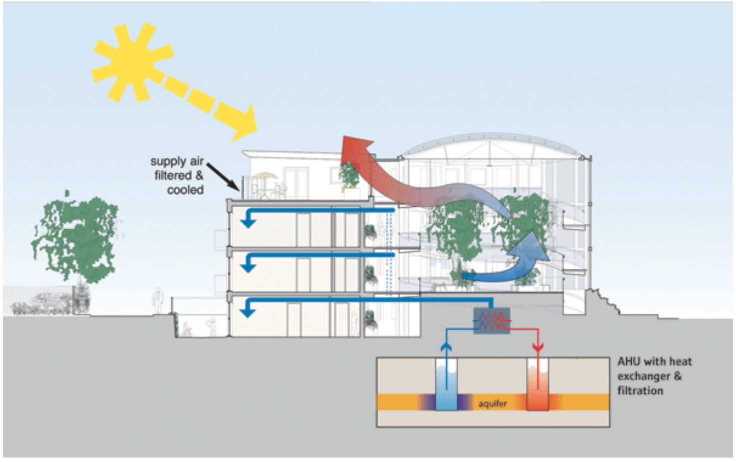
This method combines together a number of different technologies to store energy like electricity as thermal energy in energy storage reservoirs for later use. The stored energy can be used to balance out the demand of electricity and other types of energy usage between daytime and night-time. Today there are two different types of this method used[16]; these types are briefly explained below.

- **Molten Salt technology** is used to store solar energy from thermal solar power plants. This technology stores the energy as heat and the heat is pumped into a steam generator that produces steam, which goes through turbines that produces electricity.
- **Water storage technology** stores the electricity produced in the low demand period by using hot or cold storage like underground aquifers, water or ice tanks, or other types of storages materials. It uses the stored energy to lower the

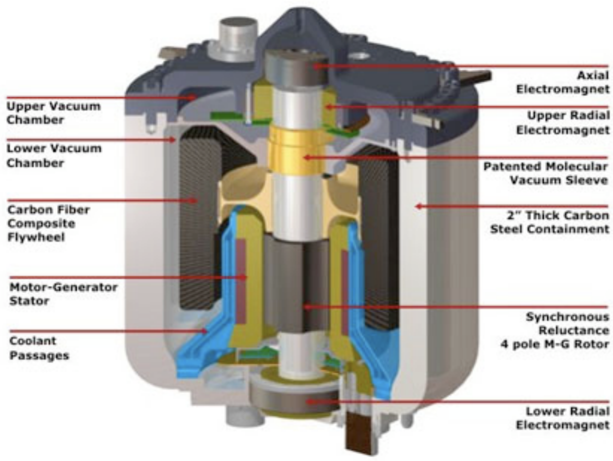
[15]http://www.physicscentral.com/explore/action/lithium-1.cfm (10.12.2011)
[16]http://www.pewclimate.org/technology/factsheet/ElectricEnergyStorage (10.12.2011)

electricity consumption of the heat and air condition systems in buildings or households during the high demand period.

The picture to the right explains how this kind of technology is used today[17].



1.5.1.5 Flywheels



This method uses a rotating mechanical device to store electricity or other forms of energy and it also takes its name from the device. This device stores energy as a rotational energy, when energy is added to the system the rotational speed of the flywheel increases and when energy is subtracted from the system the rotational speed of the flywheel decreases and it starts to generate energy. Most of the storage systems or facilities today, use electricity to accelerate or decelerate the speed of the device. However, flywheels that are using mechanical energy directly are being developed today. The picture above shows what a flywheel is made out of [18].

[17]http://ecocompass.com/blog/?p=451 (10.12.2011)
[18]http://gigaom.com/cleantech/flywheel-maker-pentadyne-raises-14m/ (10.12.2011)

1.5.2 Benefits

The usage of storing renewable energy like electricity can potentially increase the production of renewable energy in the future. However, due to the rising fuel price, geopolitical unrest in region likes the Middle East and increasing concern about the changes in global climate, the focus has shifted its attention on reducing the world's dependence on fossil fuel, by trying to replace fossil fuel with alternative types of energy sources like electricity. Therefore it could have big benefits both environmentally and economically for the world population in the future. The following sub points are going to describe briefly the environmental and economic benefits.

1.5.2.1 Environmental benefits

Will have a big affect on the CO_2 emission in future. By using the stored energy to run the power plants and generators that are used to produce energy today instead of using the natural gas, fossil fuel and coal, it would result in higher reductions of CO_2 emission. It also increases the possibility of renewable energy like electricity could be used instead of fossil fuel like gasoline and diesel to run cars, ship, as well as house heating. It would have increased affect on the CO_2 emission in the future.

1.5.2.2 Economic benefits

Due to the extra labour needed in research, developing and production of the technology used to store renewable energy, the workspace in this industry should be increased. That would result in lower unemployment rate. Furthermore, it would increase the control that energy producer have in how much they distribute each time and it would result in less waste of energy like electricity. Also it increases the quality of the energy distributed and produced, all of these changes result in lower energy prices for the end users.

1.5.3 Cost

The capital cost to implement renewable energy storage facilities or systems are high, but they vary by different types of technology used. The implementing cost can range from 500$ up to 4300$ per kWh stored (if converted into Danish krona using the rate price on the 12.12.2011 (1USD=5.64DKK) the price would range from 2820 DKK up to 24253 DKK per kWh[19]), the cheap technology used today for energy storage is ultra capacitors and the expensive one is pump hydro.

1.5.4 Conclusion

Due to the requirements of high capital cost to implement this technology and the fact that some of these technologies are still in the development stage, most of these technologies are for big scale energy storage. Most of these technologies require large area to build on. Therefore, these technologies are not suitable for Smøl due the high starting cost and requirement of large area.

Chapter 2) Law

This chapter is dealing with the current law situation in Denmark. It is structured in four parts:

1) In this part the two laws according to solar systems, premium tariff and net metering are mentioned and listed.
2) Description: This part summarizes the laws mentioned in the part before.
3) Forecast: After the summary there will be a short forecast about what is expected to be changed in the Danish law situation by the new government after January 2012.
4) Conclusion: This is the last part that gives a conclusion of the other parts.

[19] http://www.clearfx.com/currency-converter?gclid=CLThudmC_awCFZQhtAodhgvjSQ (12.12.2011)

2.1 Law Situation

There are two points of promotion according to the law situation in Denmark. These two points are considering 1) premium tariff and 2) net-metering.

