VAASAN AMMATTIKORKEAKOULU

UNIVERSITY OF APPLIED SCIENCES

Gyibah, Nathaniel

BIOMASS POTENTIALS IN FINLAND

THE CASE OF PÖRTOM

Technology and Communication

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Preface

Energy has been widely recognized as central to achieving the goals of sustainable development. It is a very important and crucial issue when it comes to an input to industrial, economical and social development. The demand for energy is fast growing and as the conventional energy sources are depleting daily, there is the need to transform the existing global energy into focus. Hence, utilization of other alternative energy sources is the only solution.

This thesis is about researching into renewable energy to find an alternative energy source for the green house farmers and the municipality buildings in Pörtom, a village that is situated 50km south of Vaasa in the Närpes municipality.

I would like to express my sincere gratitude to some individuals who have been of great help in one way or the other. Especially, the Managing Director, Nordex 2009 project in the person of Bengt Englund, senior lecturer Novia University of Applied Sciences and also to Jan Teir of West Energy who works as the owner of the project. Big thank you for the time invested in this project!

I am most grateful to Dr. Adebayo Agbejule, principal lecturer Vaasa University of Applied Sciences who having heard about this project did not only introduce to me but also encouraged me to take up the challenge that has finally proven to be my thesis work.

I am also very thankful to my Dad and Mom Mr. Nwia-Mieza Gyibah and Mrs. Agnes Gyibah, for their material and moral support through all these years.

The most important of all the thanks goes to God Almighty Jehovah, my source of life for his tender care and protection.

VAASAN AMMATTIKORKEAKOULU

UNIVERSITY OF APPLIED SCIENCES

Bachelor of Engineering in Information Technology

ABSTRACT

Author	Gyibah Nathaniel
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The objective of this thesis is to research into renewable energy sources to find an alternative energy source, and to calculate the profit possibility for a common CHP-plant in the village of Pörtom. Factors as the role of ICT in energy efficiency, the availability of materials (fuels, etc.) and the technology involved will be researched to make sure the solution is possible to realize in reality.

Keywords Renewable Energy Sources, Efficiency, Technology

DEFINITIONS

CHP	Combine Heat and Power Plant
ICT	Information and Communication Technology
KWh	Kilowatt-hour
MW	Megawatt
GW	Gigawatt
CFB	Circulating Fluid Bed
El. Prod.	Electricity production
El. Capacity	Electricity Capacity
CO2	Carbon dioxide
CO	Carbon monoxide

Contents

1. INTRODUCTION

Mission was to do research in renewable energy to find an alternative energy source for Pörtom and to calculate the profit possibility for a common combined heat- and power (CHP) plant. If this turned to be profitable, it would mean a great upswing for the greenhouse farmers and especially for the smaller greenhouses. In the environmental aspect a large power plant could easily be less pollutant compared to several smaller ones; especially if the fuel source would be located close to the power plant. This power plant would then produce both heat and electricity, with electricity as a by-product. It would not only supply the greenhouses but also the municipality buildings and possibly private owned buildings. In the search for the energy source the natural recourses in the area surrounding Pörtom will be looked at to see if there were any usable factories or waste from farms, which could be burnt or in some other way be transformed into usable energy.

1.1. Purpose of the Study

Mission was to plan a CHP (Combined Heat and Power) plant in the village of Pörtom. The project suggests a renewable energy replacement for oil burner currently used for heating greenhouses and municipality buildings in Pörtom. It has to produce the desired amount of heat, have electricity as a by-product and be economically viable.

Factors as technology involved, the role of ICT in energy efficiency, and the availability of materials (fuels, etc.) will be researched to make sure the solution is possible to realize in reality.

The background for this project is a co-operation between schools in Scandinavia to give their students project experience on an international level. Its main criteria are renewable energy and the assignment this year was based on renewable energy solutions in the village of Pörtom.

1.1.1 Pörtom

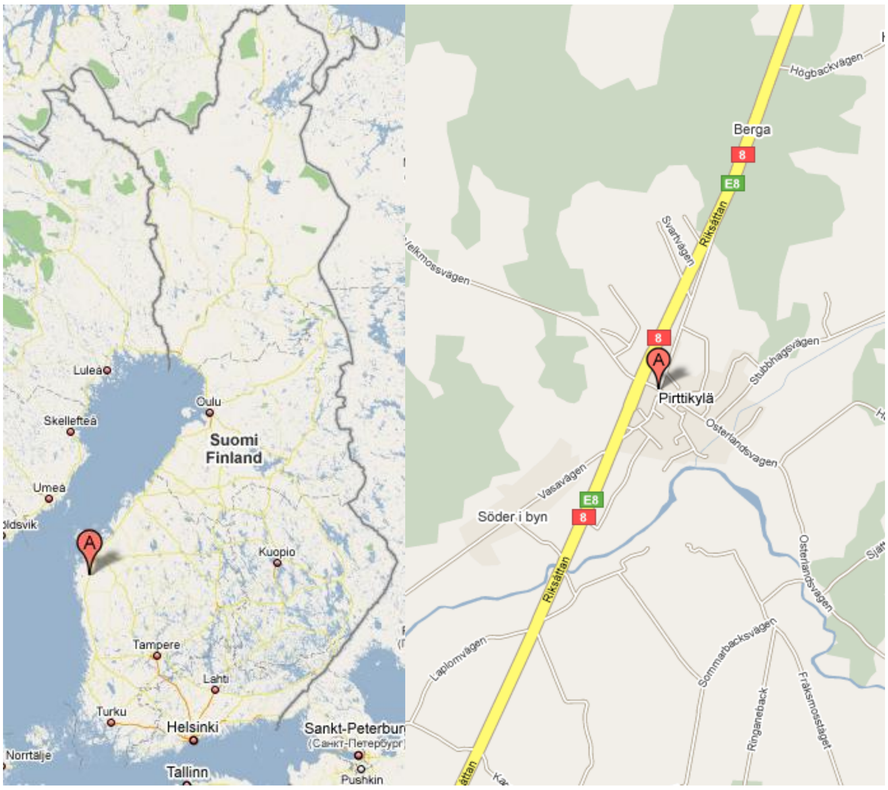


Figure1_ Location of Pörtom
Source: (http://maps.google.fi)

Pörtom is a small village in the municipality of Närpes. It is located next to road E8 about 50 km south of Vaasa and it has about 1000 inhabitants (sv.wikipedia.org) see figure 1. It is surrounded by forest and farm lands and the landscape is fairly flat. There are about 20 greenhouse farmers located in this area and the reason for the popularity for greenhouse farming is a heritage, which started several years ago. Many of the current farmers own their farms due to family heritage.

1.1.2. Renewable energy

Renewable energy sources are the main target of this project. Energy is one of the essential needs of a functioning society. The scale of its use is closely associated with its capabilities and the quality of life that its members experience. However, threat of global warming, acidification and nuclear accidents have put the need to transform the existing global energy into focus, especially since the demand for energy is fast growing (Tester, Drake, Driscoll, Golay & Peter, 2005).

In order to sustain economic growth, our economy strongly depends on large amounts of fossil fuels such as oil, natural gas, and coal (International Energy Agency, 2006). These fossil fuels have several negative effects on the environment, among which are local air pollution and climate change. Therefore, for several decades, (inter)national governments have made plans to reduce the economy's dependency on fossil fuels by the substitution of alternative energy sources such as renewable energy sources. Renewable energy sources are defined as any energy resource, naturally regenerated over a short time scale and derived either directly from the sun (such as thermal, photochemical, and photoelectric), indirectly from the sun (such as wind, hydropower and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy). Renewable energy does not include energy resources derived from fossil fuels, waste products from fossil sources, or waste products from inorganic sources.

1.2 Research Questions

The thesis will among other things answer the following three questions while dealing with biomass potentials in the village of Pörtom:

i. What are the different types of renewable energy sources available?

ii. What is the energy consumption and preferred choice of renewable energy?
iii. What is the role of ICT in energy efficiency?

1.3. The Study Outline

This thesis is divided into different chapters concerning their individual relevance to the project.

Chapter 1 introduces the thesis and focuses on the purpose of the thesis as well as its background.

Chapter 2 is centred on renewable energy sources and it will explain the elimination of different technologies, conclude with the technology decided to be used and a section that will only focuses on biomass, will discuss the direct burning and the gasification processes of biomass; and it will cut across electricity production from biomass to fuel choices. “Fuel choices” is general information about the fuels that could be used for energy production.

The research methodology is discussed in chapter 3. It deals with the methods and sources and explains how to quality check the information that will be gathered.

Chapter 4 is the largest chapter. It handles the technical analysis and will cover several sub chapters like:

The “consumers” which explains the information about energy consumption or needs that will be used to decide the technical solution and the size of the power plant.

“Plant technology” will explain the major technical components that have been decided to include or exclude from the power plant.

“Plant location” will discuss the factors behind the location considered to be the most appropriate; and “Cost calculations” will focus on the economical aspect of the development to see if this project is possible to implement in reality.

The chapter 5 discusses the role of ICTs in energy efficiency as well as ICT and energy consumption, and how ICT can influence energy efficiency.

Chapter 6 deals with the “Conclusions” which is a summary of the solutions found to be the most viable and the criteria’s involved as well as the thesis limitations and recommendations.

2. RENEWABLE ENERGY SOURCES

2.1. Energy Sources

With the mission and purpose of this project, which is to look at the most efficient, economical and feasible renewable energy sources for the green house owners in the community of Pörtom in mind, I have researched and investigated into various sources of technologies involved in renewable energy. These sources are described below.

a. Solar Power

Solar energy is "energy from the sun that is converted into thermal or electrical energy" (Solar Energy History, http://www.go-solar.net/?s=thermal, 2009). By using solar panels, which are large flat panels made up of many individual solar cells; one can collect sunlight and convert it into electricity. However, since Finland is exposed to very limited amounts of sunlight in the winter time, when the heating and electricity is mostly needed, therefore with the consent of the project owner and its managing director this resource is excluded from this project.

b. Wind Power

Wind as an energy source is based on converting kinetic energy from the movement of air to electricity through windmills. It is a renewable energy source and environmentally friendly, although some argue it disturbs the local environment as it produces noise, and changes airflow. It is also tall and visible, which is of disturbance to the local community and nature experience for tourism. The fact that the intensity of wind in the project area is unstable and sometimes not present at all, leads into the conclusion that it is an irrelevant energy source due to its lack of the stable production of energy needed.

c. Geothermal

The village Pörtom with the greenhouses needs a lot of heat. Because of that, it was necessary to take a look on geothermal energy. It gives two choices in producing energy from terrestrial heat; deep geothermal and flat geothermal. For our project, concerning the energy needs and the local area, only deep geothermal (more than 400m deep) was a serious issue. See figure 2.

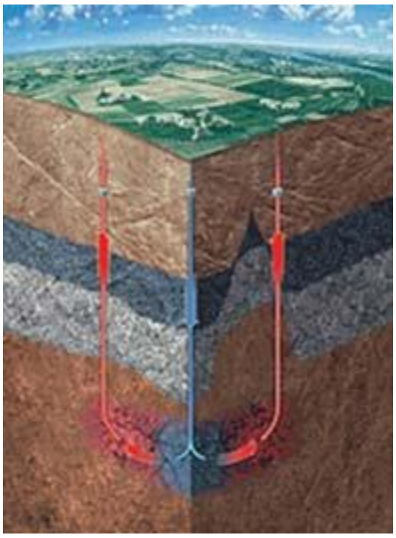


Figure 2 Deep geothermal solutions

***Source:* (*http://www.pfalzwerke.de*)**

Important for this kind of energy winning concerning the cost efficiency is:

- Attended temperature difference
- How deep
- State of the soil
- Geothermal activity

Deep Geothermal plants can only work efficient with water temperatures around 180 °C, and Finland has generally a low geothermal activity. For this temperature in the area around Pörtom is deepness from more than 7 Km necessary. The costs for the drilling and finally the energy needs for the pumps to make this kind of energy production are not suggestive. Additionally the great biomass sources in Finland, especially in the area of Närpes, make geothermal energy at this time and in the conceivable future unattractive.

d. Hydro power

Hydro electricity is obtained by mechanical conversion of the potential energy of water in high elevations. The feasibility of this technology depends on the locality and the geographical factors of runoff water (available head and flow volume per unit time).

Hydro power is an environmentally friendly renewable energy source that uses kinetic energy of water in motion to create other forms of energy, usually electricity. Because this part of Finland-Pörtom is flat, there are no rivers that contain enough kinetic energy to actually produce electricity or heat in the requested scale. As for wave power, the coastline of Ostrobothnia is only exposed to waves at very limited degree. The same goes for tidal power as an energy source as there is a minimal sea level difference. As has been the case of these three renewable energy sources, namely: hydro power, wave power and tidal power, therefore with the consent of the project owner –Jan Teir we exclude these resources.

e. Hydrogen

Hydrogen is not an energy source that can be found in nature, but an energy carrier that has to be produced through a chemical process. Hydrogen is an element. An atom of hydrogen contains one proton and one electron. Despite its simplicity and abundance, it does not occur naturally as a gas on the Earth – it has always combined with other elements. "It can be combined with oxygen without combustion in an electrochemical reaction in a fuel cell (reverse of electrolysis) to produce direct current electricity" (NUhydro). Hydrogen is an environmentally friendly renewable fuel because the raw material for hydrogen production is water and the by-product of hydrogen utilization is water and water vapour.

The hydrogen has to be pure for this process and pure hydrogen is not found naturally, it has to be produced. As there is no source for hydrogen in Finland it will be a problem to utilize this energy technology for producing electricity. This technology is also not common for big scale plants; usually one plant is in the scale of a household's energy consumption. Hence, it is not feasible to include in the project.

f. Biogas

The process

Biogas is actually a combination of several different gases, the main components being methane and carbon dioxide. Hydrogen sulphide, ammonium and hydrogen are represented in small amounts. The production of biogas from biological material is a multiple step process, where micro organisms free the energy contained in carbohydrates, fat and proteins as detailed in figure 3.

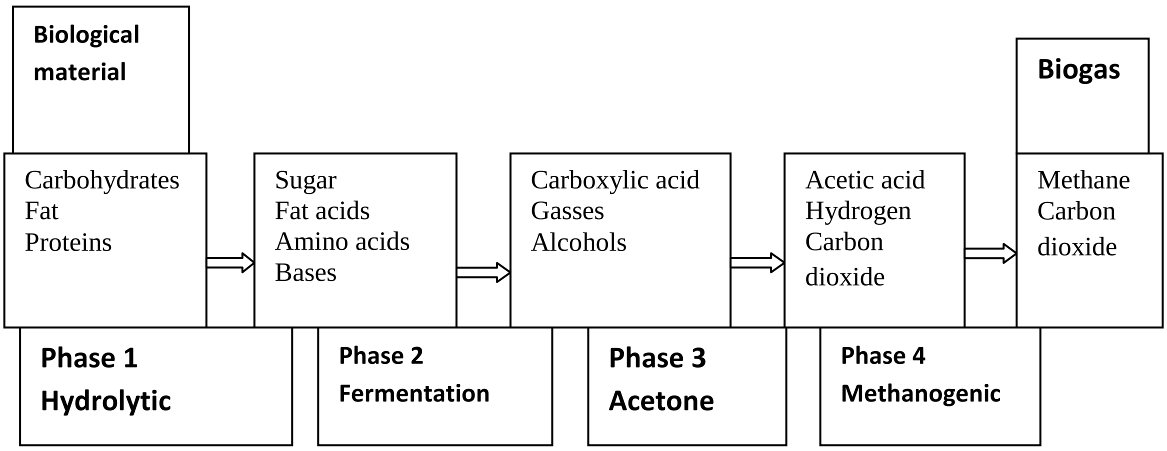


Figure 3 Illustration of the biogas process

Biogas Storage

The initial idea was to have a backup biogas plant for covering peaks of heat and power consumption, based on a continuous gas production from a manure and straw combination. Gas would be compressed and stored for later use. This requires an economical storage process.

