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Final Report

European Project Semester Autumn 2013: "Energy Commodity Logistics for Greenhouses"

bioenergi kusten

Europeiska jordbruksfonden för landsbygdsutveckling: Europa investerar i landsbygdsområden

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List of Abbreviations and Symbols

EPS	European Project Semester
UAS	University of Applied Sciences
CEDTE	Centre for Economic Development, Transport and the Environment
FFC	Finnish Forest Centre
HTML	HyperText Markup Language, the main markup language used in the creations of webpages that can be shown by web-browsers.
CSS	Cascading Style Sheets, the most used language to define the look and feel for webpages.
ECTS	European Credit Transfer and Accumulation System, a standard for comparing the study achievement and performance of students following higher education in the European Union. Defined as 27 hours of study per ECTS in Finland.

1 Introduction

The European Project Semester (EPS) is an international exchange programme by twelve European universities and universities of applied sciences in ten countries. The EPS project is focused on primarily engineering students who have finished two years of their studies. However students from other disciplines are also welcome.

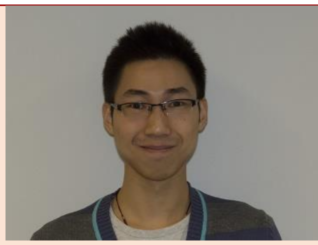
The EPS is designed to prepare students for the challenges of today's world and economy. An EPS group consists of three to six students from at least three different nationalities to create an international and interdisciplinary team. A host university may have more than one group working on a multitude of projects. Some of these groups work in cooperation with commercial or governmental entities, while others are working in a more academic setting. (Introduction - European Project Semester, n.d.)

1.1 Team Members

For the autumn of 2013 the EPS team at Novia University of Applied Sciences(Novia UAS) in Vaasa consisted of two degree students and four exchange students. The information about these students can be seen in Table 1.

Table 1: EPS team Autumn 2013

Name: Mathias Börg **Place of origin:** Vasa, Finland **University:** Novia University of Applied Sciences, Vasa, Finland **Degree programme:** Information Technology **Email:** mathias.borg@novia.fi	
Name: James Doh **Place of origin:** Strasbourg, France **University:** Ecole Nationale d'Ingénieurs de Tarbes, Tarbes, France **Degree programme:** Mechanical and Industrial Engineering **Email:** james.doh@novia.fi	
Name: Arnaud Dubourg **Place of origin:** Toulouse, France **University:** Ecole Nationale d'Ingénieurs de Tarbes, Tarbes, France **Degree programme:** Mechanical and Industrial Engineering **Email:** arnaud.dubourg@novia.fi	

Name: Corstiaan Hol **Place of origin:** Zaltbommel, The Netherlands **University:** Avans University of Applied Sciences, 's Hertogenbosch, The Netherlands **Degree programme:** IT – Software Engineering **Email:** corstiaan.hol@novia.fi	
Name: Elliot Wales **Place of origin:** Warrington, United Kingdom **University:** Nottingham Trent University, Nottingham, United Kingdom **Degree programme:** Product Design **Email:** elliot.wales@novia.fi	
Name: Yuhang Ye **Place of origin:** Fuzhou, China **University:** Novia University of Applied Sciences, Vaasa, Finland **Degree programme:** Industrial Management **Email:** yuhang.ye@novia.fi	

1.2 Project Logo

A recognisable logo was designed to represent the research topic that was being investigated. The logo can be seen in Figure 1: *EPS logo autumn semester 2013*. It was made to be used on documents that were made by the group during the EPS autumn semester.

Figure 1: *EPS logo autumn semester 2013*

The logo contains the three main foci of the project. The trees represent biofuels, together they form the greenhouse that they provide fuel for. The network in the tree tops represents the logistics network needed to get the fuel to the greenhouses.

1.3 Website

In order to make the information more easily available to the general public a website was made. The design was made with a modern style that fits the majority of the computers and mobile devices. On the front page, which is shown in Figure 2, a slideshow shows pictures from our study visits to different places around Ostrobothnia. On the website the project, information about the EPS and the team members are presented. The website was programmed in HTML, CSS and JavaScript. It was made available at mathiasborg.no-ip.org/eps.

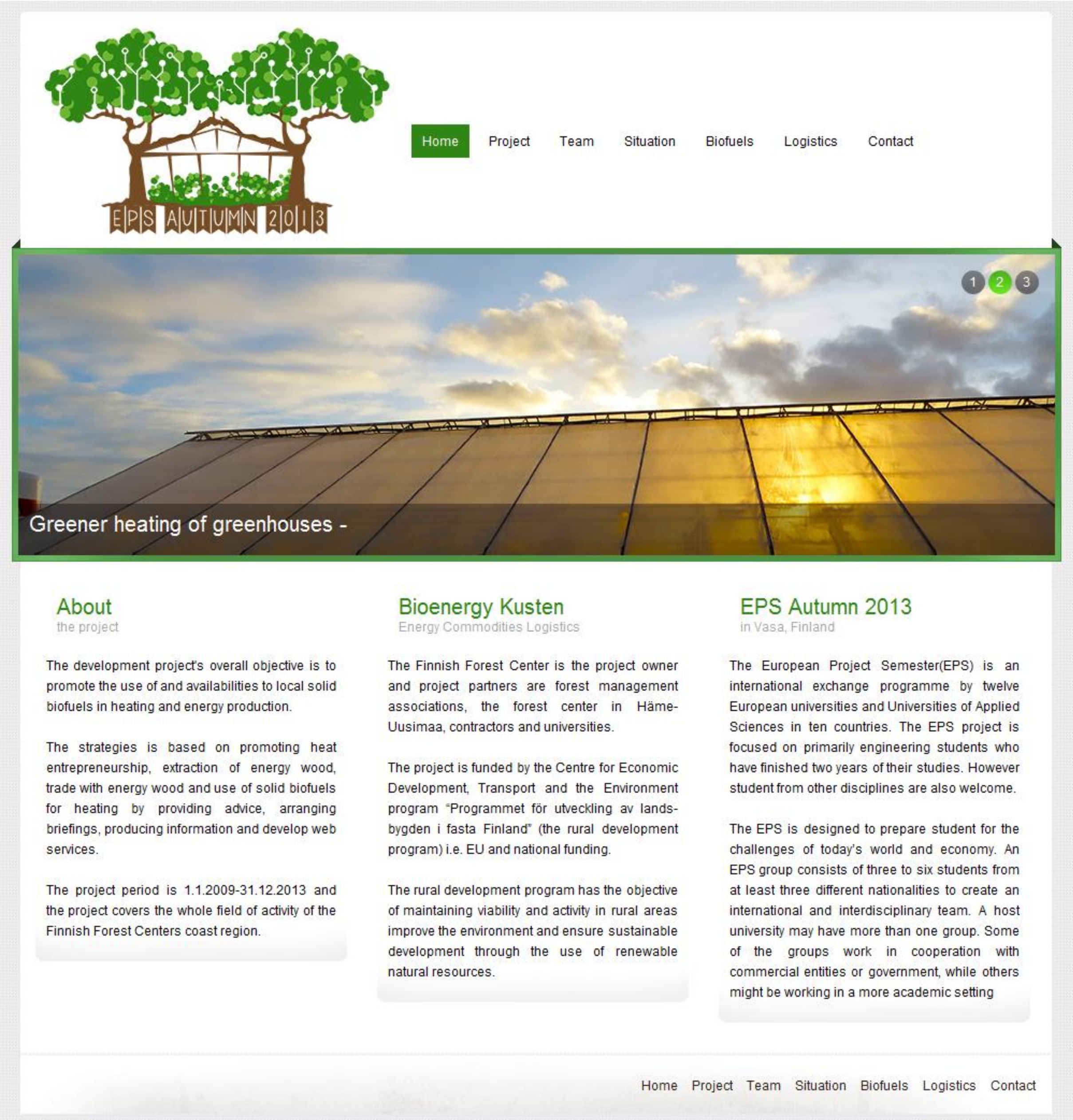


Figure 2: *Homepage of the website*

1.4 Organization

The EPS semester has been split up into two periods. The first period occurred from the 2nd of September until the 30th of October. The second period occurred from the 31st of October until the 20th of December. The first period was closed off by handing over a conceptual report and a meeting discussing that which has happened during that period.

For each period a project leader and a secretary were appointed. Together these persons where responsible for planning the project and taking minutes during the weekly meetings.

The project was monitored and evaluated by the means of a Gantt chart, updated every week by the team members.

2 Project Definition

2.1 Motivation

This project is part of an umbrella development project called 'Bioenergi Kusten', whose objective is to promote the availability and use of local solid biofuels in heating and energy production. The 'Bioenergy Kusten' project is owned by the Finnish Forest Centre (FFC) with multiple partners. It is funded by the Centre for Economic Development, Transport and the Environment (CEDTE) program named 'Programmet för utveckling av landsbygden i fasta Finland' (rural development program).

This project is named 'Energy Commodity for Logistics for Greenhouses', and is a cooperation between the FFC and Novia UAS.

2.2 Project Objectives

A better understanding of the logistics of energy commodities between forests and greenhouses is what this project aims for. Furthermore, it aims to investigate where improvements can be made in the supply chain, including transport, storage and delivery.

A list of points that were to be investigated was given to us by the FFC, such as:

- Does it pay of to build up large supplies of solid biofuels?
- Is it feasible to store the supplies in one or more warehouses?
- Is it more efficient to store the supplies in those warehouses?
- If so where should these warehouses be located?
- Propose designs for these warehouses and their specifications.

2.3 Project Goals

The main goal for this project was to produce a report and presentation about the results of the above mentioned objectives. This will be preceded with a midterm report. Both reports and presentations had to conform to the Novia UAS thesis instructions.

2.4 Constraints

2.4.1 Constraint: Time

This final report and its accompanying presentation had to be delivered before 20th December 2013. After the final check-up of the report our aim was to deliver it to Novia UAS during the week of the 9th of December.

Around 30ECTS should be spent by each fulltime student and 15 ECTS by each part-time student.

2.4.2 Constraint: Money

This project was essentially costless. However, there were some costs associated such as travelling costs to the different areas to assess the situation. There was no need for particular hardware or software to be bought or licenced.

2.4.3 Constraint: Quality

All the reports and presentations had to conform to the rules that Novia UAS has for their students' theses and have to be in proper English.

2.5 Project Risks

The following risks which may cause us to fail the project were as following:

Dropping out of one or more students

In the case that one or more students dropped out of the project due to irregularities, the remaining team might not have enough capacity to fully complete the project, meaning that they might have to hand in an unfinished report.

Low motivation in one or more students

If the motivation for one or more students dropped, the effectiveness of the project group would have decreased, possibly demotivating others too. In this case the team might not have enough capacity and/or motivation to get the project back up to speed. This could have led to having to hand in an unfinished report.

Not enough time

The possibility existed that the team had taken too much time to research the main objectives, thus leading to not reaching all the set goals.

No response from contacts or organizations

This project was highly dependent on information from contact persons and organizations from the greenhouse industry. Therefore there was a fair possibility that correspondences were delayed or not answered at all. Without their information, the team might not have been able to answer some of the research objectives.

Cancellation of the project by Novia UAS or the FFC

There was always the possible chance that the project gets cancelled by Novia UAS or the FFC. The Bioenergi Kusten umbrella project could also have been cancelled before the end of this project. This would have had the effect that our project would become superfluous. Novia UAS could have decided to cancel the project if the performance was not high enough. However, these chances were very small.

2.6 Scope

The southern regions of Ostrobothnia between Vasa and Kristinestad is the area that this project was confined to. The data received from organizations is to be kept confidential and to be removed from all storage mediums after the project ends.

3 Assessment of Current Situation in Ostrobothnia Southern Regions

An assessment of the current situation was made in order to get a better view on why greenhouses should use or are using biofuels. In the following chapters the volume of the greenhouses from which information was received, the fuel prices and the manners of procurement, the conversion between fuel and energy, and the logistics are discussed.

3.1 Greenhouse Information

Data was collected from organizations related to the greenhouse sector, including the FFC, Österbottens svenska producentförbund (ÖSP) and ProAgria Österbottens Svenska Lantbrukssällskap (ÖSL). In total the locations of 123 unique greenhouses were received of which only 35 greenhouses had their boiler sizes specified.. Due to confidentiality this data will not be made available in this report.

According to official statistics (Tike, Horticultural Statistics, 2013) 301 of Finland's greenhouses were located in Ostrobothnia in 2012, with a total heated area of 116,7 hectares. 270 greenhouses are located in the southern regions of Ostrobothnia with a total heated area of 104,4 hectare, as can be seen in Table 2

Table 2. This corresponds to 29,1% of the total greenhouse area of Finland.

Table 2: Number of greenhouses and area covered in Ostrobothnia

Area	number of greenhouses	m²	m²/greenhouse
Storkyro	2	..	..
Kaskö	1	..	..
Korsnäs	35	111	3 171
Kristinestad	11	26	2 346
Laihia	2	..	..
Malax	17	67	3 959
Korsnäs	35	111	3 171
Kristinestad	11	26	2 346
Laihia	2	..	..
Malax	17	67	3 959
Korsholm	17	12	730
Närpes	182	828	4 547
Vasa	2	..	..
Lillkyro	1	..	..
Total	**270**	**1044**	**3866,67**

Adapted from Tike, Horticultural Statistics (Energy consumption in greenhouse enterprises year 2006, 2008 and 2011 [e-publication], 2012)

3.2 Fuel Usage

According to official statistics regarding the year 2011 (Tike, Horticultural Statistics, 2012) the total energy consumption by all Finnish greenhouses above one hectare was approximately 1716 GW·h. Approximately 481 GW·h of the total consumption is electricity, this leaves approximately 1.235 GW·h used on heating. In

Table 3 the five most used energy sources for heating in terms of consumption can be seen.

Table 3: Top five used energy sources in heating greenhouses, 2011

Energy source	Consumption in GW·h	Share(%)
Heavy fuel oil	277	≈22,5
Sod peat	228	≈18,5
District heat	154	≈12,5
Chips	133	≈10,8
Light fuel oil	99	≈8

Adapted from Tike, Horticultural Statistics (Energy consumption in greenhouse enterprises year 2006, 2008 and 2011 [e-publication], 2012)

As the approximated percentage of the heated area used for greenhouses is known it is possible to reduce the consumption for heating above to an approximate for the southern regions of Ostrobothnia. Which is approximately 359 GW·h.

$$1.235 \times 29{,}1\% \approx 359 GW \cdot h$$

The distribution of this approximation for 2011 is not known. It is known however that at least the 123 greenhouses used in our dataset are using solid biofuels.

3.3 Fuel Prices

Information about the fuel prices has been collected from statistics released by Statistics Finland. The prices per MW·h are visible in Table 4, after they had all been calculated to their VAT 0% price.