2.1.1 Net-Metering

In Denmark every technology for renewable energy has the right to be promoted through net metering, except geothermal energy[20]. Every other owner of a technology that produces electricity is exempt from additional payments to support renewable energy and from public service obligation (PSO) on this electricity.[21]

Due to (§ 3 par. 3 BEK 804/2010) of the Danish laws the solar system must be connected to the collective grid system. In addition to that the system has to be installed at the place of consumption, as well as fully owned by the consumer.[22]In agreement with the law (§ 6 BEK 804/2010) it also must be listed in a key data register (stamdataregistreret).
So in the case of net metering every solar system up to maximum 50 kW has to be connected to the collective grid system – and are also exempted from PSO. Any solar system higher than 50 kW is also exempted from additional costs for renewable energy.

2.1.2 Taxes

Premium Tariff: Denmark promotes renewable energy with a bonus, which will be added to the market price. This originated sum is not allowed to exceed a certain amount of value, which is set in the law.[23]

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[20](§ 2 Nr. 6 BEK 804/2010)
[21](§ 1 BEK 804/2010)
[22]http://www.res-legal.de/en/search-for-countries/denmark/more-about/land/daenemark/ueberblick/foerderung.html (date:12.12.2011)
[23](§§ 36-48 VE-Lov)

Conforming to the present (§ 2 VE-Lov) law situation in Denmark, only solar systems with a capacity with minimum 6 kW are eligible for the premium tariff.[24] The amount of the bonus is calculated in two different methods, but in our case just one of them is relevant. This method, the maximal subsidy, which is nothing else, but the bonus plus market price, says that after the production of 6 kW the owner of the solar system has the right of a certain amount of money. In the first ten years the amount is set as 0,6 Dkk per kW/h. After those ten years the amount decreases to 0,4 Dkk per kW/h for ten more years.[25]

2.1.3 Description

As it can be summarized from the part above the Danish law situation says that a private household is just allowed to produce 6 kW for the own usage by renewable energy. The system producing renewable energy, which is solar panels in our case, must be installed on the own estate and has to be fully owned. In addition to that the system has to be registered. It is not saying that a private household is not allowed to produce more, but the over-production of energy (>6 kW) must be sold to the connected grid for a certain price, which is 0,6Dkk/kWh for the first ten years and 0,4Dkk/kWh for the second ten years.

2.1.4 Forecast

Since in some Scenarios the laws will be neglected we prepared a forecast to navigate our Scenarios in the direction the laws might change. There are three points the government is confronted with right now in order to change the law situation in the case of solar energy. As the current law situation is mentioned before in this chapter it should be easy to follow the three possible changes, which are listed here as sub-points:

- The current 6 kW limit per household may be raised for those ones who have a heat pump to 9kW
- Common solar plants (with which we are working with) may become legal
- Institutions may set up 6kW plants per each 100m^2

[24](§§ 47, 48 VE-Lov)
[25](§ 47 par. 3 no. 1 VE-Lov)

Chapter 3) Scenarios

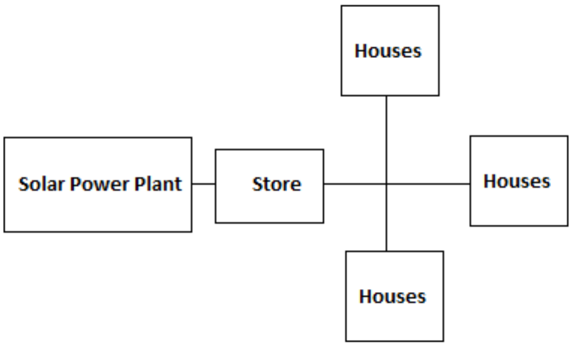
In this chapter the focus will be on how to show and evaluate the best solution for a solar power system installation in village of Smøl. The five scenarios have been lined out and evaluated according to a frame of criteria's:

1. Electricity production
2. Technical feasibility
3. Financial feasibility
4. Zero carbon (CO_2) emission (2029)[26]

Detailed descriptions about the scenarios can be found on the following pages.

3.1 Scenario 1: Common Stand Alone Solar System as Electricity Provider.

The concept of the first scenario is that a common solar power plant is used as the only electricity supply for Smøl.



In this case the village is not connected to the normal grid, so there is needed an own grid for the village. The focus here will be to find out how to ensure electricity supply all the time. Due to the lower electricity supply of solar cells[27]during the UV low periods of the day and the year it could be possible to face an electricity shortage. Bad weather days with a lot of clouds, which drop shadows on the panels, would be a problem as well.

With the use of a storage technology it is possible to provide enough electricity for Smøl during the periods where the power plant is not producing enough to cover the electricity consumption. Information about storing technologies can be found in chapter 1.5.

[26]www.projectzero.dk/ (08.12.2011)

[27] See chapter 1.2

3.1.1 Electricity Production

The electricity will be provided by a photovoltaic (PV) solar power plant.

3.1.2 Technical feasibility

Photovoltaic systems already exist and it would be technically feasible to implement a PV system to provide Smøl with electricity.
The storage technology, which would be needed to ensure a stable electricity supply, is technically useable and could be implemented as well.

3.1.3 Financial feasibility

The current price of an electricity storage system is around 500$[28] per kWh, so the realization of this scenario needs a bigger initial investment, which raises the overall costs enormously.

3.1.4 Carbon emission

The technologies used to provide Smøl with electricity are producing and storing electricity without emitting CO_2.

Below it can be seen the pro and con arguments for this concept:

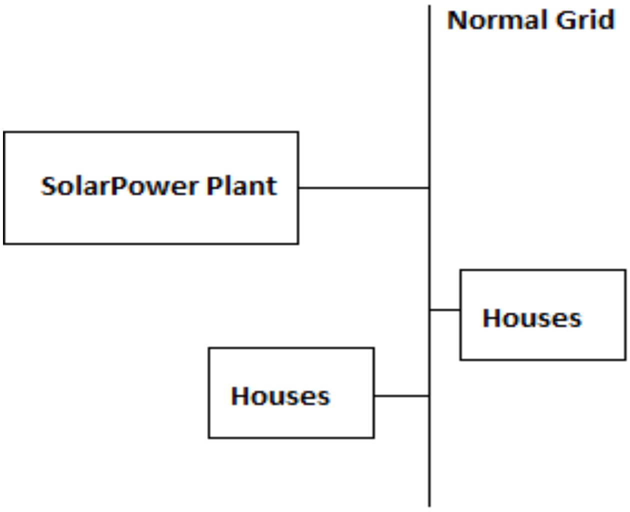
Pro	**Con**
Independent from the electricity firms	High investment
CO_2 neutral electricity	No grid backup
	Storage technology needed

Due to the high costs for the storage technology, which is still in the developing phase, we concluded to eliminate this Scenario for the next Chapter.

