EPS 2012

NOVIA
UNIVERSITY OF APPLIED SCIENCES

EUROPEAN PROJECT SEMESTER

Final Report

EPS 2012 Autumn

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1 | Introduction

1.1 | European Project Semester

European Project Semester (EPS) is a program organized by ten countries throughout Europe. In these ten countries there are 11 universities participating. The program is meant for third-year students whose studies involve engineering subjects.

Students go (mostly) abroad to participate in EPS. They work in international groups of three to six persons. The project's subject often includes green and renewable energy or environmental science. During the project the host university organizes 'project related courses' to support the EPS group with some information for the project and teambuilding activities.

1.F. 1: EPS logo

The goal of EPS is that students learn to work in an international environment and develop their intercultural competences, communication skills and interpersonal skills. It is a good opportunity to get in touch with international cooperation and to work together with other people with a different culture and different thoughts.

1.2 | Project group

The project group consists of five persons, four of them are foreign students and one is a Finnish student who participates in the project on a part-time basis. Besides Finland three other countries are participating in the project. Two students come from Spain, one from France and one from The Netherlands. All together they have been working on a project assigned by Novia University of Applied Sciences, Vaasa.

1.2.1 | Project members

Below the five members of the autumn EPS group 2012 are listed.

Name:	Vincent Fulcheri
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1.T. 1: Project members, Vincent

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1.T. 2: Project members, Xavier

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1.T. 3: Project members, Miguel

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1.T. 4: Project members, Rudy

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1.T. 5: Project members, Kristian

1.2.2 | Project logo

The team of European Project Semester Energy Village decided that it would be a good idea to have its own logo as a brand representing and identifying the team. This indicates the values of renewable energy, self-sufficiency, nature and so on. The logo appears on all computer generated documents, presentations, the website, the interim report, the final report, minutes of meeting and agendas.

A series of logos were designed, based on the same idea and similar lines. The final logo was chosen during one of the weekly meetings. The chosen logo represents the team and shows what the project group stands for.
The different concept logos that were designed for the group can be found below. Of course only one of these logos could be chosen and the group chose logo E. According to the group this logo represents the four elements of nature the best.

Logo: A	Logo: B	Logo: C	Logo: D	Logo: E

1.T. 6: Concept logo's

All logos are based on the four elements of nature and the renewable energies are extracted in it. Fire, water, wind and earth can be seen, which extract solar, hydro, wind, biomass and geothermal energy.

In the final logo the words "EPS 2012" and "Autumn" were added, as this is the season which the project is held in.
The words: "EPS 2012" are made with the font Myriad in Italic characters.
The word: "Autumn" is made with the font Myriad Pro Italic characters.

1.F. 2: Final logo with text

Furthermore more logos were made to use for other purposes. There is a black and white logo and a reverse black and white logo.

1.F. 3: Black and white logo

1.F. 4: Reverse black and white logo

The business card makes it easier to share the project goal and philosophy. It can be given to other people and companies. Like the logo, the cards were also made in Adobe Illustrator CS5.

1.F. 5: Front- and downside of the business card

1.2.3 | Website

To promote the project and give more information to the interested parties, there is also a website about the project. Several different pages describe what the project is about, something about the village "Komossa", a contact page and a photo gallery. The website is designed and maintained by the project group.

Every page has the same layout, starting with the header on top of the page. The header is a picture of the grain in Komossa together with the project group's logo and a picture of the team members including the supervisor and the contact person of the village. The grain expresses the green and renewable energy.

1.F. 6: The website's header

Underneath the header the different pages that people can visit can be found. This background also represents green and renewable energy. It is the grass near the grain. The pages that can be visited are located in the grass.

1.F. 7: The website's navigation

Homepage
The homepage contains a little summary of the project and some general information, not too much in detail. It is only there to give the reader some information about the project and the project group.

Info
This page gives information about the project in relation to EPS. It describes what EPS stands for, what it contains and some general information about EPS.

Project
This page describes the project in more detail and gives more detailed information about what is going on. It also describes the goal and the aim of the project.

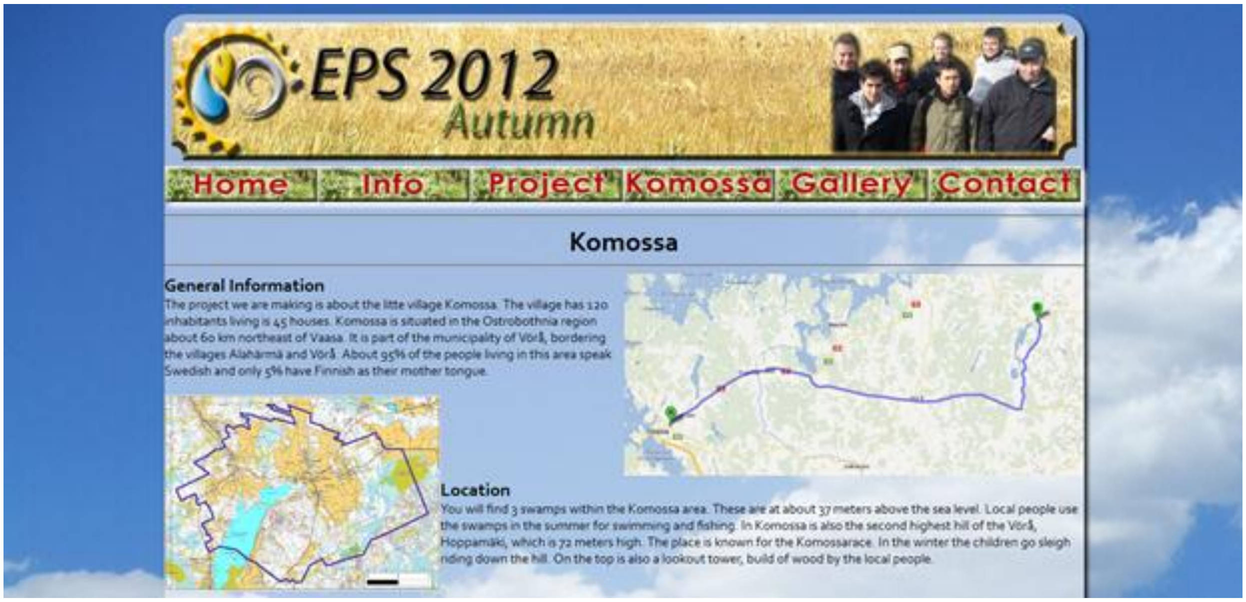
Komossa
The village that the project concerns is Komossa. More information about this village can be found on this page, for example where it is situated, how many inhabitants it has and a little about the nature.

Gallery
During the project some pictures will be taken of the interesting things going on, for example the trip to the village. All pictures can be found on this page.

Contact
To get in contact with the project group, it is advisable to visit the contact page. There are pictures of the project members and it shows everyone's e-mail addresses.

The lay-out of the website is a completely new idea. Everything is made by the project group without any template. Also the pictures for the header and the logo are created by the team. The only picture that is not made by one of the project member is the background picture. This is one found on the internet. It represents the clean air that we want to have by producing green energy. The website was built with the same idea as the logo. It represents some elements of green energy and a clean environment.

All the structures and the texts on the website are also original. The team came up with the idea and made everything look as follows:



1.F. 8: The website's layout

The website can be found on: http://eps2012energyvillage.novia.fi/

1.3 | The project

This is the description of the project. First the aim is described and later on some general information is given about what needs to be achieved and how it has been organized.

1.3.1 | Aim of the project

To make the project a success, a common goal is needed so that everyone can focus on what needs to be achieved. The aim of this project is: **"Make a plan to provide the village Komossa with green energy by producing renewable energy to make it self-sufficient."**

1.3.2 | General information

This project is part of a larger project carried out in Finland. The name of this bigger project is "Energiby". This project is aiming to provide 10-15 villages in Finland with green and renewable energy and make them self-sufficient. The intention is that in the future these villages can rely on their own renewable energy sources. To establish this several project groups get their own village and have to make a plan concerning this one and only village. The plan describes how to supply a specific village with green energy, the costs of the implementation and the payback time. For each village this can be different, depending on the village's situation and interests.
1.R. 1: Energiby website

One of the villages taking part in this project is Komossa. It is a small village in the Ostrobothnian region, western Finland. This report is for Komossa only. The calculations made in the report are based on data gathered for this area. Implementing the same solution(s) in different areas can result in deviating results.

1.F. 9: Logo of Energiby

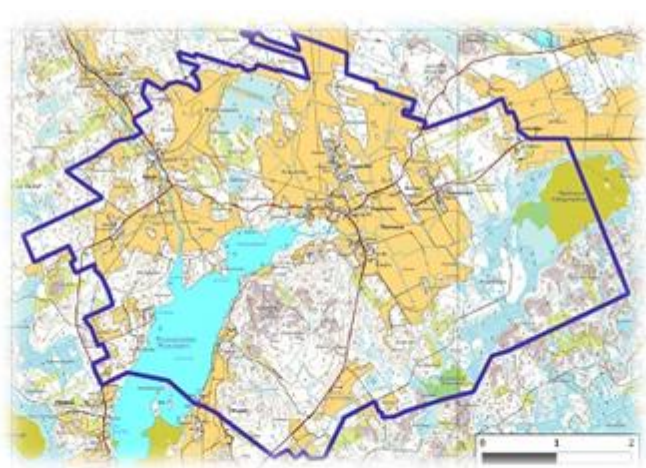
2 | Data of Komossa

The village Komossa is situated in the Ostrobothnian region which is about 60 km northeast of Vaasa. It is part of the municipality of Vörå, bordering the villages Alahärmä and Vörå. About 95% of the people living in this area speak Swedish and only 5% have Finnish as their mother tongue.

2.F. 1: Location of Komossa, from Vaasa

2.1 | Geography

There are two swamps and one lake within the Komossa area. These are at about 37 meters above the sea level. Komossa also has the second highest hill of the Vörå, Hoppamäki, which is 72 meters high. The place is known for the Komossa race. In the winter the children go sleigh riding down the hill. On the top there is also a lookout tower, built of wood by the local people.



2.F. 2: The Komossa area

There is a lot of nature in Finland and also in the Komossa area. The fields cover around 80% of the land of the village and a little bit less than 20% is forest. In the fields you find all kinds of animals, for example cows and pigs. There are also a few fox farms. The farmers also grow different sorts of crops used to feed the animals but also to supply themselves with food.

The forest is used for hunting and for recreation. There is also a lake in Komossa. In the winter this lake is frozen and used for ice skating. In the summer the lake is a nice place to go for a swim or to go for fishing. There are only 45 houses in Komossa, so there is not really a big city center. The houses are spread all over the area. Currently 120 people live in the village.

	Finland	Ostrobothnia	Vörå	Komossa
Area:	338,424 km²	7,932.36 km²	1,499.91 km²	28 km²
Population:	5,421,827 p.	175,100 p.	6,720 p.	120 p.
Density:	16.0/km²	22.0/km²	4.5/km²	4.3/km²
Visual:				

2.T. 1: Location of Komossa

2.2 | The village's interests

Wind power

The village Komossa already showed its interest in some kinds of energy sources. The first one is wind power. Because Komossa is situated relatively close to the Baltic See, there is most of the time a lot of wind. A wind power installation would therefore be a good solution to provide the village with green energy. With an average wind speed of 6.2 m/s at the height of 100 meters, this could also be profitable. This is definitely something to take into consideration in the report.

Biofuel

Because of the wide range of fields in Komossa there is also a lot of bio waste that can be used to produce energy. One part of the crops is used to feed the people and animals and the other part can be used to produce energy. Also other components from the fields could be used. When natural products are used to produce energy, we talk about biofuel. Some examples of biofuel are: barley, manure and peat.

Woodchip burning plants

Another option for the production of energy is to use the already existing woodchip burning plants. Because they already exist in the village is it probably cheaper to use them to produce energy. There are not enough woodchip burning plants in Komossa, but with one good example it would be possible to build more and use the knowledge of the existing plants. The fuel that needs to be fed in the plants is wood. There is a big forest in the Komossa area which can be used as fuel for the plants.

Central heating system

In the center of the village the houses are pretty close to each other. Therefore it could be a good solution to use some kind of central heating system. In this way it is easier and cheaper to provide all the houses with electricity. One of the possible solutions is to implement a central/district heating system.

Hill Hoppamäki

Near the lake is a hill of 72 meters above sea level. Because this is the highest point in Komossa and also one of the highest points in Ostrobothnia, it could be the best place to install a windmill. A better place with a higher average wind speed cannot be found in this area. By installing a wind sensor it is possible to measure the average wind speed and consider if it might be a good option to install a wind turbine.

2.F. 3: Sign of the highest point on Hill Hoppamäki

The lake's environment

There is a lot of sediment in the lake in Komossa. The villagers want to clean the lake and at the same time use the sediment as biofuel. The plants coming out of the lake can be burnt and the accumulated energy can be used for electricity or heat. Due the lack of information it was not possible to investigate the possibilities of the lake's sediment. In a later study data can be self-obtained or collected from experts.

2.3 | Energy in Komossa

The company that provides Komossa with an electricity grid is Herrfors. This is the grid where the people from Komossa are connected to. They can buy their energy from several companies, even from companies abroad. There are 72 electricity connections and the costs are €110.76 per year for one connection. The most recent electricity price is 14.74 cents per kWh.

2.R. 1: Herrfors website

2.F. 4: Herrfors logo

2.3.1 | Electricity network

There is a map which shows the electrical network in the Ostrobothnian region. This map displays how the network is built and if it is possible to figure out where the best place is to install a new type of energy producer, for example a windmill. This map can be found in appendix.

2.A. 1: Electricity network in the Ostrobothnia region

There are 9 transformers in this area which are connected to the houses in the village. A map of the transformers situated in the Komossa area can be found in appendix.

2.A. 2: Map of transformers in Komossa

2.3.2 | Energy consumption

In the village there are 72 electricity consumers. 45 of these consumers are houses of the inhabitants and 27 consumers are other buildings. With the other buildings we mean the farms and public buildings, for example the school or the town hall. In these 45 houses there are 120 people living, which means an average of 2.67 people per house. For the total electricity use in Komossa the following matrix applies:

	Electricity	Heating	Total
1 private user	5.0 MWh	2.5MWh	7.5MWh
45 private users	225 MWh	113MWh	338MWh
27 public users	376MWh	573MWh	949MWh
Total of Komossa	601MWh	686MWh	1286MWh

2.T. 2: Energy usage in Komossa

The total energy use in Komossa per year is **1286MWh.** This includes electricity and heating. With these numbers the cost of energy can be calculated:

	Electricity price	Heating price	Total price
1 private user	€ 770	€ 390	€ 1,160
45 private users	€ 34,720	€ 17,360	€ 52,080
27 public users	€ 57,940	€ 88,380	€ 146,320
Total of Komossa	€ 92,660	€ 105,740	€ 198,400

2.T. 3: Energy costs in Komossa

The total costs for the use of energy are **€198,400**. This is without the €110 for each connection.

2.3.3 | Potential energy

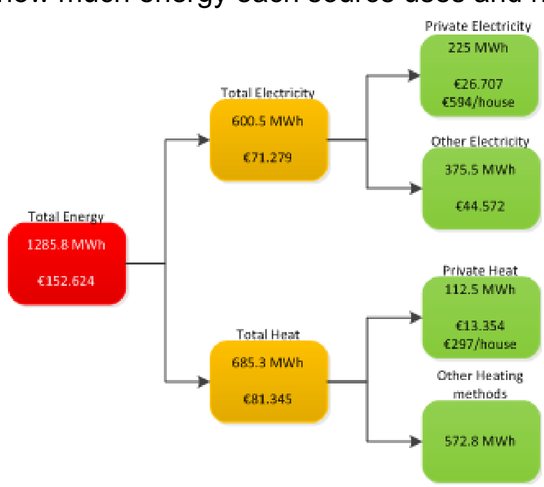
Before us another team has calculated some facts about the energy usage in Komossa. They have made a list with the potential energy production of three different types. Biogas, energy from the fields and wind energy. This is the potential energy that could possibly be obtained from these different energy sources.

In the table below is calculated how much money can be saved by using one of these potential energy resources. The potential energy in MWh is shown, as well as the savings in euros. The most recent electricity prices are used for these calculations.
2.R. 2: Konseptointi Komossa eng.docx

	Potential energy	Savings in euros
Biogas	1500 MWh	€ 231,450.00
Energy from fields	5397 MWh	€ 832,757.10
Wind energy	5837 MWh	€ 900,649.10

2.T. 4: Potential energy in Komossa

The diagram below shows how much energy each source uses and how much it costs:



2.F. 5: Energy usage in Komossa

The other heating methods, described in the diagram above, are for example woodchip burning plants and oil heaters. The school in Komossa is heated by oil and the town hall is heated by electricity. In the village there are 7 woodchip burning plants and 2 contractors specialized in heat production.

2.3.4 | Building types

There are several types of buildings in Komossa. These buildings are spread over the total area of 28 km². The most common type is a one-family house, 47% of all the houses. 2% of the buildings are two-family houses. Only half of all the buildings are private houses. Besides these houses there is one block of flats. In Komossa there are also some farms, 16% of the total buildings. There are animal farms and fur farms; the most common ones are animal farms which cover 10% of Komossa’s buildings. The other 6% of all the buildings are fur farms. The remaining 34% are described as other buildings, including saunas, the town hall, the school and so on. The matrix below shows all the numbers in a diagram:

Building type	Percentage	Average building year	Average surface
1 family house	47%	1980	118 m²
2 family house	2%	1980	183 m²
Flat block	1%	1980	115 m²
Animal farm	10%	1996	654 m²
Fur farm	6%	1992	1538 m²
Other buildings	34%	1989	167 m²
TOTAL	*100%*		

2.T. 5: Building types in Komossa

2.3.5 | Building classification

To give a good overview of the different types of energy, the houses are divided into three groups. Each group has its own advice of how to provide the group with green energy. Mentioned is also the percentage of the houses in comparison with all the buildings in Komossa. It shows how many of all the buildings belong to a certain group.

	Small	Medium	Large
Surface	< 120 m²	120 – 200 m²	> 200 m²
Electricity usage	2000 – 5000 KWh	5000 – 10000 KWh	> 10000 KWh
Heating usage	5000 – 10000 KWh	15000 – 30000 KWh	> 30000 KWh
Types of buildings	47% One-family houses 1% Flat block	2% Two-family houses 34% Other buildings	10% Animal farms 6% Fur farms
Percentage	48%	36%	16%

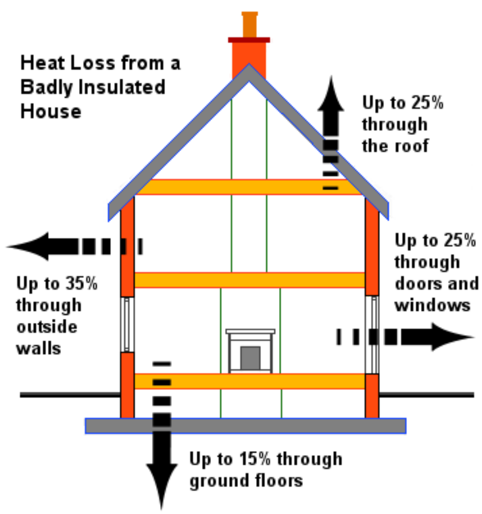
2.T. 6: Building classification

3 | Insulation

A lot of energy can get lost when a house is not well insulated. There are several ways the heat or cold can escape out of the house. For example: through the roof, walls, doors and windows. With good insulation most of the energy loss can be prevented. Here are some examples to make a house better insulated so that the residents can save money on their heating costs. Insulation is also very important because it keeps the moisture outside, which is better for the condition of the house and the health of its inhabitants.

Probably the houses in Komossa are pretty well insulated because of the weather conditions in the region. In the winter it is cold so the insulation should already be proper. But this does not mean that it could not be improved. With better insulation the same temperature can be kept with less energy. An example of a very energy sufficient house is a passive house.

A passive house is a good example of a perfectly insulated house. Of course is it not possible anymore to make the houses in Komossa that well insulated. It will cost too much money and it would then probably be better to rebuild the houses. A passive house is a good option for the future houses in Komossa and Finland.



3.F. 1: Energy loss in a normal house

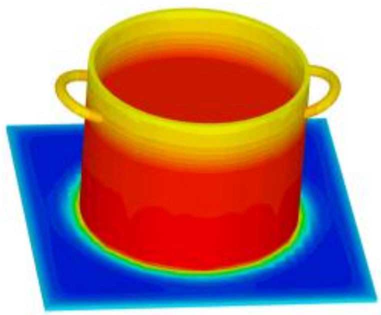
3.1 | Passive house

A passive house is a building that is totally insulated. This means that very little heat will get out of the house and the cold stays outside. There are several ways to get a house well insulated, for example: cavity wall insulation, double/triple glassed windows, floor insulation and roof insulation. This house is sun orientated so the most heat will be created by sunlight.

Winter

A passive house is designed so that only a little energy is needed in the winter to maintain its temperature. Because it keeps almost all the heat, the smallest energy source can be enough to let the house keep its temperature. The people who live in the house, their small electric devices and the sun will then be the most important energy sources. Only a little more energy will be needed to keep the house warm. This can be fed into the house by an advanced ventilation system. This means that a conventional heating system is not necessary.

As can be seen in the picture below a lot of heat is produced while cooking. This warmth will be spread all through the house and together with the other small heating sources it will be enough to keep the house warm. Also the human body produces warmth while moving. All these small energy sources together are enough for heating a passive house.



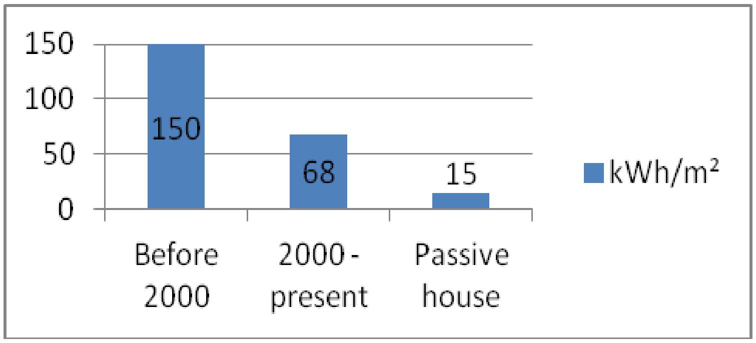
3.F. 2: Heat from cooking

Summer

Because the house is so well insulated, it does not lose its temperature in the summer. This means the house has the same temperature year-round. No energy is needed for an air conditioner, only for the ventilation of the air in the house. Of course the air needs to be ventilated to get fresh air into the house, but with a special system you can still keep the cold inside and the warmth outside. This ventilation system will spread the fresh air around the house and therefore it will not be necessary to open a door or windows to keep the house cool.

Numbers

A passive house needs about 15kWh/m² to heat a room. This means that a normal light bulb of 100 Watt is enough to heat a room of 10m². This is very efficient and 10 times less than the average house. It is even 4 to 5 times less than a newly built house. The perfect aim would be to make all the houses in Komossa this energy efficient. But the problem is that this is very hard to accomplish and it costs a lot of money and time. Therefore it would be better to provide the village with green energy.

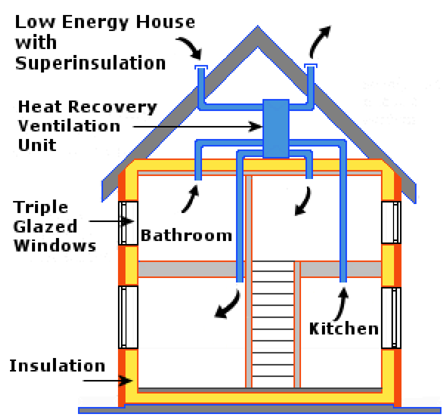


3.F. 3: Energy loss in different types of houses

Summary

The most efficient existing house is a passive house. This house needs almost no energy to keep its temperature the same during the entire year. It is designed so that in the winter the warm air cannot escape and in the summer the warm air cannot get into the house. During the whole year the house has the same temperature and almost no energy is needed for heating. Good ventilation without loss of heat and fresh air are also important in a passive house. This makes it healthier than a normal house. This is the idea of a passive house.

3.R. 1: Passive house website



3.F. 4: Different types of insulation

Several calculations were made to insulate a house in different ways. For the following calculations concerning insulation these numbers will be used:

- 1 m² of natural gas = 35.17 Mega Joule
- 100 Mega Joule = 27.78 kilo Watt hour
- 1 kilo Watt hour = 15.43 cents
- Average salary in Finland = €20.50 per hour

These numbers are needed later on to calculate the savings per year.

3.2 | Types of insulation

To get an idea of how well a house is insulated people use the value R or U. R is used for the insulation of walls, roofs and floors and the U is used for windows. Both are related to each other. If you have R it is easy to calculate U and vice versa. R=1/U and U=1/R. The U stands for W/m²K. The K in this formula is the temperature difference between inside and outside the house. If you have the U value you know how much heating energy (in Joule) gets lost per m². The R is the opposite; it gives the amount of warmth that stays in the house. A well-insulated house should have a high R value and a low U value.
3.R. 2: Website U-value

Some data

In the data sheet of the houses situated in Komossa we found out that the average building was built in 1980. This could probably mean that the insulation of the houses can be improved. We also found out that the average building has a ground surface of 117 m². Furthermore we know that one house has approximately 20m² of windows. For all the calculation we used the fact that the average house was built in 1980. So the insulation is not the newest and it is not as it should be right now, according to the current laws and regulations.

3.3 | Window insulation

An average house has around 20m² of windows. A lot of warm or cold air gets lost through the windows. By using HR++ glass this problem can be reduced very much. With the use of this special insulating glass, you can save around 600m³ of natural gas. In Finland people don't use natural gas, but the energy which equals this amount of gas can be calculated. With also taking the price of the energy into consideration, it can be calculated how much one house can save per year by using these special windows.

Savings per year

600 m² equals an annual saving of 5800 kWh. This is what one house will save after implementing these windows. With the actual electricity prices one house could save around €900 per year.
For every house the savings will be different, depending on the size of the windows. By filling in this formula the savings per house can easily be calculated. That makes this formula suitable for every house in Komossa.

(m² of windows) x 1.508 = saving in € per year.

Investment costs

The average house in Finland has a surface of around 20 m² of windows. The only costs that come with installing the HR++ windows are the installation costs. The windows are the most

expensive part of the installation which is around €110 per square meter. The total price per square meter with the labor costs, the price for the window frame and the materials included, would be around €150 per m². The total investment costs would then be around €3000.
For the costs of the installation there is also a formula which makes it easy to calculate the price for each house more specifically. The formula for the investment costs is:

(m² of windows) x 150 = total investment costs in €.