Table 4: Fuel prices in €/MW•h at VAT 0%

Energy source	Price in €/MW·h (VAT 0%)
Hard coal	28,55(preliminary price)
Natural gas	46,45
Forest chips	20,60
Peat	18,92
Light fuel oil	≈86.61

Adapted from Statistics Finland (Statistics: Energy prices [e-publication], 2013)

3.4 Fuel Availability

Hydropower, wood, peat and wind energy are the only indigenous energy resources in Finland. All of its remaining fuels, such as coal and fossil fuels, are imported. (Alakangas, 2002)

According to Virtanen & Valpola (2011) Finland's energy peat reserve is 23,7 billion m^3 *in situ* and its energy content is 12 800 TW·h. The annual production is an average of 22 TW·h, with a distribution of 90 percent milled peat and the remaining part sod peat. (Paappanen, Leinonen, & Flyktman, 2010)

According to a report from 2002 68% of Finland is covered by coniferous trees. The annual harvest is lower than the natural regeneration of the forests. (Alakangas, 2002)

3.5 Fuel Procurement

3.5.1 Heavy and Light Fuel Oil Procurement

Oil products are bought by the individual greenhouses according to their tank sizes and fuel needs. Some greenhouses are in an agreement with one or more oil companies where the tanker trucks can deposit residual load at the greenhouses. A joint procurement agreement is made between greenhouses on a local branch level. (ÖSP, personal communication)

3.5.2 Wood Procurement

Energy wood logs are bought individually by greenhouses from a mix of private forest owners and commercial wood manufacturers such as UPM-Kymmene Corporation, Biovatti, Stora Enso and Metsäliitto. The energy wood usually consists of wood which is not suitable for the timber and paper industry. The logs get chipped and transported to the greenhouse after approximately a year of drying. In a few cases there are greenhouses that have an agreement with a district heating entrepreneur. However, this requires the greenhouses to be within reasonable distances in regards to the district heating station. (ÖSP, personal communication; Bio West Oy; personal communication)

3.5.3 Peat Procurement

Peat is primarily in the sod peat form, which is easier to store. The peat origin is likely to come from one of the large peat producers such as Bioenergia, Metsähallitus, Vapo and Turveruukki. Peat is bought individually by greenhouses. (Smiths Garden Ab; personal communication)

3.6 Biofuels to Energy – Biofuel Boilers

Below follows a general description of how the biofuels, pellets and woodchips, are converted to pure energy to be used for heating in the greenhouses. We will have a more detailed look at a pellets burner and a glance at a woodchip burner. The description below consists of the burner itself and the storage container connected to it.

3.6.1 Pellet Boiler

In Figure 3 a pellet boiler according to Thermia can be seen. (Thermia Pelletsvärme, n.d.)

1. Pellet storage. Pellets are stored here in large enough amounts, which means that refilling isn't necessary too often.
2. Hole for bulk delivery and air hole to compensate for the possible overpressure building up in the pellets storage container when refilling it from the delivery truck.
3. The walls of the pellets storage container are built so that the pellets automatically slide down towards the bottom. At the bottom there is a tube with an opening. In the tube there is a spiral which rotates and delivers the pellets from the storage container to the pellets oven.
4. When the pellets reach this place they fall down into the burner.
5. Inside the boiler there is a small temporary storage container wherefrom the pellets are forwarded in small amounts to the burner itself. (This system prevents backfire)
6. The pellets are ignited automatically with a hot air cartridge. This is only used when starting the oven. At normal usage the flame is kept alive with the embers.
7. The oven heats the radiator system which then heats the radiators throughout the greenhouse. The smoke gas channel is long to make the energy output as big as possible.
8. The smoke gas is led out through the chimney.

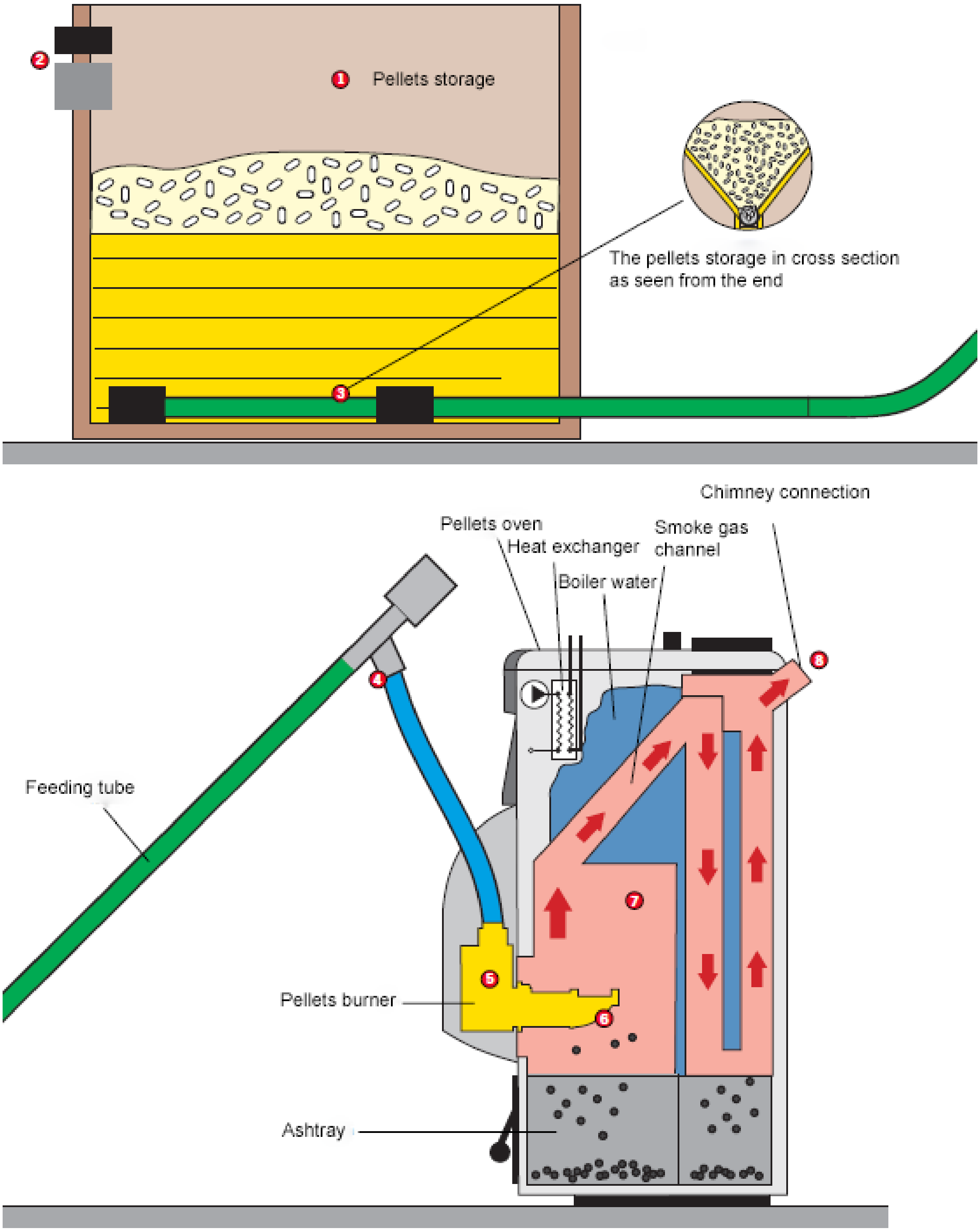


Figure 3: *Pellets burner*

Sourced from Thermia (Thermia Pelletsvärme, n.d., ss. 14-15)

Figure 4 below shows the feeding mechanism in more detail, i.e. how the pellets are transported to the boiler and how the burner portions the amount of pellets burning at a given time.

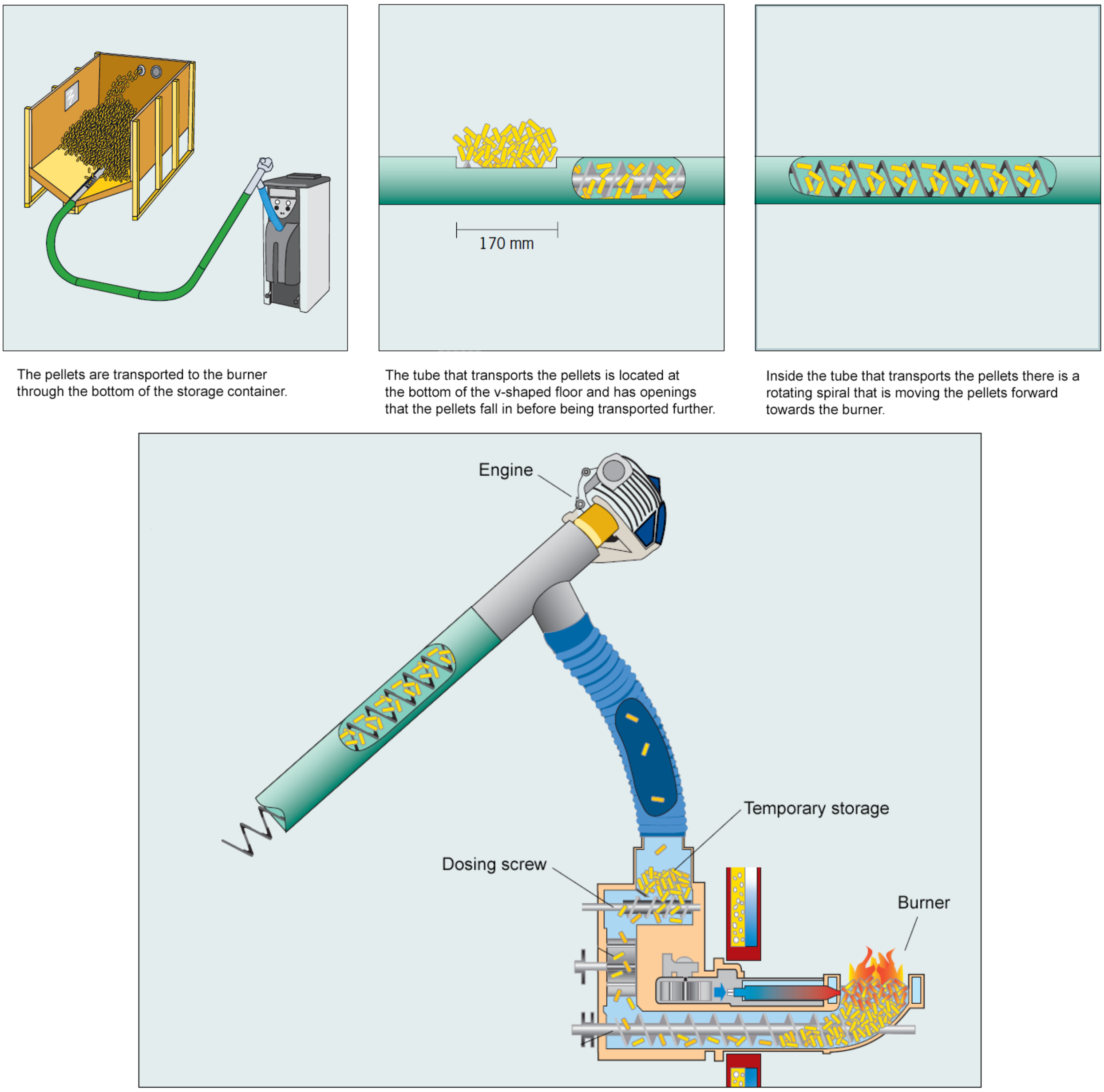


Figure 4: *Detailed view of a pellet burner*

Sourced from Thermia (Thermia Pelletsvärme, n.d., p. 25)

3.6.2 Woodchip Boiler

In Figure 5 a general description of a woodchip boiler according to Baxi (Wood chip heating, n.d.) can be seen. The woodchips are transported into the boiler through a tube with a rotating spiral. The ash is removed through an ashtray and air is inserted to the burner. Then the hot flue gases are led through a heat exchanger that has automatic cleaning to prevent ash from clogging up the heat exchanger. After that the flue gases are led out to a chimney.

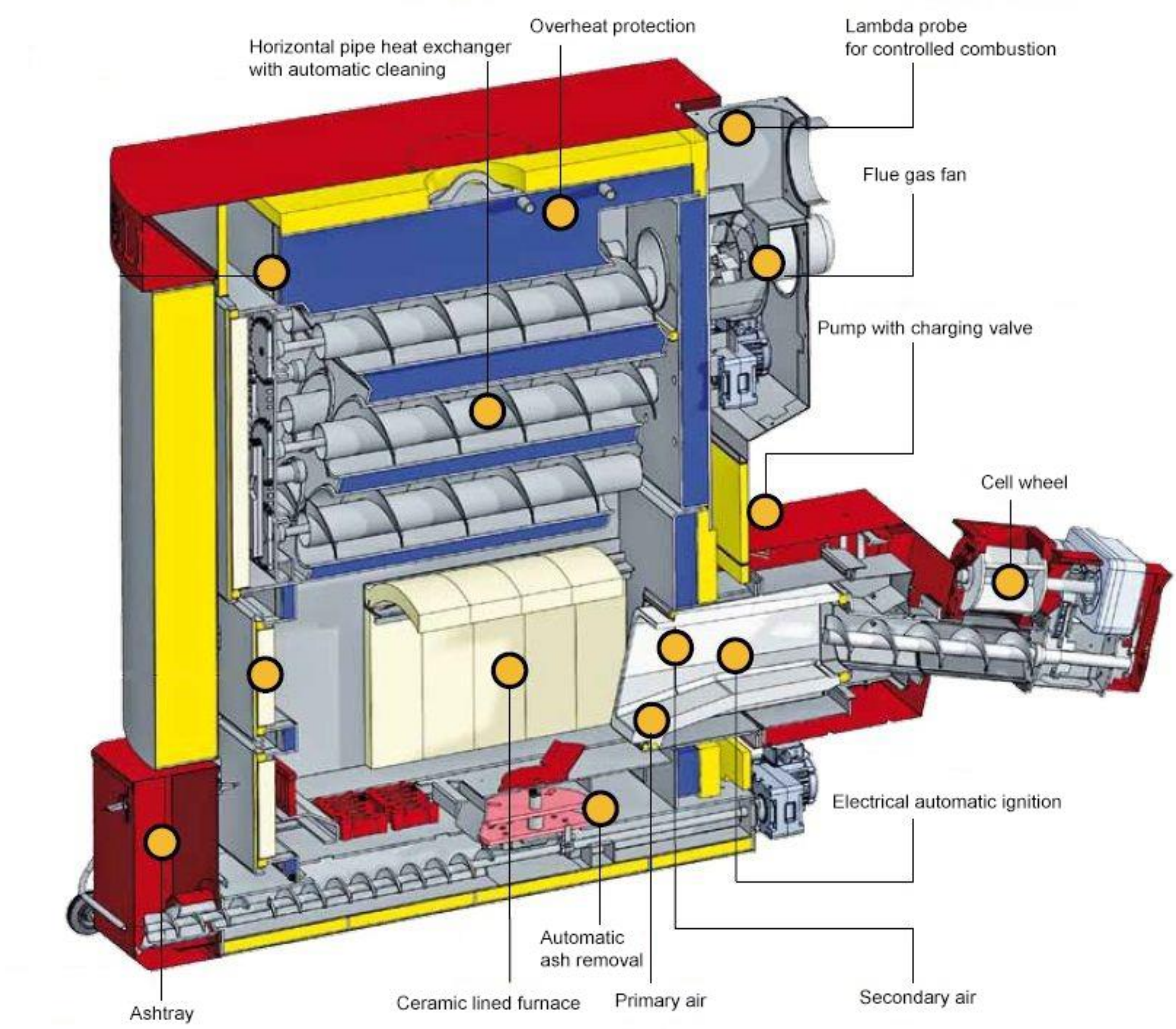


Figure 5: *Wood chip burner*
Sourced from: Baxi (Gilles Flispannor, n.d.)