[28] http://www.renewableenergyworld.com/rea/news/article/2011/08/energy-storage-industry-grows-to-integrate-wind-solar

3.2 Scenario 2: Common Solar Power System with Grid connection

The main concept of scenario two is a common photovoltaic (PV) solar power system that is placed on the field beside the village of Smøl with a connection to the normal grid that is owned by energy companies like “SydEnergi”.



In this case the PV solar power system will be used to provide each household of Smøl with the amount of electricity that helps them to cover their electricity usage over a one year base. The focus here is to ensure that everyone gets the needed amount of electricity to cover the yearly consumption. Due to the law situation (see chapter 2) each household is not allowed to get more electricity than a solar cell with 6kW peak produces over a one-year period. The estimated annual production level of a solar cell with 6 kW peak is approximately 5000 – 5600 kWh per year.

So the PV solar power system will provide each household of Smøl with approximately 5300 kWh per year. By implementing an an-part system that allows every household to buy a part of the solar power plant/system as big as needed to cover their yearly electricity consumption.

Furthermore the PV solar power plant/system is connected to the grid and all its production goes in the normal grid and is provided to Smøl through the normal grid. The normal grid provides the users who need more electricity than the estimated annual production of the PV power plant/system that is 5000 - 5600 kWh per year. The households that are inside that energy consumption limit stated by the net-metering law[29] get their electricity usage without charge.

[29]See chapter 2.1.1

Households which use more than the estimated annual production level of a 6 kW peak PV solar power plant/system needs to pay the normal electricity price[30] to fulfil their electricity consumption.

In the calculations below is this formula used:

$$\boldsymbol{Usage\ per\ year - SolarCells = over\ used\ or - unused}$$

Here are two examples:
House one uses 3570 kW/h per year while house two uses 8650 kW/h:
Case 1:
Usage per year 3570 kW/H,
Solar Cell per year 5300 kW/h,

$$3750\frac{kW}{h} - 5300\frac{kW}{h} = -1550\ kW/h$$

Case 2:
Usage per year 8650 kW/h,
Solar Cells per year 5300 kW/h,

$$8650\frac{kW}{h} - 5300\frac{kW}{h} = 3350\ kW/h$$

The calculation above explains how the concept works in theory. However, when looking at the calculation, you can see that in case 1, the household uses less electricity than the PV solar power plant/system produces over a period of one year and the household in case 2 uses more electricity then is produced over a one year period. The household from case 2 has the opportunity to get a part of the extra electricity needed to fulfill his yearly electricity consumption from the household in case 1.

[30]See chapter 1.4

3.2.1 Electricity production

The electricity will be produced and provided by a photovoltaic (PV) power system/plant and electricity will also be provided through the normal electricity grid.

3.2.2 Technical feasibility

The photovoltaic technology, which is going to be used in solar power plant/system already exists. Therefore, it would be technically feasible to implement a photovoltaic power plant/system as an electricity provider and producer from Smøl.

3.2.3 Financial feasibility

The concept of scenario two would give the citizens of Smøl the best benefits concerning energy prices today.

3.2.4 Carbon emission

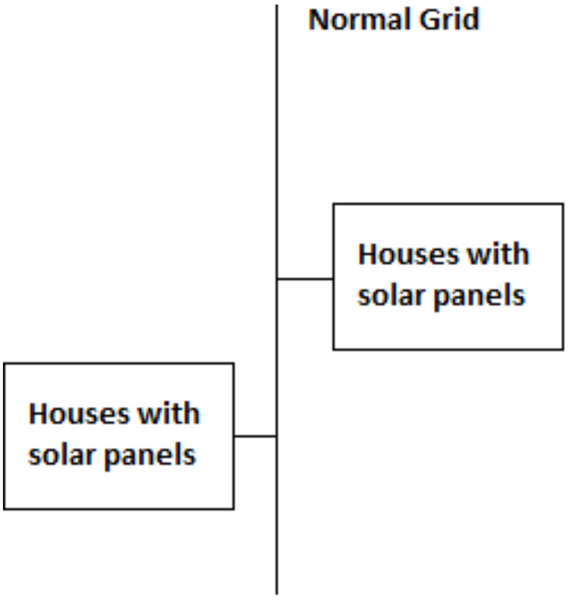
The photovoltaic (PV) system that will be used to produce and provide Smøl with electricity does produce and provide electricity without emitting any carbon (CO_2) into environment.

Below the pro and con arguments for this concept can be seen:

Pro	**Con**
Energy divided optimal	Illegal (maybe legal in 2012)
Technically feasible	
Backup by the grid	
What the citizens of Smøl would like	

Due to the law situation today, it is illegal to set up a system like this. Despite the fact that today this kind of system is illegal and also due to the fact that this scenario is what the citizens of Smøl would like, it was decided to use this scenario in the following chapter.

3.3 Scenario 3: Common Solar panels on private roofs



The third scenario has unlike to the other 4 scenarios no common solution. This scenario is shortly describing the usual way of using solar power for electricity production as a private household.

Every household would get photovoltaic panels installed on their roof or on their own area. The installed system would be adjusted in size to get the best profit out of it. This means, that a household, which is for example using about 5000 kWh per year, would get a different sized system than a household that is only using 3000 kWh per year.

The adjustment in size will be made to optimize the outcome of the regarding household. While the current law situation only allows installing a 6kWp solar system[31]the benefit is limited. The approximate annual production of a 6kWp system is 5000-5600 kWh.

To get the best profit inside these limits has the net- metering[32] to be taken into account. The amount of money received if more electricity is produced than used is only 0.60 DKK[33], which is too low to be profitable. So the best way is to produce exactly as much electricity as the household uses and not more. Due to the changing electricity demand depending on weather and other influences is it better to overproduce a small amount to be sure to get the full benefit from the net- metering.

[31] See chapter 2
[32] See chapter 2.1.1
[33] See appendix E

3.3.1 Electricity production

The electricity will be provided by a photovoltaic systems installed on the households roofs or in their own area.

3.3.2 Technical feasibility

This is the usual solution for private households to produce electricity with the use of solar cells. All technical solutions needed for this scenario are supplied by specific manufactures.

3.3.3 Financial feasibility

The concept of scenario three is technical feasible and has an approximate pay-off time of 12 years[34].

3.3.4 Carbon emission

The photovoltaic systems, which would be used to provide Smøl with electricity, are producing electricity without emitting CO_2.

Below can you see the pro and con list for scenario 3.