Payback time

With an average house of 20 m² the total costs would then be around €3000. With the payback calculator a payback time of around 3.5 years was calculated.
3.A. 1: Payback time window insulation

3.4 | Cavity wall insulation

A very important and maybe also the most common type of insulation is wall insulation. Most houses already have some kind of wall insulation, but it is probably not the best type. By changing the type of insulation the houses can be more energy efficient. One of the biggest surfaces where warmth can escape and cold air can go in is the wall surface. By improving the insulation in the walls the houses will be a lot better.

The best type of cavity wall insulation is HR++ PUR-foam. This is recommended to make the house as energy sufficient as possible. For the calculations an average cavity width of 6 cm is used. This is the standard used in most houses. The HR++ PUR-foam is applied by spraying it into the cavity. By drilling a hole in the seam the foam can be injected into the wall. This type of insulation is very effective; the savings are around 88 kWh per m² cavity wall.

3.F. 5: Insulating a cavity wall

Savings per year

The surface of an average house in Finland is around 117 m². With a height of 3 meters of the walls, the total surface of the walls is 132 m². Most of the houses have a second floor from

where the wall surface is around 27 m². Minus the 20 m² of windows, the total wall surface will be around 159 m².
By insulating the cavity wall of a house built in the 1980's it is possible to save 9 m³ of gas per square meter per year. This equals an annual saving of €2100. This formula can be used to calculate the saving for a specific house:

(m² of wall) x 13.57 = total savings in € per year.

Investment costs

The costs for the insulation only are €19 per square meter. Including the labor and materials the total costs will be around €27 per m². The total surface of the cavity wall is 159 square meters and therefore the costs of insulating the cavity wall will be around €4300. For one specific house the investment costs can by calculated with this formula:

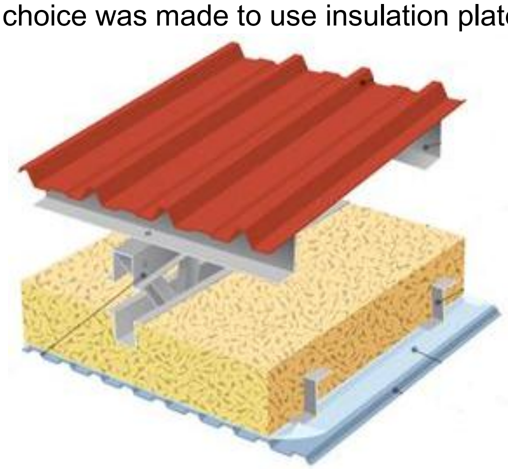
(m² of wall) x 27 = total investment costs in €.

Payback time

Because of the interest that applies on the calculations made on the payback time, a payback time calculator is used to calculate the payback time. With an interest of 4%, investment costs of € 4300 and an annual saving of €2100 the time is calculated. The payback time of the cavity wall insulation is a little under two years and two months.
3.A. 2: Payback time cavity wall insulation

3.5 | Ceiling insulation

The last type of insulation is ceiling insulation. Warm air rises and therefore it is important to insulate the roof very well. Also in the summer it prevents the warm air to get in and to keep the house cool. There are many ways to insulate the ceiling of a house; this method describes the insulation plates with a nice exterior so that there is no more extra work after insulating the roof. The houses in Komossa are not that high so assumed is that the highest floor is also used by the residents. Therefore the choice was made to use insulation plates which also look nice.



3.F. 6: Ceiling insulation

This type of insulation is easy to implement. The boards can be glued on the ceiling. On one side these boards have a special exterior which looks nice. Therefore you don't have to paint this or cover it with another board. When it is placed, it is done. It is easy and the savings are around 8m³ of gas per m² ceiling. The total ceiling surface is 140.4 m².

Savings per year

With a total roof surface of 140.4 square meters the savings per year are around €1700. This is calculated with a roof length of 13 meters and a width of 5.4 meters diagonal. The savings per square meter is then €12.06. For houses with another size of the roof this formula can be used:

(m² of roof) x 12.06 = total savings in € per year.

Investment costs

Without any costs for the labor and materials the costs per square meter of roof insulation are around €20. The price calculated with all the extra costs will be around €26 per square meter. This means that the total investment costs will be around €3700. With other roof dimensions the following formula can be used:

(m² of roof) x 26 = total investment costs in €.

Payback time

The surface of the roof is pretty big so a lot of money is needed to insulate it in a good way. Consequently there is also a large payback every year. With the payback time calculator the payback time in years can be calculated. For the ceiling insulation this would be 2 years and around 3 months.

3.A. 3: Payback time ceiling insulation

3.6 | Comparison of the insulation types

Per year:	Window:	Cavity wall:	Ceiling:	Total:
Surface	**20 m²**	**159 m²**	**140 m²**	**319 m²**
Saving per m²	€45	€9	€12	€66
Total saving *per house*	€900	€2100	€1700	€4700
Investment per m²	€150	€27	€26	€203
Total investment *per house*	€3000	€4300	€3700	€11000
Payback time	**3 years 5 months**	**2 years 2 months**	**2 years 3 months**	**2 years 6 months**

3.T. 1: Comparison of the insulation types

There are several ways of insulating a house in Komossa. One or more types of insulation can be chosen to improve the efficiency of a house. It saves a lot of money and has a short payback time.

4 | Wind energy

This part of the project is dedicated to the study of the different solutions possible with the wind potential of Komossa.
The wind strength causes rotation of the blades. This is the kinetic energy. That force is converted into electricity with a generator.
The first part presents all meteorological data necessary to carry out a wind power project. It serves as a point of comparison of data delivered by the village and it also provides a first specific study for the village. The second part presents a solution to supply the village with energy by a big wind turbine. The final part shows a specific solution for each type of building.

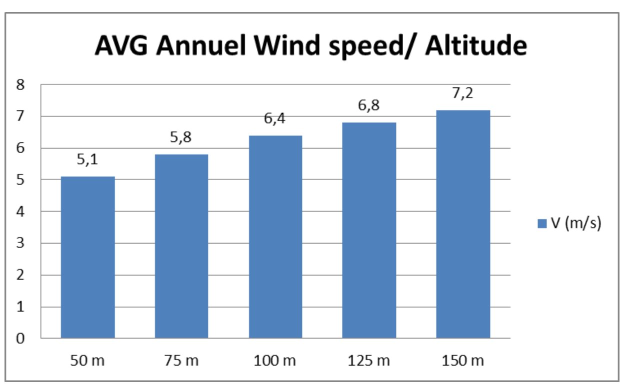
4.1| Meteorological data about Komossa

In chapter two is explained that Komossa is interested in wind energy because it is very profitable in this area and because Komossa is close to the Baltic Sea. Indeed, the village hast a great interst in generating energy by wind power.
This part describes the data that is important to make a project with wind power. The second goal is to compare the data that was obtained from the municipality of Komossa with the data found on different websites. There are some pictures of the area in Komossa where it is possible to implement a big wind turbine.
4.A. 1: Hill Hoppamäki

4.1.1 | Data found about Wind energy in Komossa

Finnish Wind Atlas:

Wind speed:



4.F. 1: Wind speed in Komossa

This first study was made in order to get an idea of the different wind speed available on the hill Hoppamäki in Komossa. The accuracy of measure is 250 m²; these measures are typical for this area of the village. A detailed month by month overview is given for every elevation in the appendices. This data is important because it will be used for sizing a wind turbine.

4.A. 2: Wind speed in Komossa

Weibull parameters:

The weibull parameters are the frequency of the wind and the exact strength of the wind. It is used to predict the energy production of a wind turbine.

4.A. 3: Weibull parameters

Icing parameters:

In cold climates such as in Finland, icing is one of the biggest challenges of operating wind turbines. Caused by icing the production of the wind turbines can be reduced the normal production.

The accumulation of ice on the blades of the wind turbine causes a decrease in electricity production and an increase of the weight of the rotor. This can damage the turbine and decrease its lifetime.

Ice on a wind turbine can have a big influence on the production of Wind energy:

- The ice changes the aerodynamics of the blades.
- Ice projection is dangerous for the surrounding people.
- The weight of this ice can cause damage to the blades of the windmill.
- Ice can disrupt the wind measurement sensors at the wind turbine and give false values. Those mistakes can stop the functioning of the wind turbine.

4.A. 4: Icing parameters

Power predictor:

Wind speed:

To get up-to-date information of the wind conditions in Komossa, a wind sensor was installed on hill Hoppamäki. During November 2012 it measured the wind speeds, wind direction and the solar activity.

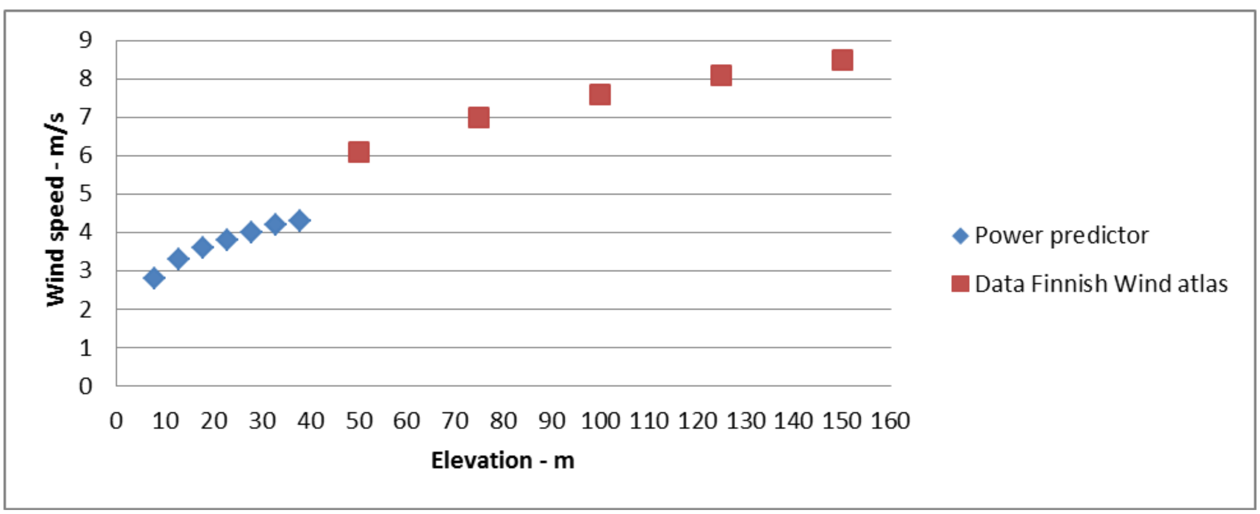
4.F. 2: Power predictor on the tower in Komossa

4.F. 3: Power predictor

The study of the sensor's data gives the following values of the wind in Komossa. These values represent the average wind speed during the month of November in 2012. These values are only estimations because the data's confidentiality is only 38%.

Elevation	8m	13m	18m	23m	28m	33m	38m
Wind speed	2,8m/s	3,3m/s	3,6m/s	3,8m/s	4m/s	4,2m/s	4,3m/s

4.T. 1: Wind speed measured with the power predictor in Komossa

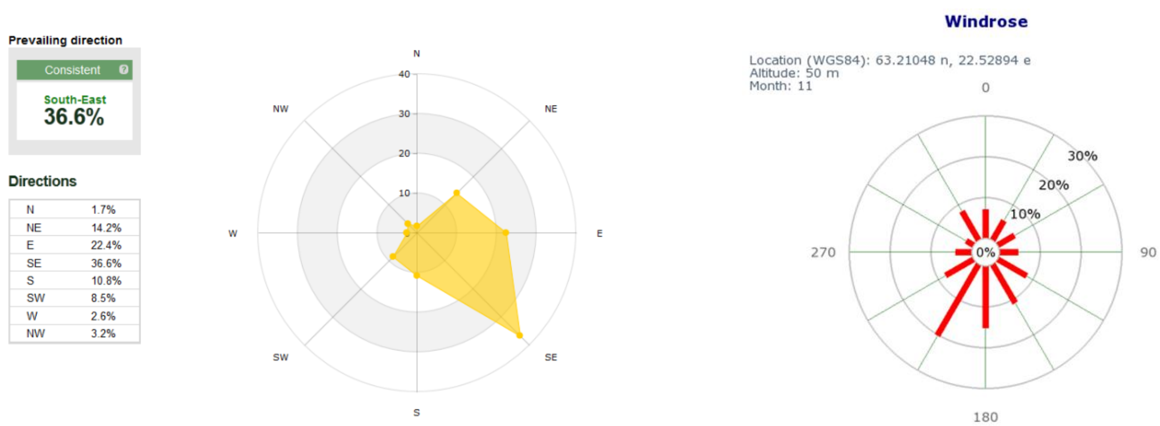


4.F. 4: Wind speed in November 2012 in Komossa

This table represents the different values measured by the wind sensor at a low elevation in comparison with the data found on the Finnish wind atlas for the month of November 2012.
It can be seen that there is some continuity. The power predictor was fixed to a certain height (13 m). The others different elevations are estimation. These values are not usable because they arise from lot estimation.

Wind direction:

The image on the following page represents the main wind direction measured by the sensor. During the installation of wind sensor we have not been able to place directly facing north. The data in Figure 4.F.5 are not correct because the sensor was not in the right direction. The correct direction of the wind is explained in Figure 4.F.5.



4.F. 5: Wind directions in Komossa power predictor and wind direction in Komossa Finnish wind atlas

4.1.2 | Conclusion

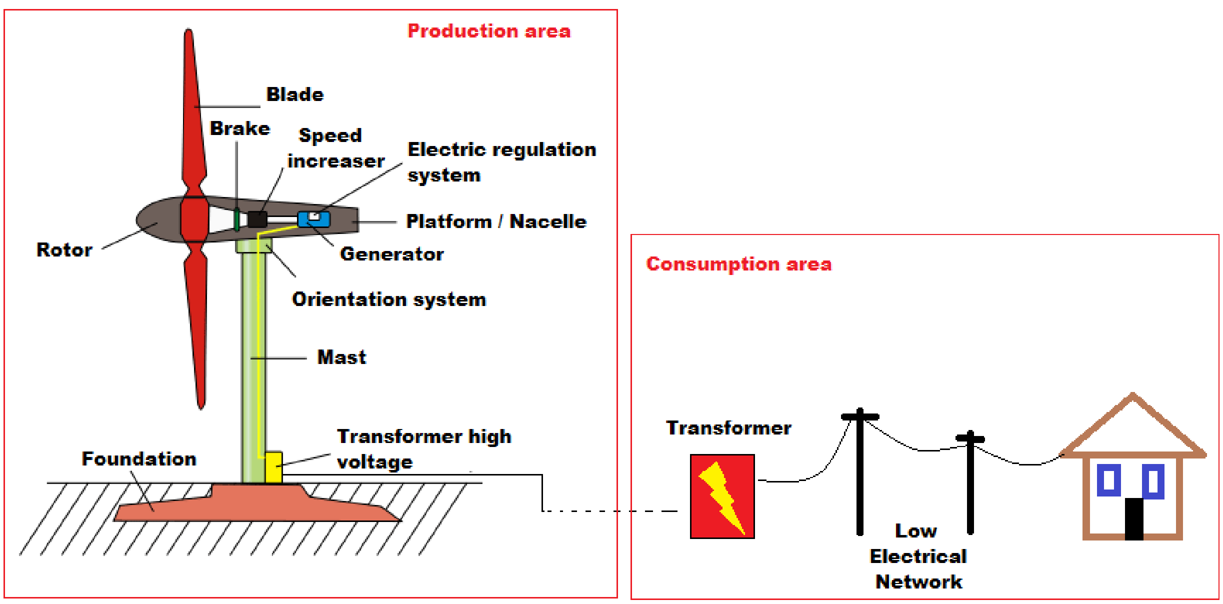
This part has been designed to find all the important data for the study of a wind project in Komossa. Data found on wind speed reflect the values estimated by the village. In addition, some other important data was found such as the icing parameters and the Weibull parameters. Now, all the information necessary for sizing a wind power is collected.
Wind speeds found on the Finnish wind atlas will be used for the study of large wind turbines. The data recorded by the wind sensor installed in Komossa are more relevant to make a study of small wind turbines. In the next part is developed the study of a big wind turbine.

4.2 | Big wind power

4.2.1 | Situation in Finland

The European Union has set a goal for Finland that 38% of the energy should be produced from renewable energy. In Finland there are subsidies and a lot of projects during the next few years. The number of wind turbine increases year by year, which allows us to conclude that wind power is in the interest of Finland. A detailed explanation of the development of wind energy in Finland and in the Ostrobothnian region is given in appendix:
4.A. 5: Localization of big wind turbines in Finland

4.2.2 | Description of all the component of a big wind turbine



4.F. 6: Overview of the energy production and consumption

A rotor: Composed of several blades (usually three) and the nose of the wind turbine. The blades act like the propeller of an airplane this is because of the blade pitch. The rotor captures the energy produced by the wind and converts it into mechanical energy of rotation.

A brake: Allows the wind turbine to operate in case of too high wind speeds. High wind speeds could damage the wind turbine. The brakes are there to reduce the speed of rotation of the rotor. The wind turbine can continue its functioning.

A speed increaser: Increases the speed of rotation of a second shaft with a gear system for the electric generator.

A generator: Converts mechanical energy of rotation of the second shaft into electrical energy like a bicycle dynamo.

An electric regulation system: Slows down the rotor when the generator is over speeding.

An orientation system: Faces the platform and the blades to the wind.

A mast: It places the wind turbine at sufficient distance from the ground for the movement of the blades. This height allows it to be driven by a stronger wind and more regularly than on ground level.
The mast house usually possesses some electrical components such as an electricity cable for the connection to the electrical network.

High voltage transformer: Transforms the produced energy from wind power into energy with a voltage suitable for the electric network.

Foundations: They are mostly built in concrete and are composed of metal reinforcement to solidify it. They allow the wind turbine to resist any weather; e.g. strong wind.

4.R. 1: Explanation of the components of a wind mill

4.2.3 | Economic estimation

The main parameters of wind power economics are:

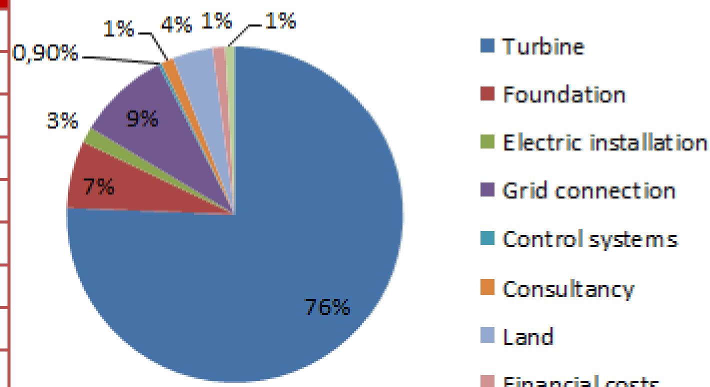
- Investment costs (cost of turbine)
- Auxiliary costs for foundation and grid connection
- Operation and maintenance costs
- Electricity production/average wind speed
- Turbine lifetime

The most important parameters are the turbine's electricity production and investment costs. As electricity production depends on the wind conditions, choosing the right turbine site is crucial to achieve economic viability.

Investment costs

The capital costs of wind energy projects are dominated by the cost of the wind turbine itself. An average turbine installed in Europe has a total investment cost of around €1230/kW. The turbine itself costs, on average, around 76% of the total investments. Other parameters are also important, such as the grid connection. This is around 9% and the foundations are around 7%. The other values depend on the project (land, financial cost, road, etc.) and may vary from the country.

	Investment (€1,000/MW)
Turbine	928
Foundation	80
Electric installation	18
Grid connection	109
Control systems	**4**
Consultancy	15
Land	**48**
Financial costs	15
Road	**11**
Total	**1228**



4.T. 2: Investment costs of wind turbines

In Europe, the cost per kW typically varies from around €1000/kW to €1350/kW.
4.R. 2: Costs and investment structure

Operation and Maintenance Costs

Operation and maintenance costs constitute an important part of the total annual costs of a wind turbine. For a new turbine, operation and maintenance costs may easily make up 20-25% of the total actual cost per kWh produced over the lifetime of the turbine. If the turbine is fairly new, this part may only be 20-35 % by the end of the turbine's lifetime. The manufacturers attempt to lower these costs by developing new turbine designs that require fewer regular service visits and less turbine stops.

Operation and maintenance costs are related to a number of cost components:

- Insurance
- Regular maintenance
- Repairs
- Spare parts
- Administration work

In Europe, operation and maintenance costs are estimated to be around 1.2 to 1.5 c/kWh of the wind power produced, during the total lifetime of the turbine.
4.R. 3: Operation and maintenance

Cost of Energy Generated by Wind Power

The calculated costs per kWh of wind-generated power are in function of the wind characteristics at the chosen sites.
The costs range from 7 to 10 c€/kWh at sites with low average wind speeds, around 5 to 6.5 c€/kWh at coastal sites, and around 7 c€/kWh at a wind site with middle wind speeds.
This can be seen in the table in appendix:
4.A. 6: Costs of wind-generated energy

4.R. 4: Costs of wind-generated energy

Subsidies

A fixed subsidy is available for Wind power plants:

- Target price for wind power is 83.50 €/MWh

Period: Feed-in tariff is paid for **12 years**

- Producer is paid a feed-in tariff, which is the difference between the target price and the average electricity market spot price

For Example: If the spot price is €50, feed-in tariff is 33.50 €/MWh (€83.50 – €50)

- Until the end of year 2015, the feed-in tariff target price is 105.30 €/MWh
  (Max 3 years for one single wind power)

4.R. 5: Production subsidy table

On Fingrid website: There is the average electricity market spot price. This value is unstable, it varies continuously between 35 and 50 €/MWh.
4.R. 6: Electricity prices in Finland

Payback Time

The payback time for a wind turbine is generally between 8 and 11 years. If you exceed **12 years**, you have to change the place of your wind turbine and find another area where the wind speed is better.

For example: For a wind turbine rated power of 1 MW, the investment price is close to 1,225 M €. The payback is done when the total revenue of electricity sold is higher than the investment cost and operation and maintenance costs.

4.2.4 | Typical sizing for the village – Enercon – E43

Specification about Komossa

- Total consumption: **1285.8 MWh**
- Localization: Hill Hoppamäki - 72 meter above sea level
- Electricity network: **110 000 V** – about **5 Km** from hill Hoppamäki
- Wind speed: Annual average **5.8 m/s** (75 m elevation) – Max: **7.9 m/s** – Min: **4.9 m/s**
- Weibull parameters – A: **6.59** – K: **2.209**
- Icing parameter (turbine stopped by the icing) – **2** to **10** days per year

Technical specifications on Enercon E - 48 / 0.8 MW

4.F. 7: Enercon E-48 / 0.8 MW

Rated power: 810 kW
Rotor diameter: 48 m
Hub height: 50 m / 55 m / 60 m / 76 m
No. Of blades: 3
Swept area: 1,810 m²
Rotational speed: 2-25 m/s
Cut-out wind speed: 28 - 34 m/s
Type: Upwind rotor with active pitch control

This manufacturer has been chosen because it is one of the most present in Finland. The aim of this approach is to be closer to the reality. As Finland is a cold country, all wind turbines cannot be set up there. A detailed study of all wind turbine manufacturers in Finland is found in appendix:
4.A. 7: Main manufacturers of wind turbines in Finland

Sizing and Power production

It has been studied that the wind turbine was able to produce 1.570 MWh / years, this is sufficient to supply Komossa with electricity. With all those data it is possible to make a financial analysis. A detailed study of this is presented in appendix:

4.A. 8: Sizing and power production

Result of the economic estimation

	Single costs (Minimum)	Lifetime : 15 years	Average	Single costs (Maximum)	Lifetime : 20 years
Investment costs	1000 €/KW	€ 810 000	€ 955 000	1350 €/KW	€ 1 100 000
Maintenance	1,2 c€/KWh	€ 283 000	€ 377 000	1,5 c€/KWh	€ 471 000
Total expense		€ 1 093 000	€ 1 332 000		€ 1 571 000
Subsidies (12 years)	41 €/MWh	€ 64 400/ years	€ 64 400/ years	41 €/MWh	€ 64 400/ years
Cost generated by Wp	8 c€/KWh	€ 125 600/year	€ 125 600/year	8 c€/KWh	€ 125 600/year
Total gain		€ 190 000/ years	€ 190 000/ years		€ 190 000/ years
Payback time: Total expense/Total gain		5 years, 9 months	7 years		8 years, 3 months

4.T. 3: Total cost of Enercon E-48 in Komossa

4.A. 9: Economic estimation

4.2.5 | Conclusion

All the conditions are very good to implement a wind turbine on the hill Hoppamäki in Komossa. The wind speed is very high and the payback time is shorter than another wind turbine installation.

However, this solution also has disadvantages, because the investment costs seem too high for a village of 120 inhabitants. Moreover, the costs of connecting to the network might be too high (redevelopment of a new network).The wind turbines produce a large amount of energy and Komossa is just a small village more interested in heating systems.

This project would be better to do on a regional scale. The entire region has only five turbines. With these wind conditions, a wind larger turbine with more power would be more cost effective and more beneficial. This wind turbine would help the region to support its need of energy and so develop the wind power as wanted in Finland.

There are several possible solutions for Komossa regarding wind energy. The small wind power could be expanded in the future.

4.3 | Small wind power

After the study of traditional wind turbines this part focuses on small wind turbines. To start it was interesting to use traditional wind turbines because the price of investment per Kilowatt was far less than for small wind turbines. Searched was for a solution to supply the whole village of Komossa with energy.

Small wind turbines can be used to supply isolated sites or to reduce the electricity bill. Small wind turbines have a good impact on the environment and are a great option for self-sufficiency in energy production.

4.3.1| Small wind turbines in Finland

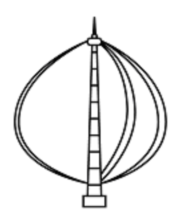
In Finland only a few small wind turbine manufacturers are fighting for the production of energy with small wind turbines. This energy production is environmentally responsible and easy to use as an alternative at the energy production, but its development is new and still low in Finland. However, the growing interest of consumers wanting an ecological life makes this energy to a constant and promising evolution.

4.3.2 | Components and axis type

Axis type

There are currently two types of small wind turbines, i.e. turbines with a vertical axis and turbines with a horizontal axis.