3.7 Logistics

3.7.1 Supply Chain

Today's energy wood supply chain can be seen in Figure 6.

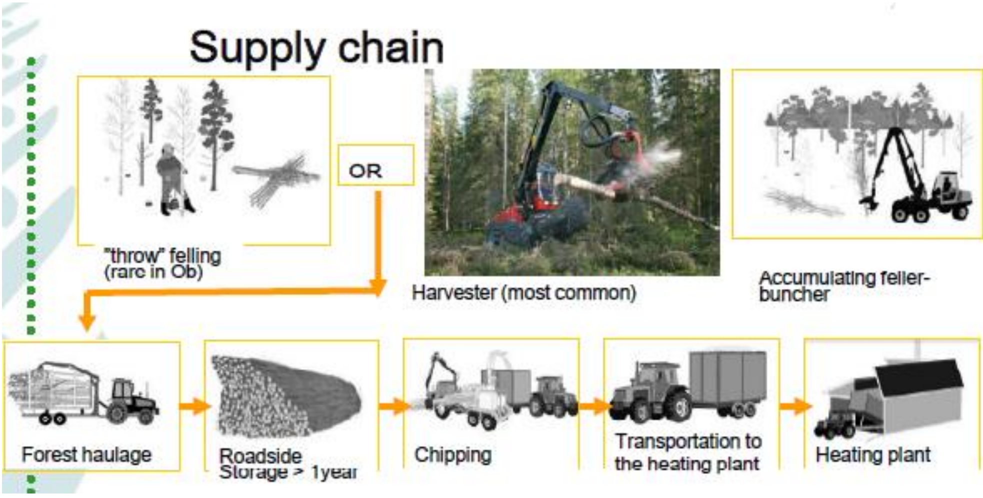


Figure 6: *Supply chain of energy wood*

During the logging stage, the trees are cut down manually or by harvesting machines. With the development of mechanization, harvesting machines have become the most common way to collect woods in the forests in Finland.

After logging, the woods are put together and then pulled out of the forest by trucks. These woods are not ready to use because of the high moisture content. They must be stored for a certain amount of time before they become dry enough. The drying time may varies according to the climate. Generally speaking, one year is the average time for storage. The places for storage are mostly beside the road due to the lower cost and more convenient traffic. There is now another alternative that the wood piles can be transported and stored in a terminal, to achieve a higher quality.

Afterwards, when the wood piles have become relatively dry, they are processed into wood chips by a chipping machine beside the road or in the terminal. The wood chips will be transported to the heating plants and eventually into the burner or storage. (Heilala, Andis, Makovskis, & Hyytiäinen, 2013)

3.7.2 Transportation Means

In Ostrobothnia, the dominating transport means for energy wood is road transport. The majority of companies use lorry as their first priority. At the same time, boat transport and train transport are being used as well, but to a much lesser extent.

Road transport is the most common way to transport relatively small amounts of freight, due to its lower cost and higher flexibility. Lorries can go anywhere as long as there is a road. Basically, the average volume of a wood chips lorry is 120 m^3, corresponding to a weight capacity up to 40 tons.

Railway transportation is more suitable for long distances with high volumes compared with road transportation. The railway transport is mainly conducted by state-owned rail operator VR Cargo in Finland. However, train transportation is not widely used in Ostrobothnia. The price and booking policies require a customer to order a whole train for a long period, which is not practical for most of the consumers.

Boat transportation is also suitable for long distance and high volume freights. The harbour Kaskinen is not frequently being used by the greenhouse owners. One reason is that the harbour was specialized for bulk products, such as forest industry goods, cellulose and so on. Even if the customer imports wood chips from abroad, the wood chips have to be delivered by lorries to the greenhouses. Another reason is that the greenhouse owners have their own specialized transport solutions, which are more efficient and cheaper. (Ehrs & Vauhkonen, 2012)

3.7.3 Transportation Costs

No exact statistics of energy wood transportation has been found so far. For this reason, a statistic for round wood transportation was used as the substitute. According to the data from Finnish forest industries and the state forest enterprise Metsäteho Ltd (Timber Harvesting and Long Transportation of Roundwood 2012, 2013) in 2012, the road transportation fee for round wood was 4,90 €/m^3 over a distance of 51 km. The average energy wood transport distance in southern regions Ostrobothnia was estimated to be around 50 km. The prices above can therefore be indicative for the road transportation of energy wood.

Long-distance Transportation of Roundwood, 2012

	Domestic roundwood				
	1 000 m^3	%	km	cent/m^3km	€/m^3
Total long-distance transportation	44 119		163	5,5	9,02
Total by road	44 441	100,7	93	7,8	7,31
By road to mill	33 180	75,2	109	7,4	8,11
Rail transportation sequence	9 478	21,5	325	3,6	11,71
By road to railway	9 987		45	10,9	4,91
Rail transportation	9 478		280	2,4	6,62
Water transportation sequence	1 466	3,3	302	3,8	11,42
Floating sequence	708	1,6	349	3,5	12,07
By road to floating point	708		51	9,5	4,90
Floating	708		298	2,3	6,72
Barge transportation sequence	758	1,7	258	4,2	10,81
By road to barge	501		50	10,5	5,28
Barge transportation	758		208	3,5	7,32

Figure 7: *Transport cost of roundwood in 2012*

Sourced from Metsäteho Ltd (Timber Harvesting and Long Transportation of Roundwood 2012, 2013)

It is noteworthy that the price of "By road to mill" as can be seen in Figure 7 was 8,11 €/m^3 over a distance of 109 km, which was much higher than that over a distance of 45 km. This reflects that road transport costs increase rapidly as the transport distance grows, though the fixed fee is lower compared train and boat transport. Consequently, short distance transport should be carried out by trucks and lorries.

4 Analyses and Methods

4.1 Energy consumption

4.1.1 Weather Influence on The Energy Consumption of Greenhouses

The most important factors for the quality and productivity of plant growth is the temperature.

The temperature outside is directly linked to the energy needed for farming in greenhouses. Information about the temperatures in Finland was collected from Ilmatieteen laitos (the Finnish meteorological institute). The information shows the mean temperature over the years 1981 through 2010.

There are also some producers that are seasonal growers and are out of operation during the coldest months. The increase of energy consumption is partially due to the climate and partially due to the harvest and production period. This means that even if there is lower production during the coldest season, the energy required would be less than expected.

Indeed, if the outside temperature was the only one cause, the chart distribution should be similar. December, November and October occur in the lower end of the energy usage table and show that another factor is also influential in creating this trend.

In

Table 5 the mean temperatures recorded over the years 1981-2010 in the region that we are interested in can be seen. The data was extracted from the temperature maps that are available on the Finnish meteorological institute website. Figure 8: *Mean temperature for the period December 1981-2010* shows the mean temperatures for December recorded in Finland in the period 1981-2010. (The mean temperature for the region is between -6°C to -4°C in December.) The coldest period in this area in Finland is December through February when the mean temperature drops to a low of -7°C.

Table 5: Mean temperature versus energy needs

Temperature		Energy Needs
February	-3 - -2	March
March	-1 – 0	April
December	-6 – -4	January
November	-1 – 1	May
October	4 – 6	September
September	9 – 11	December
April	2 – 4	June
May	8 – 10	November
June	13 – 14	October
July	16 – 17	July
August	14 – 16	August

One would think that it is during this period that the greenhouses need the most energy for heating, but since the energy needed for heating is also affected by harvest and the production period this is not the case. The most energy is needed from February onwards with the least energy needed in the period October through December with October having the lowest energy needs of the whole year.

The information about the peak needs was collected from a thesis named "Biomass potentials in Finland" (Gyibah, 2009)". He has researched this, using information from several greenhouse owners in the Pörtom area.

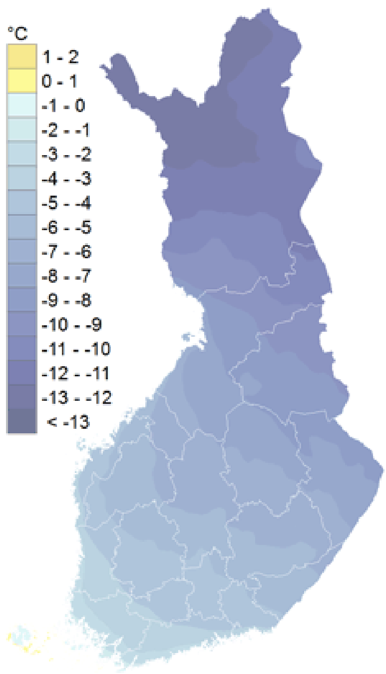


Figure 8: *Mean temperature for the period December 1981-2010*

Sourced from (Ilmatieteen laitos, n.d.)

The maps of the mean temperatures have been made by using the so called "kriging" analysis method. According to Ilmatieteen laitos (Ilmatieteen laitos, n.d.) the "kriging" method uses the topography of the terrain and the impact of the shoreline and water(streams/bodies) at each grid-point in an interpolated 10 km x 10 km grid. The maps give a good overview of the spatial variation of temperatures in Finland. The resolution is not accurate enough for a more detailed look at individual locations, but is enough for larger regions.

Finding out which vegetables grow inside the greenhouse will be significantly useful information for us when finding out the required capacity of the storage facility to house the maximum volume of fuel during peak season. Therefore we need to use statistics to know when the peak occurs approximately. To investigate about 300 greenhouses on location would be very time consuming and inefficient. However, a viable alternative would be to gather statistics from a survey carried out on some greenhouses located around Pörtom. This information can be seen in

Table 5. It ranks each month by energy consumption, from which we can make a reasoned estimate as to the volume of fuel that will be stored during the peak season.

Another factor that affects the energy needed for the greenhouses is the natural sunlight. During the time that the greenhouses have natural sunlight shining through the glass construction the greenhouse is heated naturally. This affects the energy needed for heating the greenhouses in smaller scale than the temperature outside, but it is still worth noticing when doing research. During nights or dark periods in winter, early spring and late autumn artificial sunlight is needed for the vegetables to be able to grow in the greenhouses.

Statistics of the length of the daylight through a whole year in the Närpes region were collected. The information was collected from O.Moisio (Auringon nousu- ja laskuajat Suomessa, n.d.) who has created a website where he used calculation data from the North American NOAA (National Oceanic & Atmospheric Administration) to be able to calculate the length of daylight in different locations around the world. The collected data shows that the shortest time of daylight occurs 20 – 22 December and the longest time of daylight occurs 20 – 22 June.

4.1.2 Greenhouse Energy Needs

In order to determine the volume of wood needed to provide all the greenhouses with biofuel, consumption data are required, however these were not available.

However, in one of his books Patrick Majabacka shares a formula which gives the power needed by greenhouses depending on the total area, the temperature difference between the inside and the outside of greenhouses and the thermal conductivity coefficient.

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

Where A is the area of greenhouses in square meters, k' the average thermal conductivity coefficient of greenhouse materials in W·m^2·°C, T_i the average temperature inside the greenhouses and T_o the outside temperature.

The thermal conductivity coefficient k' used in the calculations is 6 W·m^2·°C, this is the average value for glass greenhouses.

The temperature difference had to be calculated first. The results of this can be seen below in Table 6.

Table 6: Temperature difference per month

Month	Jan.	Feb.	Mar.	April	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.
T_o (°C)	-6	-2,5	-0,5	3	9	13,5	16,5	15	10	5	0	-5
T_i (°C)	25	25	25	25	25	25	25	25	25	25	25	25
$T_i - T_o$ (°C)	31	27,5	25,5	22	16	11,5	8,5	10	15	20	25	30

The outside temperature is taken from the information gather in chapter 4.1.1 Weather Analysis. The inside temperature is the inside temperature of a visited greenhouse.

The result of the P. Majabacka formula is shown below in Table 7.

Table 7: Results of Majabacka's formula

	Jan.	Feb.	Mar.	April	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.
P (MW)	194,2	172,3	159,7	137,8	100,2	72,0	53,2	62,6	94,0	125,3	156,6	187,9
Total : 1 516 MW												
Average : 126 MW												

During the visit to a greenhouse, the owner provided us with the usage percentage of his boiler depending on the outside temperature. From his values a linear interpretation has been made. This interpretation can been seen as a graph in Figure 9: *Linear interpretation of the usage of the boiler.*

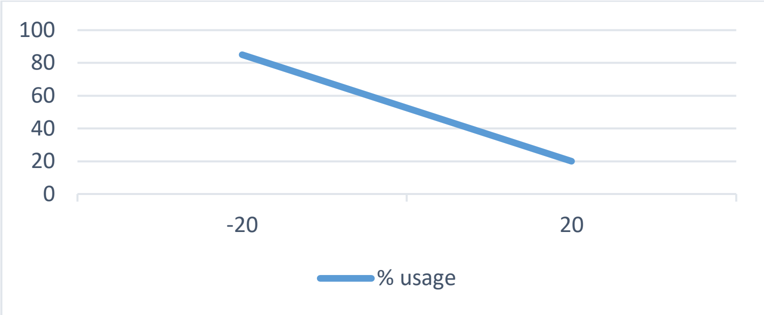


Figure 9: *Linear interpretation of the usage of the boiler*

The linear interpretation was applied to the result of Table 7. This resulted in the result in Table 8: Power needed with coefficient from the linear interpretation applied

Table 8: Power needed with coefficient from the linear interpretation applied

Month	Jan.	Feb.	Mar.	Apr il	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.
T_o (°C)	-6	-2,5	-0,5	3	9	13,5	16,5	15	10	5	0	-5
%Power	0,62	0,57	0,54	0,46	0,36	0,29	0,24	0,26	0,35	0,44	0,52	0,60
P(MW) with %P	120,4	98,2	86,3	63,4	36,1	20,9	12,8	16,3	32,9	55,1	81,4	112,8

Based on the study "Biomass potentials in Finland: The case of Pörtom" (Gyibah, 2009), we have used his monthly used power distribution in our case study. This coefficient is used to weight the greenhouses usage, (e.g. in January and august just half of the greenhouses were in use).