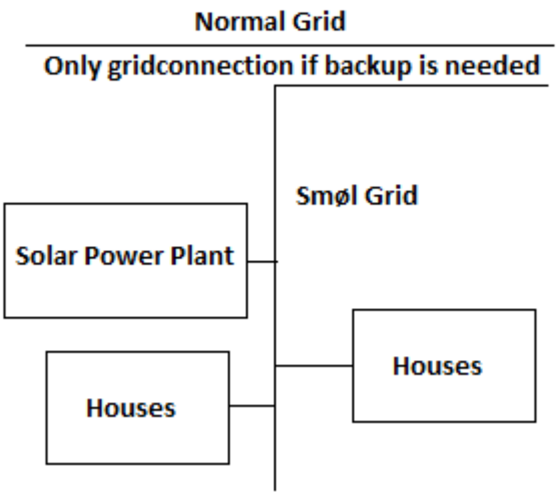
Pro	**Con**
Legal	Not the wished solution
Relatively cheap	No possibility to compensate the higher consumption of some of the households
Reliable	6kWp limit

Scenario three shows a basic overview of the current common solar energy (electricity) solution. Due to the already existing experience and knowledge about installations like the described won't we look deeper into scenario three.

[34] http://www.altomsolceller.dk/oekonomien.aspx (12.12.11)

3.4 Scenario 4: Stand Alone Solar Power System as main provider with Grid connection as backup.

The concept behind the fourth scenario is using a solar power system that is placed on the field beside the village of Smøl, as the main and hopefully the only electricity producer and supplier for Smøl with the normal grid owned by energy companies like "SydEnergi", only acting as a backup system.



In this case, the village of Smøl would be producing their own electricity and distributing it through their own electricity grid. The focus here will be to find out how to ensure electricity production and supplies all the time. Due to low UV periods of the day and the year, the production level of the solar cells is lower[35] and therefore the supply rate is lower as well. If all of these factors are taken into consideration, it is possible to see that these factors could lead to an electricity shortage for the village of Smøl. However, to ensure that the village of Smøl will not face an electricity shortage problem, they will have the opportunity to be connected to the normal grid that only acts as a backup electricity supplier in this case.

There are times, when the village is using less electricity than the system is producing. For example during summer months in general people are using less electricity. This would be considered as primal months of production. However, to avoid losing electricity, the village of Smøl should install a storage facility that stores the unused electricity. This could decrease the possibility of electricity shortages during the low UV periods. Information about storing technologies can be found in chapter 1.5.

[35]see Chapter 1.2

3.4.1 Electricity production

Photovoltaic (PV) solar power plant will by used to produce and provide electricity. However, in some situation electricity from normal grid will also be used to insure stable electricity supply for Smøl.

3.4.2 Technical feasibility

The photovoltaic (PV) technology already exists, therefore it would be technically feasible to implement a photovoltaic (PV) plant/system to produce and provide Smøl with electricity.

However, the electricity storage technology that could be used to insure low waste rate of the electricity that is being produced, also to ensure a stable supply of electricity and decrease the potential of electricity shortage. Is already a known technology, technically useful and feasible, and could be implemented as well.

3.4.3 Financial feasibility

Due to the facts that an electricity storage system has a high price[36] and requires a high starting cost, big investments and also implementing a storage system the maintenance cost would increase. The total cost of this project would increase enormously.

3.4.4 Carbon emission

The technologies used to produce, store and provide Smøl with electricity without emitting any carbon dioxide (CO_2) in to environment.

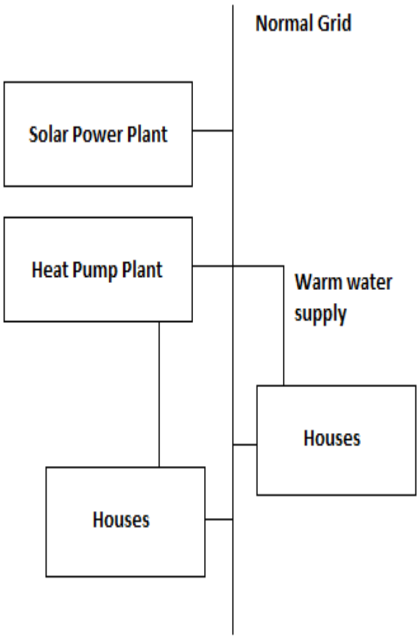
Below the pro and con argument for this concept can be seen:

Pro	**Con**
Independent from electricity firms	Illegal
Back up from the grid, if needed	High investment
Energy divided optimal	Storage is expensive
	Unknown maintenance cost

[36] see chapter 1.5 sub point 1.5.3

Due to the high costs of the storage technology, which is still under development, and because of the fact that this kind of system is illegal, it was decided not to use this scenario in the following chapter.

3.5 Scenario 5: Common Solar Power System with geothermal heating and heat pumps.



This is the last Scenario to achieve the aims of solar supported electricity in the households. As a difference to the other Scenarios we will split this Scenario in an “a” and a “b” version. Our whole report, until now, is focused on how solar energy could be implemented in Smøl to reduce their expenses – while also Sønderborg is looking forward to be a carbon dioxide free city until the year 2029. So to get closer to Sønderborg scheme this Scenario will not just concentrate on producing electricity with renewable energy, but also on the heating.

3.5.1 Electricity production

Since it is already clarified what kind of system will be used for producing electricity the question is what method we use to generate heat. There are many ways to generate heat with renewable heating technology, just as solar heating by solar thermal power plants, geothermal heating and heat pumps –to give a few examples.

- During a meeting with Project Zero we got the information that Smøl offered a big field where the common PvP could be installed. Combining that information with the goal of this scenario, Project Zero also shared their knowledge on renewable heating technologies that can be combined with photovoltaic solar panels. In their interest was a Geo Thermal heat pump with Earth Collector – while the PvPs are installed on top of the field the heat pumps are underground. One important aspect in this case that has to be considered is that the solar panels might not be installed directly above the earth collectors because the earth collectors collect the heat from the sun and also rain. Otherwise if the solar panels would be installed directly on top, these conditions are not fulfilled and the collectors would not work. Therefore the field must be big enough for both, the solar panels and the earth collectors, so that they can be installed next to each other, whereat one is in the ground and the other one on top of the ground.

- From further researches we did, we found out that the loss in heat would be too big if the earth collectors are also implemented on the field due to the long distance to the households. So the conclusion in that case is that the earth collectors are installed on the own property of each of the households, to achieve maximum performance.