For high or medium pressure storage, the biogas has to be cleaned to avoid corrosion (mainly removing of H20 and H2S). Compressors and the energy used for compression are additional costs as well. For example for propane, the storage pressure can be about 17 bar, compressing biogas to this range takes about 5.3 kWh per 30 cubic meters. Assuming methane content of 60% the compression will use about 10% of the stored gas. For high pressure storage in the 140 bar range, cleaning is even more important as corrosion is more likely. The compression is also more energy consuming with about 14, 8 kWh per 30 cubic meters. This gives a consumption of about 17% of the energy of compressed gas with 97% methane content (K. Kirch et al. 2005).

The next issue concerning gas storage for a longer time is the low caloric value of biogas, when considering the volume (1000 l Biogas = 0, 6 l heat oil). Usually storing biogas for few hours in cheap foil-pillow-storage can be useful. Figure 4 below illustrates the process.

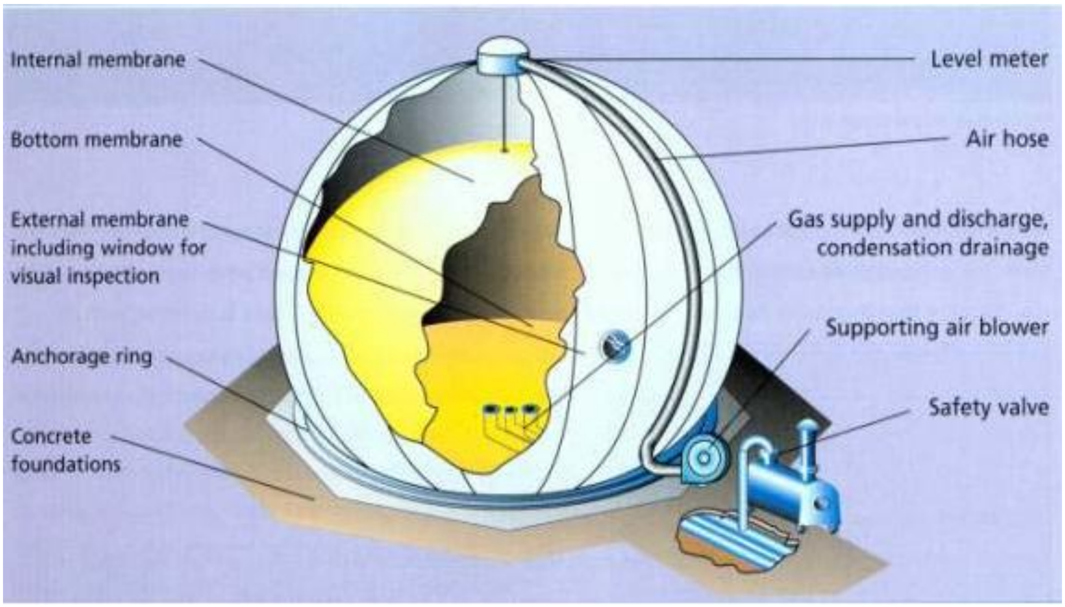


Figure 4 Foil-pillow-storage

Source: (www.atal.com.hk)

The pressure here is between 0,005mmbar - 0,1mmbar. There is also some gas inside the fermented. For high pressure storage some expensive safety-units (special values and control units) is necessary.

Small calculation of biogas storage

Biogas (low caloric value): 5 kWh/m³

To store 40 000 kWh of biogas in order to cover peak days, we need a storage volume from 8 000 m³. This equals an edge length of 20 m in a cube, which would cover 400 m2, and the height would be 20 m.

If the biogas backup plant was to have a 5 000 kW output (with about 40% el. and 45% heat), then two weeks of energy stored for this would be ca. 1 680 000 kWh. This would amount to 336 000 m3, and with a cubic tank the sides would be almost 70 m covering 4900 m2. The time to produce 1 680 000 kWh from 100 t/day of cow manure would be 52 days.

Straw as resource

Because of the high availability (70 000 tons of dry substance) and the low cost, straw is one of the main energy carriers concerning this project. To make biogas from straw you need methane bacteria from the stomach of animals, which can cut the glycoside connection of the straw. Usually a source for these bacteria can be cow dung. However, straw is generally difficult and slow to cut, it would be much more efficient to use the entire plant including the seeds, but this is far more expensive material. There is also an ethical question of using food for heat and electricity. Straw silage is also more efficient, but it needs energy and time.

In the area of Närpes we can use the dung of cattle farms (2900 animals), pig farm (5800 animals) and hens (220000 animals). That is more than enough as co ferment, but the problems with pig and hen manure is its aggressive and strongly contaminated contents. Dung cleaning would then be a necessity.

The fact that a documented gas yield from straw is not available in any of the tables we have found suggests that it is not a resource commonly or economically used for biogas production. This leads to the conclusion that straw is not yet, if ever a biogas production source.

To have a biogas backup plant is not a solution for this project. Storing of the gas in larger amounts over longer periods is complicated, energy consuming and economically impossible. The raw material is not available for the scale of power plant intended in this area when straw is not an alternative as main content.

2.2. Biomass

This aspect has been divided into direct burning and gasification because it is two different ways of using the fuel sources.

Direct Burning

Biomass is an organic material made from plants and animals. Nevertheless, for the energy production only biomass from plants is of importance.

Example of biomass fuel source includes:

- Wood & Wood Waste
- Municipal Solid Waste
- Garbage Crops (e.g. straw, willow, switch grass)

Biomass energy is considered as a renewable or sustainable energy because of its dosed carbon cycle (Diane M. Marty, May 2000). Biomass technologies use combustion processes to produce heat and electricity. Direct combustion systems burn biomass in boilers to produce high pressure steam. This steam turns a turbine connected to a generator. In addition, as the turbine rotates, the generator turns and electricity is produced.

Concerning, waste to energy plant, "plants use garbage—not coal—to fire an industrial boiler" (EIA, Sept. 2006) the process involved is as shown in the picture below.

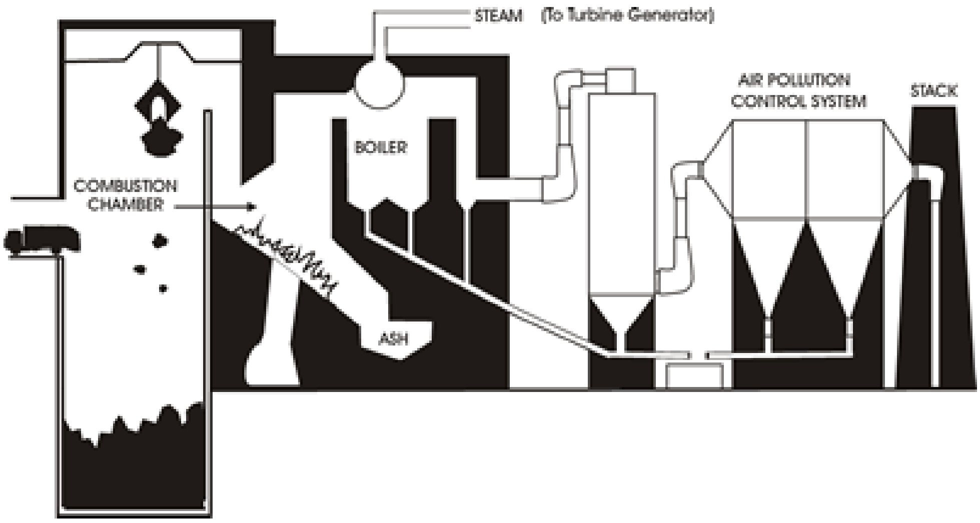


Figure 5 Waste to energy plant

Source: (EIA, September 2006).

From the above figure 5, the fuel (i.e. garbage) is burned, thus releasing heat. The heat turns water into steam and the high-pressure steam turns the blades of a turbine generator to produce electricity. A utility company then sends the electricity along power lines to homes, schools, and businesses.
The ash from the boiler is the main resource for solid waste generation in the power plant and all of them are considered as possibility to be treated comprehensively and returns to the field as fertilizers.

Gasification

Gasification of biomass is a process where biomass is heated untill it releases combustible gasses through partly combustion. The technology was first commercially installed in 1839, but was mostly dropped for oil fuelled solutions in 1920's. Interest has since occurred every now and then with the variations in oil price. During World War II the technology was used to run vehicles in Germany to avoid dependence on oil import. It also attracted some interest during the energy crisis in the 1970's. The technology is more than 150 years old, but concerning biomass it is not commercially established on the market despite maturity in age.

The Biomass gasification Process

In the process of gasification, carbonaceous material such as for instance biomass is heated with regulated oxygen access to release a mixture of gasses that is used as a fuel. Combustion creates heat for the other processes and releases carbon dioxide (CO2), carbon monoxide (CO) and steam (H2O). Between the pyrolysis and combustion several different chemical reactions occur in the absence of oxygen. CO2, H2O and heat from the combustion reacts with Charcoal to create CO and H2. This is called reduction. Pyrolysis decomposes carbonaceous material to charcoal, hydrogen, methane and tars. The end product is called Producer Gas, where carbon monoxide (CO), hydrogen (H2) and methane (CH4) are the desired combustible gasses. For example, a pilot CHP plant that uses the gasification technology is the sawmill-plant in Tervola; they experienced some problems with gas quality in the start-up phase that set back the electricity production by two years which is an indication of the insecurity of this technology. It uses wood residues like bark and sawdust from the mill and has an input of 2 MW fuel. The output is 1, 13 MWth and 0, 5 MWel, the electricity is produced from a Jenbacher gas-engine (Kirjavainen et.al. 2004, Small-scaled CHP).

The advantages with gasification are fuel flexibility, controllable and adjustable combustion of the gas. The gas can be cleaned before combustion in situations where gas quality is a problem. It also has high efficiency of electricity production, because the gas can burn on a higher temperature than biomass. Stability, complexity and level of establishment of the technology are the disadvantages. It's not possible to store the gas produced and the investment, maintenance and operational costs are higher than for other and more established technologies as table 1 shows. The economical and technical disadvantages compared to other technologies, concludes that gasification is less suited for a CHP-plant at current time.

Table 1 Economic comparison of technologies

Plant	CFB*steam gasification process	Steam turbine process	ORC
El capacity	2MW	2.3MW	1MW
Add. Inv. Cost* €/kWel	3400	2300	2600
El. Prod. Cost* €/kWhel	0.13- 0.16	0.10-0.13	0.11-0.15

Source: (Obernberger/Biedermann, CHP overview, 2005)

*CFB Circulating Fluid Bed

* Additional investment cost to a conventional biomass combustion plant with a hot water boiler and the same thermal output.

2.3. Electricity Production from Biomass

In the greenhouse community of Pörtom they need energy both in the form of heat and electricity. This means that there is need for a combined heat and power (CHP) plant.

There are several technologies available to create electric energy from biomass, but they all have one thing in common. They all use heat from combustion to create kinetic energy, which is then transformed to electrical energy. In this project different types of technologies have been investigated to find the one most suitable for the client.

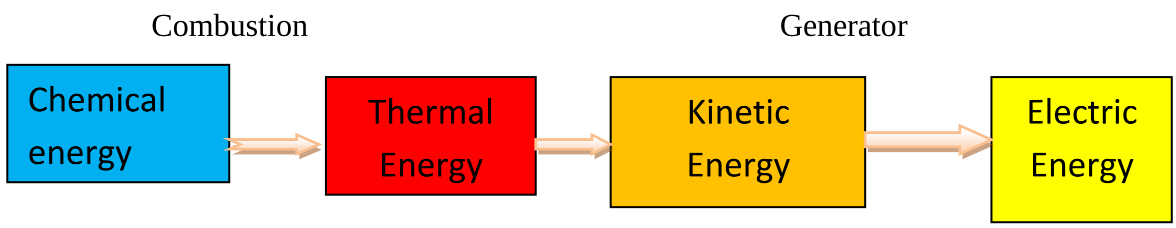


Figure 6 Electricity productions from biomass

From figure 6 above, the chemical energy in biomass is released as heat in combustion. The thermal energy will then have to be transformed to kinetic energy in order to drive a generator. This transformation is where the CHP technology does its part.

In a CHP-system utilizing the steam cycle, the heat from combustion is used to generate steam in a steam generator. The steam flows through a steam turbine that runs a generator and produce electricity. Then the steam is condensed by a condenser, and heat is extracted as shown in figure 7 below.

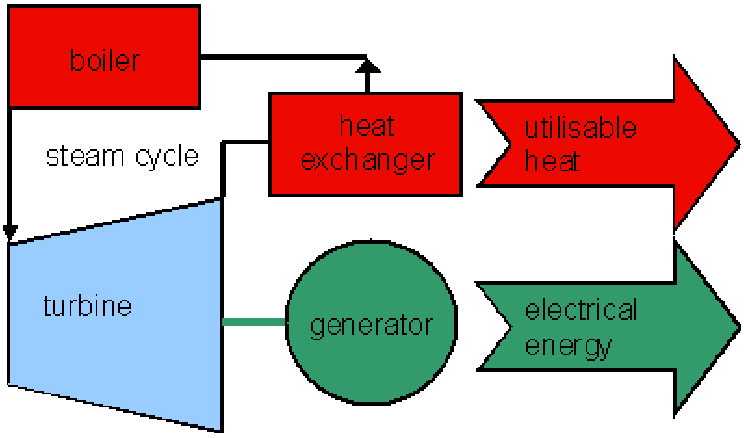


Figure 7 Steam turbine systems *(Cogeneration (CHP) Technology Portrait 2002)*

There are two main types of steam cycle CHP-plants, Figure 8 shows the steam cycle with a back pressure turbine and figure 9 shows the steam cycle with an extraction condensing turbine.