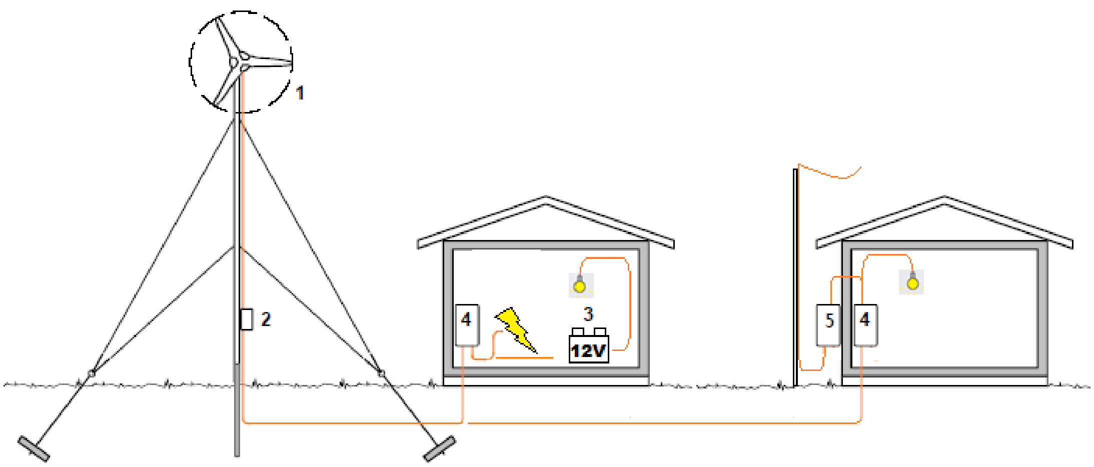
The table 4.T.1 presents the advantages and drawbacks of each of these systems.

Axis type	Benefits	Drawbacks	Pictures
Horizontal	Lots of models	Installation on a building not recommended	
	Mature technology	Noise	
	Price	Poor performance in turbulent winds	
Vertical	Less noisy	Price	
	Can be installed on the roofs of buildings	Technical complexity	
	Efficient in turbulent winds	Efficient models since shortly	
	No orientation systems		
	Own protection against strong winds		

4.T. 4: Different types of axis

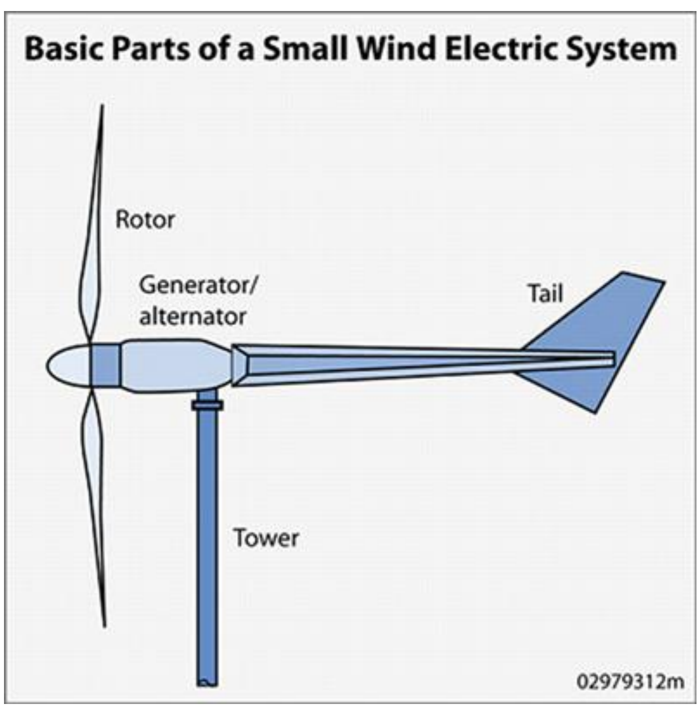
This table shows that horizontal turbines will be preferred to vertical turbines in Komossa, because they better reflect the situation of the village. The next paragraph describes in detail the components that are important for small wind turbines.

Components



4.F. 8: Main components of a small wind turbine

1 - The turbine



4.F. 9: Components of the turbine

2 - The mast

Generally, in the mast there are the main fuse and overvoltage protection. The overvoltage protection protects the ground cable and devices in the event of an electrical surge caused by lightning.

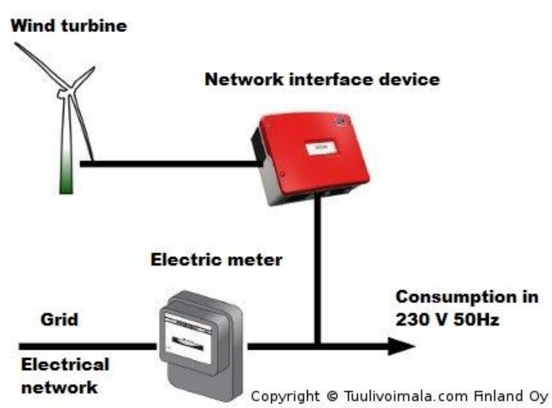
3 - Battery

Needed for isolated sites the batteries are used to store the energy produced by the wind turbine small. The important parameter is the energy storage capacity of the battery.
This capacity is measured in ampere-hours, but it is often easier to express it in terms of power produced in one hour (kWh).
For example, a battery which can store 1000 Wh is able to keep the equivalent of one hour of wind speed for a wind turbine of 1 kW of rated power.

The price is 150 € (excluding taxes) per kWh for lead-acid batteries. Their lifetime is between 10 and 15 years.

4 – 5 - Electrical housing and inverter

4.F. 11: Electrical housing and inverter



4.F. 10: Connection diagram

The electrical housing contains the main orders of the wind turbine and some devices to follow energy production and other wind generator statistics.

The inverter is intended to couple the small wind turbine to the electric network. It transforms the variable voltage of the generator of the wind turbine in alternative voltage in accordance with electrical network. The energy can be used for housing needs and the excess can be fed into the electrical network against remuneration.

The inverter shown in Figure 4.F.11 works that way. This is the inverter WINDY BOY. Its power range covers all small wind turbines. The cost of this device is between € 1.000 and € 1.600.
4.R. 7: Windy boy costs

4.3.3 | Guidebook to succeed with a small wind turbine

Why implement small wind turbines in Komossa

Previous research revealed that there is great wind speed in Komossa. However, the data found on Wind Atlas of Finland are not enough to make a decision on the implementation of a small wind turbine. The wind atlas of Finland measurements is performed between 50 and 200 meters of elevation. Those elevations are higher than most projects of small wind turbines. To get an idea closer to reality about wind speeds, we placed a wind sensor in Komossa on Hoppamäki hill at around 13 meters of elevation, during one month.

For implementing a small wind turbine you should do a study of the wind conditions in your area. We recommend this wind sensor: "Power predictor ". The price for that is around three hundred euros. The results obtained are enough to determine the viability of the project. A detailed study of this is presented in appendix:
4.A. 10: Power predictor website

If not you can rent an anemometer and request a specific study. This solution seems more expensive.
The last possibility is to ask the installer to make for you this study. It is possible that their study might be free of charge if you order a small wind turbine.

The goal of our project is to make the village of Komossa self-sufficient in energy. Small wind turbines seem like a good solution to make a house become self-sufficient in energy or cover a large portion of their electric consumption.
4.R. 8: Power predictor

Define its needs

Own consumption:

The wind turbine powers a building connected to the network itself, with or without batteries. A system automatically switches on the batteries when the power output is insufficient. If the batteries are empty the system switches on the electrical network.

Own consumption with resale of surplus production:

In this case, when production exceeds the consumption, the extra is sold to an operator in a variable rate depending on the area. The installation regularly injects current into the electrical network. The current sold has to be of good quality and an inverter is required.
In Finland you have to ask for an authorization at your local electricity company – (specific permit). If you find an arrangement with this local company you can sell this extra. If not, the excess electricity is transferred to the network for free.

How to compare / choose your small wind turbine

The following data are good parameters that can influence the performance of a wind turbine:

- Surface cover by the blades
- Rated power (KW)
- Energy output (KWh)
- Quality of the installation
- Lifetime of the turbine

But this data depend on each manufacturer. Manufacturers do not make all performance measurements in the same wind conditions. Every manufacturer chooses his conditions of wind to make data to his advantage.
A neutral data for every manufacturer is highly revealing of small wind turbine performances. You have to compare the rate of return of the small wind turbine.

Subsidies

Small wind turbines are new in Finland. At the moment there is not a typical subsidy, but subsidies for heating systems exist. It is advisable to use this subsidy to assist in the realization of a wind power project.

Steps of installation

Building your small wind project will go through the following steps, where the goal is to have an overview of the problems that can interfere in the carrying out the project.

- Civil engineering(foundation, hole for the mast , mast),installation of underground cables)
- Elevation of the mast
- Installation of the turbine
- Electric installation
- Test of installation

Important points

- Permits

You should ask your municipality if there is a permit needed to install a small wind turbine. In some municipalities it is possible to install a small wind turbine without a permit and in others it could be really difficult to get a permit. Some municipalities do not want to have wind turbine in their area.

This permit must be composed of the location on a map of the electric installation (cable, central housing) and the location of the small wind turbine.

- Electric security – laws

The average construction year of the buildings in Komossa is 1980. It is possible that the electric installation of some houses needs to be changed.

4.3.4 | Sizing

Komossa is a village of 120 people and 43 houses. To better meet the needs of the village buildings were divided into 3 categories described in Table 4.T.5.

Users	Small	Medium	Large
Surface	< 120 m²	120-200 m²	> 200 m²
Electricity used	2000 - 5000 KWh	5000 - 10000 KWh	> 10000 KWh
Heating used	5000-15000 KWh	15000-30000 KWh	> 30000 KWh
Type of Buildings	One-family house	Two-family house	Animal farm
	Block of flat	Other buildings	Fur farm
Proportion	48%	36%	16%

4.T. 5: Classification of different building types in Komossa

Small wind turbines can be a good idea to supply all electricity needs for each category of users. They can also be used to supply the heating needs of buildings .Table 4.T.6 describes the capacity of production of small wind turbines for each user. For small users such as a one-family house, manufacturers offer wind turbines to be able to power all electrical needs and a large proportion of the heating needs. This is interesting because it is about 48% of houses in Komossa. For medium users there are two possibilities for Komossa. The first one is to supply medium users with electricity only, that is if houses already have a not electric heating system. The second solution is to supply all the needs of houses (electric and heating) because some of these houses may have an electric heating system. For large users small wind turbines will only supply the electricity needs. Large users of Komossa already have a heating system (heating with wood for example).

<table>
<tr><th>Users</th><th>Small</th><th colspan="2">Medium</th><th>Large</th></tr>
<tr><td>Electricity used</td><td>100%</td><td>100%</td><td rowspan="2">100%</td><td>100%</td></tr>
<tr><td>Heating used</td><td>60 - 70%</td><td>0%</td><td>0%</td></tr>
</table>

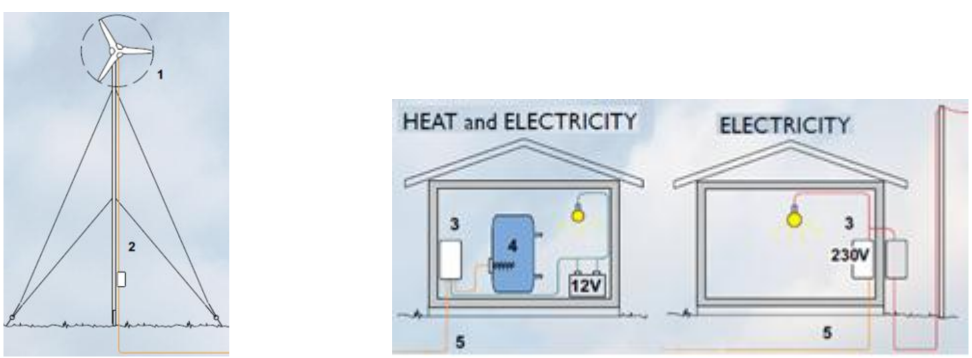
4.T. 6: Capacity of production by small wind turbines in Komossa

<u>Small users:</u>
For small users, some companies manufacture small wind turbines to make a house self-sufficient in energy. The sizing for small users will be done with FinnWind in this report.

Information about the company:
FinnWind is a small Finnish company founded in 1993. Their clients are: family and vacation homes, companies, public spaces and the construction industry. It is located around 12 km from Tampere. They work with a team of 10 people.
4.R. 9: FinnWind

Why this company:
FinnWind is advised by the Finnish Wind Power Association (FWPA). The main objective of FinnWind is to develop distributed power generation and energy self-sufficiency. FinnWind has built its wind turbine with the aim to supply energy for a "typical house" in Finland. To date, it has 30 installations from 2008 in Finland. For 2013, there are presently 10 deliveries. The goal of Finnwind is to become a world supplier of distributed energy production systems and to start exporting small wind turbines in Europe in 2012.

These small wind turbines proposed by Finnwind could be feasible for Komossa:



4.F. 12: Different types of small wind turbines proposed by FinnWind

Electricity system operations - The electricity produced by the small wind turbine is used and when the consumption is bigger than the production, the network automatically supply the gap. This system is "on grid" that is to say than the small wind turbine is connected to the electrical network.

Heat and electricity system operations - The electricity produced by the small wind turbine is used to supply the house and to load the batteries. When the consumption is lower than the production, the energy is automatically directed to the heating resistor. Water tank and batteries are included in the total cost, the capacity for the water tank is 1,000 liters and charging power of batteries is 350 Watts that is the quantity of electricity that the battery can provide at any given time. With an extra cost the capacity of batteries could be: 700 or 1,000 Watts. This system is "off grid" that is than the small wind turbine is not connected to the electrical network.

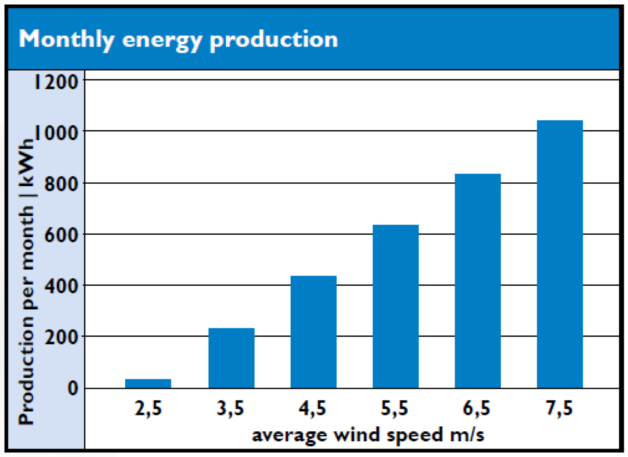
4.F. 13: FinnWind turbine

Technical information about these small wind turbines:

The small wind turbine of FinnWind was created to be able to produce almost all the energy needed by one-family house. In Finland the average heating consumption is around120 kWh/m². For one house of 120 m² the heating consumption is about 14 400 kWh/year for heating and 5 000 to 6000 kWh for electricity.

Specification	
Nominal power and wind speed	4 Kw , 10 m/s
Maximum power	5,3 Kw
Cut-in wind speed	2 m/s
Rotor diameter / swept area	5 m , 20 m²
Nomber of blades	3
Generator	Permanent magnet generator
Generator nominal voltage	0-400 V AC , 3 ~
Storm protection	Furling, automatic mechanism
Weight	140 Kg

4.T. 7: Technical specifications



4.F. 14: Energy production

In Komossa the average wind speed during one year is between 5.5 and 6.5 m/s. The electricity production per month is between 630 and 830 kWh.
4.R. 9: FinnWind

Economic estimation:
The total investment is the cost of the turbine alone, the installation (civil engineering, foundation, mast) and the electrical works (connection, equipment prices).
The cost for different versions of small wind turbine installed are around € 20 000.
There may be an extra cost, if you have to change your electric installation because of new electrical standards in force.

The lifetime of the turbine is around 20-25 years.

The maintenance and operation
An obligatory visit takes place every 5 years. The cost for a working hour in Finland is € 50-65 /hour/electrician. Generally the time of this process takes 3 to 4 hours.
The blades may need some service every 5 years. The cost for that are some hundreds of euros.
The table 4.T.8 explains the average of the cost per operation of maintenance every 5.

Technician (s)	1	2	3
3-4 Hours	260 €	520 €	780 €
Pieces to change	100 €	100 €	100 €
Total every 5 years	361 €	622 €	883 €

4.T. 8: Total cost of maintenance every 5 years

The total cost of maintenance in the most unfavorable case would be € 883 x 5 = € 4.400 for a lifetime of the turbine of 25 years. For systems on grid only, the current low electricity price is around 14-15 c€/kWh.

Payback

The total production each year is between 7,560 KWh/year and 9,960 kWh/year. The total consumption for a small user is between 7,000 and 20,000 KWh/years with an average of 13,500 KWh/year.

Energy saving:

7.560 KWh / 13.500 KWh = 56%
9.960 KWh / 13.500 KWh = 74%

Rated Power	4 Kw
Cost Turbine / Inverter	20 000
Foundation	1 000
Investment cost	21 000

Maintenance/ year	177

Energy saving	56%	74%
Payback	8 years	11 years

4.T. 9: Payback small users

Medium user

- Electricity needs: 5000 to 10000 KWh/ year

Manufacturer	Rated Power	Annual Production	Cost of the Turbine with inverter (without mast)	Lifetime
Wind power energy (WPE)	5Kw	4000-13000 kWh	13 800 €	20-25 years

4.T. 10: Specification WPE 5Kw

- Electricity and heating needs: 20000 to 40000 KWh/ year

Manufacturer	Rated Power	Annual Production	Cost of the Turbine with inverter (without mast)	Lifetime
Wind power energy (WPE)	20Kw	20000-50000 kWh	32 200 €	**20-25 years**

4.T. 11: Specification WPE 20 Kw

Large users:

- Electricity needs only: > 10000 KWh/ year

Manufacturer	Rated Power	Annual Production	Cost of the Turbine with inverter (without mast)	Lifetime
Wind power energy (WPE)	10Kw	10000-26000 kWh	21 900 €	20-25 years

4.T. 12: Specification WPE 10 Kw

Estimation cost and payback:

Rated Power	5 Kw	10 Kw	20 Kw
Cost Turbine / Inverter	13 800	21 900	32 200
Cost mast (65 € / meters)	12 - 24 m	18 - 30 m	18-30 m
Avg cost mast	1 170	1 560	1 560
Foundation	1 000	1 000	1 000
Investment cost	16 000	24 500	35 000
Maintenance/ years	177	177	177
Energy save	100%	100%	100%
Production	10 000 Kwh * 14,5 c€/kWh	30 000 Kwh * 14,5 c€/kWh	> 21 000 Kwh * 14,5 c€/kWh
Total	1 450 €	4 350 €	> 3 150 €
Payback	< 14 years	< 9 years	< 14 years
Users	Medium with just electricity needs	Large with just electricity needs	Medium with electricity and heating needs

4.T. 13: Payback estimation medium and large users

The sizing of wind turbines for medium and large users can cover the totality of their electric consumption. The energy saving is thus of 100%. The cost generated by small wind turbines is 14.5 c€/KWh. The total of energy save is thus the annual production per the cost generated by small wind turbines.
4.R. 10: Finnish Wind Power Association

4.3.5 | Conclusion about small wind turbine

Small wind turbines appear to be a good solution for powering the houses of Komossa. The small wind turbines seem more effective for small users because it covers a large portion of their heating needs. The purpose of this section has been to study the important parts in a wind project and get an overview of the tasks to be accomplished. This first study shows that the payback is good for a optimal operation of small wind turbines, but a study of the wind conditions at low altitude should be made to confirm this potential.

5 | Solar Energy

5.1 | Introduction

In this chapter solar energy is analyzed as a useful energy to feed the energy needs of the households in Komossa.

In Finland the solar energy production varies depending on the month of the year, and this fact changes significantly the solar irradiance and the useful daylight hours. Whereas for example January has four hours of sun and three of them are useful, June has 11 hours of sunshine, of which eight are useful. This fact coupled with the low temperatures in winter months; make think a priori that solar energy does not seem the best ally to supply the needs of a standard home.

For study the solar energy, is examined the two variants that this type of renewable energy have. The first part is the study of solar energy as a source of electricity power, through the photovoltaic effect, using solar panels as main actors.

The second part aims to harness solar radiation to heat fluids and used to heat the home, and for the domestic hot water (DHW), using solar collectors for this.

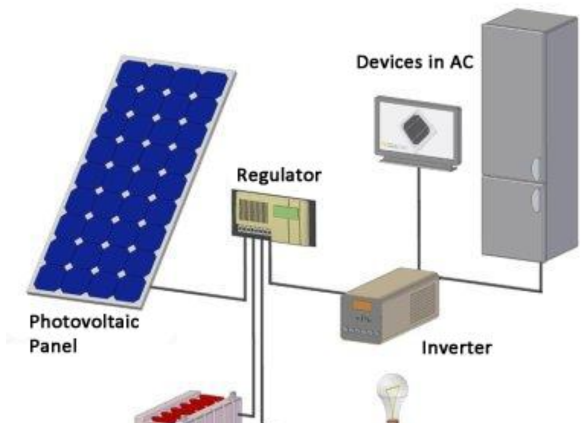
5.2 | Solar Panels

Solar panels use an effect called photoelectric to convert the radiation coming from the sun (photons) into electricity. Using this way it is possible to get electricity directly from the sun, without any intermediary, only the solar cells.

For the distribution and use of that electricity, according to the current legislation in Finland, the electricity produced by small and medium sized solar installations must be used for self-supply. This means that it is not possible to sell the "green electricity" to the electric company, or to inject the excess production on it. Therefore everything generated must be consumed instantaneously or stored in batteries, thus requiring different components in a photovoltaic installation separated from the global network.

5.2.1 | Components

A photovoltaic installation separated from the global network must have the elements shown in the following image:



5.F. 1: Scheme of isolated photovoltaic installation

Photovoltaic panels

Their number and type depend on factors such as the area available for placement, the power required for the installation and the type of solar cell to be installed. All panels installed must be the same constitution of peak powers.

For the PV panel to generate maximum power (peak power), they should receive as much light as possible on their active surface. The ideal orientation and inclination of the panels must be determined before the installation is carried out, taking into account the position of the sun throughout the months.

Accumulators and batteries

In autonomous photovoltaic systems, photovoltaic modules, once installed, are always available to generate electricity. However, the amount of solar radiation that the solar panels received is varying. Many times that the energy a PV produce, differs, by excess or defect, of demand of the elements connected. In most cases the correct supply requires energy store when production exceeds the demand, for use in the opposite situation.

The stored energy accumulator is able to transform chemical potential energy into electrical energy, and has the following functions:

- Being able to keep a stable voltage level, providing a constant voltage within a certain range regardless of the solar panels to operate at that moment or not.
- It is capable of supplying power at all times independent of the electricity production of the PV modules at the time, and it can feed consumption for several days.
- It is capable of providing a power higher than the solar panels can give at a right time.

But the use of accumulators also has its disadvantages:

- Storing energy in batteries always involves an energy loss, and not all the energy that goes into a battery can be removed after the discharge process.
- The higher use that is given for the batteries is before they reach of the end of its working life. The lifetime of a battery is not measured in years, but in cycles. A cycle is the complete process of charge and discharge. If the battery has a life of 3,000 cycles. These cycles can be fulfilled in 8 or 9 years depending on the application and use, and other factors.

Regulator

The principal mission of the regulator is to manage the electrical current that is stored in the batteries, or is transferred to the home. Monitoring the charge and discharge cycle develops a key role in the management of an autonomous photovoltaic:

The control of the regulator is always recommended for the safety and security of storage system and in almost all cases is of obligatory use.

Its task is to avoid overload and battery discharges. When the battery is full and the panel receives radiation, it tries to inject energy into the battery overloading. To avoid this injection the regulator cuts the power. In the opposite case, if the battery charge is low and the system attempts to continue extracting energy, the regulator cuts off the power supply to protect the battery.

Inverter

It is a device whose functionality is to adapt the properties of the electric current generated or accumulated, to electric current required by all or part consumption. It transforms the DC current generated by solar panels into AC current used by some appliances available in a house. It increases the voltage of 12 or 24 V (depending on the type of photovoltaic panel) to 220 - 230 V.

This inverter must incorporate an automatic start circuit that detects when you connect an appliance. While in standby and not feeding any load, the inverter uses very little power. It is activated when it detects any consumption above a present value and after the demand of energy is finished, the inverter returns to standby.

The inverter has protections such as grounding, protection against overload, short-circuit, against increasing inverter temperature, and against low voltage in the battery.

5.2.2 | Study and size

After specifying the components, the installation is sized for the different elements of a single household of 4 persons with an average electricity consumption of 5000 kW / h per year.
The results of the study are shown in appendix

5.A. 1: Calculations and size of the different elements

In the following table the necessary elements are shown, their number and the prices:

Installation Elements	Type	Price Unit €	Required Quantity	Price Total €
Inverter	Inversor Senoidal Solener ISC 5000 24V	1500-1700	1	1500-1700
Batteries	20 OPzS 2.500 3720 Ah	6000-6200	1	6000-6200
Solar Panels	AB 190 M 190W	220-260	19	4200-4800
Regulator	SS – 60 C 60A SS – 45 C 45A	260-290 200-230	1 1	260-290 200-230
			Total	**12000-13000**

5.T. 1: Direct costs of the PV installation

In the following table the estimated indirect costs of a solar photovoltaic installation are shown:

Preparation roof	100 €
Wiring and Protection Devices	400 €
Installation and assembly	650 €
Licensing and Administrative Procedures	200 €
Total	**1300 €**

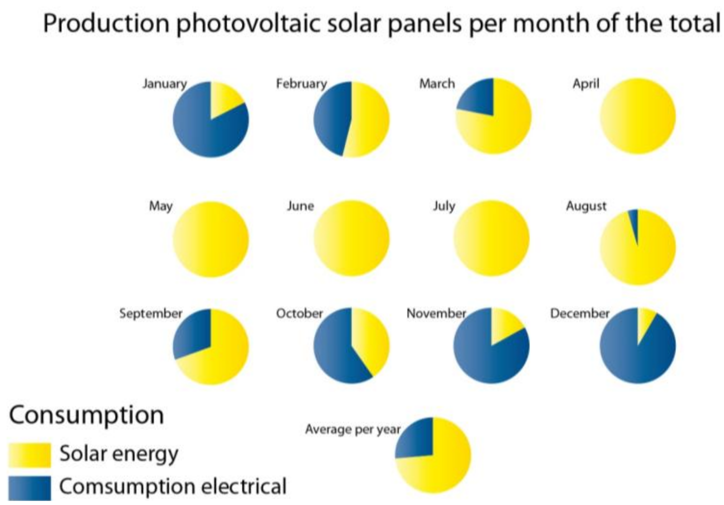
5.T. 2: Indirect costs of the PV installation

The total estimated budget is as follows:
(12000 – 13000) + 1300 = **13300 - 14300 €**

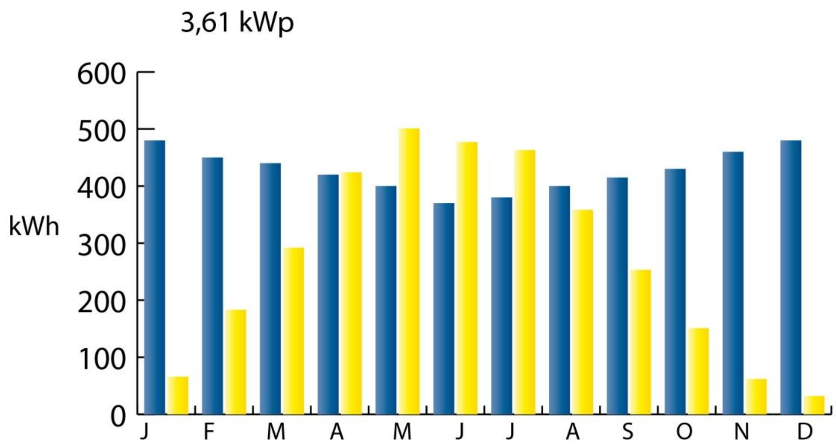
The next point is the calculated payback time taking as data, the production of the panels, the budget, and the electricity costs in Finland.