Table 9: Percentage of greenhouses usage in Ostrobothnia

Month	Jan.	Feb.	Mar.	April	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.
Coefficients	0,5	1	1	1	1	1	1	0,5	1	0,25	0,25	0,25

Table 10: Power needed with percentage of greenhouses usage coefficient applied

	Jan.	Feb.	Mar.	April	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.
P (MW)	60,2	98,2	86,3	63,4	36,1	20,9	12,8	8,1	32,9	13,8	20,4	28,2
Total : 481,2 MW												
Average : 40,1 MW												

In Figure 10: *Monthly consumption all coefficient applied for all the greenhouses in Ostrobothnia* this data is represented as a graph, showing the power needed in megawatts (MW) for all the greenhouses in the southern regions of Ostrobothnia.

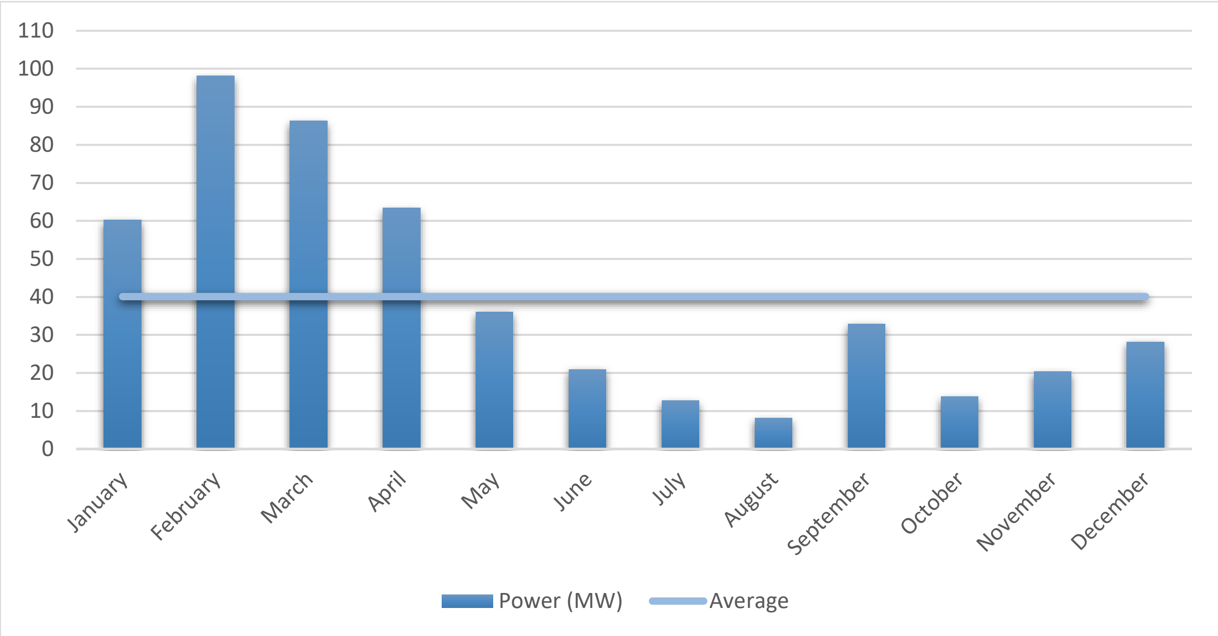


Figure 10: *Monthly consumption all coefficient applied for all the greenhouses in Ostrobothnia*

Given this distribution, we considered a power usage of 24 hours per day and a boiler efficiency of about 80%. The total monthly consumption was calculated and then the monthly weight and volume of wood needed were deduced.

Table 11: Power, consumption, wood weight and wood volume monthly needed for all the greenhouses in the southern regions of Ostrobothnia

	Jan.	Feb.	Mar.	April	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.
Hours per months (24 h/day)	744	696	744	720	744	720	744	744	720	744	720	744
P (MW)	60,2	98,2	86,3	63,4	36,1	20,9	12,8	8,1	32,9	13,8	20,4	28,2
Consumption (GW·h)	45	68	64	46	27	15	10	6	24	10	15	21
Wood chip weight (tons)	10663	16271	15280	10867	6391	3581	2264	1443	5638	2441	3490	4993
Wood chips volume (m^3)	46363	70744	66433	47248	27789	15571	9842	6272	24511	10614	15174	21710
Wood chips volume total : 362270 m^3												
Wood chips volume average : 30189 m^3												

These calculations are large based of hypotheses, but should be relatively close to what the real consumption will be.

4.2 Comparison Between Covered and Uncovered Storage of Wood

As there is a lot to gain by lowering the moisture content in wood this is one of the things this project focusses on. With a low moisture content the wood contains more energy per cubic meter of wood, so less wood is needed for the same amount of energy. By reducing the volume of wood needed, the number of truck needed to transport the biofuel can be reduced and potentially it permits to have a bigger stock of energy in case of cold winters, road traffic restrictions or overconsumption.

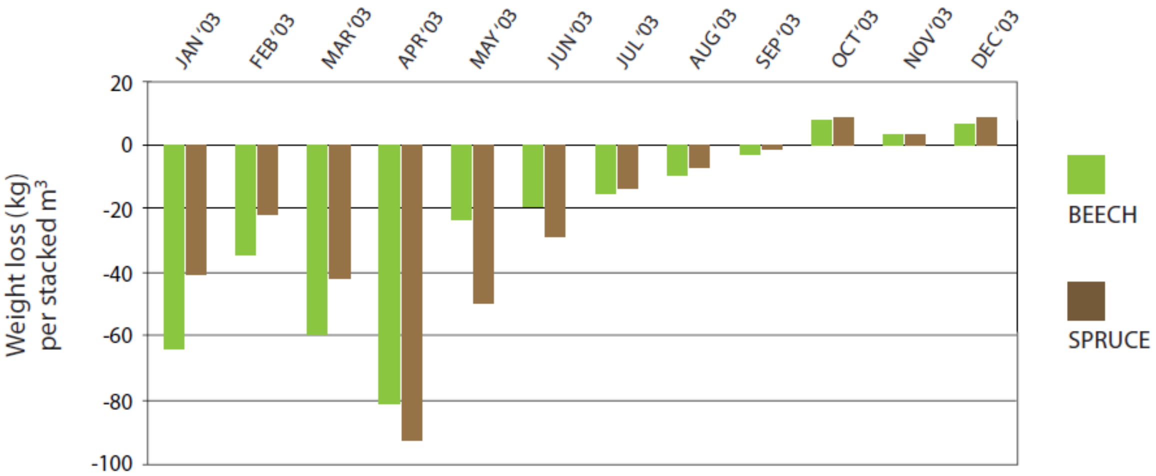


Figure 11: *Monthly dry rate*

Sourced from European Biomass Ascociation (Wood fuels handbook, 2008, p. 47)

In Figure 11, the periods when moisture content of the wood increased or decreased can be seen. Between September and December log woods gain between 5 and 10 weight in water per stacked m^3. But during 6 months between January and June important losses in moisture content occur.

Moisture content (lower is the moisture content better is the energy efficiency):

- Fresh wood => between 40% and 65%
- Seasoned in the forest => between 30% and 40%
- Seasoned in the storage => between 20% and 30%
- Ready to be burnt => less than 20% (or 25%)

To have the lowest moisture content possible, a covered terminal for storing wood was suggested in order to speed up the drying time and increase the biofuel quality. As it turns out covered wood has a lower moisture content compare to uncovered wood. In Figure 12, the result of a comparison can be seen between uncovered and covered wood carried out by Metsäntutkimuslaitos between 2003 and 2006 (Juha & Tero, 2006).

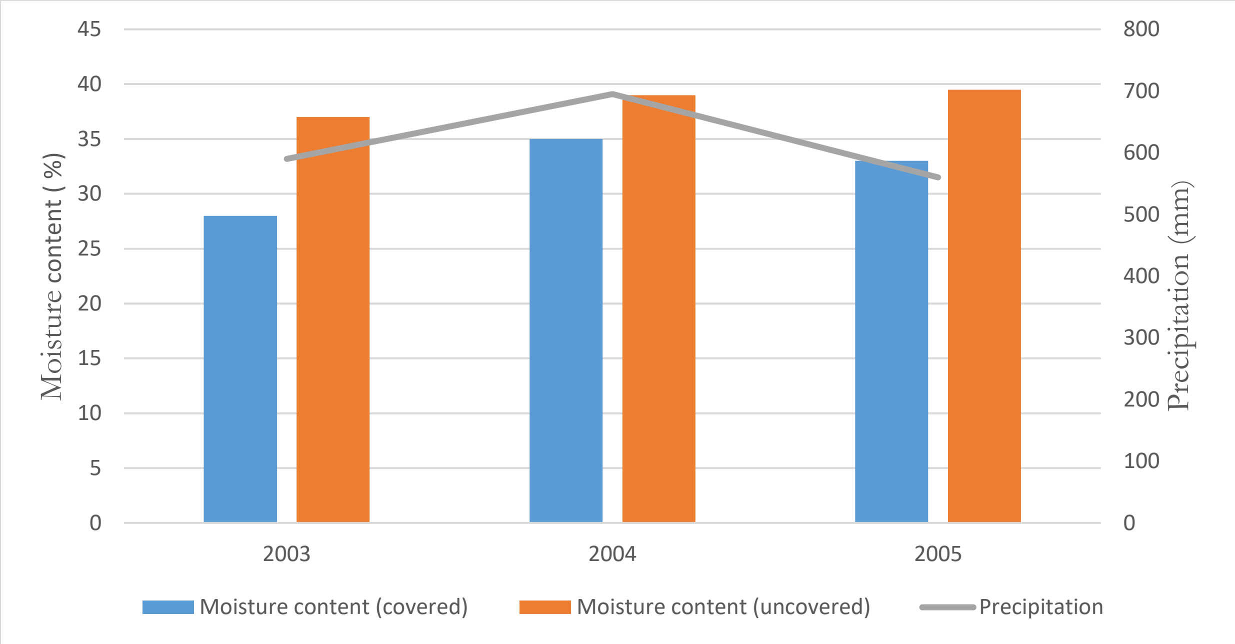


Figure 12: *Moisture content in covered, uncovered wood stock in relation to precipitation*

Sourced from Juha & Tero (Täckningens inverkan på kvalité i energiveden hos energikooperativen i Mellersta Österbotten, 2006)

In the case of a covered terminal, having all the biofuel centralised, allows to have more control of the moisture content in the wood stock. Having a better control on the moisture content allows to increase the stock quality and improve stock management. A covered terminal also allows to avoid moisture from precipitation and as a result improve the reliability of the stock. This is what it is needed in a large-scale biofuel production.

> *Covered barn storage offers the simplest and arguably the most cost effective solution for storing logs. Processing logs in to a split form aids the drying process and covered storage prevents re-wetting. Sheeting provides a less costly storage solution but equally reduces the quality and arguably the return to the contractor, as it is much harder to control the quality of the finished product. (Regen SW, 2008)*

By adding a roof to a terminal, the time needed to obtain low moisture content is reduced. A lowered time to dry the wood allow to reduce the size of the stock and smaller stock means less money tied up.

4.3 Supply Chain Structure and Optimization

The supply chain consist of a multiple steps from the logging process until the final heat production(See chapter 3.7.1 Supply Chain). These steps were investigated to identify where changes could be made.

First the modifiable are pointed out, afterwards two possible scenarios will be presented.

In order to have a better overview of the suggested improvements, the financial concerns will be analysed in general terms. Especially the costs in the different proposals:

- Costs for the supply chain structure (forest-terminal-user).
- With a terminal or no terminal

4.3.1 Modifiable Points in the Supply Chain

The supply chain components can be sort in three group which can be seen in Figure 13.

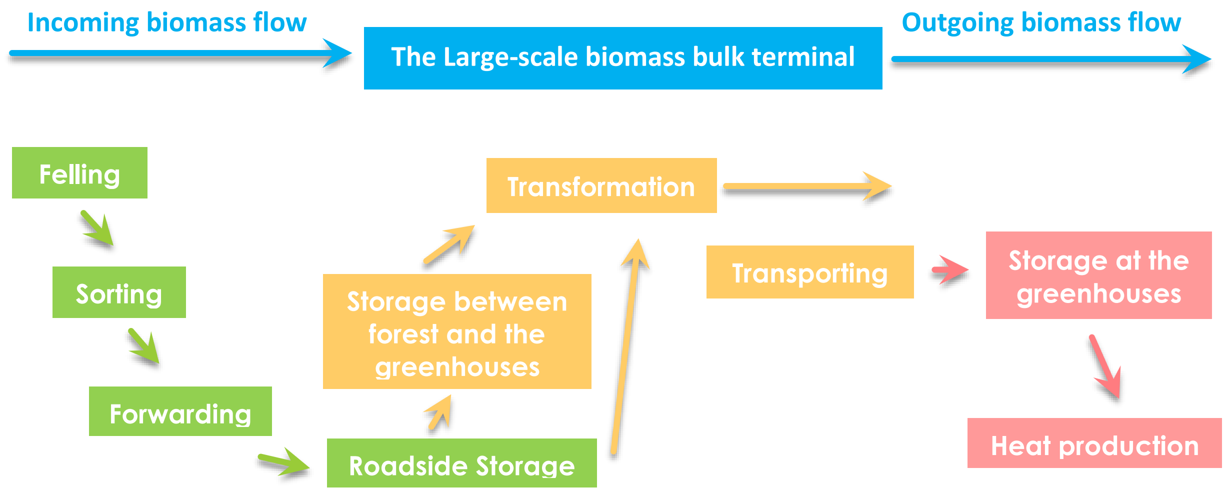


Figure 13: *Supply chain structure*

The first group, in green colour, is dependent on the biofuel and can slightly change in the steps "Forwarding" and "Roadside Storage". In the same way, the third group, coloured in pink on the schema depends on the end users facilities. The most influenceable steps, in yellow colour, are included in the second group e.g. 'Storage between forest and the greenhouses", "Transformation", and "Transporting".

4.3.2 The Envisioned Scenarios

The following proposals are suggested as a vision for the future. The two proposals consider a different fuel usage. One of these scenarios is based on 100% usage of wood biofuels, the other is based on 50% usage wood biofuels. The actual supply chain would depend on the customer needs, usage and participation.