Back pressure turbine

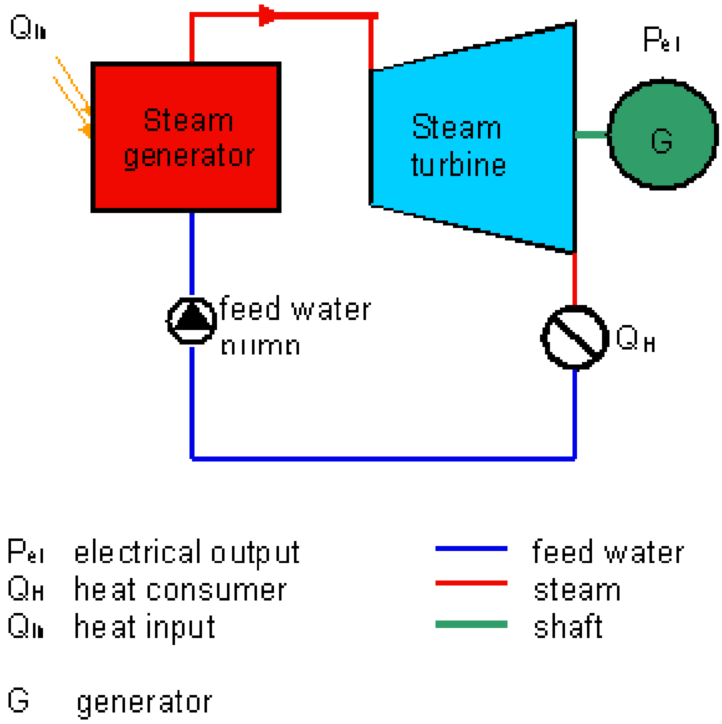


Figure 8 Steam cycle with back pressure turbine

Source: (Cogeneration (CHP) Technology Portrait 2002)

The steam cycle with a back pressure turbine is used in plants where the boiler runs on a constant temperature, there is little flexibility as the steam generator needs a certain temperature to generate back pressure for the turbine to run. This type of steam turbine plants are used for electricity production and district heating in the range of 0.5 to 30 MW of electricity and in some cases more.

Extraction condensing turbine

The steam cycle with extraction condensing turbines is quite similar to the back pressure turbine, but it has a valve control system that makes it possible to adjust the heat and electricity production to meet different requirements. These plants are used for district heating and electricity production in the range of 0.5 to 10 MW and in some cases more.

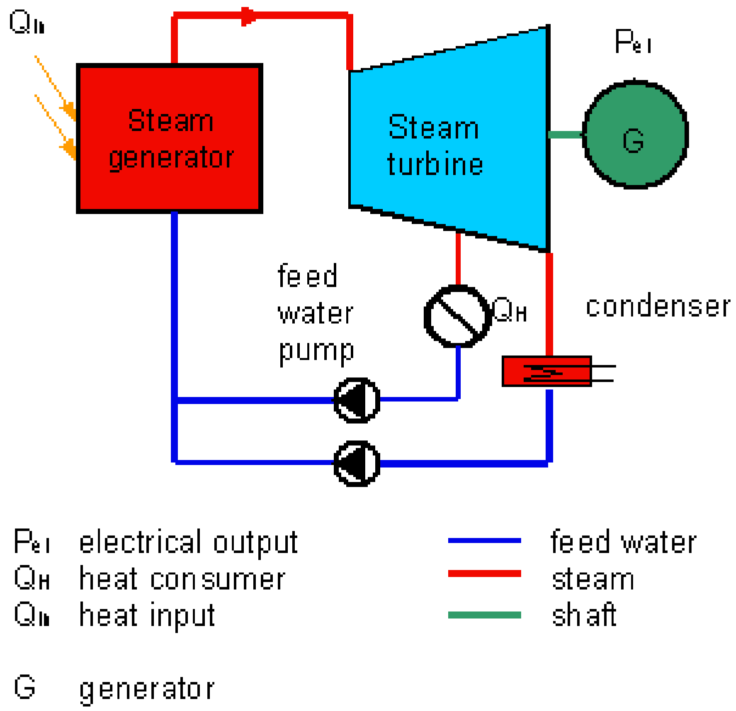


Figure 9 Steam cycle with extraction condensing turbine
Source: (Cogeneration (CHP) Technology Portrait 2002)

The advantage of steam cycle CHP plants is its flexibility in fuel choice because anything that can be burned in a boiler can basically be used. The technology is well established and the range of electricity and heat production is not limited. Disadvantages are that the electricity production efficiency is depending on the steam pressure which requires high temperature combustion. The higher the pressure the more efficient the electricity production will be, this require equipment capable of withstanding high pressure and temperature. There are also maintenance and operational costs. The water should be treated to avoid salt to be left in the steam generating system.

With Stirling engine the engine contains gas that is heated and cooled to cause expansion and compression to drive a cylinder. Energy goes from heat to pressure, then to kinetic and electricity is produced. Any type of fuel can be used as the heating is an independent process. There are no explosions in the engine, so it's a low noise process. Ash layers from the fuel burning will reduce efficiency on heat transfers and should be minimized. These engines are only available in small scale range, the company Stirling Danmark Aps (www.stirling.dk) provides sterling CHP-engines with up to 140kW of electricity production. Example of Stirling engine is as shown in figure 10 below. It is an interesting technology, but for this project the technology is unfortunately not available in a large enough scale.

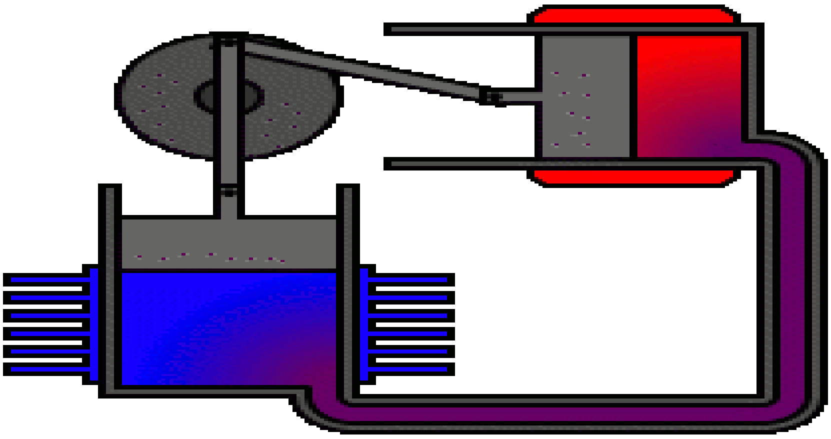


Figure 10 Two-Piston Sterling Engines
Source :(http://www.answers.com/topic/sterling-engine)

Comparisons of the different technologies have been documented by different studies and here in table 2 and 3 are some gathered data from two different sources to illustrate some properties of the different technologies.

Table 2 ***Comparison table 2***

Type	Unit	Striling Engine	Backpressure steam turbine
Size	kW_{el}	10-40	1000
Specific investment costs	€/kW_{el}	2400	1500
Specific Maintenance costs	€/kWh_{el}	0,004-0,011	0,007
Electrical efficiency	[%]	21-28	10-20
Overall efficiency	[%]	63-86	70-85
Silicon oil	€/liter		

Source: (Obernberger and Biedermann: CHP overview 2005)

Table 3 Comparison table 3

Type	Unit	Sterling Engine	Steam turbine process	ORC
El capacity	MW	0.1	2.3	1
Add. Inv. cost*	€/kW_{el}	3500	2300	2600
El. prods. Costs	€/kWh_{el}	0.18	0.10-0.13	0.11-0.15

Source: (Cogeneration (CHP) Technology Portrait 2002)

*Additional investment cost to a conventional biomass combustion plant with a hot water boiler and the same thermal output

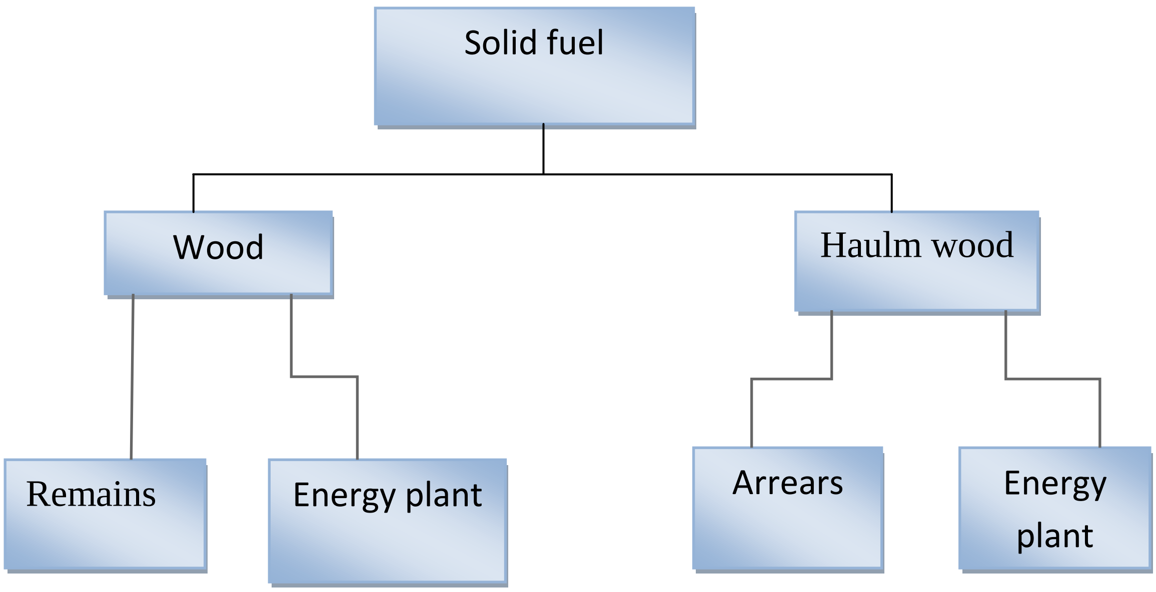
The tables tell us that the steam turbine technology has an economical advantage. The fact that it is the most established technology is also an advantage. The Stirling engine is not available for the size of power output that is demanded for this community. The conclusion is that steam turbine is the most economical technology and also the one that is available concerning the required properties.

2.4. Fuel choices

At time Finland used more than 20% biomass for their energy production (electricity and heat) and is therefore on Europeans top after Sweden and Austria. The biggest part at this is wood in the form of trees. Reasons for that are for example the extremely high sources (comparatively in Europe) in form of hardwood. The other kinds of biomass play a small part in the power production. Other reasons for that is a small energy capability concerning hydro power with a view to the neighbouring country Norway (more than 90 % electricity from hydro power). But the biggest part of the forest industrialisation is the paper and furniture production.

Biomass is plants and animals, all their products and rests. But for the energy production only biomass from plants is of importance. This kind of biomass is incurrence by photosynthesis. Figure 11 below shows a typical solid fuel from biomass.

Overview of biogenic solid fuel



•Forest rest wood.	Short ratation tree	Straw	Energy cereal
•Landscape caring w.			Cannabis
•Industry rest wood			Corn aso
•Demolition wood			

Figure 11 Overview of the typical solid fuel from biomass

The Advantages are

- A widely carbon dioxide neutral energy creation,
- Spares fossil energy carriers (this energy must be protected, needful for other important things)
- It creates new possibilities for rural areas

The plants saved the energy in form of cellulose, starch and oil. All of these are glycoside bonds. Table 4 shows an example of wood from the forest.

Table 4 Wood from the forest for example

Substance	Conifer wood[%]	Hard wood [%]
Cellulose	42-49	42-51
hemicelluloses	24-30	27-40
extractive	2-9	1-10
lignin	25-30	1-10

Properties of biomass fuel:

Important for the power production with a view of the energy efficiency and all kinds of calculation (transport, storage, emission, price, and handling) are the following facts:

- basic composition
- humidity
- ash content
- volatile matter
- density
- bulk density
- emission (environmentally aspect)

In Finland there are 300 000 people working in farming and the concerned industries. That is a major economic factor; despite comparative bad environmental terms for example short vegetation periods, acid bottoms and irregular rain periods. Only 2, 2 million hectare, 6, 5 % of the Finnish area is used for agrarian. In western and southern Finland the dominating part is the pigs-rearing and cereal cropping (barely, oat, wheat). In the north and the east are the cattle farming the focus. Finland owns a forest area of 230 000 km² and is therefore in Europe's top. The forestry is an important economical factor. More than 60% of the forest areas are private, and the legislation arrogates sustainability. Concerning that and the awareness of the Finnish people command the forest over a big biodiversity and are growing up year by year (87000000 m3). The most popular trees are pine, spruce and birch. 80% are conifers. Figure 12 below give a view about the Finnish wood flow.

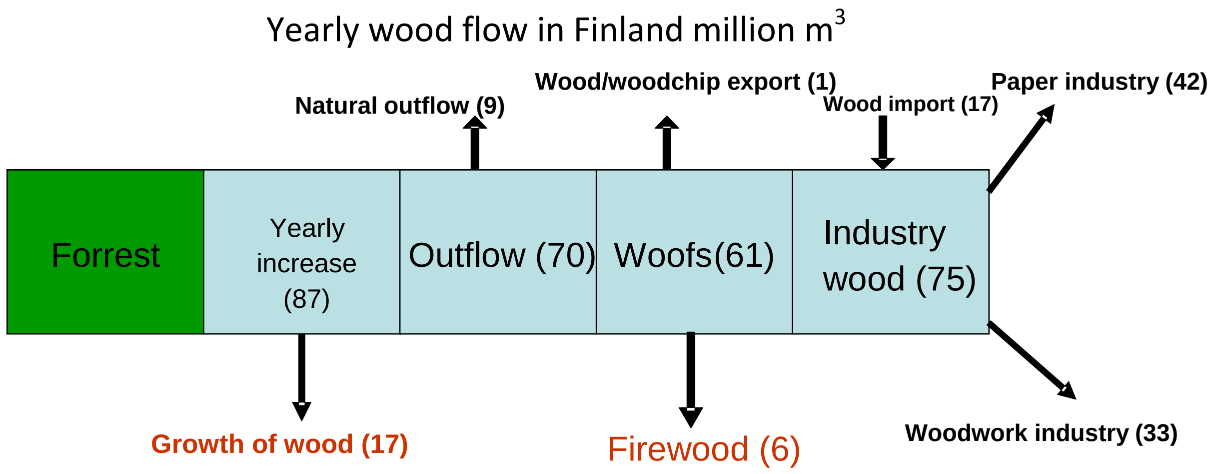


Figure 12 Wood flowchart for Finland
Source: (numbers from mmm.fi, 2009)

Concerning these facts it appears that wood from the forest, to produce energy from biomass, is one of the main alternatives. This is a big chance for an independent, environmentally friendly and economical energy management in Finland.

Peat

Figure 13 Sod peat used for energy production
(*www.vapo.fi/filebank/750-tuotepalaturve_suuri.jpg*)

Peat consists of dead organic material saturated by water in an environment with limited access of oxygen. Drying peat makes it possible to use as a fuel for energy production. 6% of the total energy production in Finland derives from peat (Wikipedia, 2009). See figure 13.

Peat is classified by the Intergovernmental Panel on Climate Change (IPCC) in its own category between fossil fuels and renewable energy sources (World Energy Council, 2007). Finland's definition of peat as a long term renewable energy source has by the International Mire Conservation Group been described as misleading. Burning biomasses such as wood or straw, releases CO2 that would have been released into the atmosphere the day they rotten. Natural growing peat lands are a part of earths green house balance because the CO2 bound up will not be released into the atmosphere (Joosten, 2007). Defending the amount of peat used with a higher natural growing of new peat land is in these terms wrong, and makes peat combustion contribute to growing CO2 emissions. The CO2 emissions when talking about produced energy are higher from peat combustion than coal.

The cost per MWh of peat is quite cheap compared to woodchips or pellets. The availability hasn't always been the best, mainly caused by wet summers. Consumers using peat for energy production in the area of Närpes has had problems getting enough peat to cover their total annual needs.

Using peat in this project would be contrary to the idea of creating a power plant that's producing renewable energy. The chances of getting subsidies from the government would also decrease.