- Price of connection per one year: 110,76 €
- Price of kW at 1-08-2012: 14,74 cents
- Consumption of a detached house in one year 5000 kWh
- Cost of electricity per year in a detached house 847,76 €

An estimated production of a solar panel installation of 3.6 kWp, in Komossa is calculated. In this overview is given the energy production and the savings per month and per year. The PVGIS application can be seen in appendix:
5.A. 2: Estimated production of a solar panel installation



5. F. 2: Energy production and consumption per month



5. F. 3: Energy consumption and usage per month

The annual saving is around 570 € per year, depending on the month. There will be a few months of surplus production, which is stored in the batteries to cover fixed autonomy days, 5 days, and to cover the energy declines during the summer months. In the winter months, it is impossible to store any surplus production, because as all is consumed.

To calculate the payback time the estimated inflation is established as each year by 4%. The annual maintenance of the installation is also include, which starts at 40 € per year, and each year up to a 4% inflation.

The payback time is between 20 - 22 years, which is a long payback time. The useful life of the installation is 24 to 28 years. It is risky, because over the lifetime of the installation can cause

malfunctions or changes in elements of the installation. It may happen that the initial cost increased, and then result in losses. These calculations can be found in appendix
5. A. 3: Payback calculations

5.3 | Solar Collectors

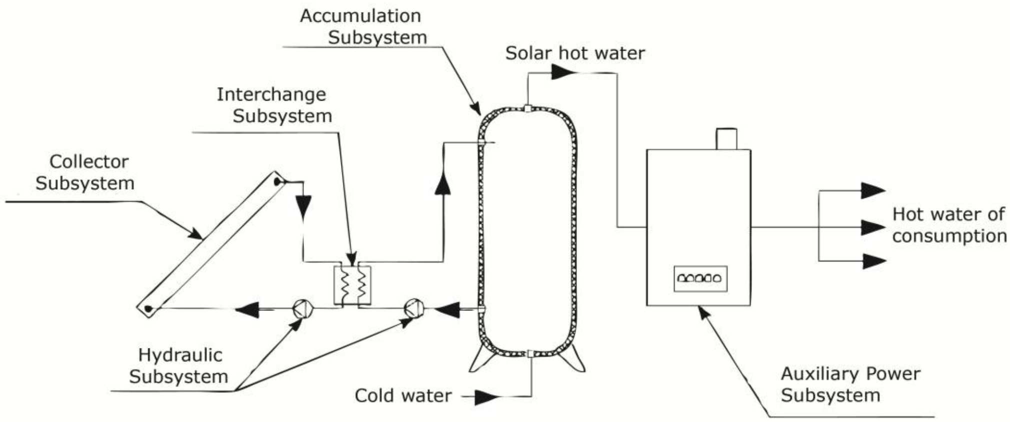
The operation principle of the solar collectors is based on collecting solar radiation, through the wavelengths coming from the sun. This device takes advantage of that radiation and transfer the heat to a heat transfer fluid to be used.

The solar collectors are used mostly for:

- Hot Water (DHW)
- Heating
- Pool Heating

5.3.1 | Components

The main elements of a solar thermal system are shown below, divided into subsystems of operating:



5.F. 4: Scheme of operation of a solar thermal installation

Collector subsystem - Solar collector (Heat Pipe)
The solar radiation incident on solar collectors raises the temperature of a fluid. This fluid called heat transfer fluid and is located inside the tubes.

Interchange is carried out through use of heat pipe:

- Hollow tube closed at both ends, subjected to a vacuum. Contain a small part of one vaporized fluid (mixture of alcohol) in its interior.
- When is heated the tube where is the fluid is inside, it´s evaporates, absorbing the latent heat of vaporization.

This vapor moves to reach the tube part that is at a lower temperature, producing condensation and releasing its latent heat associated with this state change. The fluid returns by gravity and capillary action and then the evaporation-condensation cycle repeats. The heat pipe solar collectors have the follows advantages:

- Lower heat losses
- Increase the efficiency, the solar absorber enclosed in a glass capsule from which air is extracted.
- Increase the possibility of architectural integration.

5.R. 1: Dimensionamiento Básico de Instalaciones Solares Térmicas

Accumulation subsystem – Tank

The main element of the subsystem of accumulation is the storage tank, whose purpose is to store thermal energy in form of hot water, in an efficient way, avoiding the losses of heat and favouring the stratification inside.

The high degree of stratification of the storage tank means greater efficiency of the installation because:

- The water from the bottom of the tank is sent to the exchanger to grasp thermal energy. As the water of this part is coldest, this favours transfer efficiency. Therefore the inlet pipes of cold water are placed at the bottom.
- With respect to the dimensions of the tank, the height-diameter ratio must be such that:
- The height is higher than the diameter, the tank has vertical configuration to promote the stratification and supply heated water to a constant temperature.
- The ratio between the outer surface and the volume is low to reduce the heat losses.

5.R. 2: Guia Solar Termica

Interchange subsystem

The interchange subsystem is used to prevent calcareous incrustations in the collectors, to eliminate possible corrosion problems, to allow the use of antifreeze as anti-freeze system and to use collectors with lower operating pressure to the network.

The heat exchangers are characterized by the thermal input, its effectiveness (or thermal efficiency) and the pressure drop.

5.R. 1: Dimensionamiento Básico de Instalaciones Solares Térmicas

Hydraulic subsystem

The circulation pump is used in forced circulation installations to the produce movement of fluid between collectors and accumulator.

Operating conditions:

- The pumps are characterized by the operating conditions presented, for a given working fluid, the volume flow and pumping height.

Installation:

- The pumps will be installed in line with the horizontal axis of rotation and with enough space for the motor-rotor to be easily disassembled.

Auxiliary power subsystem

The auxiliary power subsystem must be designed and calculated to supply the full demand of hot water and, in that sense, it should be considered as conventional heating water.

For the connection to a solar system are required the following aspects:

- The outlet temperature of the solar storage tank can vary over a wide range.
- The auxiliary heating system should not interfere with the process of use of solar radiation.
- Coupling must be optimized for the maximum assembly performance.

It is necessary that the water in the direction of circulation is heated first in the solar collector and then it passes through the auxiliary system before it is consumed.

5.R. 2: Guia Solar Termica

5.3.2 | Study and size

To make the sizing of a solar collector's installation in Komossa, the consumers have been divided into three types, depending on the house size, the annual consumption of electricity and heating.

Due to the difficulty of the calculations to performed the size and obtain a realistic result, we used a software called Polysun 5.1, which calculates the size taking into account many different parameters. The parameters included are: geographic location of the installation, type of household, number of inhabitants, daily water consumption, type of heating, and temperature inside the house.

5.R. 3: Software for the Renewable Energy Sector

Below the three categories of buildings are shown for which there will be a different sizing according to the needs of each.

Group 1: Small users

- Homes < 120m2
- Electricity use: <5 000 kWh/year
- Heating need: 5 000 – 15 000 kWh/year
- Approximately 48% of all buildings

Group 2: Medium users

- Homes 120m2 – 200m2
- Electricity use: 5 000 – 10 000 kWh/year
- Heating need: 15 000 – 30 000 kWh/year
- Approximately 36% of all buildings

Group 3: Large users

- Homes >200 m2
- Homes + garage/workshop/farm buildings
- Electricity use: > 10 000 kWh/year
- Heating need: > 30 000 kWh/year
- Approximately 16% of all buildings

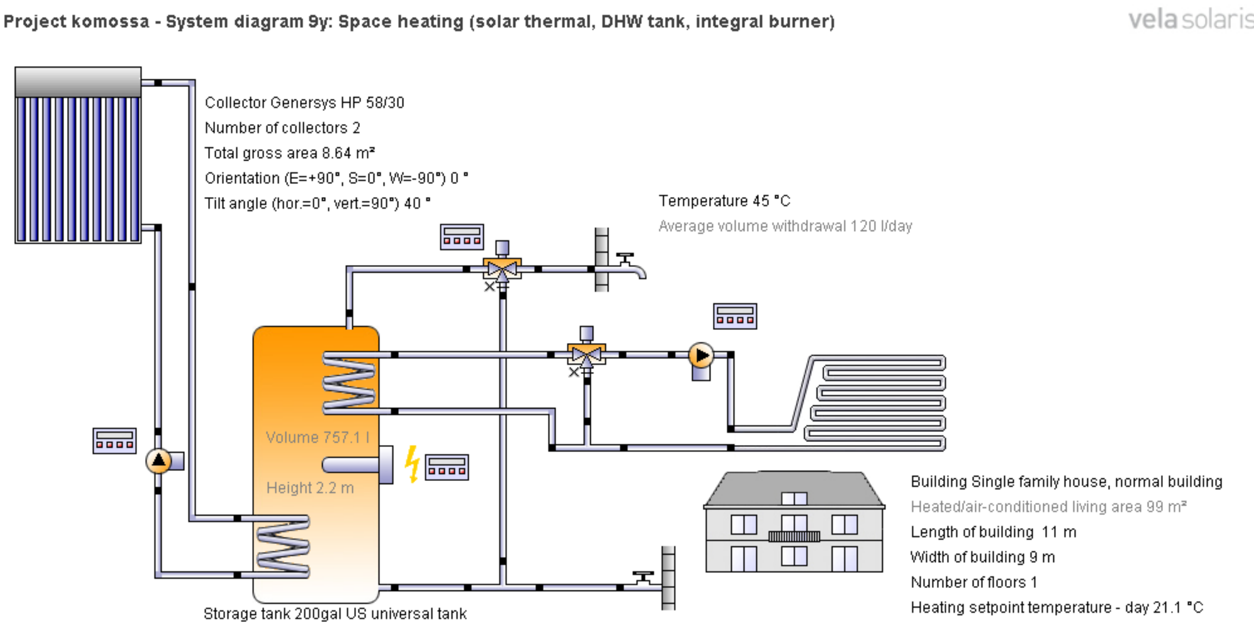
Other factors that may affect sizing are those related to meteorology and the Komossa area:

- The global solar radiation on the collector plane.
- The ambient temperature.
- Proportions of direct and diffuse radiation.
- Peak irradiance.
- Air velocity

5.3.2.1 | Small Users

First the sizing for small users is done that is, less than 120 m2 per house, no more than three persons, with an annual electricity consumption for heating of 5000 - 15 000 kWh per year.
The exact values chosen for this sizing are:

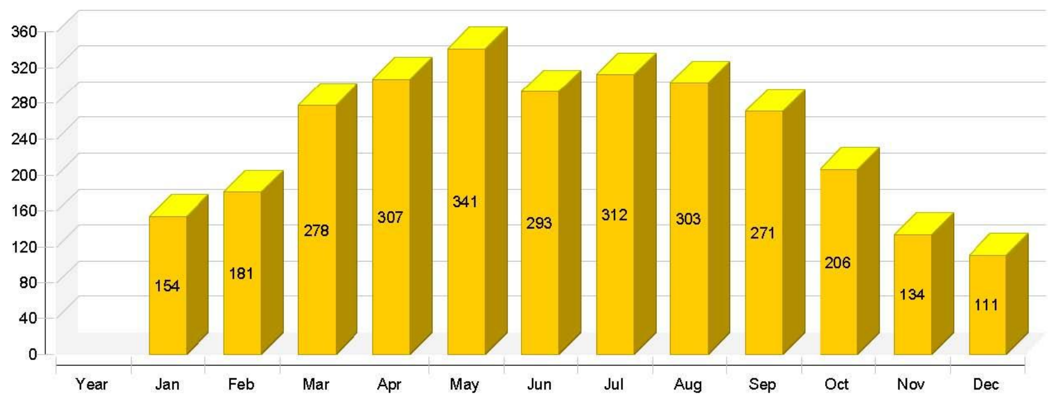
- 3 persons with a daily consumption of 120 liters of DHW, 40 per person
- The size of the house is 99 m2, and one floor.
- The desired water temperature is 45 degrees.
- The temperature inside the house 21 degrees.
- Underfloor heating



5.F. 5: Scheme of the installation for small users

Two vacuum tube collectors are used with a total area of 8.64 m. The water tank needs at least 648 l capacity, for this study is chosen one of 757 l. Data about the components. The energy efficiency of this installation can be found in appendix

5.A. 4: Data of a 'small user' installation



5.F. 6: Solar thermal energy to the system (small users)

Effective purchase cost after grants	11000-12000 €
Annual energy cost savings	427 €
Solar energy cost per kWh	0,141
Payback time	16-17 years

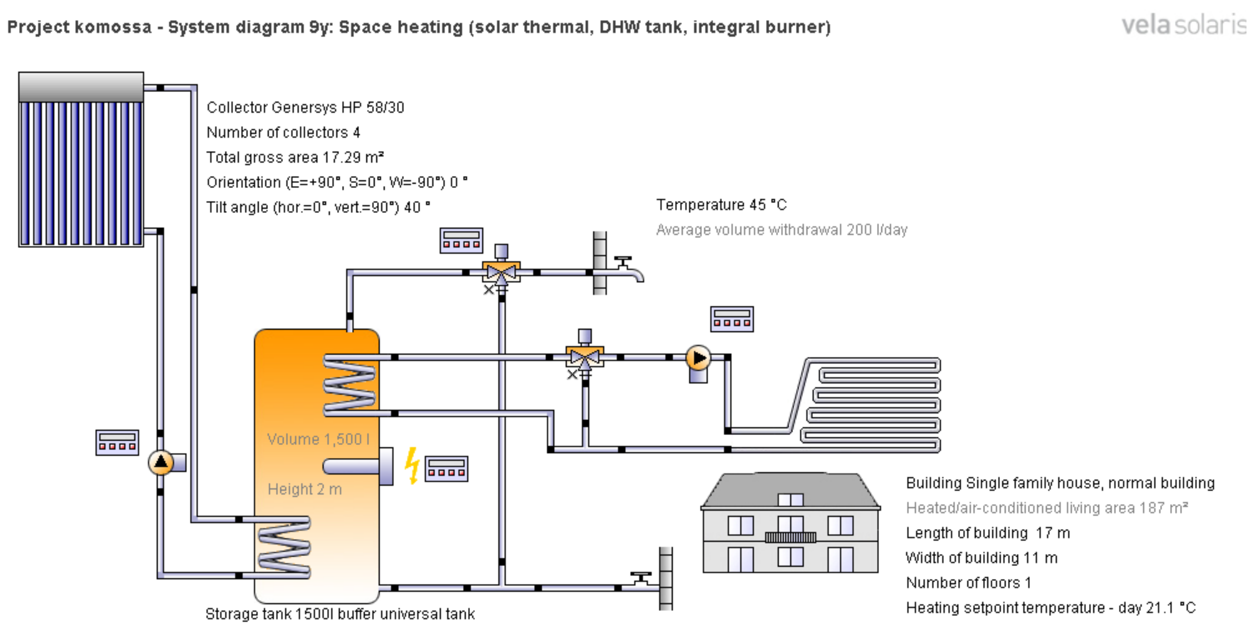
5.T. 3: Investment cost savings per year and payback time for small users.

5.3.2.2 | Medium Users

The second thing that is done is the sizing for medium users. Homes between 120 and 200 m2, where between four and six persons live. These users have an annual electricity consumption for heating of 15000 – 30000 kWh per year.

The exact values chosen for this sizing are:

- 5 persons with a daily consumption of 200 liters of DHW, 40 per person
- The size of the house is 187 m2, and one floor.
- The desired water temperature is 45 degrees.
- The temperature inside the house 21 degrees.
- Underfloor heating.

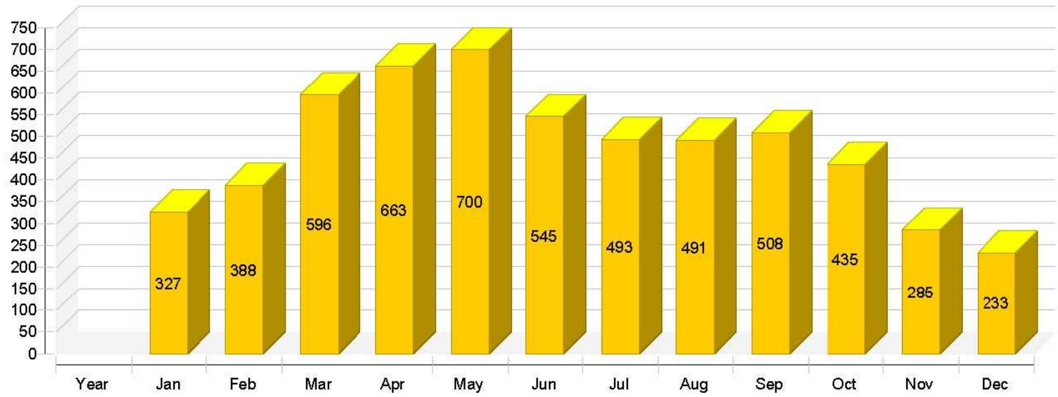


5.F. 7: Scheme of the installation for medium user

Four vacuum tube collectors are used with a total area of 21.61 m2. The water tank needs at least 1340 l capacity, for this study is chosen one of 1500 l. Data about the components, and energy efficiency of this installation can be found in appendix

5.R. 4: Data medium users installation

5.A. 5: Data of a 'medium user' installation



5.F. 8: Solar thermal energy to the system (medium users)

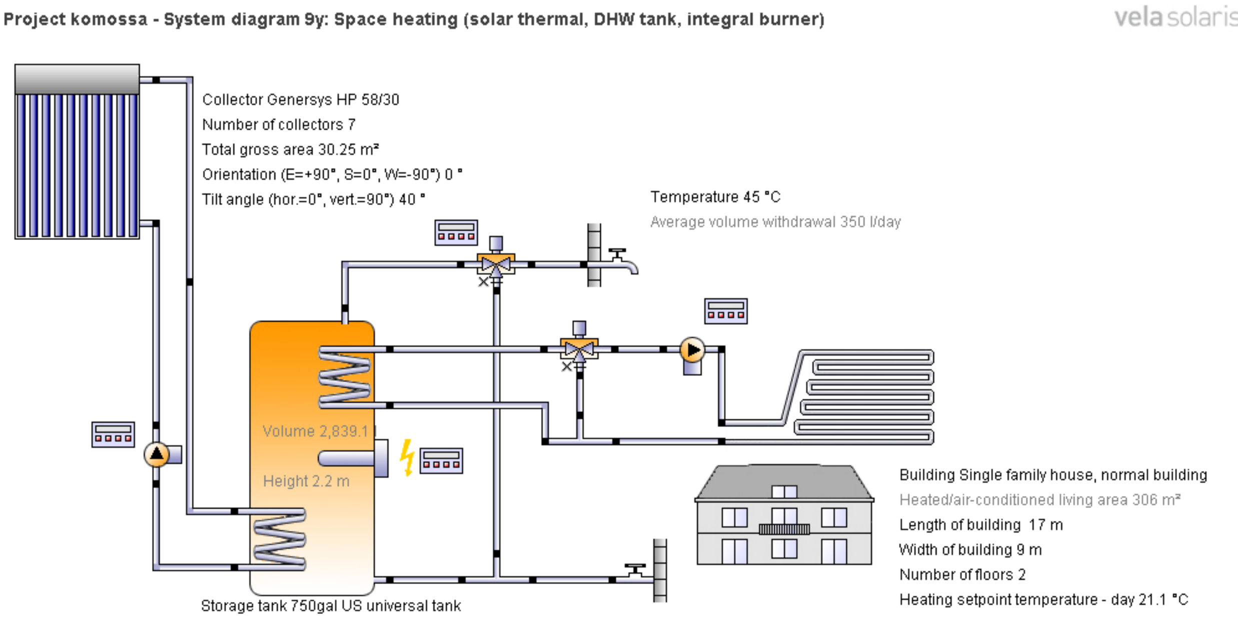
Effective purchase cost after grants	**12000 -13000 €**
Annual energy cost savings	834 €
Solar energy cost per kWh	0,096
Payback time	13-14 years

5.T. 4: Investment cost savings per year and payback time for medium users

5.3.2.3 | Large Users

Lastly the sizing for large users is done. Homes over 200 m2, where between four and seven persons live. If there is a farm the consumption of domestic hot water (DHW) is high and the same for the calorific demand. The annual electricity consumption for heating is about 15000 – 30000 kWh per year.
The exact values chosen for this sizing are:

- 7 persons with a daily consumption of 350 liters of DHW, 50 per person
- The size of the house is 306 m2, and two floors.
- The desired water temperature is 45 degrees.
- The temperature inside the house 21 degrees.
- Underfloor heating

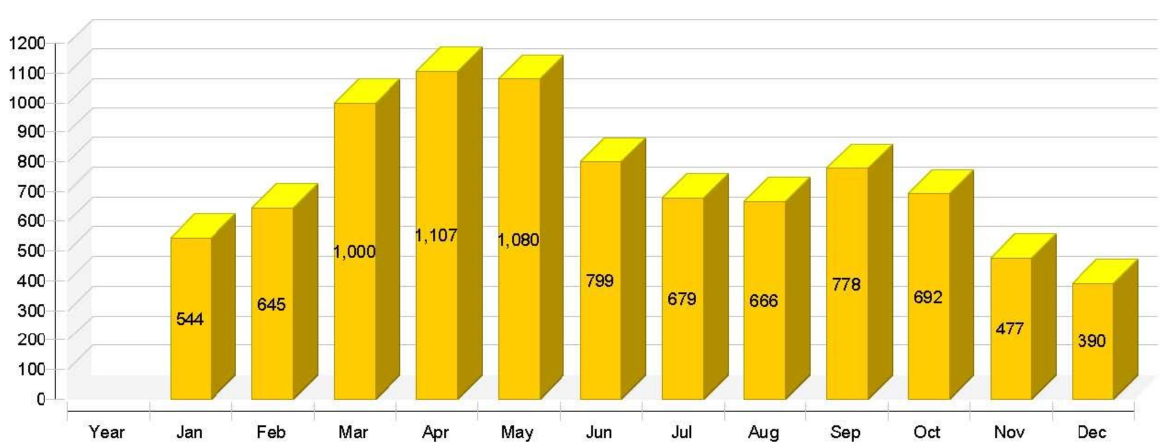


5.F. 9: Scheme of the installation for large users

Five vacuum tube collectors are used here with a total area of 30,25 m2 The water tank needs at least 2550 l capacity, for this study is chosen one of 2839 l. Data about the components, and energy efficiency of this installation can be found in appendix

5.R. 5: Data large users installation

5.A. 6: Data of a 'large user' installation



5.F. 10: Solar thermal energy to the system (large users)

Effective purchase cost after grants	26000-24000 €
Annual energy cost savings	1305,33 €
Solar energy cost per kWh	0,100 €
Payback time	15-16 years

5.T. 5: Investment cost savings per year and payback time for large users

5.4 | Conclusion

The conclusion that can be made from this study is that solar energy covers perfectly the energy needs of an average family in the spring and summer months, but in the autumn and winter it is impossible to depend solely on solar energy. Tripling the number of solar panels and with them the costs, during November, December and January, won´t it be enough to cover the needs. For the autumn and winter months, it is necessary to combine solar energy with some other type of energy, such as wind power.

As seen in the study, one of the possibilities of solar photovoltaic energy is to use it in the summer cottages. When used in summer months, the necessary production of electricity in these months is guaranteed, and with a small equipment, one quarter of the amount used in this study, one summer cottage can be self-sufficient.

With regard to the solar collectors, they are able to give the necessary energy to supply the needs in the winter months using the built-in electric heater, located in the tank.

In terms of payback time it is noted that these facilities are more cost effective for medium users, because the relationship between the size of the installation and the cost of this is lower.

The small users should make a high first payout, both by the installation of the main components, such as the pipe connections to all the components, and the benefit obtained from them in a long term, is small. The users don't obtain high savings with respect to the heating system that they had before. Large users must make a high first payout for all main and distribution components, combined with high energy demands that they need, make the performance of the installation decreases compared with other users.

6 | Biomass energy

6.1 | Introduction

Biomass is an important source of renewable energy. The most used type of biomass both today and historically is wood, but there are many different types of biomass that can be used to produce energy.

Biomass can be defined in the following two ways, first from an ecological point of view and then as a source of energy:

1. *Ecology: "The amount of living matter in a given habitat, expressed either as the weight of organisms per unit area or as the volume of organisms per unit volume of habitat."*

6.R. 1: Dictionary Reference

2. *Energy: "Organic matter, especially plant matter, which can be converted to fuel and is therefore regarded as a potential energy source."*

6.R. 1: Dictionary Reference

When talking about biomass energy, plant matter is the most common base of fuel, but biomass energy can come from any vegetable or animal material. Biomass material can be converted into useful energy in different ways. The most commonly used way to produce energy from biomass is by direct combustion to produce heat and electricity. Biomass can also be used to produce biogas in biogas reactors, or to produce bio fuels like biodiesel or ethanol.

In this chapter the main point will be on biomass as a possible energy source for the heating needs in the village of Komossa. The different possibilities to use biomass as a source of heating in the homes and other buildings in Komossa will be investigated.

6.2 | Biomass energy in general

6.2.1 | Chemical composition

Generally one can say that biomass energy is produced from solar energy, carbon dioxide and water. "Biomass is a carbon based fuel composed of a mixture of organic molecules containing hydrogen, usually including atoms of oxygen, often nitrogen and also small quantities of other atoms, including alkali, alkaline earth and heavy metals".