A good proposals would minimise the overall cost of the whole supply chain and the environmental impacts caused. The solution would have to take into consideration the existing infrastructures, characteristics of the region and its climate. It definitely would need to meet the needs in production demand.

Forest fuel production systems are typically built around the chipping phase, because the positioning of the chipper determines much of other logistics. Chipping can take place at the road side or landing site, in the terrain, at terminal or at the energy plant (Northern Wood Heat, 2007).

The envisioned scenarios are a combination of alternative solutions for each step as illustrated in Figure 14:

- Sorting on in the terrain or at a terminal
- Forwarding from forest to terminal by trucks/train/ship
- Storage and drying on the roadside or inside a terminal (covered/uncovered)
- Transporting from terminal to the end user by truck/train/ship

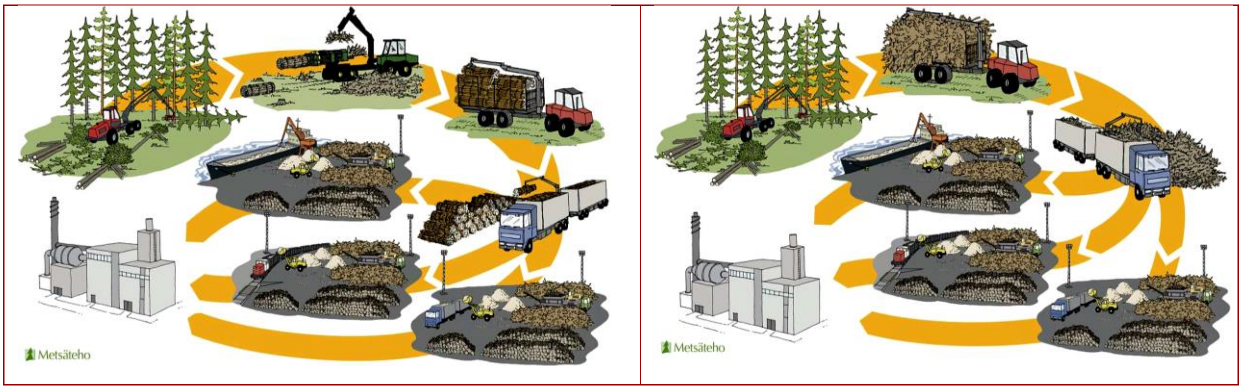


Figure 14: *Two examples of the existing scenarios* (Kärhä, 2008)

4.3.3 The Suggested Scenarios

Different solutions can be suggested depending on the final cost. However a costly scenario involves top quality for the facilities used, for the biofuel produced and security for the stock. Nevertheless, it is also possible to meet the requirements in quality with more affordable proposals. But in this way, the stock's safety and a large-scale production cannot be ensured.

The requirements sought by the customers are generally:

- Reliability / security - quantity
- Technical performance - quality
- Economic performance – price

One of the original objectives for enhancing the biomass is to buy energy, not a price. A costly scenario would trigger off a rise in price but it would chiefly improve the quality of the biofuel. Therefore if the quality is high, the quantity needed is lower. For a long-term, it would be a way of meeting the customer requirements in price.

Long-term contracts between supplier and consumers lead to a big demand in biofuel (guaranty for the suppliers) and a decrease in price. The join procurement would also be a solution for the customer in order to reduce de biofuel's price since the large-scale production allow to purchase a big amount of biofuel.

4.3.4 Scenario One

The first presented scenario is based on a use of 100% wood chips. The schema in Figure 15 represents the structure of the supply chain.

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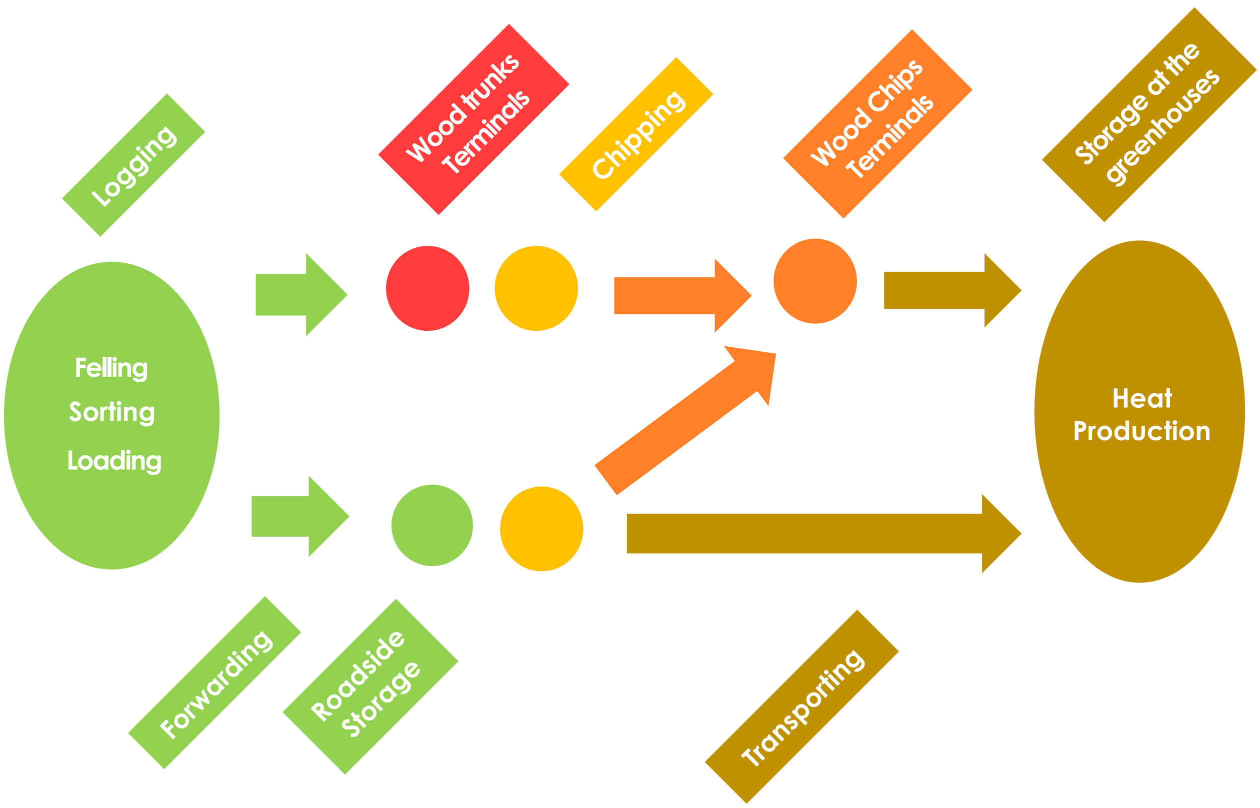


Figure 15: *Supply chain structure for scenario one*

4.3.4.1 Structure of the Supply Chain

The logging process is the first step of the scenario then,

- A part of the wood trunks are load onto trucks, skeleton car and forwarded to the terminals intended for wood trunks. A roof for the terminal will be built in order to speed up the wood drying as explained in chapter 4.2 Comparison Between Covered and Uncovered Storage of Wood.
- The wood trunks are then chipped at the same site and transported to the smaller terminals.

The smaller terminals will be scattered in the region and use as a wood chips storage. It will use a passive drying system and will be covered.

- The other part of the wood trunks is stored beside the forest (covered roadside storage). This part of the raw material will be chipped when dry enough and transporting straight to either to the nearest end users or to the smaller terminals.

Finally, when the expected moisture content level is reached the wood chips can be transported to the greenhouses where it would be stored and burnt for heat production.

In this scenario, logging step including felling, sorting and loading on to truck is done in forest sites located in the region.

The project can be considered as large-scale production for wood chips. Therefore felling, delimbing and harvesting processes have to be done with high production rate machines with harvester heads as the machine shown in Figure 16.

Figure 16: *harvesting process operate by machine with harvester heads*

Logging residues (branches and stumps), small wood and log wood are the different forest harvesting products. Currently, the branches are remained in place and used as natural fertilizer. The large-scale production can create an extra of logging residues. A way for managing this issue is to bundle the logging residues and put it away. Energy wood is harvested from young forest thinning. The log woods is intended for producing planks rather wood chips. The small woods are the preferable products (approximately about 15cm diameter).

Sorting is an important process in order to reduce the weight of the loads on trucks during the transportation.

It would be unnecessary to store all the logged wood trunks in a terminal which would be placed far away from lot of greenhouses. That's why the roadside storage will continue to be use. Natural drying along forest increases the calorific value and reduce the cost of transportation per kWh e.g. more energy and less water per travel.

Despite this measure, lot of unavoidable long-distance journeys to the terminal can be caused. They are related to the low number of terminals which can be built.

At the same time, to have a wood trunk terminal allow to dry a high wood's quantity. It is also a way to ensure the wood chips availability and quality. Build up a large stock in a terminal ensure to supply the greenhouse growers even when certain roads are restricted (A. Wikberg, personal communication). Indeed the wood trunks will be located along a road without restrictions as explained in the chapter about the location of the terminals.

Transformation means to convert the raw material in a usable biofuel. The wood chipper is the machine used for this process. In case of industrial scale, the chipping productivity can reach over 200 m^3/h (Kesla Oyj, 2013).

The chipping process has to be done on the same site as the wood truck storage. The objective is to avoid additional costs partly due to useless transport and partly caused by having a chippers in each smaller terminals.

Chipping machinery is best used outside. It should be used inside only in extremely well ventilated or forced ventilated buildings as the engine fumes affect the operators' health and safety (Regen SW, 2008).

Moreover, storing the wood chips in a warehouse allows to monitor the biofuel production and consumption. For the fuel inventory, the quantity to ensure supplying for the whole period of heating and storing the biomass for winter-time when working conditions are difficult will be easier with terminals. Combined with an ordering website, the amount of woodchips incoming and outgoing can be exactly known.

Storage at the greenhouses is monitored by the greenhouses owners. In order to conserve the quality of the supplied biofuel they should have a suitable storage, covered at least.

4.3.4.2 Advantages and Drawbacks of Scenario One

Advantages:

- Winter conditions are taken into consideration
- Effective and Low cost of crushing
- Large-scale production
- Delivery at all times
- Quality of biofuel
- Safety for availability of biofuel
- Minor roadside storage space
- Fuel inventory

Inconveniences:

- Long-distance journeys to the terminal can be caused
- The terminal set up costs
- Complexity for the suitable locating of terminals
- Environmental risks and possible impacts

The chipping and storage terminal is the key to a safe, reliable and quality supply.

Scenario Two

The second presented scenario is based on 50% wood chips combined with 50% peat fuel. The schema in Figure 17 represents the structure of the supply chain.

Figure 17: *Supply chain structure for scenario two*

4.3.4.3 Structure of the Supply Chain

The major difference between this scenario and scenario one is that only half of the energy need is supported by the wood chips supply chain. This means it will be on a smaller scale than the scenario one. The wood chips terminal are not included in the solution as it can be seen in Figure 17. Removing the wood chips terminals of the supply chain structure decreases additional costs due to transport of wood chips over long distances, facilities and management. The wood logs storage would be more efficient in terms of space needed. The wood trunk are chipped when the customers put in an order for wood chips.

4.3.4.4 Advantages and Drawbacks of Scenario Two

Advantages:

- Winter conditions are taken into consideration
- Large-scale production
- Delivery at all times
- Efficient transport
- Quality of biofuel
- Safety for availability of biofuel
- Minor roadside storage space
- Fuel inventory
- Mixing between different batches of fuels allows for a more consistent mix.
- Shorter supply chain

Inconveniences:

- Bigger terminals are needed
- Terminals will likely be too big to cover

4.3.5 Financial Aspects

The analysed example is the first scenario e.g. considering 100% of wood chips usage because of it is the most costly scenario between the proposals.

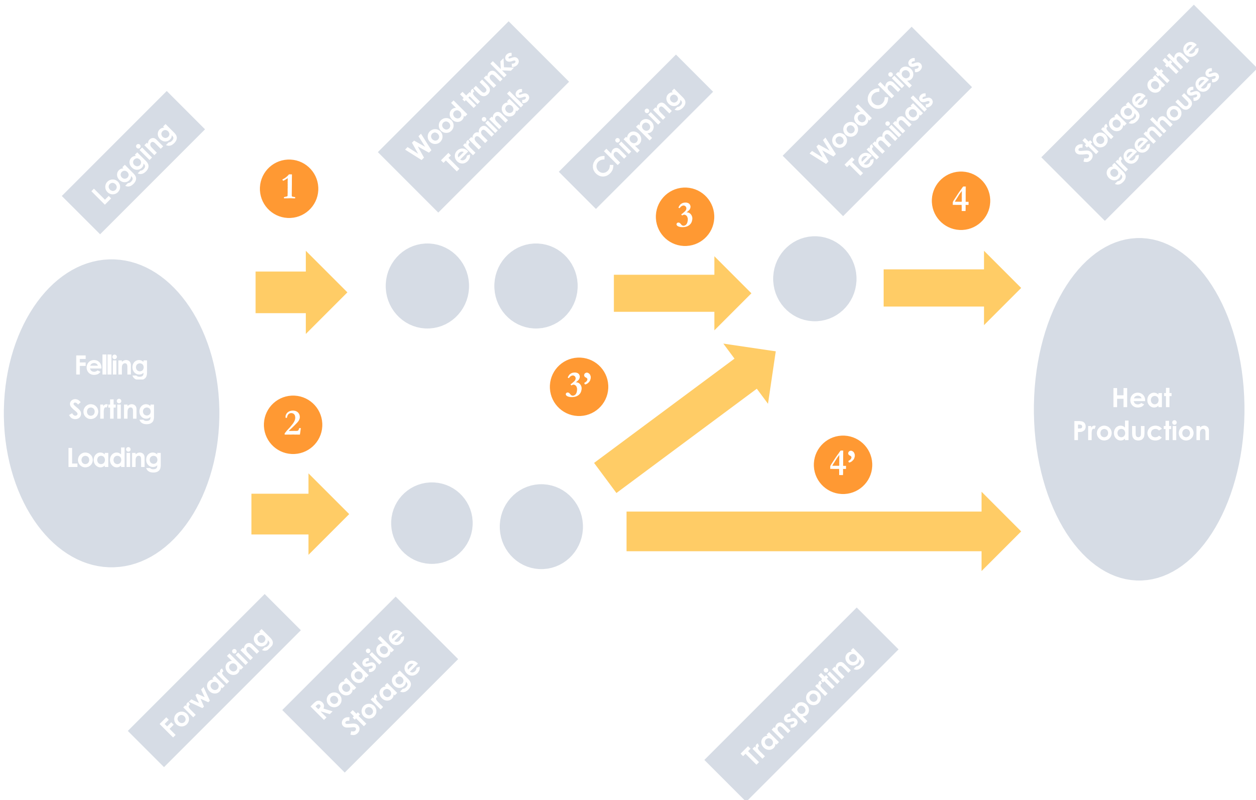
4.3.5.1 Additional costs for all the transports between forest-terminal-user.