Straw

Haulm wood is beside hard wood the other possibility for the usage of solid biomass. But concerning the discussion about food or energy and also its price only straw is of importance for this project. In Finland straw is not a typical energy choice, but in view of the local area around Närpes, with more than 14 000 ha under agriculture straw burning is a worthwhile availability. This concerns around 70 000 tons of dry substance with a calorific value of 4, 8 KWh/kg.

Figure 14 Straw
(www.windenergyplanning.com/wp-content/uploads/2009/04/staw-bale.jpg)

Straw as shown in figure 14 above is a rest product and is usual of importance for animal food. Concerning the burning and finally the power production 15 % of humidity is the absolute border. That means that drying of straw is necessary. The usual process for this is to dry the fresh cropped straw directly on the field and after certain time (weather depended) the straw will be formed into bales or cylinders. After this they are stored in sheltered storage or in special plastics on the field regular. The main advantage for straw is the price. With 5 €/MWh straw is the cheapest energy carrier but the burning is connected to some problems.

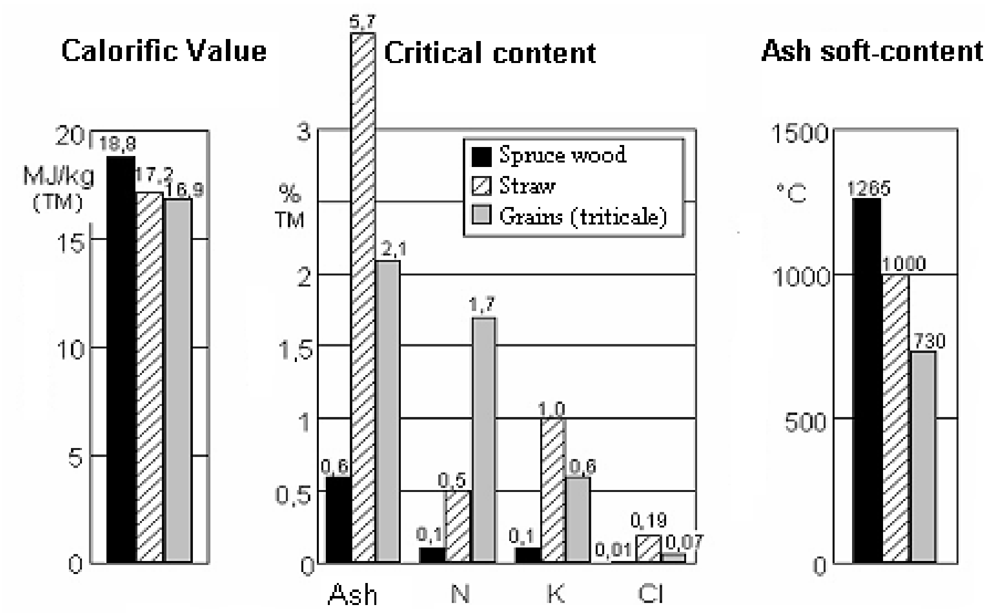


Figure 15 Content chart *(tFz Staubingen)*

The result of this is corrosion and slag building concerning the extreme high Cl and K emission and the water content. With reference to figure 15, the high N part is also a problem concerning NOx building and then the emission cleaning.
Based on these points some special technical processes are necessary. Against the slag building a special air lead, a glut bed chilling, a fuel moving and a chalk input is essential. The impacts of the slag building are high maintenance costs, a bigger particle, and CO and dust emission.

Pellets

The energy carrier in form of pellet is basically compressed biomass as shown in figure 16 below. The pellets can be divided into two different types. The main type of pellets is pressed wood; the biggest amount therefore is wood wastes from the woodworking industry (wood shavings, saw dust, sanding dust). The other types are straw pellet which for our project concerning the price (pellet production), ash content and emission is not important.

The wood pellets will be formed into cylindrical shape under high pressure without any bonding agent. Typically forms for the pellets are 6-8mm in diameter and 5-30mm long. The maximal water content is 8% (quality factor). With these characteristics the pellets are pumpable wood-based fuel.

As a result of the pressing process, they have very high energy content from 4.3 to 5.0 kWh/kg at a density of 1.2 t/m³ (bulk density 0, 65 t/m³), it have therefore a three times higher energy content than usual woodchips.

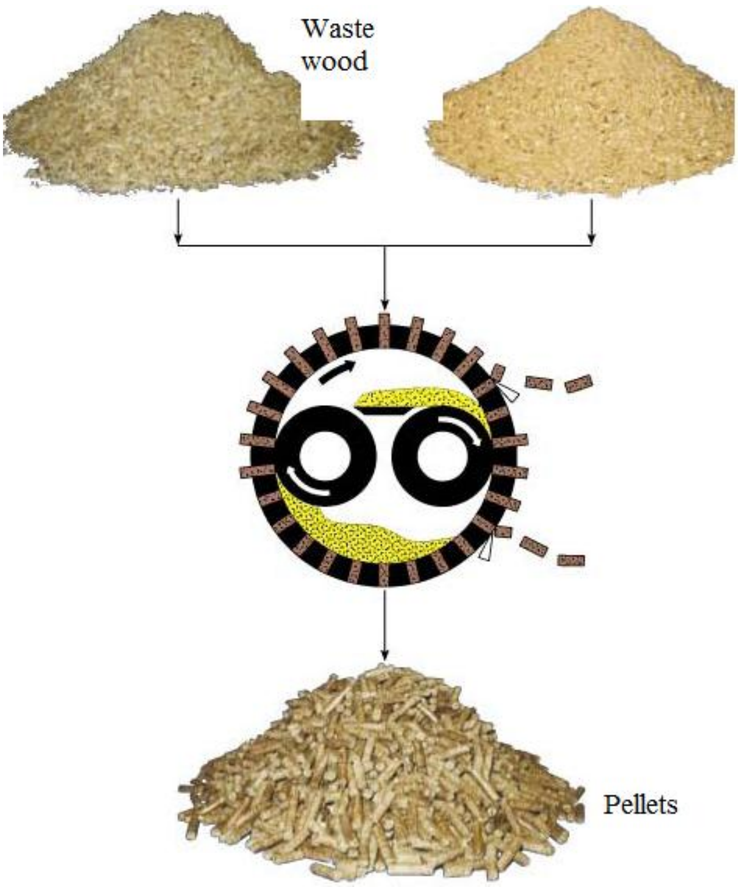


Figure 16 Process of pellets.

For wood pellets as energy carrier a classification concerning the cost calculation, boiler and storage dimension is necessary. Of importance are therefore the following questions:

1. Pelletisation of dry or wet material?
2. Can district heating for the drying be used?
3. How high is the engine investment?
4. What is the price for the raw material?
5. Plant capacity?
6. Energy needs for the Pelletisation? ‘

Usually in Finland the costs for one MWh is 40, 8 €. That is compared to the other biomass fuels very high.

Wood Chips

Wood-chips are primary made of waste wood from the forest. Trees have to be thinned to make room for commercial timber. Wood-chips are thus a waste product of normal forestry operations. The chips are produced by cutting wood with special chopper. The size depends on the machine typically the size is from one centimetre thick and 2-5 cm long as shown in figure 17. To discharge the wood-chips from the forests is in ecological terms no problem when the fruits, foliage and needles remain in the nature. The water content of newly felled chips is usually about 50% by weight. That makes drying necessary, which at best occurs in a sheltered storage.

Figure_17_Woodchips

(http://www.mdmaterials.com/playgroundsurfacing_safetywoodchips.html)

The main advantages for using wood-chips is a high efficiency (burning), and in opposite of the logs an easier handling (most automatically) and the usage of, for the industry useless rests. The price for one MWh produced by chips is 20, 1 €.

Wood Logs

The easiest way to provide this energy carrier is the using of wood logs. The costs per MWh are in the average 10 cents cheaper than the usage of wood chips or wood pellets. This is the result of small storage needs (high bulk density) and a low energy input concerning the production and a high efficiency. But the usage of wood logs is connected with some problems. Wood is mainly used in the woodworking industry. Also it is really difficult to handle the logs in view of the dosage based on the form; the result of this is a higher effort of automation. The really time intensive drying concerning the small drying surface is an important issue also. The graph in figure 18 shows how important the humidity in view of the calorific value is.

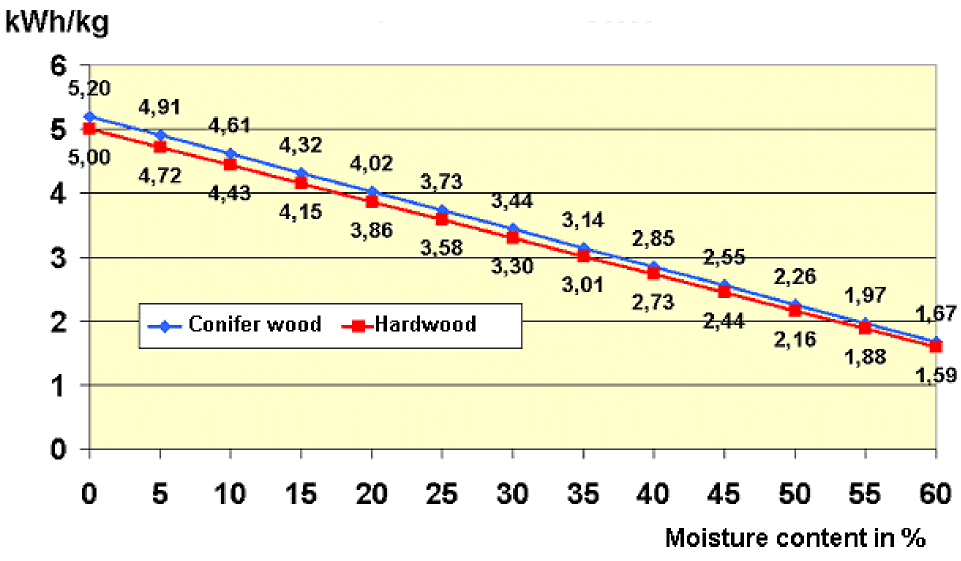


Figure 18 Energy content based on humidity

Source: (Fachagentur nachwachsende Rohstoffe e.V. Gülschow)

Based on the availability and finally the price straw is the best choice for the energy carrier. Concerning the costs, fuel based on wood is only a backup solution in case of shortage of straw. Based on the features peat is also a good energy carrier, but it needs a very long time to regenerate hence the discussion if this could be considered as a renewable energy source.

3. RESEARCH METHODOLOGY

To achieve the goal and work within the jurisdiction and scope of the project, several methods, techniques and approaches has been used to carry out the task smoothly.

To approach the information needed to solve this task, the project manager has arranged lectures with teachers on different subjects such as project managing, technology, energy sources, juridical and economical aspects. These lectures have been a significant part in early stages of the project. Although, these lectures do not state categorically what to do or include and what not to include and do in the project, having gained the knowledge and understanding, we then apply the principle and the ideology behind to suite the project area.

The project group has been in contact with people outside the school to gather information that's already available on similar research done in the region. We have visited companies and different power plants to get insight and some details pertaining to our project. We visited the project area to meet our major consumers to have a one on one interaction with them so as to know what their needs really are.

The major part of the research is based on international books, articles and reports which are mentioned in the references. A lot of this information has been gathered from the web. A major issue has been to make sure that this information derives from reliable sources. Scientific reports published by major co-operations have been preferred whenever this was possible. Cross-checking of unreliable sources like Wikipedia has been emphasized by our project manager at an early stage.

Meetings with the project owner and managing director have been arranged every week for quality control and guidance to make sure the project reaches its goals. The meetings have also worked as an update for every group member on what other members have been working on.

To monitor the progress and see whether the project were on course, the team was thought how to use Microsoft Office Project. With this knowledge the team was able to design their Gant chart which contains the entire milestones to follow from the beginning to the end of the project. Time frame is very important in project management, Taylor (2002) argues that project time must be compared to the objective of the project and there must not be any disparity among them.

3.1. Treatment of Data

Most of the data were directly received from the greenhouse farmers in Pörtom, this information contained the amount of oil burned every month for heating their greenhouses and from the illuminated greenhouses as well as their monthly electricity consumption. As the heat is the primary product and the amount of electricity produced is limited by the heat production the most important information received was the amount of oil they used. The information gathered was in different units so we started by recalculating all the numbers into the same unit (kWh). These results was then use to make various simulation models of which the annual energy usage was the most useful simulation. The information received from the farmers also contained information about the size of the greenhouses (m^2), with this information the peak needs for each individual greenhouse was calculated. E.g. even though one greenhouse was new and had never been in use the peak need was easily calculated thanks to the knowledge of the square meters. The formula used to calculate the peak need was found in the book (P.Majabacka et al., 2008, page23) and also had a one on one discussion with one of the authors of the book to discuss the formula.

4. THE CONSUMERS

NORDEX 2009 customers are greenhouse farmers, municipality occupants, and private house owners within the community of Pörtom.

4.1. Identification of Consumers

Pörtom is a village and a former municipality in Ostrobothnia, Western Finland. Pörtom was located to Närpes municipality in 1973. The northern part was transferred to the municipality Malax 1975. There are about 1000 inhabitants, while about 300 are in Northern Pörtom. Pörtom lies within Malax and Petalax basin. Pörtom landscape is flat, and is 70 meter above sea level, and is 20km from the Gulf of Bothnia. Pörtom is a small and isolated village with dozen of farmers which are concentrated in the municipality of Närpes. Significant reform and major expansion occurred in the late 1700s that made Pörtom more efficient in agriculture and which was followed by settlement expansion and relocation and new construction which gave Pörtom advantage in communication mode (Wikipedia, 2009).

There are about 20 greenhouse farmers spread over Pörtom, but only nine greenhouse farmers cooperates with NORDEX 2009 project. These farmers are scattered in various locations in Pörtom community. Farmer names are not allowed to be revealed in this thesis; rather their names have been replaced with letters. However, they shall be called consumer A, B, C, D, E, F, G, H, and I. Apart from these farmers, there are also private house owners as well as public building belonging to the municipality.

With reference to karttapaikka.fi, this was used to locate the position of the farmers. Coordinates are taken from the community centre. The map shows that five major customers are located in north east of the community with just only two in the south west and two customers are in the eastern part of the community.

4.2. Greenhouses

The greenhouses got big variations in their energy needs. Usually they have their biggest power needs in the evening just after the sun has gone down. During the day when the sun is shining, they need good ventilation to remove the excess heat and moisture.

The need also varies a lot between greenhouses depending on the construction and what they are farming e.g. tomatoes and cucumbers need about the double amount of light compared to salads. Cucumbers need a lot of heat and moisture in the air. There are a lot of factors contributing to these big variations. The energy flow in a greenhouse is explained in figure 19 below.