6.R. 2: Wood energy

In the photosynthesis process carbon is collected from the air and stored in the plant. When the plant is broken down or burned later on, the carbon is released back to the atmosphere. This

process is called the carbon cycle and is the reason why biomass energy is not considered to increase the amount of carbon dioxide in the atmosphere.
6.R. 2: Wood energy

6.2.2 | The difference between biomass and fossil fuels

Both biomass and fossil fuels like oil and coal are carbon based fuels. Like the biomass fuels, fossil fuels originate from plant and animal material. The difference is the time scale. Fossil fuels are formed during millions of years opposed to the biomass which will have a much shorter cycle from collecting the carbon, breaking it down or burning it and back to collecting carbon again. For biomass fuels this time can be from one year to 100 years depending on the type of plant material. The important part is that in a well-managed biomass energy system, the amount of plant material harvested for energy use, may it be crops or wood or other material, is always replaced by new plants and in this way maintains a closed carbon cycle with no net increase in atmospheric carbon dioxide levels.
6.R. 2: Wood energy

6.3 | Categories of biomass materials

As in the definition of biomass energy, the material can come from a wide range of different sources. Almost any kind of biomass could be used to produce energy. The factor that limits which materials that can realistically be used for energy production is usually the economical factor. If a material has a higher value used in other ways than in energy production, it is very unlikely to be considered as a good and economical energy resource. For example, high quality grain can be more valuable sold as food or animal feed than used as a source of fuel. A good biomass energy material is often residues that have no or little value for any other use than energy production. A good example of this is different kinds of wood residues. Other important factors are the characteristics of the materials, and the technology available to use the material in an economical, correct and efficient way. For example one type of material can be impossible to use in a direct combustion type of system, but can be a very good material in a biogas type system.

The different kinds of biomass material for energy production can be divided into five main categories. These categories are:

- Wood
- Energy crops
- Agricultural residues
- Food waste
- Industrial residues

6.3.1 | Wood

Wood is the oldest kind of biomass used for energy production. Today wood is the largest and most commonly used source of biomass energy in general. Of all renewable energy used in Finland today, wood is by far the most used source. This is mainly because of the large forest industry in Finland that produces a lot of wood based residues used in large scale energy production. But also in smaller scale energy production, heating of buildings, wood is a commonly used energy source.
6.R. 2: Wood energy

There are many kinds of wood material used in energy production. One type is different kinds of residues from industrial production like sawdust and bark from timber production.
Another type of wood fuel is different kinds of wood material collected directly from the forest. This can be small diameter trees or other residues from timber harvesting, like stumps and branches.

For smaller scale use, the type of wood fuels used will be firewood or wood chips made from smaller diameter trees or other trees that aren't suitable for timber production. Another popular type of wood fuel for smaller scale use is wood pellets, an industrially made product usually based on sawdust.

6.3.2 | Energy Crops

Energy crops are crops that are cultivated on ordinary farmland specifically for use in energy production. Some important factors for a good energy crop is the energy yield per area, cost and technology required for cultivation, fuel characteristics, technology needed to burn the crop and so on. Important limiting factors are the amount of available farmland and the economy of energy crop cultivation compared to traditional agricultural food or animal feed production.

Energy crops can usually be divided into two different types: grass like crops and wood like crops. Examples of wood type energy crops are willow and poplar. Examples of grass like energy crops are reed canary grass and industrial hemp. For biogas production one important energy crop used in Europe is corn.
6.R. 3: Bio Energi Portalen
6.R. 4: Energy crops

6.3.3 | Agricultural residues

Different agricultural residues can be used for energy production. They are usually divided into two different main categories: dry residues and wet residues. Dry residues can be crop residues such as straw, used animal bedding, and feathers. Wet residues can be animal manure or slurry, and leftover grass silage. The wet residues can economically only be used in biogas production because of the high moisture content which make them unsuitable for direct combustion. The dry residues can make a good fuel for heating if the material are readily available and can be collected dry enough. The problem is usually the technology available to use the fuel.
6.R. 2: Wood energy

6.3.4 | Food waste

"Food waste is usually produced in some amount in every step of the food supply chain. That means from production, industrial processing, distribution and consumer waste. Examples of different waste from food processing are peel, skin, fish residues, pulp etc. One large source is residues from different brewing processes".
Common for all different food waste is a high moisture content which makes this category of biomass most suitable for biogas production.
6.R. 2: Wood energy

6.3.5 | Industrial residues

Industrial residues as a potential biomass energy source can be divided into two categories: wood type residues and non-wood type residues. Wood type residues, other than those originating from the forest industry already mentioned, can be packaging material, wooden pallets and wood leftovers from construction work. Examples of non-wood industrial residues are waste paper, textiles and sewage sludge. These different industrial residues can be a biomass energy source where the material is readily available. The industrial wood residues and some of the non-wood type materials will be a good fuel in direct combustion types of systems. However one problem may be different kind of contaminations in the material. These contaminations can be foreign objects like metal, concrete and dirt, or there can be chemical products used in the industrial processing which can make the material unsuitable as an energy source due to environmental hazards if the material is used in energy production.
6.R. 2: Wood energy

6.4 | Potential biomass energy sources in Komossa

6.4.1 | General

In this part some of the potential biomass sources in Komossa are presented. From the different biomass energy categories the most likely sources of fuel for use in different direct combustion systems mainly for the heating needs in Komossa, have been researched. Attention has been paid to many different factors, e.g. geographic location, available farmland and forestland, available technology and economical aspects etc. One important result from these studies is the amount of theoretical potential energy of each of the different biomass sources in Komossa. Note that the potential energy is only an estimation and also that the estimations are the theoretical fuel potential. The amount of useful energy from each energy source will depend on the efficiency of the plants used to convert the fuel into useful energy.

6.4.2 | Wood

Wood can most likely be used as fuel in form of wood chips for burning in wood chip burning plants or as traditional firewood used in small wood burning boilers/stoves. Wood could also be processed into wood pellets to be used in wood pellet burning systems. The amount of potential fuel available depends on the forest area available, the annual growth of the forests, age of the forests, tree species etc. To maintain a sustainable use of wood as an energy source, the average outtake volume of wood per year can't be allowed to be any larger than the average growth volume per year.

6.F. 1: From firewood wood to woodchips and wood pellets.

The different forest data from Komossa and general data for wood fuel are given. From this forest data it can be estimated that the total theoretical energy potential from the forests in Komossa can be in the range of 6000 MWh/year. The data can be found in appendix
6.A. 1: Forest and Wood data

6.4.3 | Energy crops:

Depending on the type of energy crop, possible ways of using energy crops as a fuel source for the heating needs in Komossa include: mixing chopped energy crop material with wood chips in wood chip burning plants, using dedicated plants for either whole baled energy crops or chopped energy crop material.

Some energy crops that are used today in different scales for energy production in Finland, and could be used as fuel for energy production in Komossa are:

- Reed canary grass (swe.rörflen)
- Industrial hemp (swe.industrihampa)
- Willow (salix, swe.vide)

The amount of fuel that could be produced from energy crops depends on how large energy yield can be harvested from the different crops and how much field area could be used for energy production. According to the research done, the total area of the fields in Komossa is about 970 ha. Of this area around 50 % is needed for feed production for farm animals in the village. Therefore it is estimated that the largest theoretically available area for energy crops could be around 400 ha, which is the amount used to calculate the energy potential for the energy crops.

6.4.4 | Reed canary grass

Of the energy crops tested in Finland, reed canary grass seems to be the most promising. Reed canary grass is a perennial plant that grows naturally in Finland. The plant can reach a height of 1,5 to 2,0 meters. The crop can be cultivated and harvested with ordinary farming equipment. The crop is usually harvested in springtime when the ground is still frozen. This gives a dry material when harvested. The material can be harvested using mainly two different methods. The material can be bailed and handled in large round or square bales, or the material can be chopped to a short loose material. As a fuel, reed canary grass is usually a fuel used at large power plants, where it is mixed together with other fuels, like wood chips or peat. To be used in smaller scale energy production, a dedicated burning system is needed. Another possibility is to make pellets from the reed canary grass. These pellets will then have equal properties as wood pellets and can be burned in wood pellet systems.

6.R. 5: Canary grass

6.F. 4: Fields of canary grass

6.F. 3: Chopped canary grass

6.F. 2: Baled canary grass

An average yield of reed canary grass in Finland is 4 – 5 ton/ha. The energy content at below 25 % moisture is around 4 MWh/ton. This gives an average energy yield of 16 – 20 MWh/ha/year. If grown on 400 ha, this would give a theoretical fuel potential of 6400 – 8000 MWh/year.

6.4.5 | Industrial Hemp

Industrial Hemp is one of the faster growing energy crops known. It can produce up to 25 ton of dry matter per hectare per year in ideal conditions. In Finland the average yields have been in the range of 6 - 10 ton dry matter per hectare per year, reaching up to 15 tons at best. Industrial hemp, like the reed canary grass is a grass type crop. It can be cultivated and harvested much in the same manner as reed canary grass. As a fuel, industrial hemp is also very similar to reed canary grass.

6.R. 6: Other field biomass

6.R. 7: Turku AMK

6.F. 5: Field of industrial hemp

6.F. 6: Industrial hemp being harvested

The energy content of industrial hemp is in the range of 4,8MWh/ton. This would give an average energy yield of 30 – 50 MWh/ha/year. The theoretical fuel potential in Komossa would be about 12000 – 20000 MWh/ha/year.

6.4.6 | Willow

Willow is a rapidly growing perennial tree species that is grown on farmland for energy production purpose. The growth is harvested every 3 - 4 years and a field of willow can be productive for about 20 years without the need to replant. When harvested, the willow is chopped to a material with the same properties as ordinary wood chips, only more moist, usually around 50 % moisture. For both cultivation and harvest, special dedicated equipment is needed. *6.R. 3: Bio Energi Portalen*

6.F. 7: Willow field being harvested

In Finnish studies, the dry matter yield per hectare has at best been around 10 ton / year. The energy content is 18 – 19 MJ/kg dry matter or 5,0 – 5,3 MWh/ton. This would give an energy yield of 50 – 53 MWh/ha/year at best. The total theoretical fuel potential in Komossa would then be up to 20000 MWh/ha/year.

6.4.7 | Agricultural residues

There are mainly two potential sources of agricultural residues for energy production in Komossa. One is manure from the different animal production in the village. The manure can only be used for energy production in a biogas production system and is therefore not further investigated in this chapter. The other source is straw from grain production. The straw can be used in direct combustion if used in proper, dedicated straw burning systems. The straw can be used as loose chopped material or made into pellets. A common problem for every type of straw burning system is the large amount of ash. The ash problem makes straw a fuel only suitable in larger burning systems of over at least 1500kw power where the ash problem can be handled in a more efficient and economical way.

6.F. 8: Grain field being harvest and baled straw

The energy content of straw is 17.4 MJ/kg or 4,8MWh/ton and an average straw yield in the area can be 3000 - 4000 kg/ha. If collected from the same 400 ha area, the total theoretical fuel potential from straw would be 5760 – 7680 MWh/ha/year.

6.4.8 | Fuel data used in calculations

For all the above calculations, the energy content for the fuels has been calculated according to the fuel data. Calculating exact energy contents for different kinds of biomass fuels can be difficult because the moisture content may vary from case to case depending on factors like weather, harvest method etc. Extra information can be found in appendix
6.A. 2: Fuel data

6.5 | Technical specifications

6.5.1 | General

In this part some of the most common types of technical solutions for using the different types of biomass energy fuels will be explained. The type of solution needed depends on a lot of different factors. The most important factors are: type or types of fuels that will be used and how much heating is needed for the specific situation.

The heating solutions for biomass fuels in home heating are: wood burning boiler, wood fireplace, wood pellet burning system and wood chip burning system. These different systems will be described below.

6.5.2 | Wood burning boiler

In a wood burning boiler system, the wood is burned in a boiler usually located in a separate fireproof place of the home. Water in the boiler is heated by the combustion and the hot water from the boiler is then stored in a tank. From the tank the heat is transferred in a waterborne system to heat the building. The heat transfer from the waterborne system to the rooms can be through heat pipes in the floor, floor heating, or through wall mounted radiators. Hot water can be drawn from the boiler or from the tank through a separate hot water coil. For a regular home the power of the boiler us usually in the range of 20 – 50 kW, depending on the size and amount of heat needed in the building. The total efficiency of a well maintained and well planned wood boiler system is in the range of 80 %.

Another option for wood burning in a home is to have one or several wood burning fireplaces or stoves in the building. In Finnish conditions these fireplaces are usually only used as a compliment to other heating systems, to lower the heat needed from the main heating system. The fireplaces are used to lower the heating costs or to help the main heating system if more power is needed during very cold weather. The efficiency of the different fireplaces or stoves is usually lower than a regular wood boiler system and can vary much between different types and installations.

6.R. 8: Firewood boilers

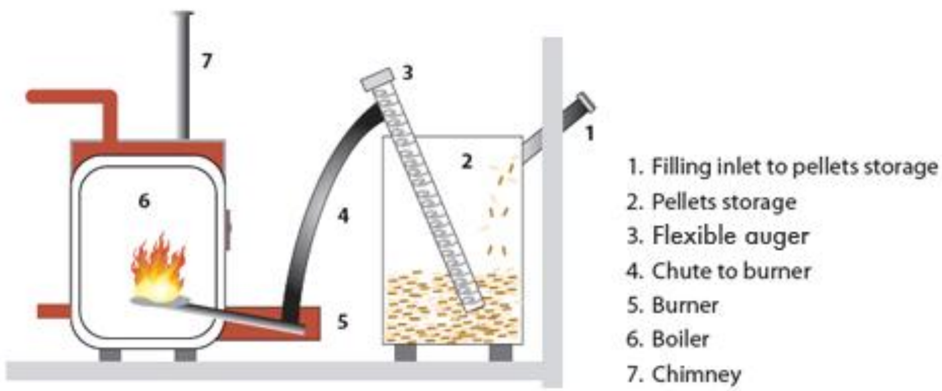
6.F. 9: Wood burning iron stove

6.F. 10: Open fireplace.

6.5.3 | Wood pellets

A wood pellet burning system is built much in the same way as the ordinary wood boiler system. The system contains the same parts: boiler, tank and waterborne radiators or floor heating etc. The difference is that a wood pellet burner is connected to the boiler. The wood pellets are stored in a storage tank located close to the boiler. From the storage tank the pellets are mechanically fed to the pellet burner. The wood pellet burner is an automated system with little maintenance work needed. An old wood or oil burning system can usually be upgraded to a pellet burning system with relatively small investments.

6.R. 9: Woodpallet solution



6.F. 11: Sketch of pellet burning system

6.5.4 | Wood chips

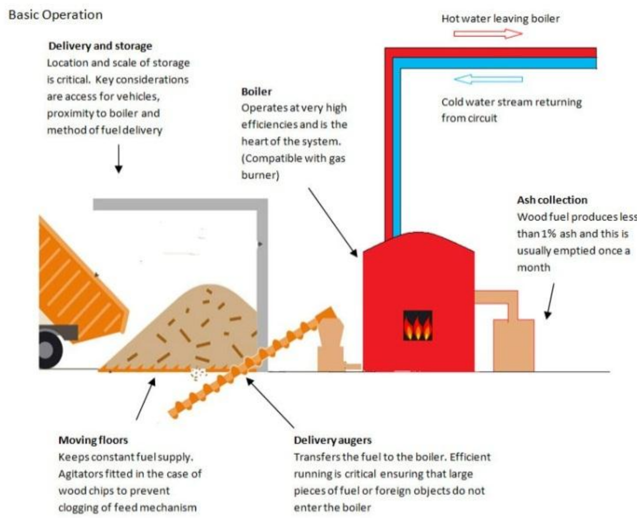
For larger heating needs, a wood chip burning system can be interesting. The basic technology of a wood burning system is the same as for the other systems; the basic components are the same: boiler, tank and waterborne radiators or floor heating etc. The difference is in the wood chip feeding and burning system. Compared to wood pellets, wood chip is a more irregular fuel. The wood chip generally consists of larger irregular pieces and can contain both oversize pieces and smaller pieces, sticks and branches or dust. In addition, wood chip fuel also contains more or less moisture. All this affects the handling of the fuel in the feeding system, which means that a wood chip feeding system and burner needs to be larger and more robust and therefore more expensive than a wood pellet system.

The system consists of a storage tank for the wood chips, feeding system to the burner and the burner itself. From the storage tank the wood chip is fed to the burner which is connected to the boiler. The wood chips are ignited in the burner and then the power is regulated by adjusting the feed rate of the wood chip feeding system and the amount of air blown into the burner. The process is automated and usually need little maintenance except filling of the wood chip tank when low on fuel. Wood chip burning systems are very effective and can have an efficiency of

80 – 90 %. These types of systems can be made in a power range from 20 kw to 1000 kw or even larger.

6.R. 10: RHI advisor

6.R. 11: ALA talkkari



6.F. 12: Basic operation of a wood chip burning system

6.5.5 | Other systems

The different systems above are the common biomass fuel systems for smaller scale use. For larger scale heating systems, for example district heating systems, there are more different system solutions for the different biomass fuels. One example of these is large plants similar to ordinary wood chip burning plants, but with improved, usually much larger feeding systems and burner to be able to use different biomass fuels like reed canary grass or straw usually mixed together with wood chips. These plants also need better capacity to handle the larger amounts of ash compared to wood chips. Another type of larger plants for biomass fuels is one type that reminds a little of an ordinary wood burning boiler but in a much larger scale. These plants are made to be loaded with whole bales of straw or canary grass or other types of fuels, which are then burned in a large furnace. These types of plants can handle almost any kind of biomass fuels, but they demand more work for loading the fuel and removing the ash.

6.R. 12: MTT report

6.F. 13: Large biomass boiler

6.F. 15: Bales burning in a large biomass boiler.

6.F. 14: Inside of a large biomass boiler

6.6 | Advantages and disadvantages of the different biomass fuels

6.6.1 | Category: Wood

Traditional firewood:

+ Low price, both base material and processing of the wood cheap.
+ Basic and reliable heating system, relatively low investment cost for system.
+ Wood heating systems likely found in a lot of houses in Komossa already.

+/- Wood heating system best suited for smaller heating requirements, like homes, not large buildings.

- Labor demanding, both processing and handling of the wood requires daily work, filling more wood in boiler and igniting several times per day when cold
- Manual work, no automation
- Not well suitable for larger scale heating because of the large amount of work needed

Wood pellets:

+ Lower fuel cost than oil or electrical heating
+ Upgrading from wood or oil heating to pellets relatively small investment, about 2500 € for a pellet burner for a home
+ Automatic system, very little work required
+ Suitable for smaller heating requirements like homes

- Higher fuel costs than wood or wood chips, due to the more demanding process to manufacture wood pellets
- Pellets manufactured in large factories, the pellets have to be bought from outside the village

Wood chips:

+ Effective, automated system
+ Well suited for large heating requirements, like farms, schools, large buildings
+ Relatively cheap fuel, easy to process and handle
+ Both base material and processing available in Komossa
+ Some existing systems already in Komossa
+ Well suited in a district heating system

- High investment costs for a wood chip burning system (starting from about 20 000 € - 30 000 € for smaller systems about 60 kW)
- Not well suited for small heating requirements, both due to high investment costs and technical reasons

6.6.2 | Category: Energy crops

Reeds canary grass:

+ Relatively large energy yield
+Can be cultivated and harvested using ordinary farming equipment already available in Komossa
+ Harvested in spring time, when the ground is still frozen and most of the snow has melted, gives a dry material
+ Can be made into pellets with the same properties as wood pellets

+/- Used as chopped material or as whole bales in larger power plants, or in dedicated biomass combustion systems

- Takes up farmland that could be used for other purposes
- No existing systems in Komossa to use chopped or whole reeds canary grass, the material would have to be made to pellets to be used in pellet burners or existing wood chip systems
- Higher fuel cost than wood chips

Industrial hemp:

Basically the same properties as reeds canary grass, only a different crop with slightly larger energy yield. Otherwise industrial hemp has the same advantages and disadvantages as Reeds canary grass.

Willow:

+ Large energy yield
+ Only needs to be harvested every 3-4 years
+ After planting, a willow field can produce energy for 20 years forward (harvested 5 – 6 times without need to plant new crop)
+ When harvested, willow is chipped to a material with the same properties as wood chips, only more moist
+ Can often be used in ordinary wood chip burning systems, usually mixed together with dryer wood chips to lower the overall moisture content of the fuel, or if the moisture content isn't a problem in the specific system, 100 % willow chips could be used.

- Special equipment needed for planting and harvesting
- High moisture content, can be a problem
- Takes up farmland that could be used for other purposes

6.6.3 | Category: Agricultural residues

Straw:

+ Already existing material in Komossa

- Needs dedicated burning systems to be used efficiently
- No existing burning systems in Komossa
- Harvesting dry straw can be difficult, depending on the weather

6.7 | Conclusions about the different biomass fuels

- Wood category fuels, a good option for Komossa
  - Already in use, existing systems and experience
  - Relatively low prices
  - Room to develop and use more

- Energy crops and straw
  - Large energy potential
  - Relatively low price of fuel
  - No existing systems for using the fuel
  - High investment cost in new systems

6.8 | Economic aspects

6.8.1 | General

When comparing and evaluating different fuels and solutions for heating there are many important factors. One is the economic factor. The economy of the different fuels and heating solutions depends on several factors. Fuel cost is one important factor but many other factors such as the investment costs, maintenance, longevity of the system etc. affect the total economy for any heating solution. First some of the most common biomass fuel options for heating a home will be compared to direct electrical heating and oil heating systems.

One important economic factor to consider when planning for new heating systems, is the ever increasing price rise of fossil fuels, oil and coal, together with increasing electricity prices. For the biomass fuels this increase in price is much less significant. This will probably lead to an even larger price difference between biomass fuels and fossil fuels or electricity in the future, which will make biomass even more important as an economical energy solution. This information is displayed in appendices

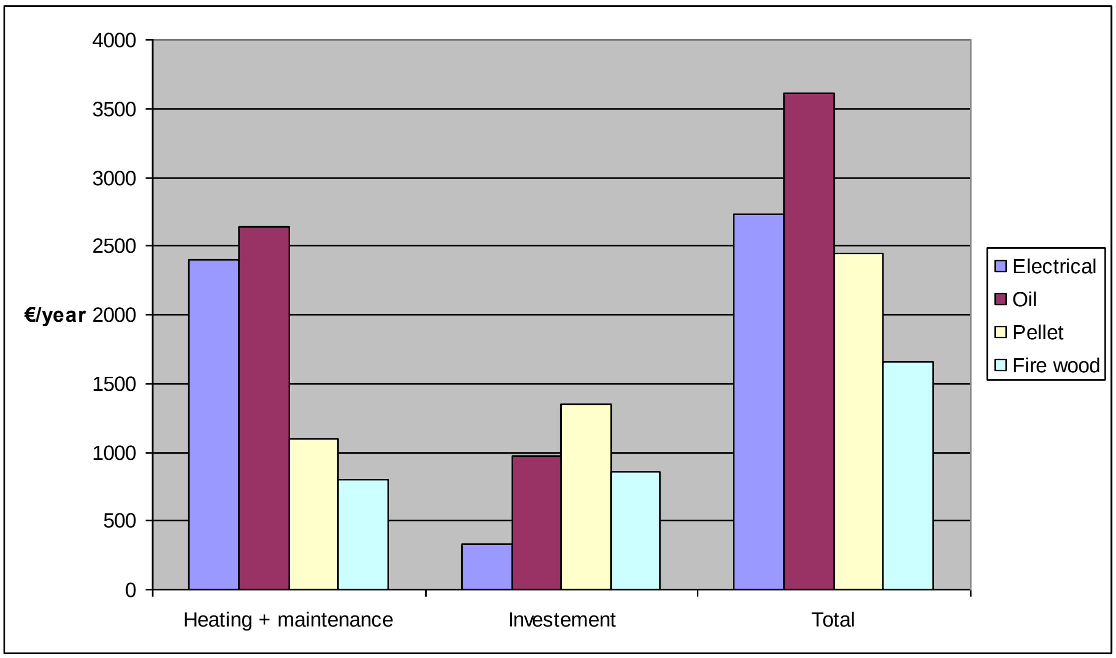
6.A. 3: General fuel prices in Finland today

6.A. 4: Price trends of fuels

6.8.2 | Economic comparison of the different solutions when building a new home

For this comparison the heating cost + investment cost for building a new heating system in a new house are added together. The house in the examples is an average size home of 150 m^2. The amount of energy for both heating and hot water for this house has been estimated to be 20 000 kWh/year. The energy prices used in the calculations are the existing energy prices today. The price development for the future isn't considered in these calculations.
The calculations are presented in appendix
6.A. 5: Heating systems when building a new home

Graphic comparison:



6.F. 16: Price comparison of heating systems

These results show that the biomass fuel heating systems can be a good economic alternative to consider when building a new house. This comparison is a general example, but there may be many specific factors to consider for every case.

6.8.3 | Upgrading existing heating systems to a biomass heating system

In this part the different possibilities to upgrade an existing heating system to a new biomass fuel system will be investigated. According to the research the three most common types of heating systems in Komossa are: direct electrical heating, fuel oil heating and firewood heating. The reasons for upgrading an existing heating system may vary between different cases, but some of the main reasons may be: economic reasons, practical reasons (work needed), technical reasons, environmental reasons or that the existing heating system might be old and near the

end of its technical lifetime. These are all important factors to consider in each case, but many of them can be difficult to compare or put a number on. The economic factor might be one of the most important factors, at least in some way in most of the cases. In this part the different economic factors are compared.
The different types of buildings and heating needs have been divided into three main categories; small, medium and large energy. The upgrading alternatives, cost and sizing all depend on specific requirements for each individual case, but these three categories will give an general indication for each group. For these different categories three biomass alternatives have been calculated: firewood, wood pellets and wood chips. See appendix
6.A. 6: Different groups of energy users in Komossa

6.8.4 | Replacements for existing heating systems in general

In the following a general indication matrix is given of the suitability for replacing each existing heating system with an alternative biomass heating system. The different groups of energy users are indicated by the numbers 1, 2, 3 for small, medium and large users.

	Firewood			Fuel oil			Electrical			Existing main heating system
Alternative heating systems:	1.	2.	3.	1.	2.	3.	1.	2.	3.	Group
Firewood	-	-	-	[blue]	[blue]	[yellow]	[red]	[red]	[red]	
Wood pellets	[yellow]	[blue]	[blue]	[yellow]	[blue]	[blue]	[red]	[red]	[red]	
Wood chips	[yellow]	[yellow]	[blue]	[yellow]	[yellow]	[blue]	[red]	[red]	[red]	

[blue] Suitable / Good option
[yellow] Might be suitable / average option
[red] Not suitable / bad option

In this matrix the existing direct electrical heating systems are not considered to be a good system to upgrade to a biomass system. This is because the biomass heating options are waterborne systems and if the existing main heating system is a direct electrical system, a complete new waterborne heating system would have to be installed leading to larger investment and installation costs. If one liked to lower the heating costs in a direct electrical heating system with biomass, one option would be to install a wood burning stove as a complement heating system, if not already existing.