3.5.2 Technical feasibility

The functionality of a heat pump is almost as similar to a fridge, whereat the fridge takes its heat from inside and gives it to the outside the heat pump takes the energy from the environment and relays into the houses. To fulfill the needs of heating and water heating in households the heat pump requires an operating power of 25%, where 75% is the heat it takes from the environment. But since our electricity supply is by PvPs the operating power is also produced with renewable energy, which means that the entire heat and electricity for Smøl is generated with carbon dioxide (CO_2) free energy.
To realize that we will need a heat source for the heat pump – as it is told before in this scenario the source is the property of each household. For an optimal usage of the given space we chose earth collectors which need 200-250 m^2 area to fulfill the heating needs for one single-unit detached house. These collectors work with a pipe system, which is placed horizontally under the ground near to the frost line – 1 to 1.5 meters deep.

3.5.3 Carbon emission

Heat pumps are not just environmental but also cost-conscious – with only 25% added energy it is able to produce 100% thermal output.

In this case there are two different ways to introduce this scenario to Smøl:

a) A common photovoltaic solar plant is installed on a field to fulfill the electricity needs of the whole Smøl inhabitants. Those plants are also connected to the grid that functions as a backup. In addition to that earth collectors are implemented underground on each property. The special aspect in this case "a" is that there is one big common heat pump that is responsible for the heat in all 22 units (houses) of Smøl.

b) The difference in this case is that there are installed more heat pumps instead of just a big one for all the units. A single heat pump is responsible for 1 unit (house).

In order to choose the best solution, either "a" or "b", there will be prepared an evaluation with the pro and con arguments for both listed.

Pro	Con
Optimal use of field	Not in every citizens interest
Most green solution	Low efficiency the first year in heating[37]
Include a heating system	
Gives a estimated 66% savings on heating bill.	

This is the best solution because it does not only concentrate in electricity supply but also in the heating. Therefore this scenario is concluded in the following chapter.

[37]See chapter 1.3.2

Chapter 4) Business Case / Models

This chapter focuses on the business cases concerning the scenarios 2 and 5. For instance, the proposal and then the calculations, which include the estimated pay-off rate and an estimation of how high the implementing cost, would be. All the calculations are done without adding the bank interest rate that is approximately 5% but can be different between banks. Also calculation give a estimation to the maximum price, due to the fact that it is calculated with high solar cells price and low electricity price. So, if setting up a system like seen in chapter 2 and 5 the prices for the solar system could (most likely would) be lower and the pay- off rate would decrease.

4.1 Scenario 2

This sub-point is going to focus on the business case concerning scenario 2. In this section the proposal and the calculation to the recommended scenario will be explained.

4.1.1 Proposal

The idea is about installing a solar power plant/system, which is going to provide the citizens of Smøl with enough electricity to reduce their current electricity cost of each citizen. However, hopefully in the future it is going to be the main electricity provider for the village of Smøl. If further explanations are needed, see chapter 3-sub point 3.2.

Furthermore, by installing a solar power plant/system in the village of Smøl, Sønderborg kommune and Project Zero would be one step closer to their goal of having a 0% carbon dioxide (CO_2) emission in the Sønderborg area in the year 2029.

4.1.2 Calculation[38]

These calculations are going to show how much it would cost for the village of Smøl to implement the facilities fulfilling all the requirements of scenario 2. Furthermore it will also include the estimated pay-off rate and the estimated annual savings that the village will save by implementing the recommended system in scenario 2. These calculations are done out from the assumption that only raw materials are needed, not including labour, smaller materials, rebuilds of houses if needed or smaller special equipment's that may be needed to finish the implementation.

4.1.2.1 Implementing Cost (Solar Cells Power Plant/System)

Implementing price for a photovoltaic solar cells plant/system:
Since we did not get a response on how much a common solar plant costs we calculated with solar plants for single household – which then will be multiplied by 22 (households). This is done because we assume that the price difference between this and a common plant will not be high.
A standard solar plant for a single household costs around **175.000 DKK** this is the case where the solar cells are placed on the roof of private owned houses. For Smøl we placed the solar cells on the ground in order to use the sun optimal, due to the different location of the houses.
The estimated total price for the solar cells plant/system would be around:
175.000 DKK x 22 households = **3.850.000 DKK**

4.1.2.2 Savings

These calculations are done, when the solar cells are providing a 90% efficiency rate and the electricity price is 2,00 DKK per kWh.
Savings per year at 90% efficiency: 2,00 DKK x 5.300 kWh = **10.600 DKK**
If the entire town is benefitting from the solar plant and using it's maximum capability the estimated total benefit for the village of Smøl would be:

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[38] http://www.climacare.dk/pages/id726.asp (Contacted by phone) (date:02.01.2012)

2,00 DKK x 116.600kWh = **233.200 DKK**

4.1.2.3 Pay off rate

The payoff rate at 2,00 DKK fixed for the savings (electricity prices are said to raise by 4% pr. year) will be around:
3.850.000 KK / 233.200 DKK pr. year = **approximately 16 years.**

For a single household would the calculation look like the following calculation:

$$\frac{175000\ Dkk}{10600\ Dkk} = \mathbf{16\ Years}$$

Where we have 175.000 DKK as the implementing cost for the solar system (without labour and bank interest rate) and 10.600 DKK as the annual savings.

4.2 Scenario 5

In this sub point the focus is going to be on the business case regarding scenario 5. The following sections are going to explain the proposal and the calculation behind the prescribed scenario.

4.2.1 Proposal

The idea is to install a solar power plant/system, which will also involve an earth collector heating system. These systems together are going to provide the citizens of Smøl, both electricity and warm energy that will heat up their houses. This is going to have the benefits of reducing the current electricity and heating costs for each citizen of the village Smøl. Furthermore, in the future the solar power plant/system can hopefully be the main electricity provider from the village of Smøl. If further explanation is needed concerning this scenario see chapter 3 sub point 3.5

By setting up a solar power plant/system for the village of Smøl, the Sønderborg kommune and Project Zero get closer to their goal of reducing carbon dioxide (CO_2) emission to 0% in the Sønderborg area in the year 2029.

4.2.2 Calculation

The following calculations will show how high the total estimated price would be for the village of Smøl, if they decide to implement the recommended facility talked about in scenario 5. It also will show an estimated pay-off rate and the estimated annual savings that the village would save by implementing this system. These calculations are based on raw materials, not including labour, smaller materials, rebuilds of houses if needed or smaller special equipment's that may be needed to finish the implementation.

4.2.2.1 Implementing Cost (Earth Collectors)[39]

A normal house uses between 200 and 600 meters of earth collector pipes. Because the biggest part of the houses in Smøl are relatively old buildings and may not have an ideal isolation we assumed that 400 meters of pipes are needed per house.