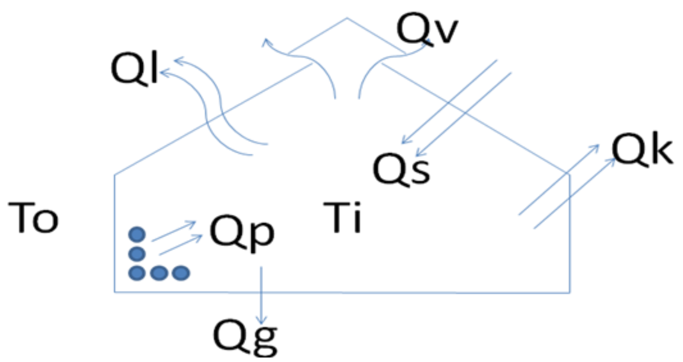


Figure 19 explaining the different energy flows in a green house.
Source: (Borg/Bäckström/A.Majabacka/P.Majabacka/Ohlis/Olofsson, 2008, page 21)

Qg = Energy flow to the ground

Qp = Energy provided by heating system

Qs = Energy from outside radiation

Qk = Energy flow through the thermal conductivity of the wall

Qv = Energy flow through ventilations

Ql = Energy flow through different types of leaks

To = Temperature outside

Ti = Temperature inside

4.3. Energy Consumption

To know how much energy production the consumers would need, we had to calculate the energy needs and simulate the yearly consumption. This chapter explains the process that gave us the numbers we've relied on in sizing the power plant and its properties.

When calculating the energy needs you have to look at it in two ways; the annual energy consumption and the peak needs. They are both equally important and they are the foundation when determining the size of the power plant.

When you calculate the annual energy consumption you basically look at the amount of fuel used to keep the greenhouses warm during a typical year. Then you transform the fuel type into kWh using a table of energy content over various fuel types e.g. as shown in table 5.

Table 5 the Energy content in various fuel types.

Energy densities (kWh/kg)	
Hydrogen	38
Petrol	14
Flywheel	0,9
Thermal storage (water 100 °C)	0,12
Lead Acid Batteries	0,04
Capacitors	0,0003
Hydrostorage (100 m high)	0,0003
Compressed air	2 (kWh/m^3)

Source: (Mats Borg, Energiteknik 1 Kompendium, 2008)

The fuel that the greenhouse farmers used was heavy fuel oil which has an energy content of 40,8MJ per kg and one kWh equals to 3,6 MJ so then a conversion factor was calculated to be used when converting kg oil into kWh as shown below:

$$Factor = \frac{40{,}8MJ}{3{,}6MJ} = 11{,}33$$

Now this factor can easily be used when calculating the energy need for the greenhouses to make the annual energy need simulation. You multiply this factor with the amount of oil they used on a monthly basis. Here you can see the annual energy need simulation for Consumer D in table 6 below.

Table 6 Annual energy need for Consumer D and Total annual energy need.

2007	Heavy Oil (kg)	Oil Energy (kWh)	Usable energy from the oil (kWh)	Total amount of heat (kWh)
January	5 000	56 665	50 999	2752532
February	65 000	736 645	662 981	4555584
March	63 000	713 979	642 581	4131807
April	43 000	487 319	438 587	2961636
May	32 000	362 656	326 390	2035381
June	14 000	158 662	142 796	1182696
July	14 000	158 662	142 796	1135135
August	20 000	226 660	203 994	1211663
September	35 000	396 655	356 990	2506352
October	5 000	56 665	50 999	1568438
November	2 000	22 666	20 399	1469277
December	2 000	22 666	20 399	1637990
Total	**300,000**	**33900,900**	**3059,911**	**27148491**

4.3.1. Peak Needs

As mentioned before, when calculating the peak needs the area of the greenhouse plays a vital part in the calculations, but you also need the knowledge of several other data in order to achieve an accurate result.

The formula used to calculate the peak need is as shown below:

$$\mathbf{P = A \times k' \times (T_i - T_o)}$$

Where

P = the peak need for the greenhouse [kW]

A = Area of the greenhouse [m^2]

k’ = thermal conductivity coefficient [W/m2/ºC]

(Ti - To) = temperature difference in – out [ºC], calculated with a maximum of 40ºC

Concerning the thermal conductivity coefficient, 7 out of 9 of the greenhouse farmers included use regular glass greenhouses and two uses modern block greenhouses. When determining the k’ value, this has to be taken into consideration. The k’ value for a typical glass greenhouse would be about 10 W/m^2/ºC, but in the calculations it was realized that it should be lower and after some hours of research and interviews a k’ value of 9,4W/m^2/ºC was chosen although information from certain greenhouses shows it’s still too high. (P.Majabacka et al., 2008, page 23)
With the temperature difference (in-out) in order to get the correct ΔT we contacted the Finnish meteorological institute and got the minimum and maximum temperatures in 2007 on a monthly basis. With the ΔT for every month in 2007 we were able to calculate the peak need for every month separately which was more than we had expected to achieve. Below in table 7 you can see the minimum temperatures for 2007 on a monthly basis.

Table 7 shows the lowest temperature for 2007 every month

Month	Min. temperature out
February	-20
March	-17,6
April	-8,5
May	-6,4
September	-2,3
January	-20
June	2,9
July	7
August	2
December	-12,3
November	-10,3
October	-4,4

The *Months were organized after highest peak needs. Low production makes some months appear lower down on the chart.*

Area

We summed up all greenhouse areas and ended up with a total of 55 828 m^2 but because some farmers were seasonal farmers and are out of operation during the coldest months we had to make a simulation over how many m^2 was in use every month. The result can be found in table 8.

Table 8 Amount of square meters operational every month.

Month	m2
February	55828
March	55828
April	55828
May	55828
September	55828
January	27914
June	55828
July	55828
August	27914
December	13957
November	13957
October	13957

With this information the peak need was calculated for every month, both the total and for every individual consumer. Below in figure 20 you can see the total peak need calculated for every month in 2007.

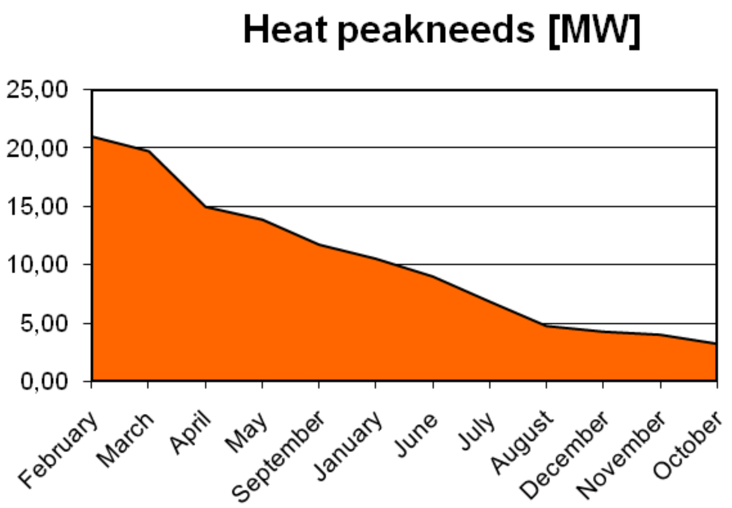


Figure 20 Monthly peak needs.

As shown in figure 20 above and also in table 9 below, the month of February has the highest heat demand.

Table 9 Monthly peak needs

Month	Peak needs [MW]
February	20,99
March	19,73
April	14,96
May	13,85
September	11,70
January	10,50
June	8,97
July	6,82
August	4,72
December	4,24
November	3,98
October	3,20

4.3.2. The Municipality

For the municipality we had to use slightly different calculations. The information we received about the municipality contained data like the amount of square meters and oil they used in a year. When calculating the peak need we used a simple formula normally used for calculating the heat need in public houses. The formula is shown below:

$$P = (A \times W)/1000$$

$$A = Area\ of\ municipal\ buildings = 56000m^2$$

$$W = Rated\ power\ need\ per\ m^2\ for\ old\ public\ houses = 32W$$

Based on this formula we calculated the peak need to be 1,7 MW for the municipal buildings.

Because we knew how much oil was used during a year and that it was light fuel oil, we were able to calculate the annual energy consumption. Light fuel oil has an energy content of 36, 7 MJ/kg and we calculated the conversion factor to be 10, 2. The municipality was using 360 000 kg of oil per year and if we then multiply that with 10, 2 the result will be 3 700 000 kWh. Now we also have to take the efficiency of the oil burner into consideration and as before we estimate the efficiency to 90%. This then gives us the result that the annual energy need for the municipality is 3330 MWh.

The calculations for the peak needs could also be done in different ways and the most accurate way would probably be to actually go to the greenhouses and use instruments for measuring the peak needs, but as we did not have that possibility we choose to use the formula, it has been tested on several greenhouses and has proven to be fairly accurate. The one thing that could be discussed further is the thermal conductivity coefficient. There are a lot of factors that must be considered when determining this coefficient. Especially the weather conditions will affect the coefficient e.g. if it’s a windy day the thermal conductivity would be higher resulting in a higher peak need.

4.3.3. Simulation of Energy consumption

The simulations are based on data received from a greenhouse in the same area, where information of temperature and thermal energy consumption had been registered every 5 minutes during parts of the year. The produced thermal energy from the power plant is set to 8 MW in these simulations to give an indication of a production and needs scenario.

To simplify the simulation of the energy consumption, an average factor was calculated on hour basis. This was done for 3 days with different temperatures in February to create 3 different categories for simulation. One day in November was also simulated to give an impression of consumption during periods of less energy need. Then to simulate a whole February month temperature history from Vaasa in February 2009 was gathered (Weather Underground Inc.), days were categorized based on average and variation in temperature.

To scale up the energy consumption from one consumer to cover the whole system two methods were used. These methods are the peak method and the average method.

a. The peak method

The absolute peak consumption value calculated was used as reference; the absolute peak from one consumer was used as the 100% of the absolute peak. All the other consumptions were divided by the consumer peak value and multiplied by the absolute peak as can be seen in table 10 below.

Table 10 Example of the peak method.

Absolute peak	21	MW	
Consumer peak	432	kW	
Time	Use[kW]	Use/peak	Up scaled use [MW]
03:00	432	1	21
04:00	253	0,585648	12,29861

b. The average method

The average method uses the monthly average consumption calculated to scale up monthly average consumption of one consumer to system level. An average of all consumption data is calculated, then the average for one hour is divided by the monthly average and the result is multiplied by the total average factor. See table 11 below.

Table 11 Example of the average method

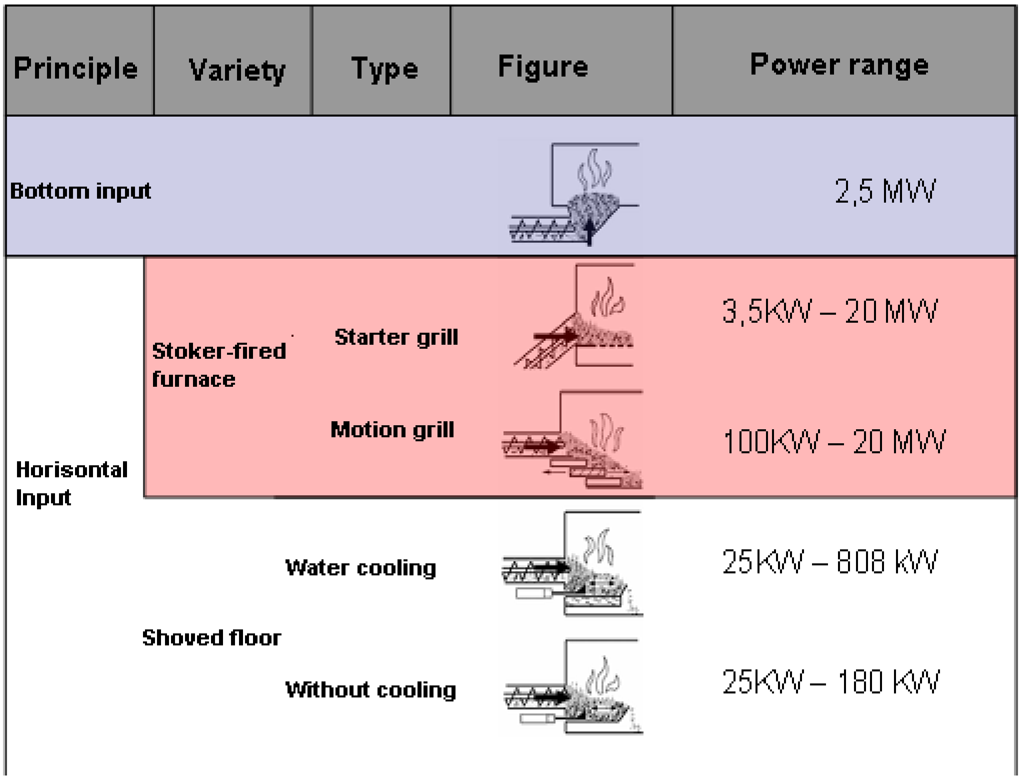
Monthly system avg.	7000	kW	
Monthly consumer avg.	195	kW	
Time	Use[kW]	Use/average	Up scaled use [MW]
03:00	432	2,215385	15,51
04:00	253	1,297436	9,08

4.4. Plant technology

4.4.1. Boilers

This chapter gives an insight in direct combustion boiler technology in the range concerning this project (around 15 MW input power).

Direct combustion boilers have different feed inputs as shown in figure 21 below. The first possibility and the most usual is a horizontal input, the other way is feeding from the bottom. For the second possibility, 2, 5 MW is the maximum power. For our project a horizontal feed input is needed based on the power maximum, the following schedule gives a rough model of this. The stationary fluidized bed burner and the circulation fluidized bed burner are excluded based on the high alkali amount in straw.

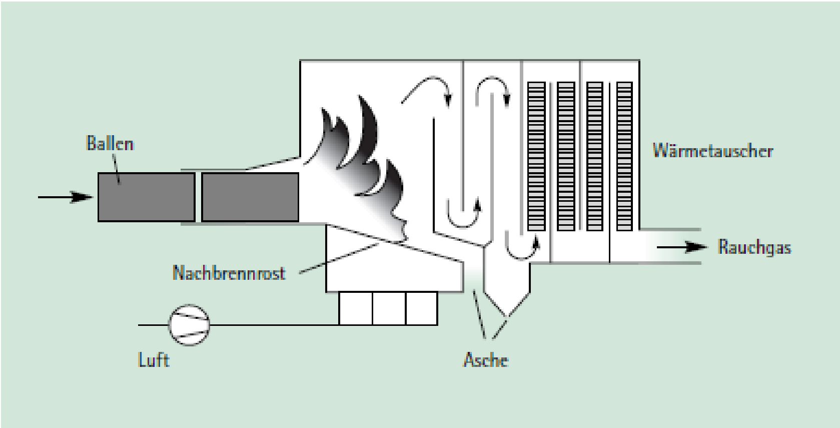


Principle	Variety	Type	Figure	Power range
Bottom input				2,5 MW
Horisontal Input	Stoker-fired furnace	Starter grill		3,5KW – 20 MW
		Motion grill		100KW – 20 MW
	Shoved floor	Water cooling		25KW – 808 kW
		Without cooling		25KW – 180 KW

Figure 21 Fuel input possibilities (Scheffknecht)

The cigar burner is the best possibility considering straw as the energy carrier. A country with tradition and experience in straw burning is Denmark. There they also primarily use this kind of burner. Figure 22 shows the operation principle. The straw bales will start burning on the front side and then they will be slowly pushed into the combustion chamber. Pieces of the straw are falling down on the slanting grill and burned completely. The advantages of the type are the simple construction, a simple feed input, low feed preparation and an easy automation. The output for the ash is ensured by the grill. Also, is water chilling for the grill against the slag building possible? During the process is a CO building possible?