6.8.5 | Economic calculations for upgrading alternatives

The economic aspects of the different upgrading options have been analyzed by calculating different costs caused by the heating system. The most important factors considered are: energy cost, maintenance, cost of equipment and material needed, interest cost and payback time compared to fuel oil heating.

The calculations can be seen in the following appendices:
6.A. 7: Heating costs for different heating systems
6.A. 8: Investment size for different heating systems
6.A. 9: Graphs of energy of maintenance costs for different heating options
6.A. 10: Graphs of size of investment for different heating options

The payback times have been calculated using an interest rate of 4 %. The savings are calculated compared to the cost of oil heating. The results of the payback time calculations depending on the different ranges of energy users are presented in the following table.

Payback times for different heating options when changing from an oil heating system:

	Group 1.	Group 2.	Group 3.	
Fire wood	6 - 20	5 - 8	4 - 6	Years
Wood pellet	17 +	13 +	9 - 18	Years
Wood chips	17 +	10 - 24	7 - 15	Years

6.8.6 | Conclusions about the economy of upgrading to biomass

From the calculations for the different energy options it is clear that the economy of the upgrading options depends on the amount of heating energy needed. If the existing heating need is very small, the savings of an alternative heating system will not cover a very large new investment. So for a very small energy user it can be difficult to justify a new biomass heating alternative with only economic factors. But the larger the existing heating need is, the larger the savings will be and can therefore cover a much larger investment and still be a good economic option with a relatively short payback time. The payback time will generally be shortest for a firewood heating system because of low investment costs and low fuel and maintenance costs. But a firewood heating system might still not be a very good option for larger heating needs, because of other factors, mainly the work needed. The other options, wood pellet and wood chips, can also be good economic options. Here the investment costs are larger, but if the existing heating need is large enough, the savings will cover the investment costs in an acceptable time.

7 | Biogas

7.1 | Introduction

Biogas is a mix of two gases with methane and carbon dioxide being the main components. It is produced as a result of fermentation of organic matter. The fermentation process is generated in a tank with no air inside allowing bacteria to produce this chemical reaction. This process is also called anaerobic digestion.
To feed this system there are a lot of organic wastes that make it possible to obtain biogas such as manure, energy crops, waste from landfill, straw and other organic waste. Depending on the fuel safety rules, dangerous bacteria or unexpected fungus should be controlled.
On the other hand, methane is one of the powerful gases that increase greenhouse gas. It is at least 20 times more pollutant than carbon dioxide. The farmers that store manure in direct contact with the atmosphere are contributing to global heating. By using the biogas technology the amount of contaminant emissions is reduced at the same time as energy is being produced.
As mentioned before, the main components of biogas are methane and carbon dioxide. Methane is the main component (40-70%) and its production is the aim of biogas technology. Methane is a powerful gas having calorific power similar to other fuel or gases from oil. The second main gas in the biogas is carbon dioxide (30-60%).
Biogas production is usually used to generate heat, to produce combined heat and power and it can even be optimized to fuel vehicles.

7.2 | Resources in the village to feed biogas systems

Komossa is a rural village where farming and livestock are the main activities. The fields surrounding the village and the farms are close to the centre. In fact, although biogas systems can be fed with several kinds of fuel, Komossa can supply a perfect fuel. As a result of the activities in the village, manure livestock and crops from fields would be the main fuel for the production of biogas. Moreover, the proximity situation of this fuel decreases the fuel transportation costs significantly.

7.2.1| Crops

The main crops growing in the village are barley, oat and wheat. Barley is the most important crop growing in Komossa where the production can reach 80% of the whole harvest. Oat and wheat are almost the whole crop production. Because 50% of this harvest is used to feed the animals, only the remaining 50% can be used to produce biogas. According to the calculations below and the crop quantities produced, the harvest should be kept in a big store, which means an efficient management of the source for a continuous biogas production.

7.2.2 | Manure

The second way to produce biogas is to use manure from farms. Manure is a farm waste usually stored in huge stores until it is used to fertilize the fields. Two negatives points should be mentioned. The first one is that while slurry is stored waiting to be used, it produces gas with a big concentration on methane, which is released to the atmosphere contributing to the greenhouse effect. The second one is slurry transport and spreading, which might be uncomfortable for people. At the moment in Komossa there are 17 farms in total divided in 3 cow farms, 1 pig farm and 1 fur animal farm. The livestock farming in the village is composed of: 120 cows, 11 beef cows, 206 young cattle below 24 months, 2100 pigs and 36 adult female hogs.

7.3 | Potential energy calculation

Identifying all kinds of fuel needed to feed the biogas plant and its data, it is possible to make a raw estimation about which biogas potential exists in Komossa. This estimation is grouped in four types of livestock to make the calculation easier.
7.R. 1: Livestock in Komossa

7.3.1 | From livestock amount

Vestock	Number	Biogas m3 prod./day/anim.	Biogas m3/day
Cattle	131	1.2	157.2
Young cattle	206	0.8	164.8
Pigs	2100	0.09	189
Breeding pig	36	0.18	6.48
		Total m3 biogas livestock/year	**188,880.2**

7.T. 1: Biogas production from livestock

7.3.2 | From farming

Continuing with the raw estimation and making the estimation easier. In this calculation only appears barley as the only one crop that's why barley represents the 80% of the whole harvest. So in a future strict estimation the other 20% of the harvest should be kept in mind. Meanwhile the biogas production per cubic meter of barley is 505.5 per tonne.
7.R. 2: Crops in Komossa

Crop	Ha	kg	m3 Biogas prod./tone
Barley	388	1361880	505.5
		Total m3 biogas/year	688,430.34

7.T. 2: Biogas production from farming

7.3.3 | Biogas production estimate

As a result of the estimation the biogas production is almost nine thousand cubic meters per year. Every day the production would be around 2400 cubic meter of biogas per day.

Total biogas/year	**877,310.54 m3**

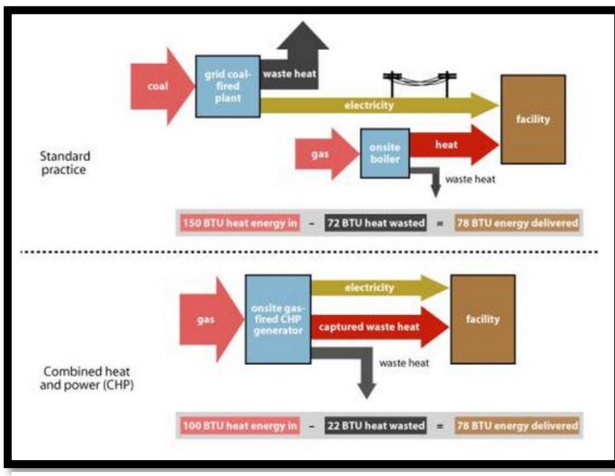
7.T. 3: Biogas production per year

7.4 | Way of energy production until energy distribution

The purpose of this section is to describe the possible ways of using use biogas production. It is important because it doesn't make sense working on a solution for Komossa is energy needs if the way of household energy consumption is ignored. In other words, the correct solution starts studying which resources Komossa has until how the costumer can receive this energy at his home.

7.4.1 | Combined heating and power (CHP)

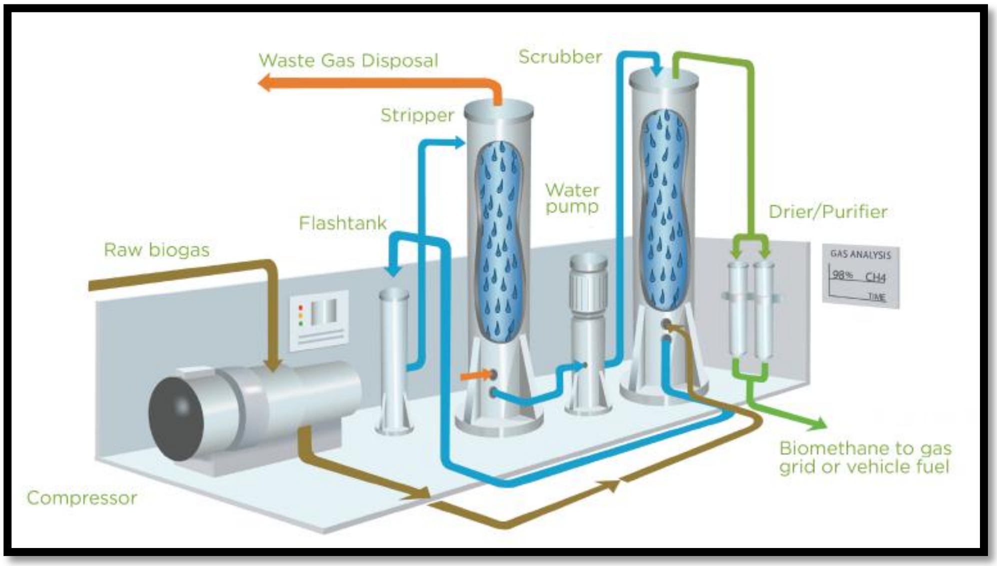
The cogeneration system is a combined production of electricity and heat at the same time with a high efficiency. The efficiency for electricity generation is around 35% and 45% per for heating process, which means that just 10% are losses This efficiency is reached thanks to the heat recovered spread from combustion engine. This system is useful for industries and for big buildings like hospitals where the heat recovered can be used for hot water for humans, heating and cooling using an absorption machine. Although cogeneration is being introduced nowadays in villages or small towns, the main aim is to cover big energy quantities.



7.F. 1: Comparison between conventional and combined production

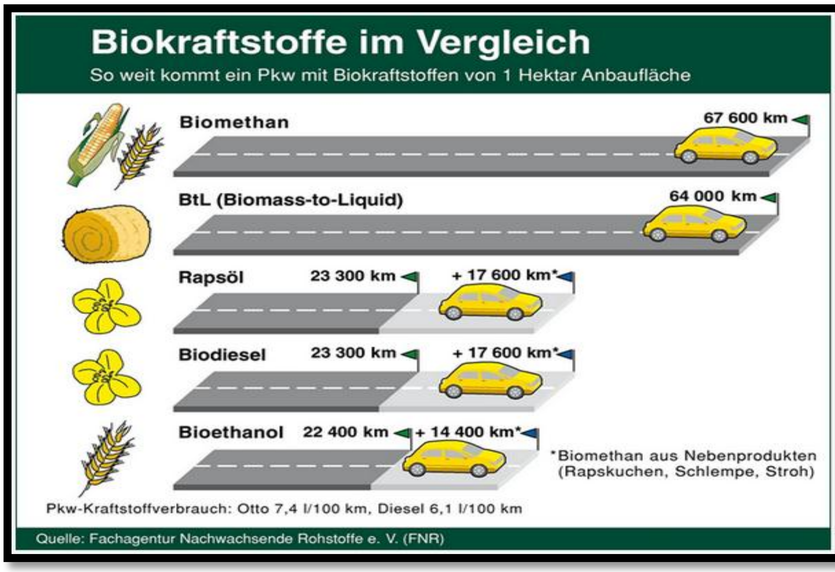
7.4.2 | Biogas optimization to achieve bio methane

Biogas has between 50-75% of methane in its composition, so other possible use for biogas is the optimization to bio methane. In other words biogas is cleaned removing carbon dioxide and others substances from it and the result is a gas with 98% of methane. To upgrade biogas there are different ways. A process called water scrubbing is considered the best way to optimize biogas. Water scrubbing it is a physical process that consists on washing biogas with water. Pressurized biogas is led through a pipe on top of a tank and in the opposite direction, the water collides against biogas removing carbon dioxide and others substances like the dangerous hydrogen sulphide. This process is possible because those substances are soluble in water.



7.F. 2: Water scrubbing flow diagram

Bio methane is currently the most efficient biofuel and that is the reason why this an interesting investment. Making comparison with biodiesel, which is the most biofuel used at the moment, the bio methane far exceed the biodiesel efficient. So with the biogas production and the upgrading biogas equipment this way could provide great benefits. In Finland, bio methane has the same price as natural gas.



7.F. 3: Kilometers done by different kinds of biofuel

7.5 | Description of the most important elements

Digester

The digester is a closed tank in which the biogas is produced trough a chemical reaction. It is very important to be hermetically closed because the reaction is called as well as anaerobic digestion and the living bacteria will not be suitable. Inside the tank the organic matter is placed with water and a fitting temperature where the fermentation or the chemical reaction is produced. There are two kinds of digesters, mesophilic and thermophilic and it depends on the way to produce the biogas. The first one is the reaction time of the organic matter, in other words, the time that this fuel will be closed inside the tank. The tank is loaded with the fuel and closed during a particular period of time producing biogas. The mesophilic digester has a reaction time longer than mesophilic. The second one is the temperature inside the tank. The mesophilic system requires a less adequate temperature control, which means that the equipment need is cheaper than thermophilic. This kind of system is used for low-medium scale biogas plant in cold countries with big temperature changes.

7.F. 4: Digester

Mixer

Mixer or agitator homogenizes the organic matter facilitating living bacteria allowing an uninterrupted chemical reaction. In addition this element has the aim of avoiding solid surface formation and consequently the free biogas release to the top, where it will be led to the biogas storage tank.

7.F. 5: Mixer

Heating unit

7.F. 6: Heating unit

This heating unit is a network of pipes installed inside the reaction tank. It provides warmth for the living bacteria and a good biogas production. Heating unit can be placed in two different ways, inside the tank or surrounding the reaction tank’s walls. Depending on the tank system chosen, the heating would supply 35ºC for the mesophilic system and 55ºC for the thermophilic.

Gasholder

Gasholder is a tank made mostly of PVC and with ultraviolet light protection. It stores the result of the whole biogas production waiting to be used. In addition, it needs a simple installation with a low maintenance.

7.F. 7: Gas holder

7.6 | Economic estimation biogas plant

The feasibility of a biogas plant is based basically on three aspects such as biogas production utilization, waste treatment and fuel transportation costs. With a good management the production can increase either by reducing the energy bill or by receiving benefit. On the other hand the subsidies and requirements from the government are mentioned. In addition, this chapter talks about the main investment and the hypothetical way to use this biogas. The electricity need in Komossa is:

- 600 MWh for electricity
- 690 MWh for heating

7.R. 3: Energy need Komossa

7.6.1 | Main investment

The biogas plant would receive manure equals to 2,400 m^3 of biogas per day so a biogas plant:

- With all the equipment, project documentation, engineering and construction cost 876,000 €
- Maintenance means 2% of the investment = 17,520 €/year
- The working lifetime is 20 years length

7.R. 4: Biogas equipment price
7.R. 5: Biogas plant maintenance cost
7.R. 6: Biogas plant lifetime

7.6.2 | Biogas production uses

7.6.2.1 | Boiling

With this process the biogas production would be flared in a boiler. In this case, the boiler doesn't have mobile engines, meaning few energy losses and reaching 90% efficiency.

- Total biogas production: 877310.54 m^3
- Boiling efficiency: 90%
- 1m^3 of biogas = 6 kWh

$$877310.54\, m3 \cdot \frac{6kWh}{1m3} \cdot \frac{0.9}{1000} = 4{,}548.86\, MWh/year$$

With this heat production by boiling biogas, the heat need would be covered and exceed considerably the heat need in the village. Boiling the biogas, the heat generation is almost 7 times as big as the heat need in the village. However, without a heating distribution system this biogas use is unfeasible.

7.6.2.2 | Combined heat and power production

The electricity production is produced by combined heat and power engine. To not lose the heat generated, it should be distributed by district heating system.

- Total biogas production: 877,310.54 m^3
- Electricity generation efficiency: 35%
- 1m^3 of biogas = 6 kWh
- Heat generation efficiency: 45%

7.R. 7: Biogas energy equivalent

Electricity production

$$877310.54\, m3 \cdot \frac{6.1 kWh}{1m3} \cdot \frac{0.35}{1000} = 1{,}873.06\, MWh/year$$

Heat production

$$877310.54\, m3 \cdot \frac{6.1 kWh}{1m3} \cdot \frac{0.45}{1000} = 2{,}408.22\, MWh/year$$

Subsidies for combined heat and power production

- 83.5 €/MWh + 50 €/MWh heat if the efficiency reach minimum 50%
  Requirements
  - The generator capacity must be at least100 kVA
  - Only for new plants
  - Power generation from landfill is excluded
  - Subsidies only available during 12 years

- Selling the whole electricity production to the network

Electricity excess = 1,873.06 - 601 = 1272.06 MWh

$$1{,}272.06\ \mathrm{MWh}\ \cdot\ 83.5 \frac{€}{\mathrm{MWh}} =\ 108501.6\ €/\mathrm{year}$$

- Subsidy for heating

$$686\, MWh\ \cdot\ 50 \frac{€}{\mathrm{MWh}} =\ 34300\ €/\mathrm{year}$$

7.R. 8: Biogas subsidies

After year 12, the electricity would be sold with the price for renewable energy in the energy market. This is not important because the difference between the average of the price of electricity and the subsidy, and the normal price of electricity are similar. In this case the heat generated should be distributed using a district heating. If not, the whole heat production would be wasted. The calculated power of the engine need is 214 kW so an engine with a high power generation would be enough. A gas engine for CHP costs 242,000 € and its maintenance is 1% of the CHP engine price.
7.R. 9: Price of a CHP engine

7.6.2.3 | Optimizing biogas and selling as bio methane

Bio methane available production

- Total biogas production: 877,310.54 m3
- CNG costs about half of the price of petrol, 85 cent/l petrol equivalent
- 1m3 of biogas contains 60% CH_4
- Level of purify of CH_4 after cleaning: 97%
- Nowadays biogas for fuelling vehicles is free from fuel tax

7.R. 10: CNG price in Finland
7.R. 11: Purify of biomethane
7.R. 12: Biogas taxes

$$877{,}310.54\ m3 \cdot 0.6 \cdot 0.97 = 510{,}594.7\ m3\ of\ biomethane$$

Note: Nm3 refers to biogas in concrete conditions: 1atm and 273K. So to convert Nm3 to m3 by the biogas utilization conditions. In Finland the temperature average is 3º so must be considered equaling Nm3 and m3 the mistake produced can be ignored.

Upgrading requires an additional investment to acquire a suitable equipment. The details of a water scrubbing equipment are:

- Equipment with capacity to treat 250Nm3 of bio methane is 265,000 €
- The costs of maintenance and production reach 110,000 €/year
- The price of 1Nm3 upgraded biogas is 0.13€
- Bio methane or CNG obtained per year 877,310.54 Nm3
- 1Nm3 = 1.588 l when pressure is 1 atm

7.R. 13: Price of biogas upgrading equipment
7.R. 14: Price of upgraded biogas

$$877310.54\ m3 \cdot 0.85€/= 510{,}594.7\ m3\ of\ biomethane$$

Benefit per year

$$510594.7\ Nm3\ of\ biomethane * \frac{1.588l}{1Nm3} * \frac{0.72€}{1l} biofuel = 583{,}792.76\ €$$

7.6.3 | Economic estimation resume

Biogas plant + CHP engine

- Investment
  - Biogas plant = 876,000 €
  - CHP engine = 242,000 €
- Outputs
  - Maintenance biogas plant = 17,520 €/year
  - Maintenance CHP engine = 2,420 €/year
- Inputs
  - Selling electricity (12 years, subsidy) = 108,501.6 €/year
  - Heating produced (12 years, subsidy) = 34,300 €/year
  - After 13 year
    Selling electricity = 50,882.4 €/year
- Interest
  - 5%

Payback = 35 years

Biogas plant + upgrading biogas

- Investment
  - Biogas plant = 876,000 €
  - Upgrading equipment = 265,000 €
- Outputs
  - Maintenance biogas plant = 17,520 €/year
  - Maintenance upgrading equipment = 110,000 €/year
- Inputs
  - Selling biomethane (CNG)Energy savings = 583,792.76 €/year
- Interest
  - 5%

Payback = 13 years

7.7 | Conclusion

To produce electricity and heat and after that sell them it is a complex idea. Firstly, the electricity produced with a combined heat and power production engine is only 35% per cent of the biogas's energy. The other point is the heating distribution, also called district heating, a system to distribute the heat recovered from the biogas combustion. The negative point is that district heating needs a big investment. Moreover, the payback time is too long, and that is why it is ignored.

Upgrading biogas is a good way for business, which is shown by the payback time. Nowadays the bio methane consumption for vehicles is growing every day. To adjust the vehicle in order to work with this green fuel is cheaper than people think. At the moment bio methane or CNG, the commercial name, doesn't have taxes, which is a good point for betting for this technology. The payback time is also very short.

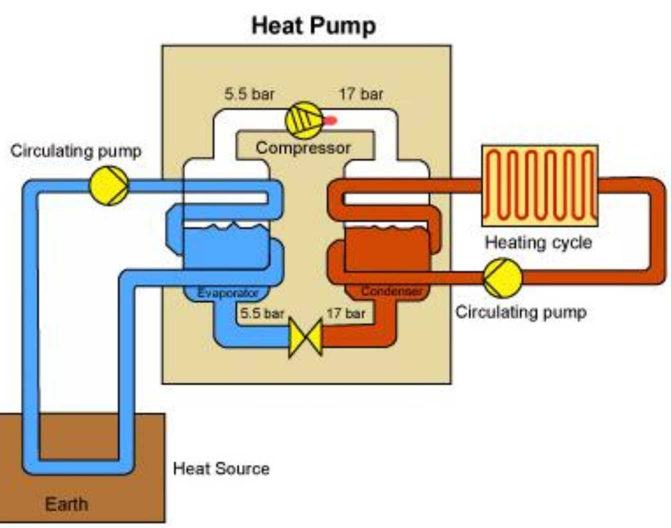
8 | Geothermal energy

8.1 | Uses of geothermal energy

- *Geothermal Electricity Production*
  The system of generating electricity from the earth's heat is only available with a steam resource located in the ground, for example in Iceland.
- *Geothermal Direct Use*
  The biggest problem with producing heat directly from hot water within the earth is that the heating ability can be reduced at frozen temperatures and that is why an electrical resistance is needed to keep the heating production.
- *Geothermal Heat Pumps*
  Using the shallow ground to heat and cool down buildings is the most interesting solution associated with the low temperature in the ground.

8.2 | Heat pump

A heat pump increases the temperature of a subsurface, 15 °C, at a temperature of up to 60 °C. The heat pump works like a refrigerator, only in the reverse way. Essentially it consists of two heat exchangers, a compressor and an expansion valve. Water flowing through the perforation enters the first heat exchanger (evaporator) at a temperature of 15 °C, is cooled between 3 to 6 °C and returns to the borehole, where it is reheated again. On the other side of the evaporator a refrigerant fluid passes that evaporates at a low temperatures and remains in its gaseous state. This gas is compressed by the compressor and this is how the heat is born. The gas transfers the heat through the second heat exchanger (condenser) of the heating system and the DHW. The gas cools down and becomes liquid again. By expansion valve loosens the coolant, cools and returns to evaporate more again. Reversible heat pumps produce heat in winter and cool in summer. The process describe above is reversed during the summer



8.F. 1: Heat pump working diagram

The heat pump needs electricity. For every kWh consumed, 4-5 KWh generated as heat or cold to the building. Between 75% and 80% of the energy comes from the earth for free. This relationship is called COP (Coefficient of Performance) and indicates the performance of the heat pump The COP of the heat pump is based on constant temperatures on both the uptake and on the side of the heater.

8.3 | Heating production and distribution scenario

The heating production systems installed in Komossa are as follows *8.R.1: Houses in Komossa.*

- Oil
- Woodchips
- Energy crops
- Wood
- Solar collectors
- Air pump
- Direct electricity
- Borehole or vertical geothermic
- Horizontal geothermic

The heating system distribution installed in the village has

- Heaters or radiators
- Under-floor heating or radiating floor

Several types of heating production systems are installed in Komossa although there are only a few heating distribution systems. If the way to produce heat changes because geothermal installation is chosen, the distribution won't do it and it won't increase the costs for improving the heating installation very much. The owners that use direct electricity for heating will have to choose the heating production and distribution system according to their investments and their energy needs.
The owners will receive the solutions and proposals and then they will be able to choose the best solution according to their investments and the building division in Komossa.
8.R. 2: Houses in Komossa

With a new geothermal system the running heating installation may increase. The geothermal system works with lower temperatures than other heating system, so that's why geothermal needs more surface to spread the heat. In other words, if a customer with a firewood boiler and radiators heating distribution decides to change the boiler for a geothermal heat pump, the radiators surface would be increased to spread the same amount of heat. However, it doesn't mean a big expense. In addition, there is some information for those people who want to install a new radiator or under-floor heating distribution.

An estimation for a new radiator installation or for an extension costs 93 €/m2. If the aim is to retrofit an older installation the cost reaches 185 €/m2.

- Under-floor heating
- Installing a new under-floor heating costs 68 €/m2 (Elliot heating)

8.R. 3: Radiator installation cost
8.R. 4: Underfloor installation cost

Some factors before the calculation

Not all the surface of the building is heated, 80% of the whole surface is heated, places like stairs or pantries are ignored.

To calculate the power of the pump, the period when the pump works with full load must be considered. It happens in wintertime when the heating system works almost the whole day and there is a big temperature difference between outside and inside the building.

The working time considered for a geothermal installation and relation with climate conditions is:

- Average of the days working per year: 3 months x 30.5 days/month = 91.5 days
- Average of the hours working per day: 20 hours

Then for sizing the pump it will have 1830 hours working with full load.