Transport of wood logs:

- **1** - Forwarding of wood trunk from forest to roadside
- **2** - Forwarding of wood trunk from forest to wood trunk terminal

Transport of wood chips:

- **3** - Transporting of wood chips from trunk terminal to wood chips terminal -
- **3'** - Transporting of wood chips from roadsides to wood chips terminal
- **4** - Transporting of wood chips from wood chips terminal to greenhouses
- **4'** - Transporting of wood chips from roadsides to greenhouses



4.3.5.2 Area covered by wood chips and wood logs

The stockpiling of wood chips in terminal would cope four months of consumption e.g. three months with non-incoming wood logs from forest and one month for ensuring safety. Considering that the annual consumption is about 360 270 m^3 and a monthly average about 30 023 m^3. A way is building up a stock of 2 months of wood chips in the terminal intended for it and the equivalent of 2 month of wood chips in wood trunks stored in the biggest terminals.

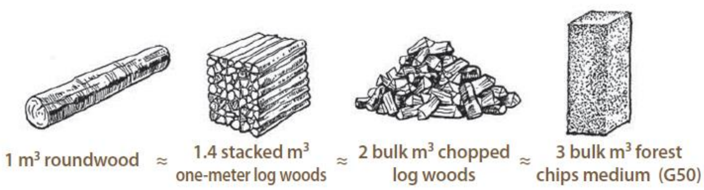


Figure 18: *Roundwood/ log woods/ wood chips conversion rates*

Sourced from European Biomass Ascociation (European Biomass Association, 2008)

With using the rate presented in Figure 18 the area covered by biofuel can be calculated:

- 2 months' worth of wood chips is 60 046 m^3 divided up in five terminals. The height of the stock should be approximately about 5 meters. The area is 12 010 m²

- 2 months' worth of wood chips in wood logs 1,4 m^3 stacked one meter log woods is 3 m^3 wood chips. 5600 m^3 of stacked logs wood divided up in two terminals. The stock would be approximately about 8 meters high. The area is 5 600/8=700 m². Some areas intended for path between stack of wood logs have to be kept in consideration. The estimated area is 3 500 m².

The total area is 16 000m².

4.3.5.3 Structure costs for the supply chain.

The full price is divided up 6 parts as shown in Figure 19

First, the cost for construction of terminals has been estimated by calculating the profitability cost.

The area covered by the stock is 16 000 m². A common price rate for this kind of building e.g. wood terminal is about 500€/ m² (Union Régionale des Associations de Communes Forestières Rhône-Alpes, 2012) . The investment account reaches 8 000 000€.

In the case of a return on investment after five years and annual production about 362 270 m^3 the price for 1 cubic meter of wood chips goes up by 4.5€.

The current price in Finland has been added to the previous price. (METLA, 2007)(A. Wikberg, personal communication)

1. Harvesting/forwarding : 12€ / m^3
2. Chipping : 3.75€ / m^3
3. Road transport (wood logs) : 5€ / m^3
4. Road transport (Wood chips): 2.50 € / m^3
5. Management: 1 € / m^3

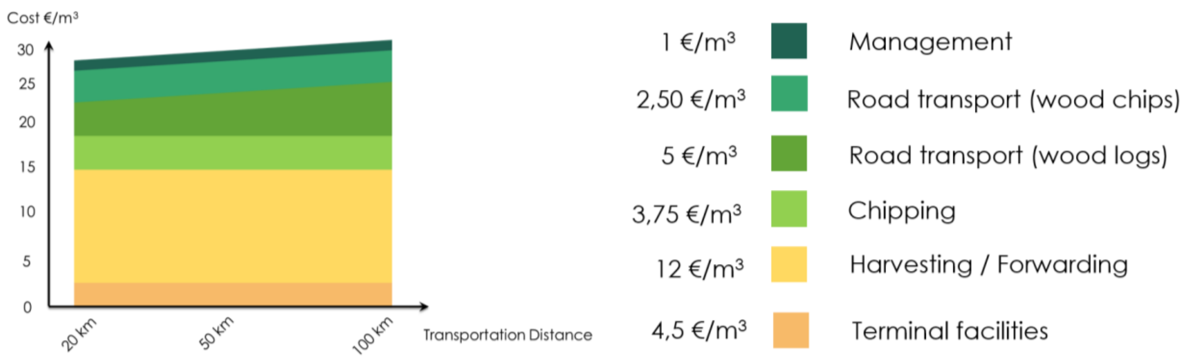


Figure 19: *Cost structure of supply chain for the scenario one*

Finally the price for the supplier is 28.75€/m^3. This cost allows competitive price for the customers slightly higher than the common fuels used as it can be seen in Table 4.

4.4 Optimum Time to Build Stock

To know when to build up multiple thing had to be kept in consideration.

The energy consumption and the peak of energy needed, according to the calculations carried out, influence a lot the stockpiling time. A big amount would be burnt during the peak period namely, January-April. The probable forest road restrictions occur during few weeks of spring and during a rainy autumn (A. Wikberg, personal communication), April and May both have been locked to take this fact into consideration, in the same way September, October and November are locked.

The last factor is the amount of active greenhouses, the same factor was used in the energy needed calculations. The percentages are presented in Table 9.

The stockpiling period is deduced by stacking the factor's layer as shown in Figure 20. The summer and the winter would be the suitable time to build up the stock. From December to March and from July to August, harvesting and stockpiling can be carried through. For the end of these periods, the terminals have to be full to support the greenhouse consumption in energy.

That means 3 months without additional incoming wood logs from the forests: April – May – June and September-October – November.

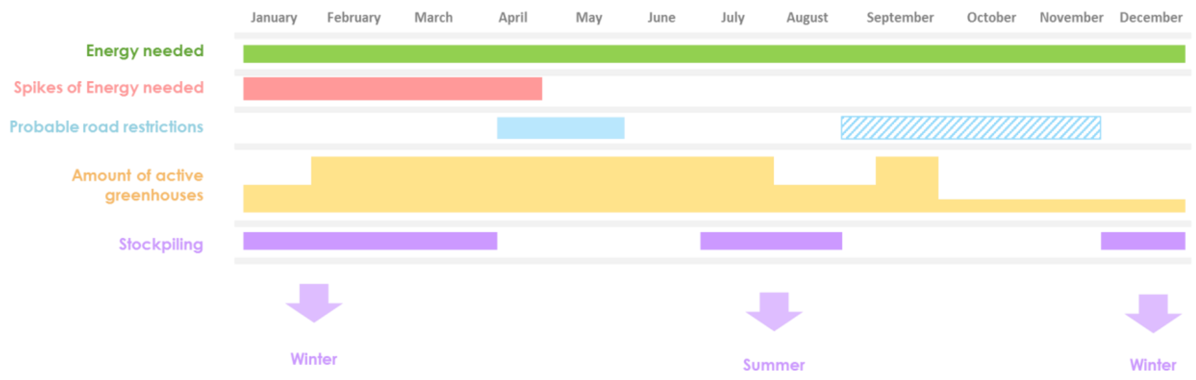


Figure 20: *Factors analysed for stockpiling*

4.5 Environmental Impacts of Modifying The Supply Chain

The warehouse and its associated logistics entail environmental issues. The commodity storage and commodity transportation might have a multitude of environmental impacts. Consequently, this aspect has to be considered in the reasoning.

The responsibility for the environmental protection is shared by everyone: uncontrolled actions undertaken without previous global thinking in this way (e.g. the projects designed for the only way of immediate profit and without environmental assessment) usually cause a deterioration of our heritage, our life quality and our health.

It is likewise a good way of making sure that the needs and requirements related to the warehouse project are known.

The bio terminal should abide by the environmental policy (Lindholm, 2002) especially because the stored commodities are wood biofuel. Coupled with this factor, the logistics covers the whole region of Ostrobothnia and involves heavy truck traffic.

Our main objectives in this environmental protection thinking are:

- To help us design the best warehouse that respects the environment where it is located,
- To estimate and know what damages and impacts may happen and make choices according to those,
- To inform people, in particular forest organisations and greenhouse entrepreneurs (a good way is to also consider their opinions, by contacting them and getting some feedback in order to optimise our suggested logistics' solution).

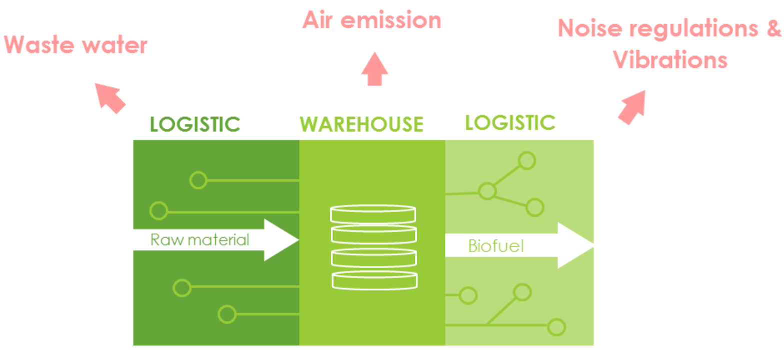


Figure 21: *Diagram illustrating the project*

The overall project can be illustrated with a simple schematic diagram, which can be seen in Figure 21. The diagram shows for a set of three parts including the storage of commodities and the logistic (e.g. One supply chain from timbers to the warehouses and another one from the warehouses to the end users). This three parts caused damages on our environment. The harmful effects are for in most cases due to either waste water, air emission, noise regulation or vibration (Hannuksela, 2013).

The identification of the environmental impacts have been carried out in two different parts: transportation and storage.

4.5.1 Commodity transportation

One substantial part of impacts is linked to the transport method. The main pollution provenances are the following:

- Energy consumption,
- Pollutant emission,
- Noise pollutions,
- Vibrations,
- Impacts of infrastructures on the ecosystem and the natural landscape.

Moreover, the quoted factors of damages are harmful to the human health as well. Diseases can occur due to air quality deterioration and stress partly caused by the noise pollution.

Finally, these effects lead to a rise in costs for the warehouse owners and the local authorities for protecting or repairing the damage done.

4.5.1.1 Energy consumption

Figure 22 shows the differences between the energy balances of the different modes of transport, comparing the power needed to transport one tonne over one kilometre.

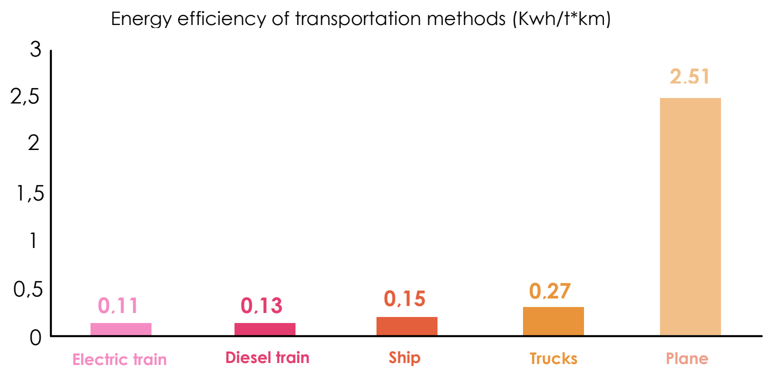


Figure 22: *Energy efficiency of transportation methods*
Adapted from Vlaamse Milieumaatschappij (Vlaamse Milieumaatschappij, 2006)

The road transport method consumes almost the double amount compared with the shipping method and more than double compared with the railroad transport (Strale, 2007). Unfortunately the area is not sufficiently served by different modes of transport, thus the choice is not large. As explained in the chapter about Warehouse locating, the truck transportation is the most advisable method in order to transport biofuel in Ostrobothnia. Nevertheless it shows that the energy consumption by truck must be followed and controlled. That also creates a financial issue due to the transportation fuel cost which tends to level off (Statistics Finland, 2013). (Statistics Finland, 2013). One way to reduce the energy consumption is gathering delivery routes and limiting the speed of trucks.

4.5.1.2 Emissions of pollutants

Gas emissions can be reduced by limiting the travel between the terminals and the end users. However, the decline in demand is a factor that allows a decrease of the emission of pollutants. The demand has to be satisfied, so that is not a parameter which could be influenced. Furthermore, the multimodal transport type is not a viable solution in our case: as explained before, the infrastructures in the region don't allow us to change the method of transport in transit.

4.5.1.3 Noise

Another aspect related to the transport impact on the environment is the noise caused by the circulation of vehicles.

Noise is a sound pollution when this perception becomes unpleasant and can eventually cause a deterioration in the quality of life.

> *"It can cause nervousness, sleep disorders and communication problems on exposed people. It also causes a nuisance to the natural environment and the wildlife which are subject to it, such as animal exile and stress" (Strale, 2007)* (Translated from French to English)

In our case the trucks and engines will use highways and forest roads. They will also move around on the terminal site. There is a maximum fixed value of 55 dB. (Ministry of the Environment, 2007, p. 11) Which is a low limit in this case. A speed limit might reduce noise emissions and vibrations induced in buildings located near roads.

4.5.1.4 Congestion

The environmental consequences of congestion are difficult to estimate. When the traffic on the road is important, vehicles drive more slowly and their emissions seem lower, in fact, they run longer. Moreover, if traffic has ground to a halt on roads, the vehicles consume fuel unnecessarily. Delivering and supplying concurrently with the rush-hour traffic would be avoided especially in the Närpes surrounding area and along the Vasavägen road.

4.5.1.5 Infrastructures

The supply chain requires either the development of the transport infrastructure or the use of existing roads, parking etc.

These infrastructures are environmentally harmful (Bruinsma F., 2002).They consume the space, cause an increase in urbanisation and create an artificial landscape instead of conserving the natural areas.

The construction of long and straight infrastructures such as roads, canals and railroad cuts the natural areas, especially chiefly if passages intended for wildlife are not planned before.

4.5.2 Commodity storage

4.5.2.1 Integration in the landscape

In order to store enough biofuel, the terminals must be spacious. Accordingly, to have an important size for each terminal leads to trouble the visual comfort of the neighbourhood.

4.5.2.2 Impact on the protected areas

Our approach for finding the best suited location is based on setting up the bio terminals far away from the protected areas. Since the warehouses are kept out of the natural and protected areas, the warehouses are not able to cause damages on these areas.

4.5.2.3 Light pollution

The region is dimly sunny especially during the winter (chapter Weather Analysis). An artificial light scheme will be implemented for the path on the site and in the warehouse as well. However this light should not disturb the neighbourhood and the wildlife.

4.5.2.4 Noise emissions

Noise pollution is released by the load and unload process, by the traffic of trucks and engines. Another notable source is the wood chipper. The noise is not constantly produced over the day and the night: The sound level emitted depending on when the machines operate.