Schedule of a Cigar Boiler:



Quelle: „Leitfaden Bioenergie", 2000, FNR

Figure 22 Fuel input possibilities (Leitfaden der Bioenergie, 2000 FNR)

4.4.2. Emission Cleaning

Burning biomass produces a lot of emissions. On one hand, the elements in the ash content, and on the other hand, the smoke dust which is going out of the chimney.

The following tables show the type- and the amount of emission in the ash content. The calculations are based on a 15 MW energy input (see table 12, 13 and 14 for the different fuels emissions).

Table 12 Straw ***[3, 2 tons/hour]***

Output	[%]	m [kg/h]
Ash	7	224
N	0,5	1,12
K	1	2,24
Cl	0,19	0,43
S	0,0756	0,17

Table 13 Woodchips ***[3, 6 tons/hour]***

Output	[%]	m [kg/h]
Ash	0,8	28,8
N	0,23	0,067
K	0,089	0,026
Cl	0,008	0,003

Table 14 Peat ***[4, 2 tons/hour]***

Output	[%]	m [kg/h]
Ash	5,8	224
N	0,12	0,27
K	0,08	0,18
Cl	0	0

If ash is to be used as fertilizer, cleaning is necessary. This process is done in an energy intensive centrifugation.

For the exhaust, air cleaning and dust removal is necessary. A continuous control of the Cl, S, and N content is also necessary. The best way for an efficient and cheap dust removal is the usage of an aero cyclone. The sphere of action is from 5 µm – 1000 µm. If the emission amount after the centrifugal dust removal is still too high, a tissue filter is activated. The sphere of action by this filter is 0, 1 µm - 1000µm. With this process, the N, S, Cl and dust emissions should be generally under the emission border decided by the government. The following picture shows us the process of the emission cleaning. Other filters are excluded concerning the masses and separation efficiency.

4.4.3. Fuel Storage

In cases of emergency due to for instance delayed deliveries, rough weather or other unforeseen happenings it is necessary to have fuel storage close to the plant. We have calculated with storage to run the plant for two weeks on maximum capacity (15 MW feed input). Table 15 and 16 gives an overview.

Table 15 Fuel needs for 14 days of full work load.

Straw	Peat	wood chips
	5040000 KWh	
1050 t (4,8 kwh/kg)	1417,5 t (3,555 kwh/kg)	1195 t (4,22 kwh/kg)

Table 16 Storage volume.

Straw Bales	sod peat	wood chips
	14 days	
5530 m³ (190kg/m³)	4050 m³ (350 kg/m³)	5200m³ (230kg/m³)

Other requirements for the storage are fast energy input and output, a smart airflow concerning decline humidity and a clearing devise system.

Output of the fuel on the belt into the boiler:

- straw 3,2 t/h **[15 Bale/h]**
- sod peat 4,2 t/h
- wood chips 3,6 t/h

Water as fluid in combination with simple pipe system and heat sensors are the best choice for the clearing device system.

Storage design

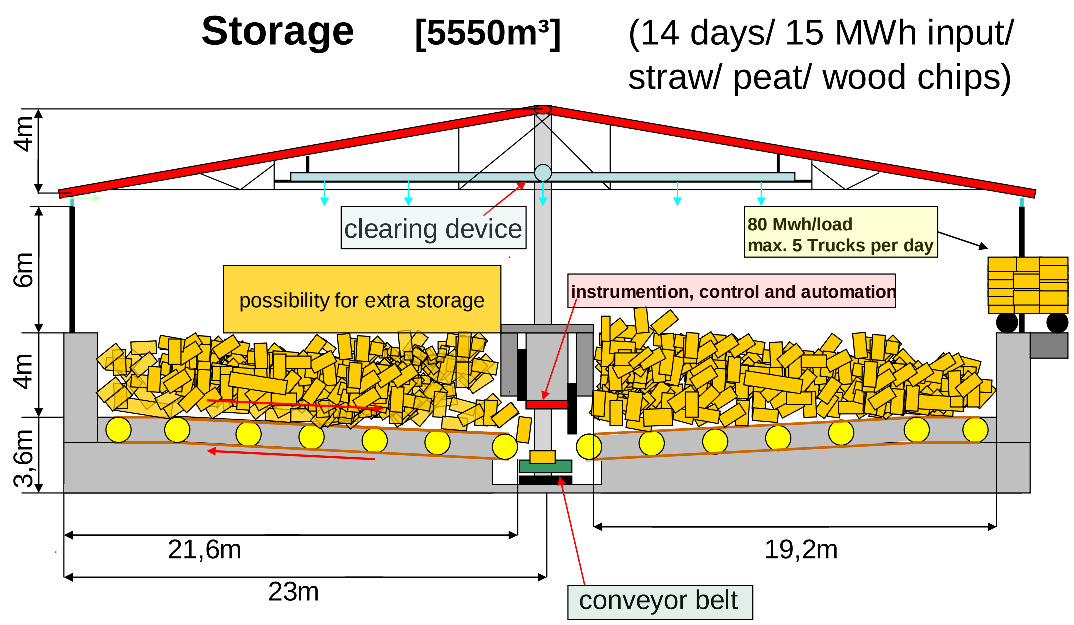


Figure 23 Storage facility profile

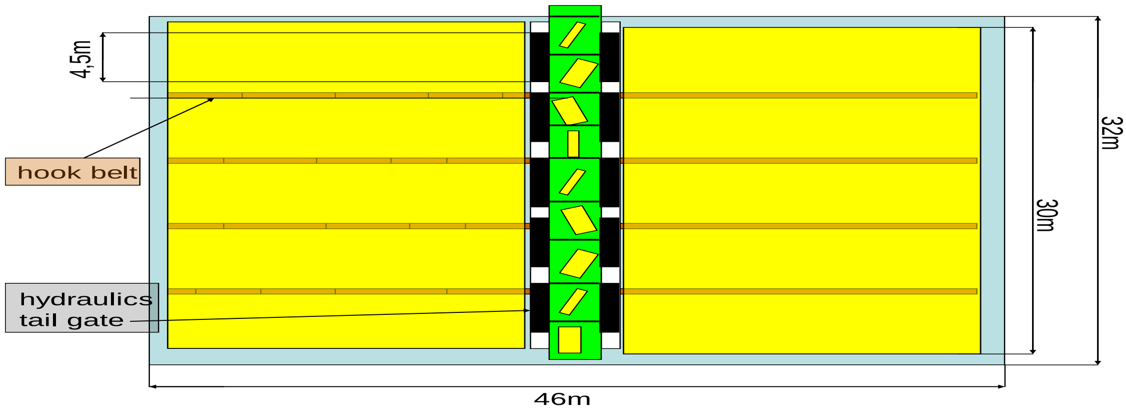


Figure 24 Storage facility

The above figures (figures 23 and 24) show the facility and device needed for the storage. And as shown it gives into details the size of the storage house, the quantity of or maximum fuel intake. And below in table 17 shows the cost involved in setting up the storage facility.

Table 17 Costs calculations for the storage facility.

Element/Unit:	**Price [€]:**
Clearing device:	18 000
Belt and Hook Belt with motor:	150 000
Hydraulics gates and automation:	200 000 – 300 000
House building (all incl.)	250 000 – 300 000
Total	**600 000 € - 800 000 €**

The biggest advantages for the storage are the high atomization and the fast fuel input and output. On the other hand we have the high building costs, and another disadvantage is the fuel transportation into the boiler. The maximum incline for straw bale transportation is 13°. The input by the boiler is around eight meters high. It means 11m of completely height difference from the storage belt to the power plant input. Based on this the application of a special belt or an elevator system is necessary. These kinds of belts and elevator systems are even much more expensive than the belts in the calculation (see table 17).

The result of this is the possibility of another fuel storage based on Danish examples as shown in figure 26 below. Between 250 000 and 400 000 € are the total costs of this variant.

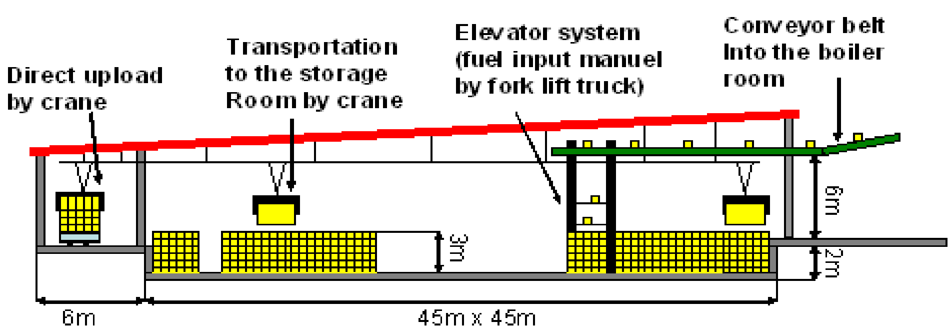


Figure 25 example of Danish fuel storage

In this project a lot of different technologies have been researched to come up with the right suggestion for a complete power plant. The consumer needs and the instruction that both electricity and heat was required products using a renewable energy source are the basis of the conclusions.

The energy source available in the geographical area of the project in large scale is biomass and for the most energy demanding times it is the only possible solution. Because the energy source was decided to be biomass, different technologies using biomass as energy source was investigated.

The studies concluded that direct combustion with a cigar boiler was the most practical, established and economical way to meet the demands. The boiler has flexibility in choice of fuel, but straw was found most attractive as a main fuel because of the price and local availability. Other supplemental fuels for times when straw for some reason would be unavailable would for instance be wood chips, peat or pellets.

The electricity production process most suited for a power plant of the desired scale would be a steam cycle system with a steam turbine. This is the most economical, standardized and established combined heat and power technology with heat output in the range of 8 MW. This gives us a 3, 7 MW electricity production and a 15 MW fuel input.

Fuel storage is necessary to avoid fuel shortage and we have suggested an on sight storage to cover two weeks of full production. This amounts to a storage area volume of around 5 500 m^3.

A cyclone and tissue filter cleaning system is necessary to make sure the exhaust meet the laws for emission release.

4.4.4. Plant Location

According to Yang and Lee (1997) they describe facility location as a decision which involves organisation seeking to locate, relocate or expand an existing facility, which also encompasses the identification, analysis, evaluation and selection among alternatives. Examples of facilities to locate are power plants, warehouses, retail outlets, terminals, and storage yards (Yang and Lee, 1997).

Ko (2005) argues that "every enterprise is faced with the choice of selecting the best place for location of the new plants". Also from their own contribution, Yang and Lee (1997) stated that plant location selection starts with the recognition of a need for additional capacity. However, there are many factors that are put into consideration before reaching the optimal solution for the plant location.

Plant location is referred to as the choice of region or industrial site and the selection of the best location for a power plant. But the choice is made only after considering cost and benefits of different alternative sites. It is a strategic decision that cannot be changed once taken. If at all changed only at considerable loss, the location should be selected as per its own requirements and circumstances. Each individual plant is a case of itself. An organisation tries to make an attempt for optimum or ideal location.

Ko (2005) argue that, an ideal location is one where the cost of the product is kept to minimum, with a large market share, the least risk and the lowest unit cost of production and distribution. For achieving this objective, location analysis is highly needed. Yang and Lee (1997) supported statement made by Ko (2005) by "recognising that plant location as we are working on has an important strategies implications for the plant to be located, because location decision normally involves long-term commitment of resources and be irreversible in nature". In support of Yang and Lee, Ko (2005) explain that facility location is one of the popular research topics in decision-making activities and these problems have received much attention over the years and numerous approaches, both qualitative and quantitative, have been suggested. Facility location has a well-developed theoretical background and research in this area has been focused on optimizing methodology (Ko, 2005). Business logistics has also contributed to the interest of plant location decisions (Ballou and Master, 1993).

Extensive effort has been devoted to solving location problems employing a wide range of objective criteria's and methodology used in the decision analysis, for instance, includes decomposition, mixed integer linear programming, simulation, Analytical Hierarchical Process (AHP), Scoring model, and heuristics model that may be used in analyzing location problems. Ko (2005) argued that a "suitable methodology for supporting managerial decisions should be computationally efficient, lead to an optimal solution, and be capable of further testing”. Other researchers stress the importance of multiple criteria that must be included in the decision analysis many methodologies have been utilized to solve the facility location problem.

Many have solved the location problem for minimum total delivery cost with nonlinear programming. Others have incorporated stochastic functions to account for demand and /or supply. Also other approaches that have been employed include dynamic programming, multivariate statistics using multidimensional scaling and heuristic and search procedures. In many location problems, cost minimization may not be the most important factor. The use of multiple criteria has been thoroughly discussed in the literature (Ko, 2005).

Ko (2005) enumerates numerous criterion for locating a new or an existing power plant which includes availability of transportation facilities, cost of transportation, availability of labour, cost of living, availability and nearness to raw materials, proximity to markets, size of markets, attainment of favourable competitive position, anticipated growth of markets, income and population trends, cost and availability of industrial lands, proximity to other industries, cost and availability of utilities, government attitudes, juridical, tax structure, community related factors, environmental considerations, assessment of risk and return on assets. Qualitative factors are crucial but often cumbersome and usually treated as part of management’s responsibility in analyzing results rather than quantified and included in a model formulation of the facility location problem (Ko, 2005).

Qualitative decision factors can be readily incorporated into plant location problems, analytic hierarchical process can be employed by combining decision factor analysis and AHP, but this study will analyze the evaluation of the plant location by focusing on the use of scoring model.

Specifically, this research concerns the stage in the decision-making process when the weighted score of potential decision criterion of community of Pörtom will be ranked and scored accordingly as shown in figure 26 below for better decision.

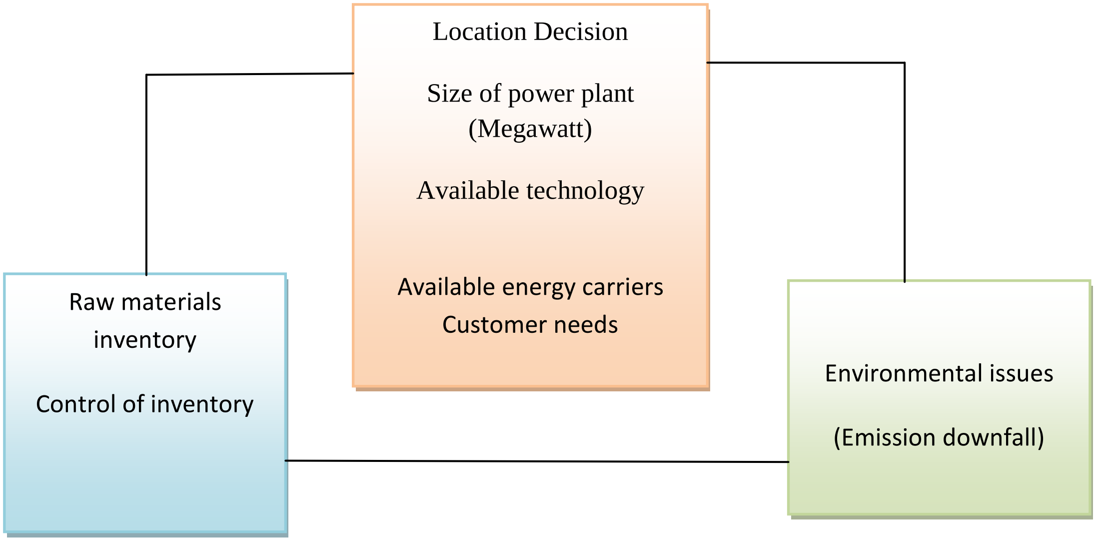


Figure 26 Strategic Planning of Power Plant Location.
Source: (Adopted from Ballou and Masters, 1993)

Scoring Model

For selecting among several alternatives according to various criteria, a scoring model is the method mostly used. There are several ways of scoring models, decision criteria are weighted in terms of their relative importance, while each decision alternative is graded in terms of how well they satisfy the criteria. (Taylor, 2002).

$$S_i = \sum g_{ij}\, w_j$$

Where

w_j = the weight between 0 and 1.00 indicating relative importance, 1.0 is extremely important and 0 is not important at all. The sum of the total weight equal 1.00.

g_{ij} = a grade between 0 an 100 indicating how well the decision alternative satisfied criterion , where 100 indicate extremely high satisfaction, and 0 indicates virtually no satisfaction.