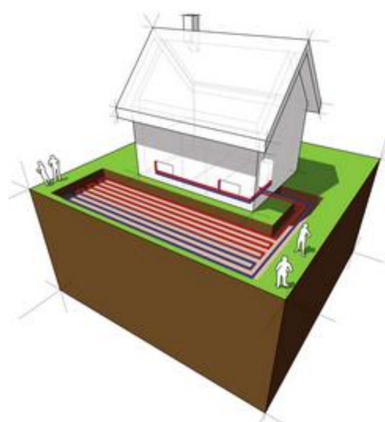
The depth of the borehole is calculated with the ground heat transfer and the power of the pump. According to studies about geothermal energy in Finland, the heat transfer in the area that Komossa belongs to is 49W/m. *8.R.5: Ground heat transfer in Finland*

Ground source heat pumps require simple maintenance *8.R.6: Heat pump maintenance* consisting on a yearly check of the elements by the owner. The more thorough checks must be done by a technician. Every 3 – 5 years. The lifetime for the whole geothermal installation is 25 years. 8.R.7: *Geothermal installation lifetime*

Type of installation and characteristics

Horizontal

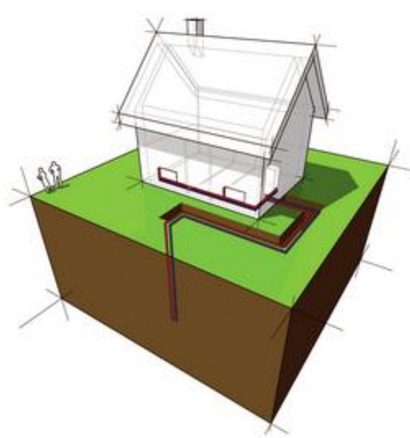
- Surface need is to install the pipes is between 1.5 and 2 the surface to be heated, so 1.75 is chosen. *8.R.8: Surface heated by geothermal installation*
- Trenching depth 1.2 m. *8.R.9: Trenching depth for horizontal installation*
- Trenching cost: 49.43 €/ m^2. *8.R.10: Trenching cost*
- The average of piping warranty is 50 years. *8.R.11: Piping warranty*
- Depending on the power of the pump, the pipes length will be longer. An installation with a 10 kW pump needs around 550 meters of pipe. The price of the pipe is also included in the duct-work.



8.F. 2: Horizontal installation

Borehole

- The average of borehole depth in Finland is 170m although depending on the energy need and which kind of ground the depth may change. *8.R.12: Average of borehole depth*
- The cost of drilling per meter is 35 €/m. *8.R.13:Cost of drilling*



8.F. 3: Borehole installation

8.4| Budgets

To calculate the budget the average of the heating consumption of all kinds of user is considered. It gives an idea to the customer about his situation. Depending on which type of building an estimation of a geothermal installation is given below.

8.4.1 | Small users

- Heating need: 5,000 – 15,000 kWh/year (10,000 kWh/year)
- House's surface: <120 m^2 (110 m^2)
- Surface to be heated: 110 x 0.8 = 88 m^2

Pump

- Power need: 10,000 kWh / (3month x 30.5 days x 20 hours) = 5.5 kW
- Pump power: 6 kW
- Pump price: 5,200 €

Type of installation

- Horizontal
  - Surface need: 88 x 1.75 = 154 m^2
  - Trenching: 154 m^2 x 17 €/ m^2 = 2,600 €
  - Pipes length = 330 m
  - Pipes and ductwork = 6.20 € / m x 330 m = 2,050 €
- Borehole
  - Depth need: 6000 W / 49 W/m = 122.5 m
  - Drilling: 122.5 m x 35 €/ m = 4,300 €

Total cost

- Horizontal installation: 7,800 €
- Borehole installation: 9,500 €

8.4.2 | Medium users

- Heating need: 15,000 – 30,000 kWh/year (22,500 kWh/year)
- House's surface: 120 - 200 m2 (160 m2)
- Surface to be heated: 160 x 0.8 = 128 m2

Pump

- Power need: 22,500 kWh / (3 months x 30.5 days x 20 hours) = 12.3 kW
- Pump power: 14 kW
- Pump price: 6,800 €

Type of installation

- Horizontal
  - Surface need: 128 x 1.75 = 224 m2
  - Trenching: 224 m2 x 17 € / m2 = 3,800 €
  - Pipes length = 330 m
  - Pipes and ductwork = 6.20 € / m x 550 m = 3,400 €
- Borehole
  - Depth need: 14,000 W / 49 W/m = 286 m (143 m x2)
  - Drilling: 286 m x 35 € / m = 10,000 €

Total cost

- Horizontal installation: 10,600 €
- Borehole installation : 16,800 €

8.4.3 | Big users

- Heating need: > 30,000 kWh/year (35,000 kWh/year)
- House's surface: >200 m2 (210 m2)
- Surface to be heated: 210 x 0.8 = 168 m2

Pump

- Power need: 35,000 kWh / (3 months x 30.5 days x 20 hours) = 19 kW
- Pump power: 20 kW
- Pump price: 17,000 €

Type of installation

- Horizontal
  - Surface need: 168 x 1.75 = 294 m2
  - Trenching: 294 m2 x 17 €/ m2 = 5,000 €
  - Pipes length = 330 m
  - Pipes and ductwork = 6.20 € / m x 1,100 m = 6,800 €
- Borehole
  - Depth need: 20,000 W / 49 W/m = 408 m (204 m x2)
  - Drilling: 408 m x 35 € / m = 14,300 €

Total cost

- Horizontal installation: 22,000 €
- Borehole installation : 31,300 €

Notes

- Price of heat pump *8.R.14: Heat pump prices*
- Vertically heat transfer *8.R.15: Ground heat transfer in Finland*

8.5 | Savings

Before calculating the savings with a geothermal heating system, the estimation costs per kWh for all the heating systems and geothermal have been calculated and compared. For this estimation, the price and calorific value of fuel and the performance of the system for each heating installation are needed.
The electricity price changes depending on the user. The small user electricity price is 17.50 c€ / kWh, the medium user price is 14.70 c€ / kWh and the big user pay 12.20 c€/kWh *8.R.16: Electricity price in Finland*. The next calculation is based only on small users. The reasons are the electricity price for this users is the most expensive and small users represent 46% of the buildings in Komossa.
For firewood and wood chip, the energetic value has been estimated with 50% of humidity. The price of firewood is around 70 € / kg.
8.R.17: Price of Wood
8.R.18: Wood chip price

Heating kWh cost using different heating systems

- Direct electricity
  Price: 0.1566 € / kWh
  Performance: 96%
  CP: 860 kcal / kWh

  860 kcal / kWh x 0.96 = 842.8 kcal / kWh
  842.8 Kcal / kWh: 860= 0.98
  0.1219 € / kWh: 0.98 = **0.18 € / kWh**

- Oil
  Price: 1.143 € / l *10.R.19: Oil price for heating in Finland*
  Performance: 88%
  CP: 8.550 kcal / l

  8.550 kcal / l x 0.88 = 7.524 kcal/ l
  7.524 kcal / l: 860 = 8, 75 kWh/ l
  0.89 €/ kWh: 8.75 kWh / l = **0.10 €/ kWh**

- Firewood
  Price: 0.12 € / kg
  Performance: 80%
  CP: 2.7 kWh / kg

  2.7 kWh / kg x 0.8 = 2.16 kWh / kg
  0.12 € / kg: 2.8 kWh / kg = **0.056 € / kWh**

- Wood-chips
  Price: 0.13 € / kg
  Performance: 90%
  CP: 2.7 kWh / kg

  2.7 kWh / kg x 0.9 = 3.15 kWh / kg
  0.13 € / kg: 3.15kWh / kg = **0.053 € / kWh**

- Air-pump
  Electricity price: 17.47 c€ / kWh
  Performance (COP): 240% (2.4)
  CP: 860 kcal / kWh

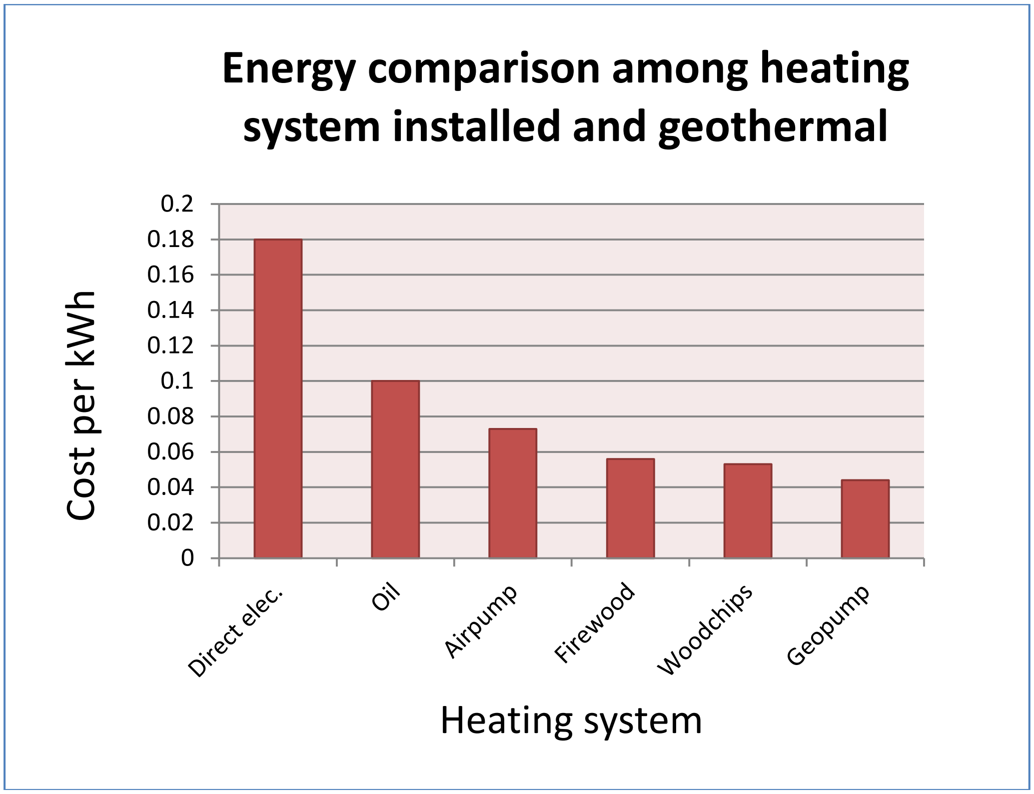
  860 kcal / kWh x 2.4 = 2.064 kcal / kWh
  2.064 kcal / kWh: 860 = 2.4
  0.1747 € / kWh: 2.4 = **0.073 € / kWh**

- Geo-pump
  Electricity price: 17.47 c€ / kWh
  Performance (COP): 400% (4)
  CP: 860 kcal / kWh

  860 kcal / kWh x 4 = 3.440 kcal / kWh
  3.440 Kcal / kWh: 860 = 4
  0.1747 € / kWh: 4 = **0.044 € / kWh**

Solar collectors don't appear in the energetic comparison. The calculation is based on cold weather when there is a big heating need. In these conditions the solar collector heating contribution is very small, being none during the winter season. This is why solar collector is ignored.

Heating system cost graph



8.F. 4: Energy comparison among heating system installed in Komossa

8.6 | Payback

To calculate the payback time, the maintenance costs have been estimated to be around 250€/year. A geothermal system doesn't need a strict control because this system doesn't have movement. Every 5 years a technician has to check the installation. This maintenance costs reach 250€ for each checking. The payback time is in years, as shown below:

	Users		
Installation	Small	Medium	Big
Horizontal	11	6	9
Borehole	15	11	13

8.T. 1: Payback time in years depending on size of building and kind of installation

8.7 | Conclusion

The geothermal heating system is preferred when the installation is horizontal. However, a horizontal system requires a surface to install it according to the energy needs. 46% of the buildings are small; a lot of them are detached house. For small users the surface needed to install the pipes is around 150 m2.
Boreholes are more expensive than a horizontal installation. The reason for this are found remains in the costs for drilling although the installation time is shorter for horizontal system. The geothermal system works with a ground source heat pump and it is able to produce more than 4 times as heating production as electricity consumption. This decreases significantly the electric bill. The maintenance is another good point for this technology; a fast yearly check done by the owner and a strict check done by a technician every five years. This maintenance is the cheapest among the other heating systems.

9 | Conclusion

After completing the appropriate studies and the dimensioning, for find out what energies are likely to be used in the Komossa village with satisfactory results, a plan has been made for the Komossa residents.

In our research a variety of different kinds of energies have been analyzed, i.e., electrical power, wind power and solar energy. For the implement option of heating into homes a large number or resources have been studied, such as:

- A biogas plant.
- Boilers for burn the biomass.
- Solar collectors on the roof for heat fluids.
- Use the energy stored inside the earth based on the geothermal principle.

All this has been studied and adapted to the needs of Komossa. Three categories have been established depending on the consumption of electricity and heat, and the size of the homes or buildings.

After performing the preliminary study some alternatives were discarded, because they did not satisfy the expectations expected. Solar panels to supply the electricity needs in one household, were discarded because in the winter months they will not be able to produce even 20% of the energy needed. The biogas plant for the entire village, was also discarded because of high the investment costs and the difficulty of distributing the heat to every home in Komossa. Thus, the energy solutions that have been accepted in the final study all able to supply the minimum energy requirements.

The following table shows the results of the final study, with the energies ordered depending on the type of power for supply, the investment costs, lifetime of the installation and the payback time.

9.1 | Small Users

Electricity and Heat	Investment cost	Life cycle	Payback time
Wind Power + Boiler 65%	21.000 €	20 - 25 years	8 – 11 years

Heat	Investment cost	Life cycle	Payback time
Biomass Firewood	4.000 – 5.000 €	≈ 30 years	6 – 20 years
Biomass Wood Pellets	6.000 – 7.000 €	15 – 25 years	17 + years
Biomass Wood Chips	10.000 – 15.000 €	15 – 25 years	17 + years
Solar Collectors	11.000 – 12.000 €	25-30 years	16 – 17 years
Geothermal Horizontal	8.000 €	25 years	11 years
Geothermal Vertical	9.500 €	25 years	15 years

9.2 | Medium Users

Electricity	Investment cost	Life cycle	Payback time
Wind Power	16.000 €	20 - 25 years	≈ 14 years

Electricity and Heat	Investment cost	Life cycle	Payback time
Wind Power + Boiler	35.000 €	20 - 25 years	≈ 14 years

Heat	Investment cost	Life cycle	Payback time
Biomass Firewood	6.000 – 7000 €	≈ 30 years	5 – 8 years
Biomass Wood Pellets	≈ 10.000 €	20 – 25 years	13 + years
Biomass Wood Chips	16.000 – 19.000 €	20 – 25 years	10 – 20 years
Solar Collectors	16.000- 15.000 €	25 – 30 years	13 – 14 years
Geothermal Horizontal	11.000 €	25 years	6 years
Geothermal Vertical	17.000 €	25 years	11 years

9.3 | Large Users

Electricity	Investment cost	Life cycle	Payback time
Wind Power	24.500 €	20 - 25 years	≈ 9 years

Heat	Investment cost	Life cycle	Payback time
Biomass Firewood	9.000 – 10.000 €	≈ 30 years	4 – 6 years
Biomass Wood Pellets	≈ 15.000 €	20 – 25 years	9 – 18 years
Biomass Wood Chips	≈ 25.000 €	20 – 25 years	7 – 15 years
Solar Collectors	24.000 – 26.000 €	25 – 30 years	15- 16 years
Geothermal Horizontal	22.000 €	25 years	9 years
Geothermal Vertical	31.000 €	25 years	13 years

For the small users several alternatives are presented with options in some of them. At the time as for the type of energy that will supply the electricity power, only there was only option, wind power. In this case a study has been made in which an initial cost of 21000 €, is possible obtain total dependence of wind energy. With an electric boiler is possible obtain the 65% of heating needs cover, with high lifecycle and very low payback time.

The biomass option is seen to have low initial investment costs, a slightly lower lifecycle, which depends on the use to be given to the boiler, and a payback time that varies depending on the installation in every. It is important to differentiate between the types of biomass to burn, because the yields can vary and also the boiler lifecycles.

A solar collector would be a remarkable choice. A solar collector installation does not have a high initial investment cost and a long life. The only disadvantage is the maintenance of the entire system, which makes the payback somewhat long.

Geothermal energy for small users is an option to consider as well. It has a very low investment cost, and short payback time. There are some differences between the vertical and the horizontal installations, as the latter is more economical. However it is less efficient and it requires much more area for the installation.

In conclusion, the best energy investment to choose is wind power for the supply of electricity and part of the heating. Wind power can be supplemented by another installation, e.g. a small biomass boiler.

For medium users the initial investment is the cheapest in comparison with big users. However, medium users have the longest payback time. Although this option has a short payback time, it requires an important amount of money.

Generating electricity and heat at the same time may not be a good option. Medium users have the worst values of all the users. The combination between electricity generation by wind power and heating production by a most expensive woodchips boiler equals this option economically. The good point remains with electricity and heat production by wind mill the payback is half of the payback on the way explained before.

There are three groups among the heating solutions for the medium users. The first group consists of the woodchips boiler, the solar collector and the vertical geothermal installation. They all have more or less the same investment costs, lifetime and payback time. The second group is the horizontal geothermal installation with a low investment and a short payback time. The third is the best solution. This is the firewood boiler with the least investment costs and recovery time compared to the other resources.

As it happens with the previous case of the study, for the large users the electricity power only derive from wind energy, if offers high service life and short payback. In regard to the heating, choose biomass is cheaper for the large areas, although the initial investment costs may slightly vary depending on the building's size. Payback time also decreases in relation with medium and small users, different from the lifecycle, which is increased.

The solar collectors increase as payback is refer, so, need a large installation for be able to supply all the demand in large buildings. What happens is that the cost of investment and the maintenance cost, makes the annual savings will not be as great as in small buildings.
Observing the geothermal alternative, offer as in previous cases, low payback, and affordable investment costs, being the horizontal option always most economical. In the case of large buildings it is necessary to take one variable into account. The horizontal geothermal requires between 1, 5 and 2 times the size of the area to be heated, which is why this option requires a large area around the building.

Observing all the options, the most profitable alternative for this kind of user is to use biomass, with pellets or firewood as feedstock. Then it will be possible to get great yields at low costs.

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EPS 2012

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UNIVERSITY OF APPLIED SCIENCES

Appendices

EPS 2012
Autumn

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Vincent Fulcheri
Kristian Granqvist
Xavier Agustí Sanchez
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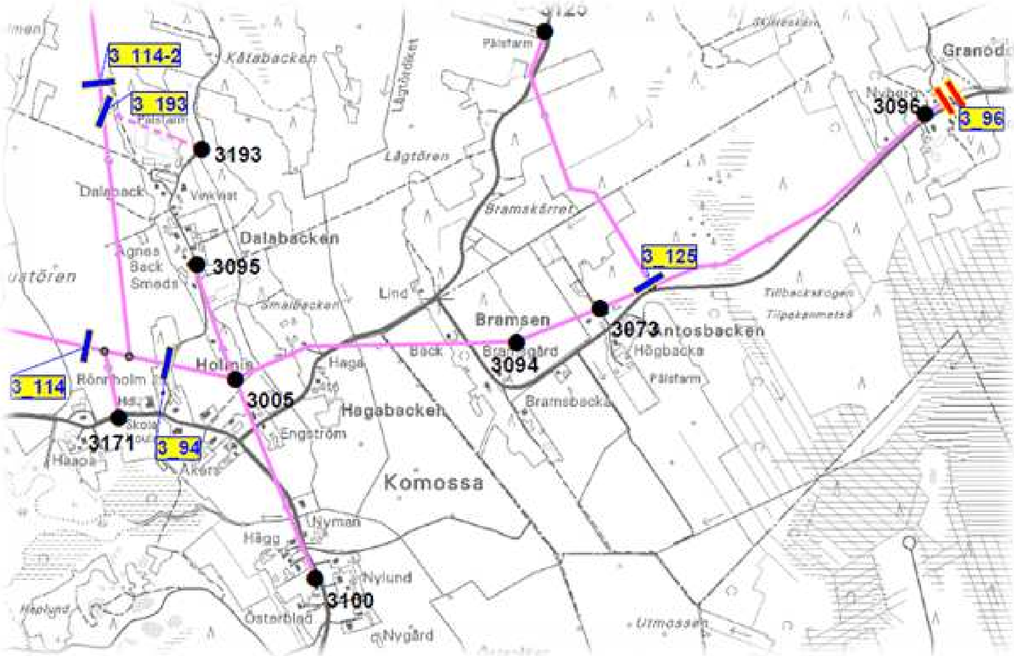
Appendices

A.1 | Chapter two

A.F.1. Electricity network in the Ostrobothnia region



A. F. 2. Map of transformers in Komossa

A.2 | Chapter three

Half-year	Total costs	Annual costs	Interest	6 months savings
	3000	0	1.995%	450
1	2609.85			
2	2211.916508			
3	1806.044242			
4	1392.074824			
5	969.8467172			
6	539.1951592			
7	99.95210263			
8	-348.0538529			

A.T. 1: Payback time window insulation

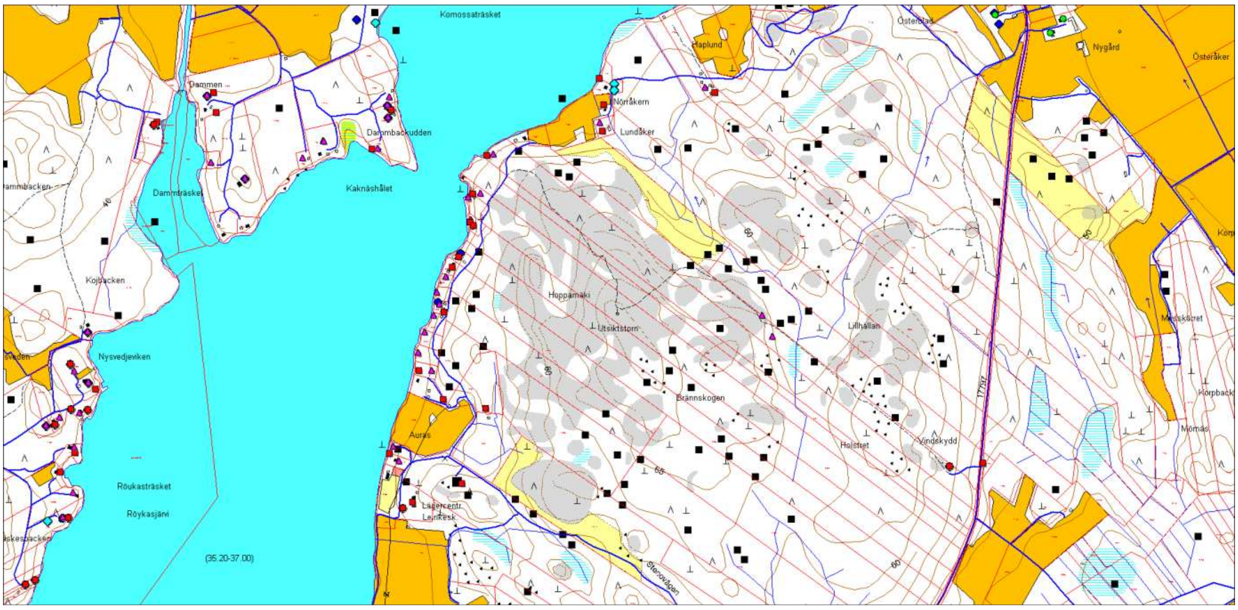
Half-year	Total costs	Annual costs	Interest	6 months savings
	4300	0	1.995%	1050
1	3335.785			
2	2352.333911			
3	1349.262972			
4	326.1807686			
5	-717.3119251			

A.T. 2: Payback time cavity wall insulation

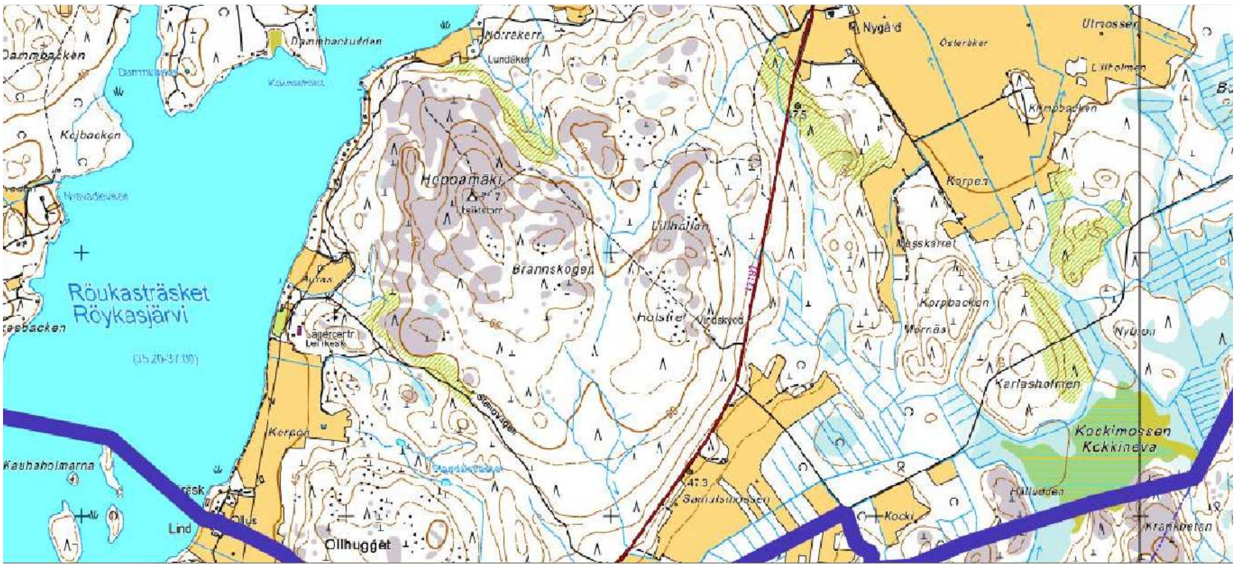
Half-year	Total costs	Annual costs	Interest	6 months savings
	3700	0	1.995%	850
1	2923.815			
2	2132.145109			
3	1324.681404			
4	501.1087982			
5	-338.8940813			