Required equipment:[40]

Types:	Price Ex. moms:	Price Incl. Moms:
Queen LV12DC Combi. ST (heat pump + tank)	75.028 DKK	93.785 DKK
Jordslange, Ø 40mm/35.2, PE-rør TN10 á 200m	3.200 DKK	4.000 DKK

The prices of 40mm Ø pipes are 4.000 DKK/ 200m

[39] http://www.jordvarme.dk/varmeberegning/jordvarme-dc.html (date 02.01.2012)

[40] http://www.jordvarme.dk/files/manager/pdf/dvi_priskatalog_15.09.2010.pdf (date 02.01.2012)

$$\boldsymbol{Total\ price\ of\ the\ pipes\ needed}:$$

$$4.000\ DKK\ \ast 2(\text{Jordslange}, \text{Ø}40\ \text{mm}, 200\text{m}) = 8.000\ DKK$$

A heat pump needs to be installed to each house, has the estimated total price of 94.000 DKK.

$$\boldsymbol{Estimated\ total\ price\ per\ Household}:$$

$$8.000\ DK + 94.000\ DKK = 102.000\ DKK$$

So the total price for the village of Smøl to implement the earth collector below ground and install the heat pump into each house:

$$102.000\ DKK\ \ast 22\ households = 2.244.000\ DKK$$

4.2.2.2 Savings

The annual heating bill per household is around 10.000 DKK compared to an 8.5 kWh/litre oil stove. Due to the estimated savings of approximately 66% of the annual heating bill, the savings would be about 6.600 DKK per year

$$\boldsymbol{Total\ savings\ per\ year\ for\ entire\ village\ of\ Sm\text{ø}l}:$$

$$6.600\ DKK\ \ast 22\ houses = 145.200\ DKK\ per\ year$$

This number is an approximation since we don’t know the average heat consumption per year for Smøl.

4.2.2.3 Payoff rate (Earth Collectors)

$$\boldsymbol{The\ payoff\ rate\ for\ the\ earth\ collectors}:$$

$$\frac{Total\ implementing\ price\ for\ earth\ collectors}{Total\ savings\ due\ to\ earth\ collectors\ per\ year} = \frac{2.244.000\ DKK}{145.200\ DKK}$$

$$= approximately\ 15\ years.$$

This payoff rate calculation is based on the assumption that the village of Smøl is only going to implement an earth collector facility.

4.2.2.4 Payoff rate (Recommended Solution from Scenario 5)

These calculations below are based on the assumption that the village of Smøl is going to implement and install the recommended solution in scenario 5.

$$\boldsymbol{Total\ implementing\ price}:$$

$$2.244.000\ DKK + 3.850.000\ DKK[41] = 6.094.000\ DKK$$

$$\boldsymbol{Total\ Savings}: 145.200\ DKK + 233.200\ DKK[42] = 378.400\ DKK$$

$$\boldsymbol{Payoff\ rate}: \frac{Total\ Implementing\ Cost}{Total\ Savings} = \frac{6.094.000\ DKK}{378.400\ DKK}$$

$$= \boldsymbol{approximately\ 16\ year}$$

[41] See chapter 4 sub-point 4.1.2.1
[42] See chapter 4 sub-point 4.1.2.1

The cost for the single household would look like the following calculation:

$$\frac{277.000\ Dkk}{17.200\ Dkk} = \boldsymbol{approximately\ 16\ Years}$$

Where we have 27.7000 DKK as the implementing cost for the solar system and the earth collectors system (without labour and bank interest rate) and 17.200 DKK as the annual savings.

Chapter 5) Stakeholders

This chapter is going to focus on the stakeholders, which are involved in our project. Below is the stated structure on what is included in the following sub points about each stakeholder.

1) What role do they play in our project
2) Information we got from them
3) What do they expect from us

5.1 Project Zero[43]

As it is already mentioned before in the report Project zero is known for the vision to create a carbon dioxide free Sonderbørg Kommune until the year 2029. Therefore they created a "concept which is based on energy efficiency combined with renewable energy from the county´s own green sources", as the say on their homepage.

Since renewable energy is the main task in our report we had Project Zero working in cooperation with us. They were always up-to-date about our project progress, gave us many tips – mainly in the scenario part and who we could talk to if we have specified questions – and helped us along by developing Scenarios for the report.

[43] http://www.projectzero.dk/ (date: 02.01.2012)

5.2 Sønderborg Kommune[44]

The Kommune gave us the opportunity to work on this project as a semester project, by inviting us to choose from different projects that involve villages in the rural district around Sønderborg and they were provided to us through the university.

After the selection of the project that we worked with, did the Kommune provide us with contact information to arrange a meeting with the village Smøl, which is the village, involved in our project.
Furthermore, did they provide a network that was used to assist with collecting information about the law situation in Denmark and energy consumption of Smøl.

Their exception is to get a report, which gives them good information, and solutions that fits the requirements given by the village of Smøl, Project Zero and Sønderborg Kommune. However, they also expect a well structured and detailed report.

5.3 Esbensen Rådgivende Ingeniører A/S[45]

Our supervisor Marianne Stenger provided us Torben Esbensens contact information who is the director of Esbensen Rådgivende Ingeniører A/S. During a meeting with Torben we have been able to get information regarding the current law situation and estimation on how the laws might change in future. Also Torben provided us the contact information of European Energy A/S.

[44] http://sonderborgkommune.dk/ (date.22.12.2011)
[45] http://www.esbensen.dk/ (date: 22.12.2012)

Conclusion[46]

We were able to create different scenarios, including Smøls wishes and what Project Zero and we thought was the best scenario.
With help from different internet pages mentioned in the references and phone calls to different companies we have been able to make some basic calculations to support the final scenarios and to give Smøl something to work with.
All in all we can conclude that it is possible to implement green energy. Even though it has a high initial price it can pay itself off within a reasonable time of 10-15 years.

Group Reflections

In general it can be said that the group worked good together, even when some deadlines were not followed all the time. But there were some complications such as sickness or other kinds of factors that kept group members from finishing tasks on time. However the group reached its target even though there was a discussion about the group progress.
As a conclusion to improve the group work we should have worked better on the organisation. This could have been clearified by declaring a group leader who would hold people up on their deadlines. At the end we can say that we learned to get in contact with firms, other organizations, inhabitants of villages, so we got in contact with real people. We also learned how to analyze data and research information by using different types of sources, as well as implementing the outcome of those into the report.
In addition it can be stated that we learned what is important to keep a nice climate in group work for the future.