S = the total score for decision alternative, where the higher the score is, the better.

For proposing the location of power plant at Pörtom, the following criteria were considered:

- Transportation of raw materials
- Nearness to customers
- Environmental effects (emission downfall)
- Juridical aspect

Although these criteria will depend on the type of power plant proposed in which the technology adopted will influence these criteria as well. The following scoring was done based on the map in figure 27 provided and the available data on the heat consumption rate of customer calculated.

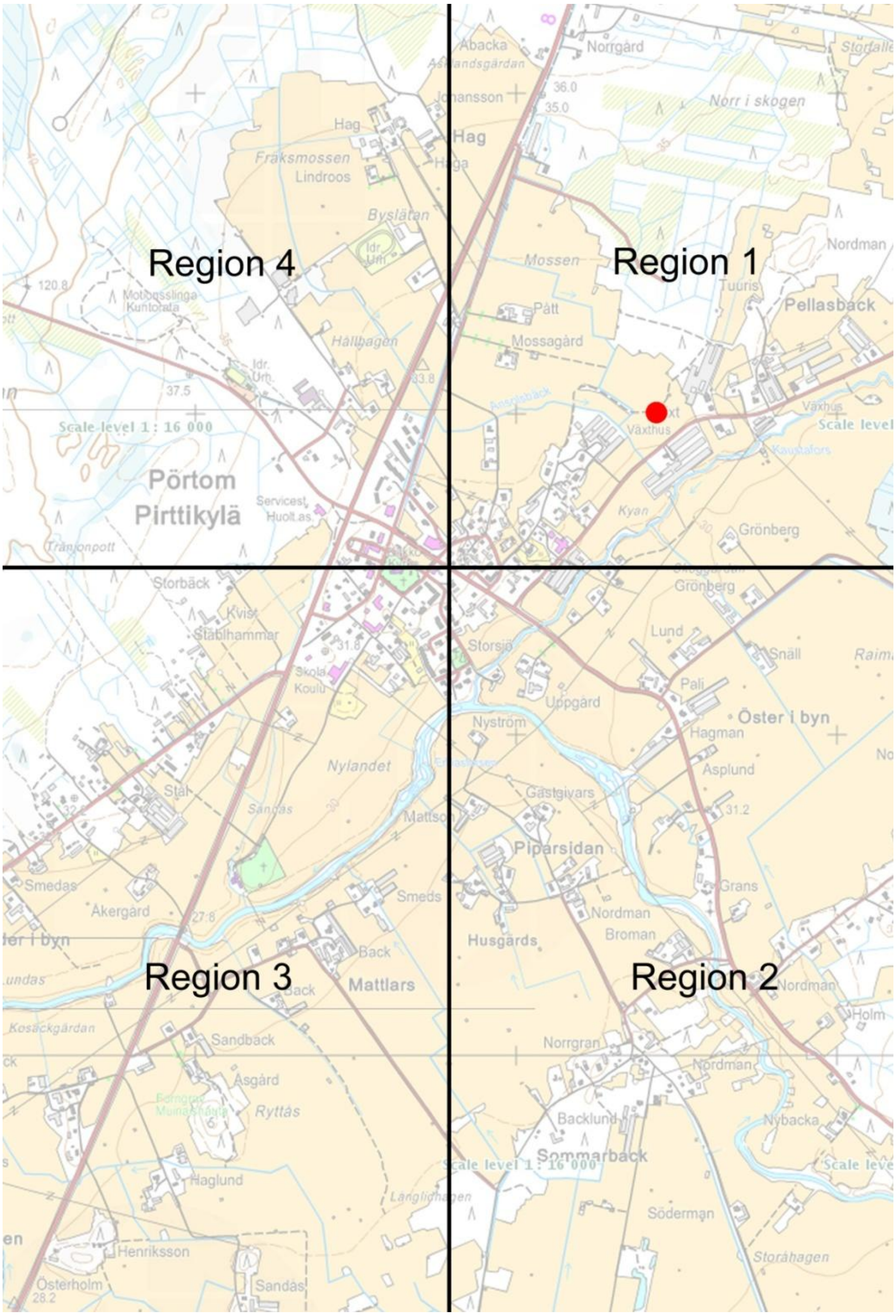


Figure 27 Map of Pörtom

Source: (adopted from www.karttapaikka.fi, 2009)

Table 18 Scoring model (adopted from Taylor, 2002)

Decision Criterions	**Weight (0 to 1.0)**	**Grades for alternatives (0 to 100)**			
		Region 1	**Region 2**	**Region 3**	**Region 4**
Transportation of raw materials	0,25	70	70	80	80
Nearness to Customers	0,40	95	40	30	40
Environment Issues	0,20	50	50	50	40
Juridical issues	0,15	30	30	30	30
Total scores	1,00	70,0	48,0	46,5	48,5

Based on the above scoring model, Region 1 will be selected for the power plant site, since this site is having the highest score. The selection was based on scoring of the above factors in relation to the region (see table 18).

These four regions are based on the map of Pörtom provided from karttapaikka.fi. The map was divided into four cardinal points by taking the cardinal course from the community centre and also those four factors above were considered along with the four cardinal sources.

For transportation of raw materials, region 3 and 4 was scored higher because of nearness to the main road (See map on figure 27). Transportation was weighted 0, 25 because of the importance of raw materials in the power production.

Nearness to consumers was considered the most important factor because of heat transportation and was weighted 0, 40. Region 1 contained the largest consumers and was weighted highest.

Environmental issues looked at each region and decided if positioning a power plant there would affect the environment. Region 4 got the lowest score because of lower population and more untouched areas.

Ko (2005) claim that “facility location decision is a more complex problem due to the uncertainty and volatility of distribution environments. The location decision process involves qualitative as well as quantitative factors. Decision makers can no longer ignore the influence of sensitive factors such as the population status of a candidate region, transportation conditions, market surroundings, location properties and cost factors related the alternative location”.

Reason for the present location of power plant

The use of scoring model was used for locating the present alternative 1. Region 1 was better than others regions going by the calculation. Looking at region one, it was discovered on Pörtom map that a small river cut across part of the region. With this river, it is not possible to locate the power plant on the other side of the river because of higher expenses for the piping. Also, we contacted regional planner and we were told the located point can be used.

Alternatively, the power plant can be located on any available land between the four major greenhouse farms on region 1 provided the following condition are met

1. Permission from the land owner
2. Permission from the municipality regional planner
3. Square meter of land needed for power plant (size of the plant)
4. Traffic situation on the available road.
5. Wind direction.

4.4.5. Emission Downfall

Finland Location

Finland is located between the latitudes 60N and 70N in the Northern Europe. Its climate is, in spite of the northern location, very favorable to living conditions due to the warming effect of the Gulf Stream which orientates the cyclone tracks towards northeaster directions (Finnish Metrological Institute).

According to FMI, Finland average wind speed is 3 to 4 m/s inland, slightly higher on the coast and 5 to 7 m/s in maritime regions and wind speeds are typically highest in winter and lowest in summer.

Wind direction for Pörtom area

A wind rose is a graphical tool used to get a picture of how the wind speed and direction are distributed at a certain location.

In Finland, it's most common that the wind blows from southwest, and the least common that the wind blows from northeast.

Finnish Meteorological Institute, climate research and applications gave information about how wind directions are distributed in Finland, the table 19 below shows the typical wind direction information.

Table 19 wind directions.

The distribution of wind in Finland		
Station	Porvoo, Emäsalo	
Start of measures	01.01.1971	
Start of measures	01.01.1971	
End of measures	31.12.2000	
Direction	Speed (m/s)	% - Share
Average	6,1	
North	4,2	11
Northeast	4,1	9
East	5,9	10
Southeast	6,2	11
South	7	11
Southwest	7,7	19
West	6,9	16
Northwest	5,6	13
Calms		1
Number of measures	47345	Times

As shown in the table, winds from southwest are once again the most common ones.

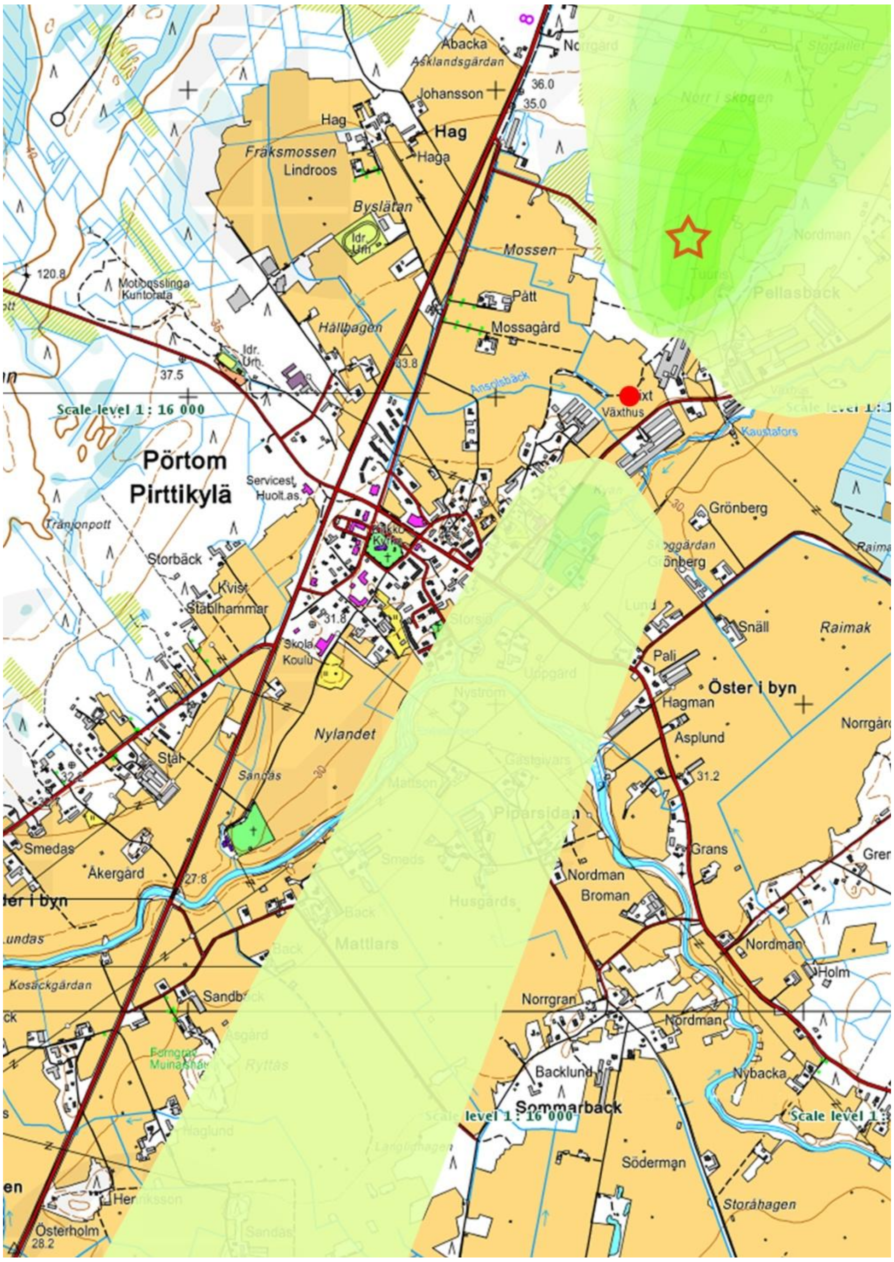


Figure 28 Emission downfalls in Pörtom
Source: (adopted from www.karttapaikka.fi, 2009).

From figure 28 above the attached map reference was taken from Fågelberget which is about 50km from Pörtom. The wind blowing across Fågelberget was also taken as reference, as it is shown on the map. Pörtom is an agricultural area and the current location of the plant, as shown on the attached map, is a land reserved for agriculture based on the information received from the regional planner of the community. Also the wind directions shown indicate that the residue from the smokestack blows from southwest towards northeast direction as shown on the attached map.

The wind blew from southwest towards Pörtom, and if the plant location is located on the spot shown on the map, it will definitely save the community from falling particles, which is assumed to fall on the forest some kilometers away from the community.

In conclusion, after a careful consideration on those decision criteria's mentioned above and couple with the use of scoring model for the analysis of those criteria's, the proposed power plant for the community of Pörtom will be located in north east of Pörtom and very close to those major consumers. Also another reason for the choice of this site is that it will save the community from bad experience of emission downfall due to the wind direction. This decision will also reduce cost which is associated with piping cost and as well as nearness to the transportation of raw materials.

4.4.6. Economical Aspects

The cost calculation is done to find out if this project is worth running from an economical point of view. It gives a clear picture of why we would like to use straw as the main fuel source. Life cycle cost analyses is not implemented and could change the economical benefits from each fuel to some extent. Explanation of what the numbers in the calculation represents and flaws in the used information is presented in this chapter.

7

Table 20 the Cost of running and income from running the power plant the first 10 years with different fuel sources.

Cost calculation

Power plant costs	10 000 000	€
Heat accumulator	122 490	€
Piping costs	1 654 000	€
Investment costs	11 776 490	€
Subsidies (30%)	3 532 947	€
Investment	8 243 543	€
Interest rate	5	%
Payback time	10	Years
Annuity	1 067 577	€/year
Operation	400 000	€/year
Maintenance	360 000	€/year
Total	1 827 577	€/year

Heat output	8,0	MW
Electricity output	3,7	MW
Production loss (15%)	2,2	MW
Pipe loss (10%)	0,9	MW
Fuel input	14,9	MW

Fuel	Price	Input	Expenditure
Straw	5,0 €/MWh	130 165 MWh	650 824 €/year
Peat	12,6 €/MWh	130 165 MWh	1 640 077 €/year
Woodchips	21,3 €/MWh	130 165 MWh	2 772 511 €/year
Pellets	40,8 €/MWh	130 165 MWh	5 310 725 €/year

Energy	Price	Produced	Sold	Income
Heat	38,4 €/MWh	70 089 MWh	29 155 MWh	1 119 558 €/year
Electricity	45,0 €/MWh	32 708 MWh	32 708 MWh	1 471 864 €/year
Total		102 797 MWh	61 863 MWh	2 591 422 €/year

Fuel	Straw	Peat	Woodchips	Pellets
Investment	1 827 577 €/year	1 827 577 €/year	1 827 577 €/year	1 827 577 €/year
Expenditure	650 824 €/year	1 640 077 €/year	2 772 511 €/year	5 310 725 €/year
Income	2 591 422 €/year	2 591 422 €/year	2 591 422 €/year	2 591 422 €/year
Sum	113 021 €/year	-876 232 €/year	-2 008 666 €/year	-4 546 880 €/year

The payback and investment can be seen clearly from table 20 above.