Current regulations define sound levels and emergence thresholds on industrial property lines with the neighbouring residents. There is a maximum fixed value of 55 dB beyond the property lines. (Ministry of the Environment, 2007, p. 11)

According to Skogscentralen (A. Wikberg, personal communication) and the witnessed situation of an already existing terminal location owned by Bio West Oy, some possible solutions are:

- To build sound reducer walls around the property,
- To keep an important distance between the warehouse and the neighbourhood, approximately 1 km.

4.5.2.5 Air Quality

The emission of pollutants remains limited to the use of chippers and handling machines consuming fuels. A drying system will be implemented in the warehouses to speed up the decrease in the moisture content.

4.5.2.6 Waste water

In order to build facilities environmentally harmless, the facilities must be able to collect waste water on the site, control it and treat it if required. Different kind of waters can be released and they have different origins:

- Sanitary water,
- storm water,
- wash water,
- accidentally polluted water,
- fire extinction water.

4.5.2.7 Fire

One of the biggest risks that the biofuel storage facilities can have is a fire. It may cause a very destructive blaze on the timber and the surrounding area.

4.6 Warehouses

4.6.1 Warehouse requirements

To improve the logistic supply chain efficiency in biofuel, building one or multiple storage terminals could be a good solution. In terms of what we plan to achieve (log wood storage and wood chip storage), there are several possibilities which are listed below. (European Biomass Association, 2008)

Storage possibilities:

1. On the ground
2. Stable and dry floor, open sky
3. Stable and dry floor with a roof
4. Stable and dry floor, open sky with walls
5. Stable and dry floor, passive ventilation, with roof and walls
6. Stable and dry floor, active ventilation, with roof and walls
7. Stable and dry floor, active ventilation blowing air heated, with roof and walls

The terminal requirements were mainly made by the team, project owner and the laws and regulations. However, most of them are the same no matter what we choose. Below is a list of the requirements for the different types of storage:

Requirements for a closed wood storage:

- A stable floor (concrete) to allow heavy load (truck, wood)
- A dry floor to permit wood drying and avoid moisture pollution
- Woods must be protected from moisture and rain (low moisture content = better energy efficiency)
- Let the air and the sun go through walls or roof to permit wood drying and low moisture content
- The storage room must be well ventilated roof to permit wood drying and low moisture content
- The wood storage itself has to permit the airflow to speed up the drying process
- To respect the Finnish laws and environmental policies

Environmental issues involved in the terminal:

- Fire protection – As we store dry wood the fire hazard must be considered
- As fire precautions there must be emergency exits and a system to evacuate smoke
- Water treatment – In case of fire water must be collected and treated to avoid ground pollution
- The EN ISO 11690-1 standard recommends a maximum noise level of 70dB for manufacturing workplaces. (ISO/IEC, 1996) Noise must be kept to a maximum of 55dB for neighbouring areas.
- Location – Make sure that the building doesn't infringe or directly affect the natural landscape in the surrounding area.
- Visual pollution – Make sure that the building is sympathetic to the surrounding architecture
- Dust – Making sure any air born particles are correctly ventilated and do not exceed the legal limit for a Finland work space
- Accessibility – Make sure the roads accessing the site are capable of supporting the vehicles that will be used and that the gangways inside the terminal meet the fire safety standards.
- A waste treatment system to avoid direct pollution of the area also have to consider also have to be consider

The different points broached above are largely explained in the "Environmental impact of the supply chain" part of this report.

Nowadays wood logs are stored outside near a road close to the forest. If these logs are used as biofuels, they must be stored properly. Below some main requirements are presented:

Requirements for outside wood log storage:

- Keep the wood out of rain (for example covered by fabric which permits air flow)
- Avoid needles and leaves, because they hold back a lot of water in the wood
- Avoid direct contact with ground to avoid humidity to go through the wood

All these requirements are an answer to the moisture content problem. If you allow air flow and avoid some humidity source, you can speed up the drying process. The dryer the wood is the more efficient it is and the more energy can be generated from an equivalent mass of fuel.

4.6.2 Location of the Terminals

Another major area of concern was finding feasible locations of the proposed terminals; several influential environmental factors that were highlighted in the brief were taken into account in accordance with the region's map sourced from the town of Närpes (Närpes Stad, 2013). To find the best suited location to build the terminals means analysis of the whole region, in particular the existing infrastructures and wildlife in addition to the greenhouses' dispersal. A terminal and a bioterminal (i.e. warehouse dedicated for the biofuel storage) might cause environmental damages and impacts, especially in conservation areas.

Due to the European and Finnish policy (Lindholm, 2002) the environmental issue is a sensitive subject, especially in Finland. Making sure that the terminals are located in the most efficient location to suit all regional greenhouses whilst also avoiding nearby areas of natural conservation and of course commercial and private buildings is a key factor in our project. It goes without saying that this approach is also based on the greenhouse location because the greenhouse entrepreneurs are the customers.

According to Ehrs "Finding out the adequate place is a very long and complicated process, because the choice of a poor location can be very costly." (Ehrs, personal communication).

The first stage of research required research of existing man-made infrastructure including: energy transmission lines, railroads, roads, harbours and sites of archaeological interest. These locations were then overdubbed with natural conservation locations, which cover quite large expanses of the region and would play a big part in determining the terminal locations. Finally, having sourced the addresses of the individual greenhouses in the region, they were plotted on top of the map, and by the means of the digital triangulation program ArcGIS, the most geographically efficient location could be found.

4.6.2.1 Wildlife area

The first analysed map highlights the conservation area for wildlife (The Ministry of Environment of Finland, 2013). Nowadays, the majority of the natural areas are protected by the Natura 2000 network which can be seen in Figure 23. The project involves a sustainable development thinking. It makes no sense if the ecosystem is disturbed. We have to make sure to place the warehouses far away from those areas and optimise the space in order to reduce encroachment on the natural landscape. In the town of Närpes, there are some protected areas and some small private conservation areas.

Conservation areas must be considered in order to preserve the characteristics and diversity of Finnish nature.

> *"The zone surrounding Närpes is includes the following peat bog areas: Kackurmossen, Risnäsmossen, Sanemossen, Hinjärv, Orrmossliden and Bredmossmyran. Parts of the Närpes archipelago are also included in the Natura 2000 network. In Kaskö, one part of the archipelago is included in the Natura 2000 network." (Granlund & Nylund, 2013)*
>
> *[Translated from Finnish into English]*

As can be seen on the map in Figure 23, the left side has no conservation areas while the other is quite close to a peat bog protected area. Moreover the amount of greenhouses is considerable. This factor narrows the allowed area for the bio terminals.

The river which flows through Närpes is located within the zone. One way of choosing a suitable place is by also thinking about providing water security. The removal of sewage (runoff water, firefighting water…) might contaminate the natural channel of water. The terminals should be put as close as possible to sewer utilities and that should be considered in the terminal requirements.

4.6.2.2 Transport infrastructures and the greenhouse localisations

The greenhouses are spread over an area which goes from Vaasa to Kristinestad. Nevertheless, the distance need to be minimised between the biofuel consumers and the bioterminals to reduce transportation costs. The terminals would be built to serve multiple end users. As it can be seen on the map of the greenhouse locations: one large part of them stand close to the main roads or in a surrounding area. A major part is located around Närpes in particular along the road Vasavägen which goes through Närpes.

Since the bio terminals need to have good transport/sewer connections, the best way to reduce the costs for delivering and logging is to use existing infrastructures.

Regarding the shipping method, the closest harbour is situated in Kaskinen. There is no other dock between Kristinestad and Vaasa. The harbours around the coast are used by fishermen. Obviously, the choice of the transportation method slightly depends on the implemented biofuel. Indeed, the transportation costs change in function of the transportation method and the transported biofuel. The bio terminals should be placed as close as possible to the available infrastructures.

Transportation by water is used for long transportation distances with high volumes. Studies (Karttunen, 2012) have been carried out on the transportation of wood chips in Finland using barges. The problems of water transportation in Finland are similar to those of railway transportation. Water routes cover only the areas in eastern and south-eastern Finland, with only a few loading and unloading locations.

> *"The waterway supply chain of forest chips was cost-competitive to road transport by truck after 100–150 km. Transportation should be carried out by truck when the transportation distance is less than 120 km. For greater distances, transportation should be carried out by floating or by rail." [Sic] (Heilala L. L., 2013)*

The distance that separates the two cities Vaasa and Kristinestad is approximately 100 km by the E8 road.

Almost all greenhouses are located along the main roads in this region (Strandvägen and Vasavägen) as can be seen in Figure 24.

Being the main traffic axis (E8, Strandvägen and Vasavägen roads), it is a feasible and realistic option for the transportation of heavy loads (wood chip at least). Some others smaller roads are usable to transport commodities. These ones allow shortcuts through the region for the deliveries to the end users.

Nevertheless, a part of the roads e.g. unpaved roads are restricted during certain periods. This issue has been presented in the chapter about the optimal time to build up the stock. Thus the terminals will be located along roads without restrictions.

To sum up a location near the main roads, crossroads and probably as close as possible to Vasavägen should be found in order to optimise the supply chain.

4.6.2.3 Geolocating approach

To get a point based on the geolocating approach, ArcGIS software was used.. Only the greenhouses located between Vaasa and Kristinestad have been taken into consideration when this analysis was carried out. The process considers the location of each greenhouse and gives us two points which are drawn on the map, Figure 23 and Figure 24. One is mean centre (average of X and Y greenhouses coordinates). The other one is median centre (Euclidian centre, so it tries to minimise the distance between the centre and all greenhouses.)

The median centre is close to a conservation area. If considering of what has been said previously, the mean centre seems be the most suitable one.

4.6.2.4 The suitable locations

The strategy for advising suitable locations for both the wood trunk terminal and the wood chips terminal is based on the region's characteristics, the number of terminals needed and our suggested solution explained in the chapter about the advisable scenario. Two terminal intended for the wood trunk storage and the five terminals intended for the wood chips storage have to be set up. The first and biggest wood trunk terminal will be placed in the middle of the greenhouse zone of Närpes. The second will be located near the town of Korsnäs. Regarding the wood chips terminals, they will be scattered in the region. Two of these will be set up at the same place as the wood trunk terminal in order to reduce the travels and gather the services e.g. materials, machinery and employees. The three terminals left would be placed, near the surrounding area of Malax, north and south of the greenhouses zone of Närpes.