[46] The danish version of the conclusion can be found under appendix D

Task Division

Below you can see who has done which part of the report. The chapters that are not mentioned below where done as a group.

Chapter 1) Research and Analysis

1.1 Town Analysis**(Bjarnhéðinn and Felix)**
1.2 Solar Cells **(Ufuk Ören)**
1.3 Heat Pumps with Earth Collectors **(Bo Jessen)**
1.4Price**(Felix Haakon Lenz)**
1.5 Electric Storage Technology **(Bjarnhéðinn Guðlaugsson)**

Chapter 2) Law

2.1 Law Situation**(Ufuk Ören)**

Chapter 3) Scenarios

3.1 Scenario 1**(Felix Haakon Lenz)**
3.2 Scenario 2**(Bjarnhéðinn Guðlaugsson)**
3.3 Scenario 3**(Felix Haakon Lenz)**
3.4 Scenario 4**(Bjarnhéðinn Guðlaugsson)**
3.5 Scenario 5**(Ufuk Ören)**

Chapter 4) Business Case / Models

4.1 Scenario 2
  4.1.1 Proposal**(Bjarnhéðinn Guðlaugsson)**
  4.1.2 Calculation**(Bo Jessen)**
4.2 Scenario 5
  4.2.1 Proposal**(Bjarnhéðinn Guðlaugsson)**
  4.2.2 Calculation**(Bo Jessen)**

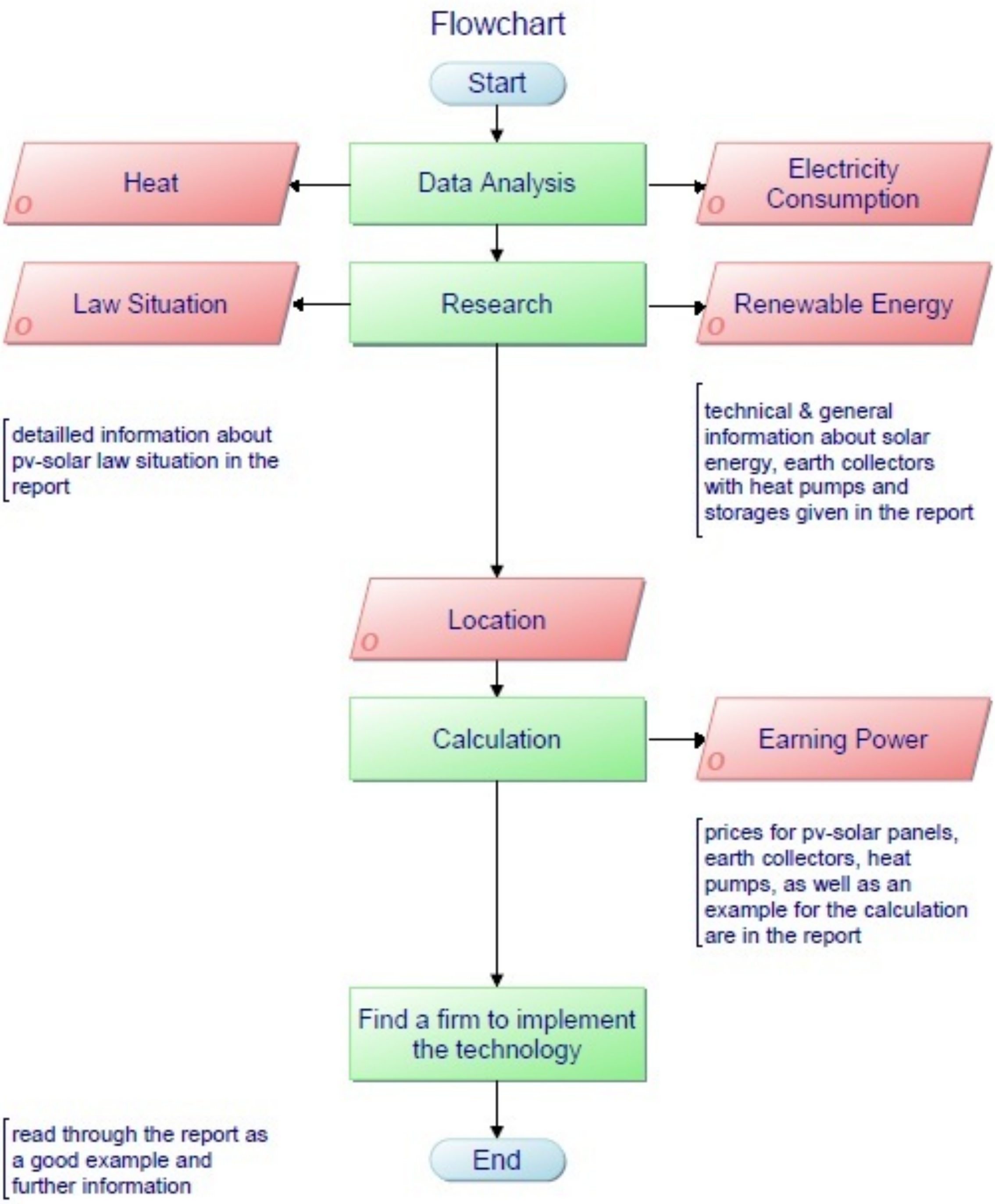
Chapter 5) Stakeholders

5.1 Project Zero**(Ufuk Ören)**
5.2 Sønderborg Kommune **(Bjarnhéðinn Guðlaugsson)**
5.3 Esbensen Rådgivende Ingeniører A/S**(Felix Haakon Lenz)**

References:

All the materials used during the creation of the report can either be found in the attached appendix, the footnotes or digital appendix (CD).

Flowchart for others



Appendix

Appendix A Data Table

Appendix B Meeting Notes

Meeting notes from 19.09.2011

Project Solar

Tasks:

- Infrastructure
- Solar research
  -Cost
  - Lifetime
  - Production
  - Pay- off rate
  - Example projects
    - Vollerup
    - Ærø
    - Auf der Jahnhöhe
- Project Plan
- E-mail
  - Kommune (Connie)
  - Smøl (smoel.infoland.dk - smoel.22@it.dk)
- Statistics
  - World wide
  - Denmark
  - Sønderborg

Plan for the first meeting with them:

- Short presentation of our group
- Our interests
- Their interests
- Get contacts

Meeting 21.09.2011

Meeting 22.09.2011

- Introduce our selves
- Get information about what they want us to do for
  - the project
    - what they want to use the energy for (heating, electricity or both)
    - plans on how to set up the panels
  - the presentation 29.09.2011
- Give them a basic idea of what we know about solar cells

Solar cells

- First 12 years 90 % efficient warranty
- After 12 years 80 %
- Lifetime approximately
- Decent solar panels 125-150.000 DKK mounted - pay off rate 12-15 years
- Output 6kW

What we are doing for them

- Create Business plan
- Finding good solutions
- Strategy for power solutions
- How they can use the power
- Check for better alternatives

Meeting Notes from Monday 26th of September

Meeting (town council) topics of conversation:

- Facts of energy consumption
  - Sønderborg
  - Smøl
- Share of solar energy (just as with the windmills)
- Are there any price support for the funding
- Law situation – Net-metering
- Is it possible to create a test-village?