The price of the power plant is based on a factor of 2 700 €/kW of electricity, received from KMW Energi in Sweden. The heat accumulator prices were based on the calculated size needed. This volume was then put into a formula 806, $3 \cdot (\text{Volume})^{0,71}$ (Kostowski/Skorek, 2004, page 9) which gave the price for each tank in USD. We used a currency of 0,769 EUR per USD.

Table 21 the Size and price of each storage tank.

Storage tank	Volume (m3)	Price (€)
Power plant	830	73277
Consumer I	83	14288
Consumer H	49	9828
Consumer F	37	8051
Consumer G	30	6937
Consumer A	52	10251
Total	1081	122632

From the above table 21, it's cheaper to make 6 tanks in 3 sizes than in 6 sizes, the price could probably have been dropped if we sized the 4 smallest tanks to the same size. Changes in currency and the fact that the calculation formula is from 2004 leaves other insecurities and could suggest that the price should be higher.

Subsidies from the government were set to 30 %. The exact amount of subsidies that would have been granted to this project is unknown. Without subsidies, the payback time would've been 15 years with straw as the fuel source.

We decided to use 10 year payback time and 5 % interest rate. Information received from Ekenäs Energi (Frank Hölmström, Project Leader, 2009) on one of their power plants under construction indicates that this is close to the reality.

Maintenance and operation costs were also received from Ekenäs Energy. This could probably be reduced to some extent since it’s based on a power plant with more than two times the output of ours.

Fuel Prices

The fuel prices for pellets, peat and woodchips indicates how much it would cost to get the fuel delivered. These prices were added to show clearly that straw is the most economical solution.

To calculate the straw price, we had to create a scenario where the farmer collects the straw and store it at his property. Transport to the factory will be taken care of by another part.

If we pay the farmer 4, 5 €/MWh of straw, it would mean he'd have an income before taxes of 110 €/ha. Some of this money would have to be invested in a storage and equipment to prepare the bales. Including the investment costs, we still think the farmer would have an income of 90 €/ha of straw. Table 22 shows an example of yearly income for a farmer who owns 100 ha of land.

Table 22 Investment costs roughly estimated.

Farmer income from straw sale				
Investment costs	25000	€		
Interest rate	5	%	Factors	
Payback time	25	year	100	Ha
Annuity	-1774	€/year	5	ton/ha
Income straw sale	10800	€/year	4,8	MWh/ton
Sum	9026	€/year	4,5	€/MWh

The transportation would be taken care of by another part. To cover the input of straw for the power plant each day, 4-5 truckloads of 80 MWh/truckload is needed. With 0, 5 €/MWh received, 5 truckloads would mean an income of 200 € each day for transportation.

This adds up to the total price of 5 €/MWh of straw. It should be reminded that this is just one scenario on how to bring straw to the power plant. No clear solution has been investigated.

Heat Price

The greenhouses currently produce 27 000 MWh of heat from oil burning based on our energy need calculations. This means they need 30 000 MWh or 2 650 tons of heavy oil with a burner efficiency of 90%. The municipality buildings use 360 000 litres or 3700 MWh of light oil.

The average income price from heat sale we've calculated with is based on how much we think the consumer would be willing to pay regarding their current expenses. Table 23 shows the balance between current fuel prices and the new price they'd have to pay. The costs of having a private oil burner (maintenance, operation) and the factor of unsecure oil prices make the demanded heat price viable.

Table 23 Oil prices

Fuel costs for heating			
Fuel	Needs	Price	Costs
Heavy oil Light oil	30000 MWh 3700 MWh	31,3 €/MWh excl. VAT 51,7 €/MWh excl. VAT	939000 € 191290 €
Heat price from power plant	33700 MWh	38,4 €/MWh excl. VAT	-1294080 €
Summary			-163790 €

Electricity Price

The electricity price is based on the average feed price to the grid in Finland in 2008 (Fingrid webpage, www.fingrid.fi).

Energy production

To determine the production loss and electricity produced from the power plant, we used numbers from a straw burning CHP power plant in Haslev, Denmark (International Energy Agency, 1998). It was based on the desired amount of 8MW heat to the consumers. Production loss was calculated to 15 %, energy production 25 % and heat production 60% of the fuel input. 10 % of heat was then calculated as loss in the pipe system. Figure 29 below show the calculated result.

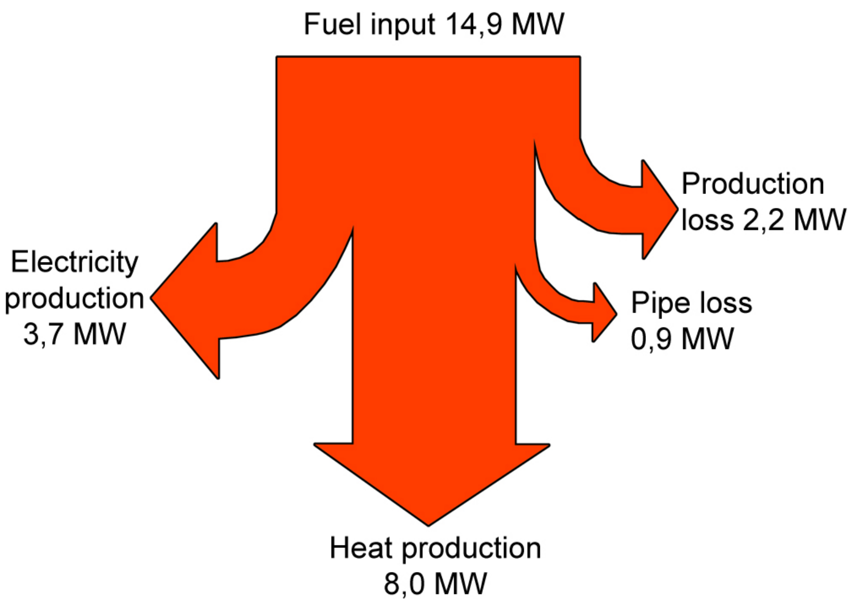


Figure 29 shows the calculated production and loss.

The biggest economical challenge in this project is the large gap between peak and average heat needs in greenhouses.

Considering the average needs, this power plant is oversized and produces large amounts of waste heat. If we want to cover the peak needs, the investment cost is too high compared to the income from heat sold. This makes the usage of regular biomass fuels such as peat, pellets and woodchips non profitable.

Straw makes this project possible because it's cheap. Running the power plant at full production throughout the year is beneficial because of the balance between fuel expenses and income from electricity sale.

5. ROLE OF ICT IN ENERGY EFFICIENCY

According to the Commission of the European Communities (Brussels, 13.5.2008) a high potential that could be the most appropriate avenue for addressing the energy efficiency through ICTs is as follows:

- ***ICT itself***, which is a small but very visible energy consumer, through RTD and take-up aimed at improving energy efficiency at the level of components, systems and applications and through adopting green-procurement and substitution technologies.
- ***ICTs as an enabler to improve energy efficiency across the economy***, through enabling new business models and improved monitoring and finer control of all sorts of processes and activities. All sectors of the economy, now increasingly ICT-dependent, will benefit to a varying degree, although the initial focus will be on the power grid, on energy-smart homes and buildings and on smart lighting.

ICT have an important role to play in reducing the energy intensity and increasing the energy efficiency of the economy (i.e. reducing emissions and contributing to sustainable growth). And moreover, ICTs have a major role to play not only in reducing losses and increasing efficiency but also in managing and controlling the ever more distributed power grid to ensure stability and reinforce security as well as in supporting the establishment of a well functioning electricity retail market.

5.1. ICT and Energy Consumption

ICT can be referred to micro- and nano-electronics components and systems, but also to future technologies such as photonics that promise both far greater computing powers for a fraction of today's power consumption and high brightness, easy controllable, power-efficient lighting applications.

The enabling potential of ICTs to reduce energy consumption will make a major contribution to improving energy efficiency in all sectors of the economy. Networked embedded components will add intelligence to systems (e.g.

production plants), making it possible to optimise operations in variable environments.

The three energy intensive sectors, power grids - from production to distribution, buildings and lighting have a high potential for energy efficiency. Energy generation and distribution uses one third of all primary energy. Electricity generation could be made more efficient by 40% and its transport and distribution by 10%. ICT could make not only the management of power grids more efficient but also facilitate the integration of renewable energy sources.

Heating, cooling and lighting of buildings account for more than 40% of European energy consumption. ICT would, for instance, provide consumers real-time updates on their energy consumption to stimulate behavioural changes. In Finland, this smart metering encouraged consumers to increase energy efficiency by 7%.

About 20% of world electricity is used for lighting. Changing to energy efficient light bulbs could halve today's energy consumption for lighting by 2025. Intelligent light bulbs, which automatically adjust to natural light and people's presence, will have an even greater effect (*Energy & Enviro Finland*).

5.2. An Effective Recommendations for ICT

To put ICTs at the core of the energy efficiency effort and to enable them to reach their full potential, the following needs to be done:

- Firstly, it is necessary to ***foster research*** into novel ICT-based solutions and ***strengthen their take-up*** — so that the ***energy intensity of the economy can be further reduced*** by adding intelligence to components, equipment and services;
- Secondly, efforts should be made so that ICT leads by example and ***reduces the energy it uses*** — ICT industry accounts for approximately 2% of global CO2 emissions6, but is pervasive throughout all kinds of

economic and social activities, and increasing its use will result in energy savings from the other industries;

- Thirdly and mainly***, it is crucial to encourage structural changes*** aimed at realising the potential of ICT to enable energy efficiency across the economy, e.g. in business processes through the use of ICTs, e.g. substituting physical products by on-line services ('dematerialisation'), moving business to the internet (e.g. banking, real estate) and adopting new ways of working (videoconferencing, teleconferencing).

5.3. Executive Summary on how ICT can influence Energy Efficiency

Global warming, together with the need to ensure security of supply and enhance business competitiveness, make it ever more vital and pressing for the EU to put in place an integrated policy on energy combining action at the European and the Member States' level. As a milestone in the creation of an Energy Policy for Europe (EPE) and a springboard for further action, the European Council adopts a comprehensive energy Action Plan for the period 2007-2009 (Annex I), based on the Commission's Communication "An Energy Policy for Europe". The European Council notes that Member States' choice of energy mix may have effects on the energy situation in other Member States and on the Union's ability to achieve the three objectives of the EPE (*Brussels, 2 May 2007*).

Energy production and use are the main sources for greenhouse gas emissions, an integrated approach to climate and energy policy is needed to realise this objective. Integration should be achieved in a mutually supportive way. With this in mind, the Energy Policy for Europe (EPE) will pursue the following three objectives, fully respecting Member States' choice of energy mix and sovereignty over primary energy sources and underpinned by a spirit of solidarity amongst Member States:

- increasing security of supply;

- ensuring the competitiveness of European economies and the availability of affordable energy;
- promoting environmental sustainability and combating climate change

The European Council reaffirms that absolute emission reduction commitments are the backbone of a global carbon market. They therefore asked developed countries to continue to take the lead by committing to collectively reducing their emissions of greenhouse gases in the order of 30 % by 2020 compared to 1990. They should do so also with a view to collectively reducing their emissions by 60 % to 80 % by 2050 compared to 1990.

This communication highlights the potential of ICTs for improving energy efficiency (i.e. enabling energy productivity growth) and opens a debate on priority areas. It proposes to focus on the most promising domains — namely the power grid, smart buildings, smart lighting and ICT itself — to boost awareness raising and exchange of best practices, reinforce RTD, promote take-up and foster demand-driven innovation. It also notes that special attention should be paid to urban areas, which represent a particular challenge in this context and can provide the right setting for testing, validating and deploying ICT-based solutions.

Without action, the EU's energy consumption is expected to rise by as much as 25% by 2012, which would increase EU emissions despite renewable energy targets.

However, ICTs, if directed to sustainable uses, could increase energy efficiency in all areas of the economy while continuing to account for 40% of Europe’s productivity growth (*Energy & Enviro Finland*).

6. Summary

This thesis task was to research and find an alternative common renewable energy source to supply the greenhouses and the municipal buildings in the village of Pörtom. This meant a very broad approach to the problem, every possibility was initially considered, but the options were narrowed down based on the properties of the different technologies. Important factors were the demand of the consumers, availability of different energy sources and price of the energy produced. The energy source selected was biomass, as it was most practical for this geographical area. Both heat and electricity was demanded products, different combined heat and power (CHP) technologies were considered. Direct combustion was found as the best way to suit the consumers and the steam turbine was chosen as the technology most reliable for electricity production based on technology maturity, costs and standardization in the desired production scale. Based on the needs of the consumer the plant was set to have a thermal output of 8 MW with a water tank heat storage system to level out the variations in energy needs. Derived from this was a fuel input of 15 MW and an electricity production of 3, 7 MW. The plant location was set to avoid particle downfall in the populated areas. The plant has flexibility in combustion of different fuels, but straw is chosen as the main fuel based on the economical advantages.

7. CONCLUSIONS

In conclusion, there is an opportunity of building a power plant in Pörtom with the possibility to supply our consumers with the amount of heat needed. This can replace the current used oil-burners and give the municipality green energy at a competitive price. Regarding the present oil-market, it will bring safety to the consumers with more stable and probably cheaper energy prices for the future.
The direct combustion of biomass with a cigar boiler is the most practical, established and economical way to meet the demands. The boiler has flexibility in choice of fuel, but straw was found most attractive as a main fuel because of the price and local availability. Other supplemental fuels for times when straw for some reason would be unavailable would for instance be wood chips, peat or pellets.

Straw makes this project possible because it’s cheap. Running the power plant at full production throughout the year is beneficial because of the balance between fuel expenses and income from electricity sale.

The electricity production process most suited for a power plant of the desired scale is the steam cycle system with a steam turbine. This is the most economical, standardized and established combined heat and power technology with heat output in the range of 8 MW. This gives a 3, 7 MW electricity productions and a 15 MW fuel input.

The suggested position of the power plant is located north east of the city centre. 8MW of heat will be supplied, with heat accumulator tanks storing excess heat to cover the peak periods. 3, 7 MW of electricity sold to the grid will give the extra income needed to make the project beneficial financially.
The timeline means this project will take about 3 years to finalize. The decision if the power plant should be owned by the municipality, some of the major consumers, or by a third part, is still to be made. Though, there are clear hints in the calculations that this could be a beneficial project for the owner.

This thesis did not discuss factors such as “District heating”, “Juridical aspects” as well as “Energy savings”; but I strongly recommend that a future expansion of this project should do well to consider these factors. For instance, a careful consideration of “District heating” will help to decide how to distribute the heat produce from the plant to the various consumers. Consideration of the “juridical aspect” will enable one to know if there might be a need for building permits with regards to the plant installation. Looking into “Energy savings” will help to see possible solutions that can be made for reducing the energy needs, which would in effect affect the size of the power plant.

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