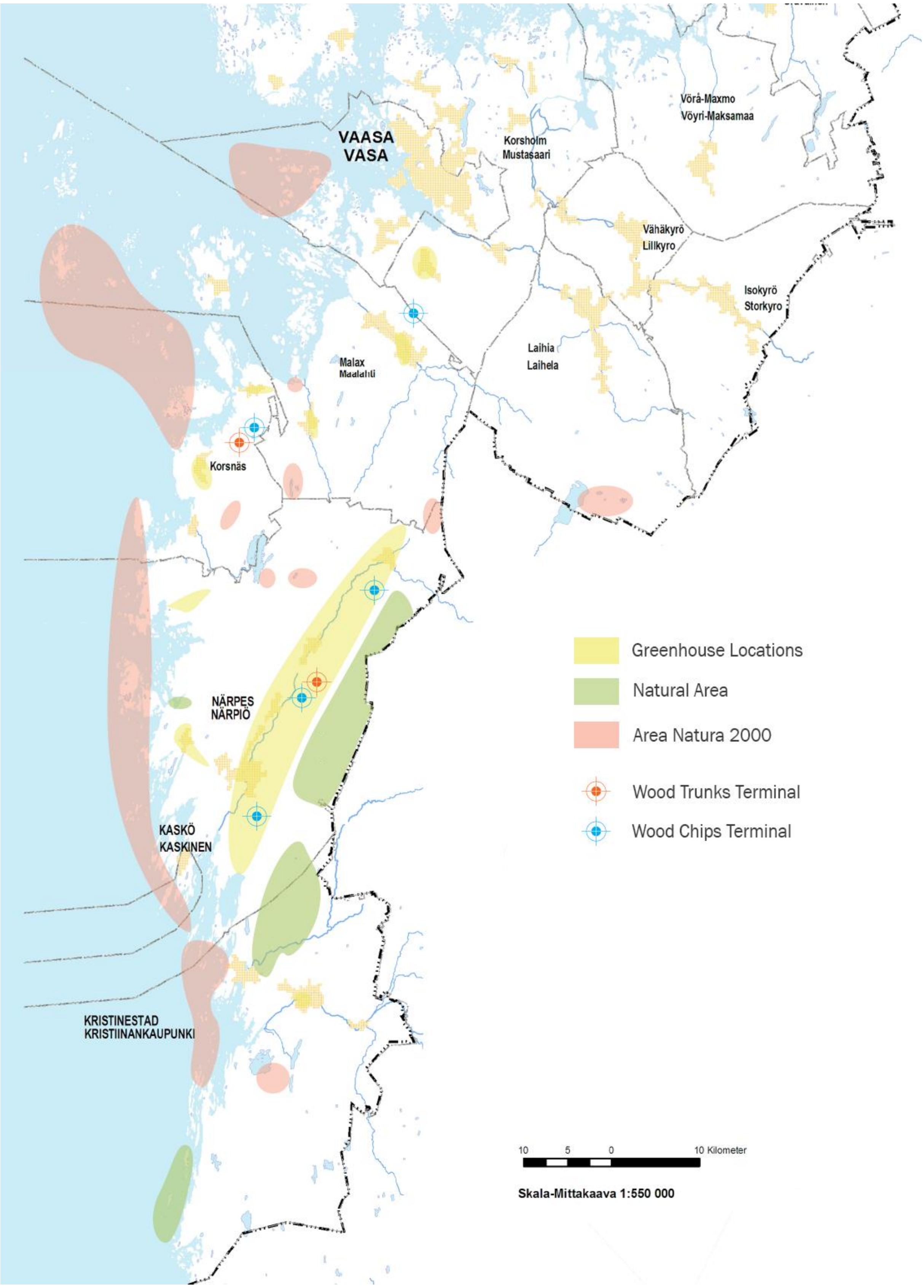


Figure 23: *Plan of situation: conservation and greenhouse areas*

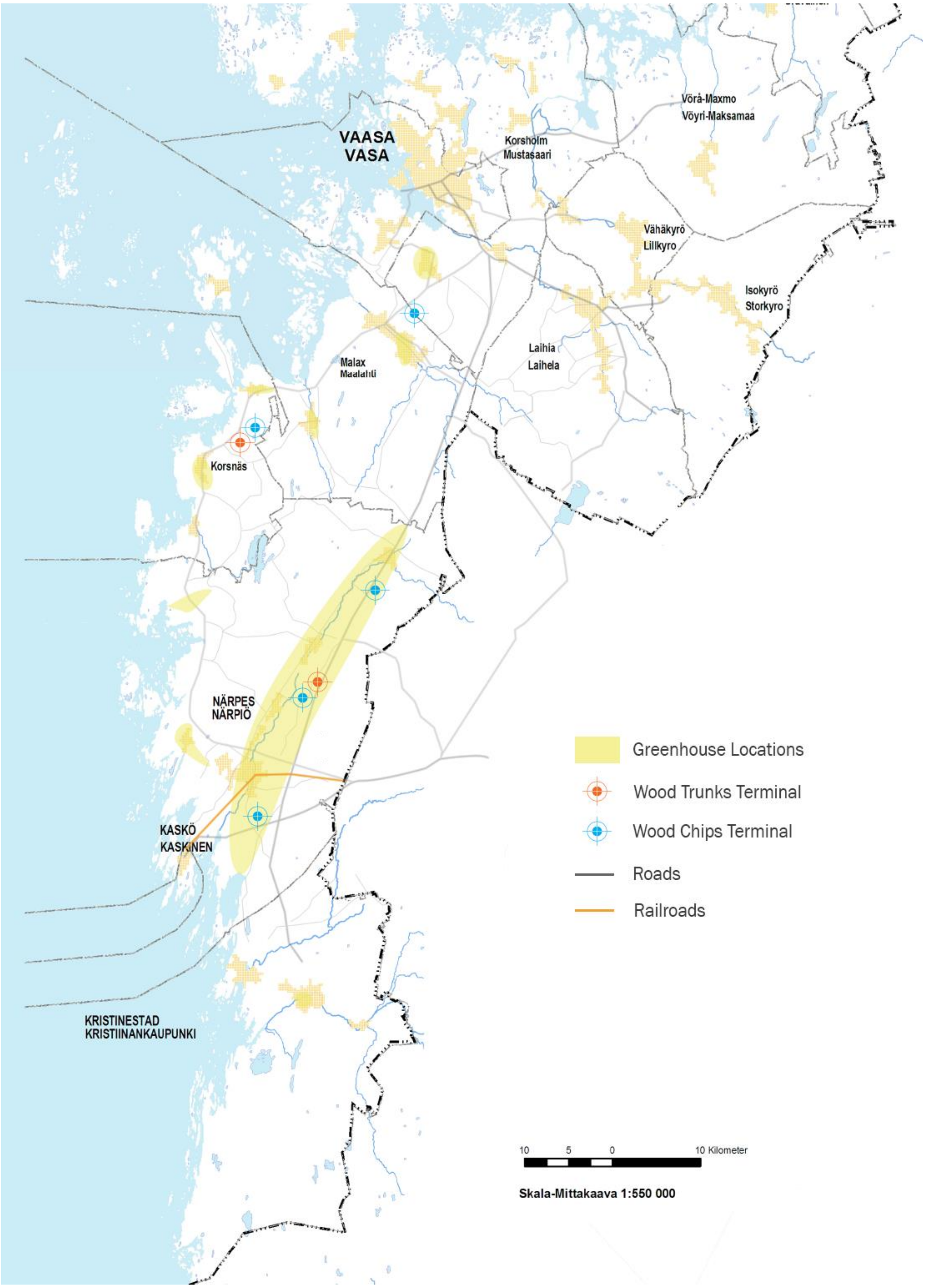


Figure 24: *Map of infrastructures and greenhouse locations*

Likewise, it would make sure that the needs and requirements related to the warehouse project are known.

The bio terminal should abide by the environmental policy (Lindholm, 2002), especially because the stored commodities are wood biofuel.The diagram shows a set of three parts, including the storage of commodities and the logistic (e.g. one supply chain from timbers to the warehouses and another one from the warehouses to the end users). These three parts cause damages on our environment. The harmful effects are in most cases due to either waste water, air emission, noise regulation or vibration (Hannuksela, 2013).

The road transport method consumes almost the double amount compared with the shipping method and more than double compared with the railroad transport (Strale, 2007). Unfortunately the area is not sufficiently served by different modes of transport, thus the choice is not large. As explained in the chapter 4.6.2 about Warehouse locating, the truck transportation is the most advisable method in order to transport biofuel in Ostrobothnia. Nevertheless it shows that the energy consumption by truck must be followed and controlled. That also creates a financial issue due to the transportation fuel cost which tends to level off (Statistics Finland, 2013). One way to reduce the energy consumption is by gathering delivery routes and by limiting the speed of trucks.

Noise is a sound pollution if this perception becomes unpleasant and can eventually cause a deterioration in the quality of life.

> *"It can cause nervousness, sleep disorders and communication problems on exposed people. It also causes a nuisance to the natural environment and the wildlife which are subject to it, such as animal exile and stress" (Strale, 2007)* (Translated from French to English)

In our case the trucks and engines will use highways and forest roads. They will also move around on the terminal site. There is a maximum fixed value of 55 dB, (Ministry of the Environment, 2007, p. 11) whichbut in fact they run longer. , especially in the Närpes surrounding area and along the Vasavägen road.

These infrastructures are environmentally harmful (Bruinsma F., 2002).They consume space, cause an increase in urbanisation and create an artificial landscape instead of conserving the natural areas.

The construction of long and straight infrastructures such as roads, canals and railroads cuts the natural areas, especially if passages intended for wildlife are not planned before.

Current regulations define sound levels and emergency thresholds on industrial property lines with the neighbouring residents. There is a maximum fixed value of 55 dB beyond the property lines. (Ministry of the Environment, 2007, p. 11)

According to Skogscentralen (A. Wikberg, personal communication) and the witnessed situation of an already existing terminal location owned by Bio West Oy, some possible solutions are:

- To build sound reducer walls around the property,
- To keep an important distance between the warehouse and the neighbourhood, approximately 1 km.

5 Conclusions

The investigation and the research carried out show that the advisable biofuel in this project is wood chips. However, peat fuel being abundant in Finland and relatively close to the project area, different scenarios were considered. The suggested scenarios are different ways to achieve greater efficiency in the supply chain. They are a vision for the future with the possibility to supply the consumers with the amount of heat needed. The scale of production depends on the customer needs, usage and participation. How does one achieve a large-scale considering 100% usage of wood chips and a smaller production scale based on 50% usage wood biofuels (wood chips combined with peat).

In the two proposals, the most efficient transportation method considering the geographical circumstance and the cost of transport is by trucks and lorries. Moreover, the storage methods that should be implemented in the supply chain to support consumption are the covered terminal storage combined with roadside storage. The storage terminal is the key to a safe, reliable and quality supply.

A suitable solution to place the terminals is by scattering some terminals around the greenhouse zones in the project area. The number of terminals ,depends on the production scale, but it still remains low due to the cost, as shown by the financial aspect. The other main thing shown by the financial aspect is that a competitive price can be reached with our solutions.

According to the factors linked with the consumption and the regulations, the optimum time to build up the stock is during the winter and summer periods while spikes of needed energy occur from January to April.

Regarding the stock optimisation, on the one hand the stock would be able to cope with peak periods and avoid traffic restrictions, but on the other hand storing a small amount of biofuels could lead to reduced storage and stockpiling costs.

There is no way of saving money by importing peat, partly due to the high costs especially in case of a large-scale supply chain and partly due to the biomass fuel classification issue.

Long-term contracts with the greenhouses are a way for the forest owners to increase the demand in of biofuels. It is a guarantee for the suppliers. The multi-year contracts and the joint procurement of biofuel can lead to a decrease in price. It is a solution for the customer in order to meet their needs in price.

It would be advisable to later research if an online ordering system would be beneficial in the delivery of biofuels from the terminals. If this scheme was implemented it would allow to exactly know the amount of woodchips coming in and going out. It is also a way of making planning deliveries to the greenhouses easier.

6 Cited works

Alakangas, E. (2002). *Renewable energy sources in Finland.* Jyväskylä: OPET Finland.

Baxi. (n.d.). Gilles Flispannor. *Gilles Flispannor.* Retrieved November 16, 2013, from http://www.baxi.se/visa_produkt.asp?produktid=264&Kategori=58&Produkttyp=999

Bruinsma F., K. M. (2002). Social Cost of Direct and Indirect Land Use by Transport Infrastructure. *European Journal of Transport infrastructure research*, 73-93.

Ehrs, M., & Vauhkonen, T. (2012). *Innologistik I: utvecklingsmöjligheter kring logistik i Sydösterbotten.* Vaasa: Vaasan yliopisto.

European Biomass Association. (2008). *Wood fuels handbook.* Legnaro: AIEL - Italian Agriforestry Energy Association. Retrieved from http://www.aebiom.org/IMG/pdf/WOOD_FUELS_HANDBOOK_BTC_EN.pdf

Francescato, V., Antonini, E., & Bergomi, L. Z. (2008). *Wood Fueks Handbook.* Legnaro: AIEL - Italian Agriforesty Energy Association.

Gilles. (n.d.). Wood chip heating. *Wood chip heating.* Retrieved November 16, 2013, from http://www.gilles.at/images/pdf/englische_folder/GILLES_Folder_Wood%20Chip_2013_engl.pdf

Granlund, H., & Nylund, M. (2013, 11 15). *Naturskydd.* Retrieved from Mustasaari: http://www.mustasaari.fi/fi/document.aspx?DocID=15639&MenuID=0&TocID=16

Gyibah, N. (2009). Biomass potentials in Finland. *the case of Pörtom.* Vaasa: Vaasan ammattikorkeakoulu.

Hannuksela, P. (2013, 10). Environmental legislation and EHS Guidelines in international projects.

Heilala, L. L. (2013). *Biocoal and energy wood production and logistics in Finland and Latvia.* Helsinki: Department of Forest Sciences.

Heilala, L., Andis, L., Makovskis, K., & Hyytiäinen, J. (2013). *Biocoal and energy wood production and logistics in Finland and Latvia.* Helsinki: University of Helsinki, Department of Forest Sciences.

Ilmatieteen laitos. (n.d.). Suomen ilmastoa kuvaavat vertailukauden 1981-2010 keskiarvot. Retrieved November 9, 2013, from http://ilmatieteenlaitos.fi/ilmastollinen-vertailukausi

Introduction - European Project Semester. (n.d.). Retrieved October 25, 2013, from European Project Semester: http://www.europeanprojectsemester.eu/info/Introduction

ISO/IEC. (1996). EN ISO 11690-1:1996. *Acoustics -- Recommended practice for the design of low-noise workplaces containing machinery -- Part 1: Noise control strategies.* Geneva, Switzerland: International Organization for Standardization.

Juha , N., & Tero, T. (2006). *Täckningens inverkan på kvalité i energiveden hos energikooperativen i Mellersta Österbotten.* Kannus: METLA-Skogsforskningsinstitutet.

Kärhä, K. (2008, Mars). *Hakkuutähdehakkeen tuotantoketjujen prosessikuvaukset.* Metsäteho Oy.

Karttunen, K. V. (2012). The operational efficiency of waterway transport of forest chips on Finland's Lake Saimaa. *Silva Fennica 46(3)*, 395–413.

Kesla Oyj. (2013). *Wood chippers.* Retrieved from Kesla.fi: http://www.kesla.fi/en/woodchippers

Lindholm, A. (2002). *Finland in EU Evironmental Policy.* Helsinki: Ministery of the Enviroment.

METLA. (2007, August). *Fuel price components.* Retrieved from http://elearn.ncp.fi/: http://elearn.ncp.fi/materiaali/kainulainens/nwh/woodfuel_supply_chains/material/Fuel%20price%20components.pdf

Metsäteho. (2013, March 3). Timber Harvesting and Long Transportation of Roundwood 2012. Retrieved December 2, 2013, from www.metsateho.fi/files/metsateho/Tuloskalvosarja/Tuloskalvosarja_2013_03b_Timber_harvesting_and_long-distance_transportation_of_roundwood_2012_ms.pdf

Ministry of the Environment. (2007). *Government resolution on noise abatement.* Retrieved from http://www.environment.fi/publications

Moisio, O. (n.d.). Auringon nousu- ja laskuajat Suomessa. Retrieved November 12, 2013, from http://moisio.fi/taivas/aurinko.php

Närpes Stad. (2013, 11 15). *The portal: map and plan.* Retrieved from Website of the town of Närpes, Ostrobothnia, Finland : http://www.narpes.fi/invanare/bygga-bo/kartor-och-planer

Northern Wood Heat. (2007). *Woodfuel supply chains.* Retrieved from Forest Energy Education: http://elearn.ncp.fi/materiaali/kainulainens/nwh/woodfuel_supply_chains/index.htm

Paappanen, T., Leinonen, A., & Flyktman, M. (2010). *Peat Industry in Finland.* Retrieved November 2013, 29, from http://www.epagma.eu/_SiteNote/WWW/GetFile.aspx?uri=%2Fdefault%2Fhome%2Fnews-publications%2Fnews%2FFiles%2FMainBloc%2FCountry%20reports%20all%20121010_371eb97a-5d9b-4f29-820c-65e1da1f4114.pdf

Regen SW. (2008, August). *Wood fuel Storage.* Retrieved from http://www.regensw.co.uk/

Statistics Finland. (2013, September 18). Statistics: Energy prices [e-publication]. *2nd quarter 2013*. Helsinki. Retrieved December 2013, 2, from http://www.stat.fi/til/ehi/2013/02/index_en.html

Strale, M. (2007). *L'impact environnemental du développement de la logistique.* Bruxelles: Université libre de Bruxelles.

The Ministry of Environment of Finland. (2013, 11 18). *Suojelualueet.* Retrieved from Ymparisto: http://www.ymparisto.fi/fi-FI/Luonto/Suojelualueet

Thermia. (n.d.). Thermia Pelletsvärme. Retrieved September 17, 2013

Tike, Horticultural Statistics. (2012, May 14). Energy consumption in greenhouse enterprises year 2006, 2008 and 2011 [e-publication]. Helsinki. Retrieved December 3, 2012, from http://www.maataloustilastot.fi/en/horticultural-statistics-2011-final-statistics-and-energy-consumption-greenhouse-enterprises_en

Tike, Horticultural Statistics. (2013). The number and area of horticultural enterprises in 1984 - 2012 [Data file]. Retrieved December 2, 2013, from http://www.maataloustilastot.fi/sites/default/files/puutarhayritysten_lukumaara_ja_ala_1984-2012_1.xls

Union Régionale des Associations de Communes Forestières Rhône-Alpes. (2012). *Guide technique de mise en oeuvre des plateformes et hangars de stockage de bois énergie.* Chambéry: Maison des Parcs et de la Montagne.

Virtanen, K., & Valpola, S. (2011). Energy potential of Finnish peatlands. *Geological Survey of Finland*(Special Paper 49).

Vlaamse Milieumaatschappij. (2006). Milleurapport Vlaanderen (MIRA). *Achtergronddocument, sector transport.*