Presentation for Thursday:

- Headpoints
- Good "punchlines"
- E.g. use of videos, pictures…
- Last slide – conversation points to keep the track
- Solar Plant costs – 125.000-150.000 D.kr. mounted
- Pay-off is approximately 11.000 D.kr. per year
- Pay-off rate is 12-15 years

Solar Facts:

- 0-12 years 90 % efficiency
- 13-25 years 80% efficiency } guaranteed
- 6 Kw/h = more or less 30 m^2
- Loss: 0.5 % efficiency pr. C°
- Lifetime: 30+ years
  - 5.77 kW
    5500 kWh p.a.
    121.000 kWh p.a.

12 households:

- 10x Inhibitors < 4 kWh
- 1x Heat pump 9 kWh
- 1x Farmer 15 kWh

Authors: Bjarnhéðinn Guðlaugsson, Bo Jessen, Ufuk Ören& Felix Haakon Lenz

Meeting 29.09.2011

Participants:

- Baddi, Bo, Ufuk, Felix
- approximately 30-50 citizens

Meeting structure:

- Introduction to the meeting (Aage Hansen)
- Information about the project (Connie SB Kommune)
- Presentation on what we will work with (Bo & Felix)

Questions:

- A women is rebuilding her house and will maybe install solar panels. Would it be possible to install a 4 kW system and buy a share of 2 kW (or how much she would need to cover the complete electricity consumption) from the community system?

  - Yes, our first very basic concept would include the possibility to buy shares of the whole system to get the optimal benefit
- How to finance the project

  - We don't know it yet and are not sure if we will look into it
- What about heat pumps?

  - We are only focusing on solar power (given project delimitation)
- How much is a 6 kW (legal maximum for private households) system producing per year?

  - 5 kW - 5,5 kW p.a.
- Options to get funds from the energy concerns

- We will probably check what possibilities we have

- How much would a common system cost?

  - Depends on how many would join (We can't provide any precise cost information right now)

- Possibility to plan the project to bend the laws (creating an example to get the politicians informed about the problems)

  - Could be a possibility

- What about new houses? Would it be possible to integrate them?
  - Depends on the final concept

Other points:

- A group of Smøl citizens is creating a work group to get information by their own
- The overall atmosphere at the meeting seemed quite positive
- The energy consumption of the last 3 years will be collected before monday the 03.10.11

Project Zero Meeting: 11.10.2011

- Questions we prepared before the meeting:
- Q1: Do you know a certain person that could help us in the questions about test-villages?
- Q2: Is project zero involved in the project? And if so, are there any special aspects we have to consider in the report?
- Q3: Are there any specific Databases you can recommend us? - Mainly about the energy consumption in Smol and Sonderborg.
- Q4: Do you have any knowledge about the law situation and funding? – Or any idea how this project could be realized.

Meeting with Marianne 08.12.11

- Clear statement of the problem regarding energy in rural districts
- Info about the first smøl meeting

Problem formulation:

- Clear question
    - Steps to solve the problem
- Tech. info about the 37° south!!!!!!

Smøl analysis:

- Short explanation in the beginning what we did

1. Table:

- House => Persons in household

Average elec. consumption for a normal 2-4 people household

The total usage 2010:

- 6kWp SOURCE!!!

Stakeholders should be included

Meeting with Torben Esbensen

Law

Money for electricity overproduction: 0.6 DKK

Changes in law:

- Change of 6 kWp limit my be done for households with heat pumps

- Common solar plants may become legal

Institutions may set up 6 kWp per 100 m^2

Tech

Earth collectors under the solar panels are not possible.

Electricity share:

- Illegal right now

- anpart system may possibly come in the future

Farm

Should be taken as a normal household:

- Electricity use of the farm should not be included! Only the private use

Contact information

Esbensen Consulting Engineers A/S
Torben Esbensen
Møllegade 54
6400 SB
torben@esbensen.dk
www.esbensen.dk

To contact for information about a common solar plant - price

European Energy A/S
Jan Vedde
jan.vedde@mail.dk

Other Solar Firm

PA Energy A/S
Peter Ahm
ahm@paenergy.dk

Appendix C Project Plan and group rules

Rules:

- Worktime: every Monday and Wednesday 9:00 o'clock (optional other days) unless nothing else is agreed
- Sending a progress document to Marianne every week (Friday)
- Sickness and other excuses should be told prior to the meeting (if a person is missing a decision will be made)
- Divide the work in groups of 2 persons (optional)
- Language: English
- Alert time: The day before

Project Plan

<u>Energy Consumption in Households</u>
:Report writing and assembly

Q1 (Overview of how energy (electricity and heat) is produced today in rural districts)
: Research
Project Zero
Danish Bank of statistics
Internet
Meeting with Sønderborg Kommune
Meeting with Project Zero
Meeting with Marianne
Analysis Data form the research
Meeting with Marianne
Q2 (What are the citizens needs, wishes and demands if they should become CO2 neutral (social needs, economy, risk assessment))
Meeting with Marianne
Q3 (Which (technical) solutions are available today)
Meeting with Marianne
Q4 (Which legal barriers are there)
Meeting with Marianne
Q5 (Which common social and technical solutions could be possible in the future (concepts, business models illustrating return on investment and reduction of (CO2))
Meeting with Marianne
Q6 (Feedback from users, customers etc)
Meeting with Marianne
Group Feedback and last min, report work.
:Report writing and assembly

Appendix D Conclusion in Danish

Det var muligt for os at skabe forskellige scenarier, hvor Smøls ønske og hvad vi (og Project Zero) valgte som den best mulige løsning indgik.
Med hjælp fra internettet (jordvarme.dk) og telefonisk kontakt (climacare.dk) kunne vi lave nogle basis udregninger til at understøtte den endelige scenarier, samt give Smøl noget at arbejde videre med.
Alt taget I betragtning er det muligt at få grøn energi ud i landdistrikterne, det har sin pris, men anlæggene kan betale sig selv inden for rimelig tid (10-15 år)