A.T. 3: Payback time ceiling insulation

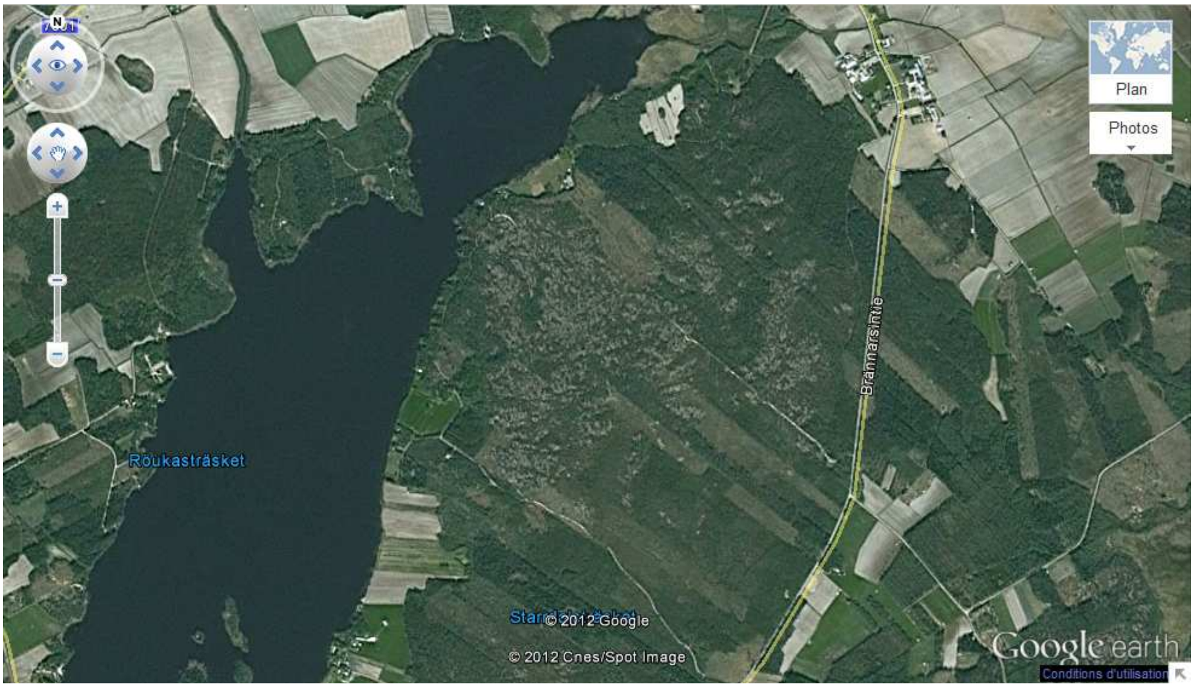
A.3 | Chapter four



A.F. 4. Hill Hoppamäki

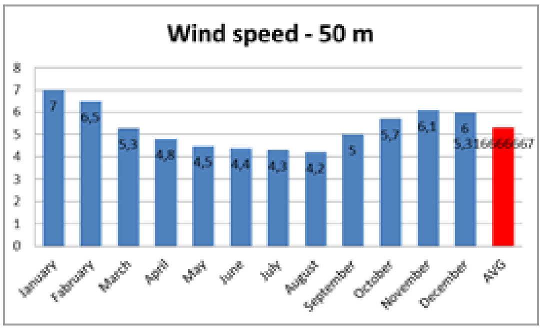


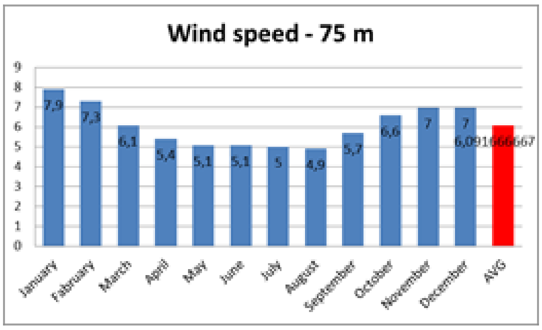
A.F. 5. Hill Hoppamäki

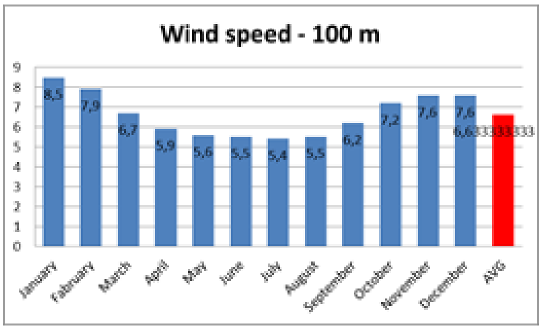


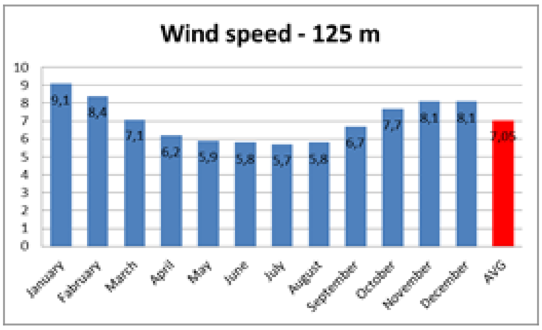
A.F. 6. Hill Hoppamäki

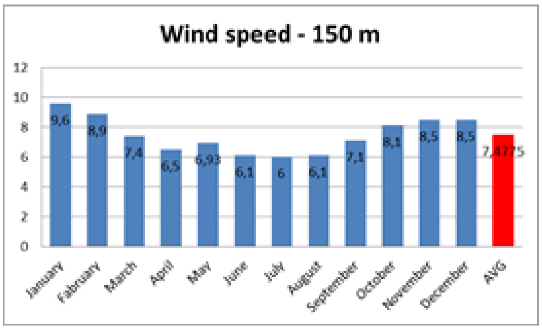
A.F. 7. Hill Hoppamäki











A.T. 4. Wind speed in Komossa

Komossa	Altitude (m)	V (m/s)	Weibull A	Weibull k
	50	5.10	5.73	2.045
	75	5.80	6.59	2.209
	100	6.40	7.21	2.303
	125	6.80	7.68	2.350
	150	7.20	8.09	2.396

A.T. 5. Weibull parameters

Explanation of the Weibull parameters:

Natural wind speed varies continuously. We measure the average wind speed every 10 minutes with an anemometer. The values obtained can be classified into different classes ranging from 1m/s. We can express the energy potential of a site according to the frequency of different speed classes.

A: is expressed in m/s, it allows to express the chronology of a characteristic velocity. It's proportional to the average wind speed.

Komossa	Altitide (m)	Active icing, > 10 g/h/m (h/Year)	Active icing, 10-50 g/h/m (h/Year)	Active icing, 50-100 g/h/m (h/Year)
	50	40.50	27.00	6.75
	100	67.50	33.75	15.75
	200	454.50	186.00	86.25

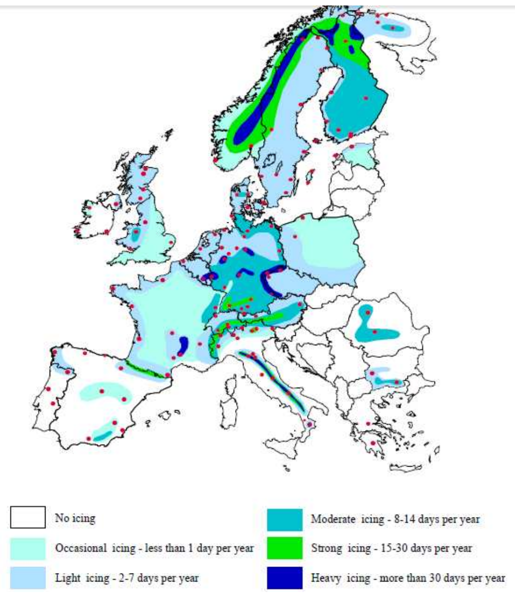
Altitide (m)	Active icing, > 100 g/h/m (h/Year)	Passive icing, > 10 g/m (h/Year)
50	6.75	1085.25
100	18.00	1446.00
200	182.25	2745.75

A. T.6. Icing parameters

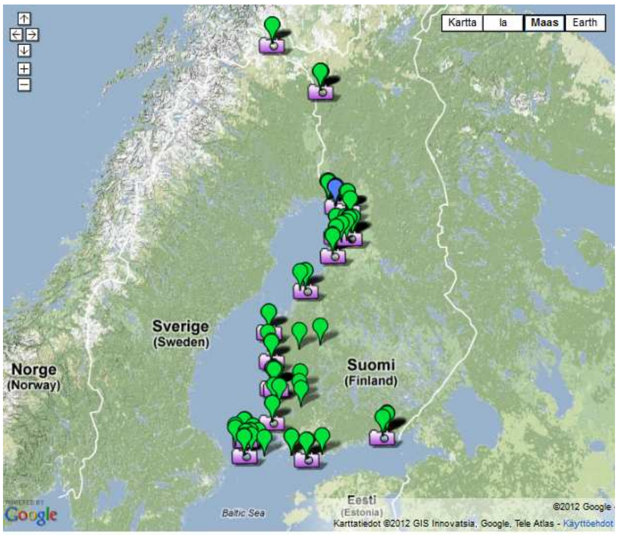
Explanation of the Icing parameters:

Four of the values represent the average length of the active icing periods in 4 different strength classes. The 5th column represents the average length of the passive icing periods.

The active icing period is the time when the ice is growing on the windmills (Cannot function) and the passive icing is when there is ice on the rotor blades

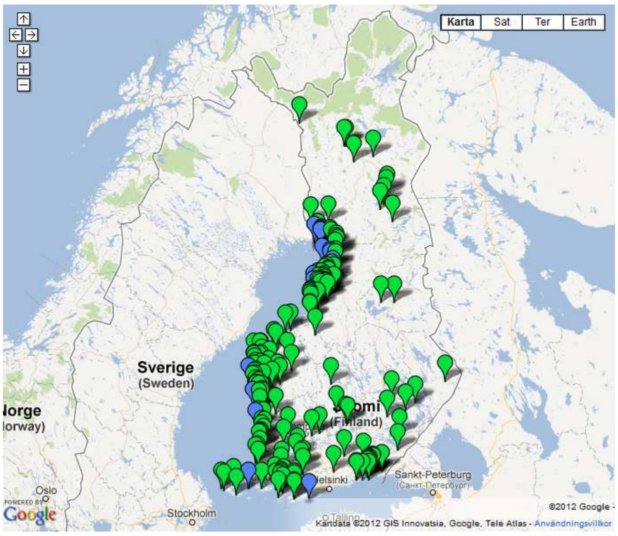


In Finland:



A.F. 8. Localization of big wind turbines in Finland

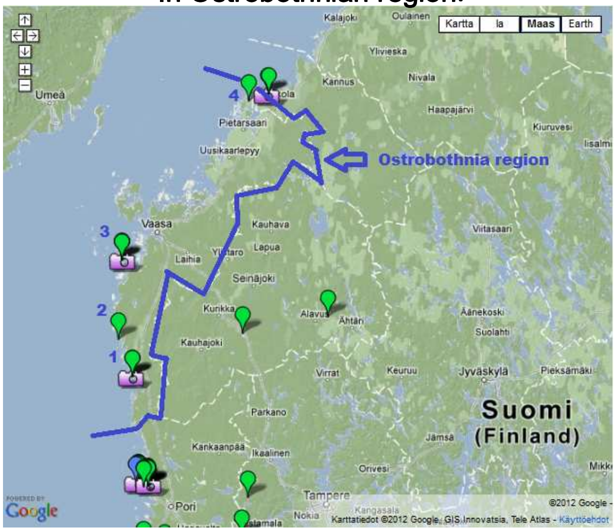
At the end of 2011 there were **130 wind turbines** in Finland. The total capacity was **197 MW**. In August 2012, there were **145 wind turbines** with a total capacity of **234 MW**.



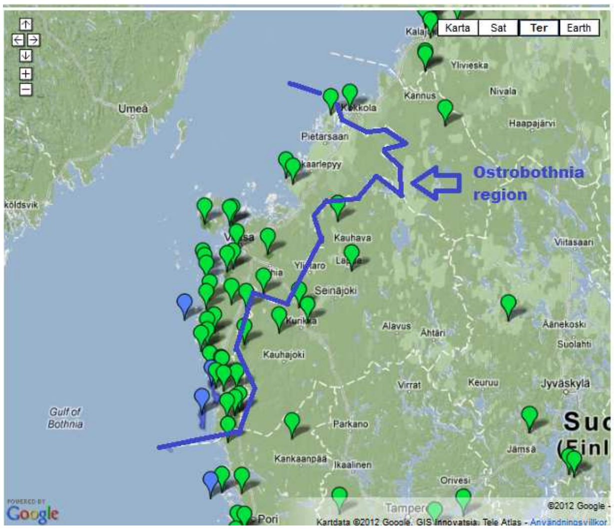
A.F. 9. Localization of big wind turbines in Finland

By the end of January 2012, there was over7800 **MW worth of wind power projects published in Finland**, of which about **3000 MW is off shore projects**.

In Ostrobothnian region:



A.F.10. Existing wind turbines



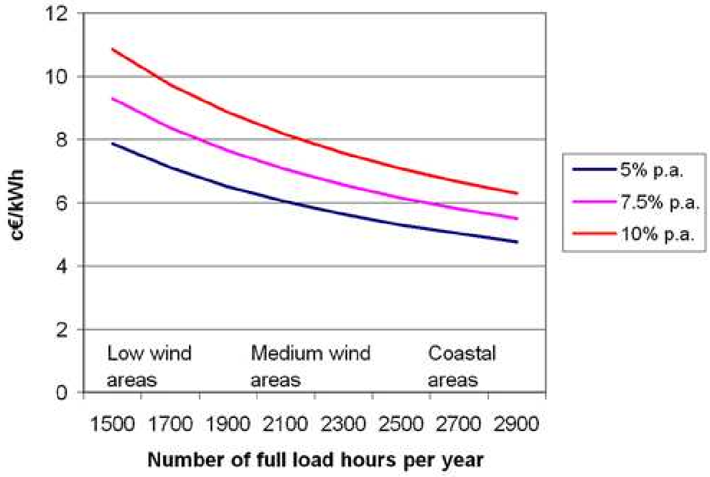
A.F.11. Wind turbine projects 2012

Name/Location	Power Turbine	Manufacturers
Kristiina T1	1 MW	WinWinD
Oskata 1	0.75 MW	NEGmicon
Korsnas 1	0.2 MW	Nordtank
Fransviken 1	1 MW	WinWinD
Vaasa*	3.6 MW	Mervento test turbine

A.T. 7. 5 Wind Power in Ostrobothnian region.

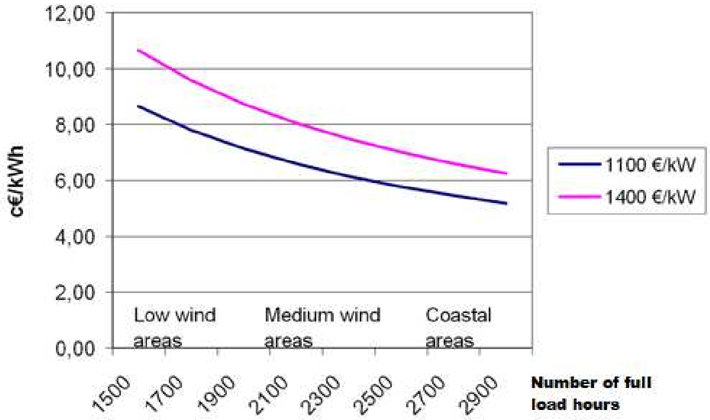
This map represents the project about Wind Power in Ostrobothnia Region. There are lots of projects identified during the year 2012. The wind power is a way of production that is expending in Finland in the years to come.

4.A. 6: Costs of wind-generated energy



The cost of energy generated by wind power

In terms of number of full load hours



The cost of energy generated by wind power in function of

the discount rate*. (For a cost installed of 1,225 €/kW)

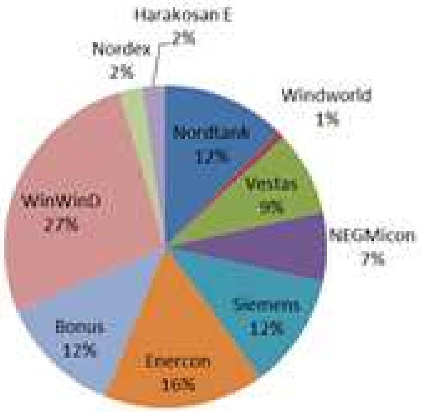
A.F.12. Costs of wind-generated energy

**.The discount rate is the cost per Kwh in function of the investment cost and maintenance during all the time life of the turbine dividing by the annual production of electricity.*

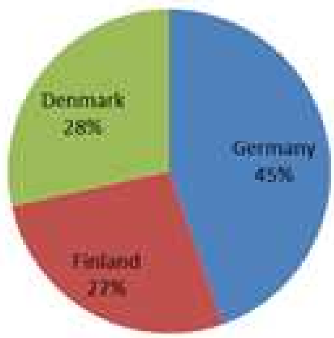
4.A. 7: Main manufacturers of wind turbines in Finland

Manufacturers	Number of turbines	Country
Nordtank	16	Denmark
Windworld	1	Denmark
Vestas	11	Denmark
NEGMicon	9	Denmark
Siemens	15	Germany
Enercon	21	Germany
Bonus	16	Germany
WinWinD	35	Finland
Nordex	3	Germany
Harakosan E	3	Germany
Total	**130**	

A.T.8. Main manufacturers of wind turbines in Finland



Percentage of manufacturers, in Finland.



Percentage of manufacturers per country, in Finland

A.F.12. Main manufacturers of wind turbines in Finland

4.A. 8: Sizing and power production

Power Calculator

Wind speed distribution

Either you can estimate the Weibull distrubtion for your site with the Weibull calculator or the power calculator approximates a distribution for the mean wind speed that is entered.

○ Weibull parameters A: 6.59 m/s k: 2.209

◉ mean wind speed v: 5.8 m/s

Air Density

You can calculate the air density for your site with the air density calculator.

Air density: 1.225 kg/m³

Power curve

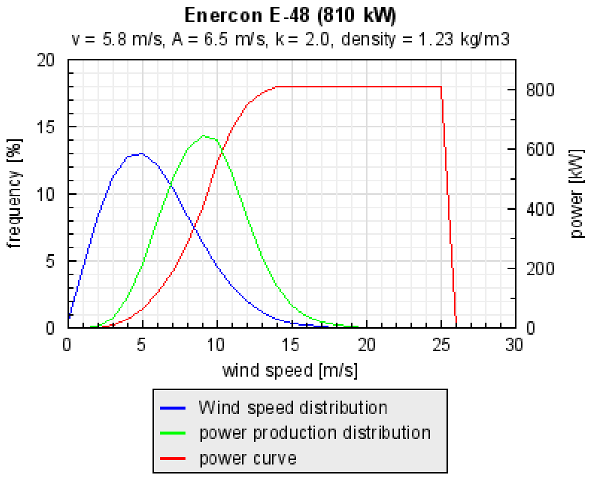
Choose a turbine type from the list or choose "user-defined power curve" and enter your own power curve in the table.

Enercon E-48 (810 kW) ▾

1 m/s	0	kW	11 m/s	671	kW	21 m/s	810	kW
2 m/s	2	kW	12 m/s	750	kW	22 m/s	810	kW
3 m/s	12	kW	13 m/s	790	kW	23 m/s	810	kW
4 m/s	32	kW	14 m/s	810	kW	24 m/s	810	kW
5 m/s	66	kW	15 m/s	810	kW	25 m/s	810	kW
6 m/s	120	kW	16 m/s	810	kW	26 m/s	0	kW
7 m/s	191	kW	17 m/s	810	kW	27 m/s	0	kW
8 m/s	284	kW	18 m/s	810	kW	28 m/s	0	kW
9 m/s	405	kW	19 m/s	810	kW	29 m/s	0	kW
10 m/s	555	kW	20 m/s	810	kW	30 m/s	0	kW

Result

Producer	Enercon
Type	E-48
Capacity	810 kW
Rotor diameter	48 m
Power Production	1'571'855 kWh/year
Capacity factor[1]	22.1%
Full load hours[2]	1'939 h/year
Operating hours[3]	8'312 h/year



'The capacity factor is the ratio between the annual production and the maximum possible production of a wind turbine. Capacity factors of 30-40% are considered very high for coastal areas.

[2] It is the theoretical number of hours that the wind turbine has to run at full load in order to produce the annual yield.

[3] Operating hours are the expected number of hours a year the wind turbine produces electricity.

4.A. 9: Economic estimation

- ✓ **Investment cost:** In Europe,1,000 €/KW to 1,350 €/KW with this average value, 1,227 €/KW.
  Rated Power of Enercon E-48: 810 KW.

  Investment cost: [€810,000for (1000 €/KW) to €1,100,000for (1350 €/KW)]

- ✓ **Operation and Maintenance:** In Europe, 1, 2 c€/KWh to 1, 5 c€/KWh.
  New wind turbines may have a lifetime until 20 years.
  This estimation will take 15 to 20 years.

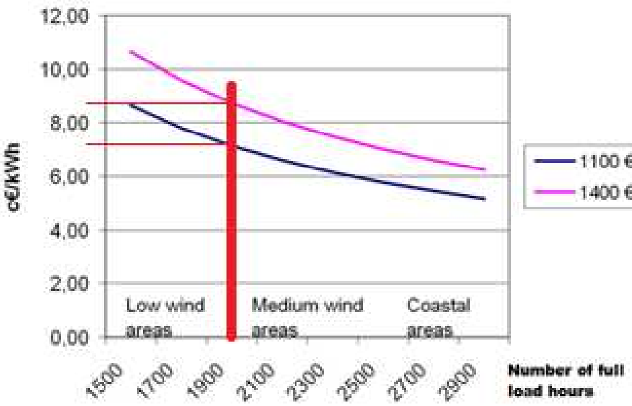
  Enercon E-48. Annual production: 1,570,000 KWh.

  [Price of maintenance (c€/KWh) * Annual production * No. of years]

  Operation and Maintenance cost:

  [€283,000 for (1.2 c€/KWh – 15 years) to €471,000 for(1.5 c€/KWh – 20 years)]

- ✓ **Cost of Energy Generated by Wind Power:**



Full load Hours Enercon E-48: 2000 h

Cost of Energy Generated by Wind Power: 8 c€/KWh

[Cost of Energy Generated (c€/KWh) * Annual production]

Cost of Energy Generated by Wind Power:[125 600 €/year]

- ✓ **Subsidies:** Electricity market spot price is between 42.5 €/MWh

  83.50 € - 42.5 € = 41 €/MWh

  For 1 year:[Annual production * subsidy]

  1570 MWh * 41 €/MWh = 76 160 €/year

Subsidies:[64.400 €/year] – Maximum period: 12 years.

4.A. 10: Power predictor

User Guide

This device has been designed to provide quality data on wind speeds and on solar potential of a site. It is composed of three parts:

- a solar sensor
- a wind speed sensor
- a wind direction sensor

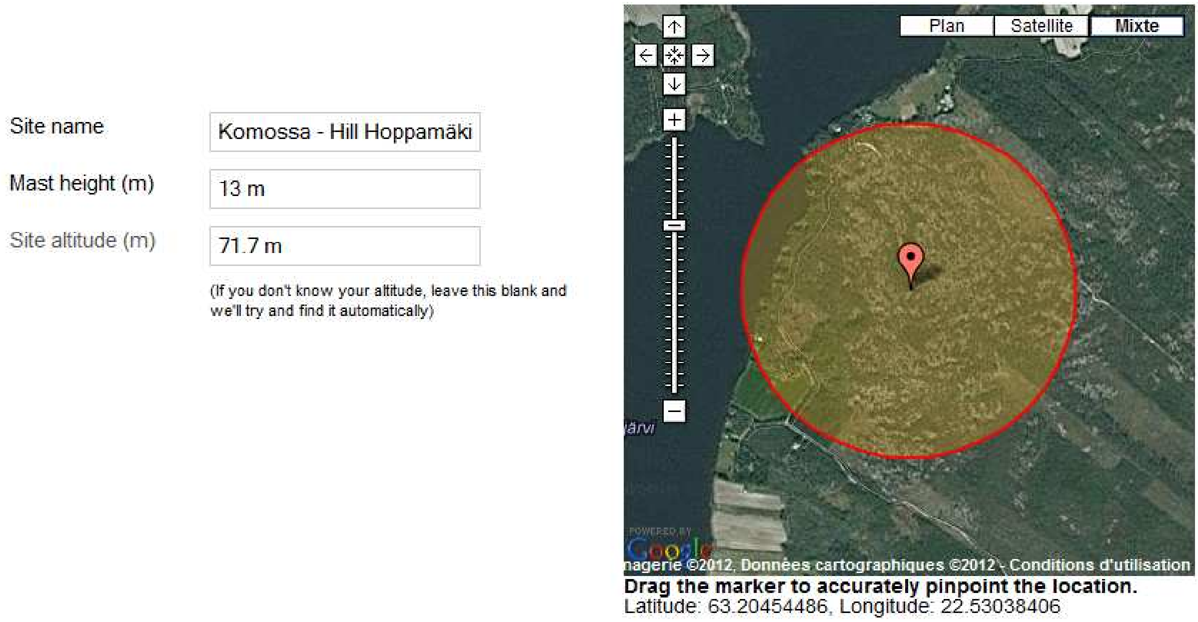
Its autonomy can be longer than one year. If the duration of your measurements is big. Yours percent of data confience will be great.

A.F.13. Power Predictor

Implement your wind sensor in the area of your choice. The cabinet becomes composed of some components like the wind sensor, fixing cables, memory card (for recording data), manual of utilisation.

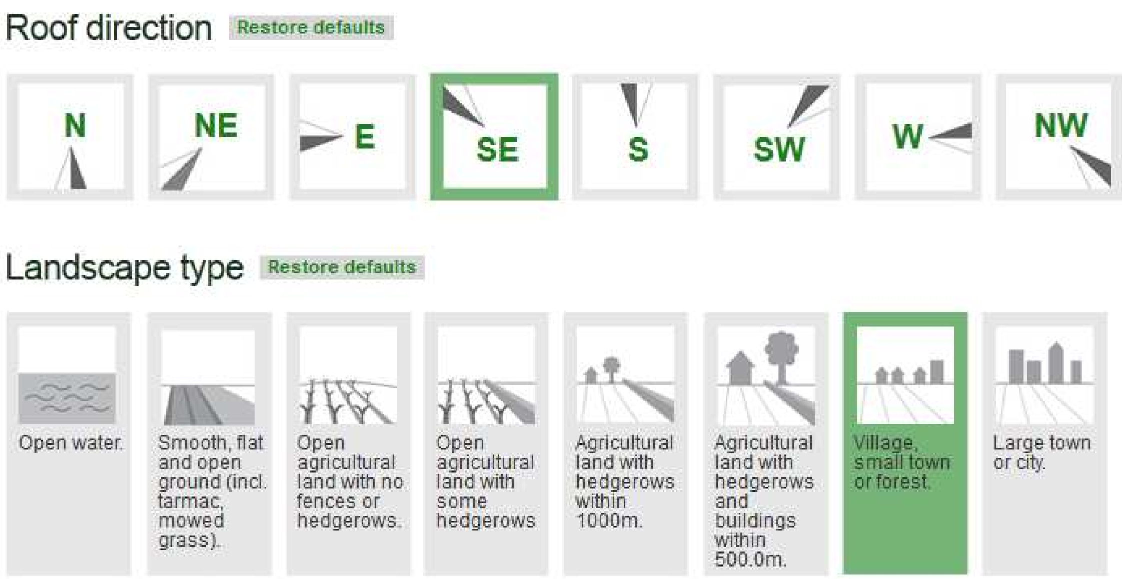
Web site to exploit the sensor data

During your first connection, you have to entry the activation key of your sensor. The second step is to define the location of your sensor on a map like you can see in the next figure.



A.F.14. Location on the website

After this you have to choose your roof direction and your landscape type among various possible solutions. The next figure shows this solution.



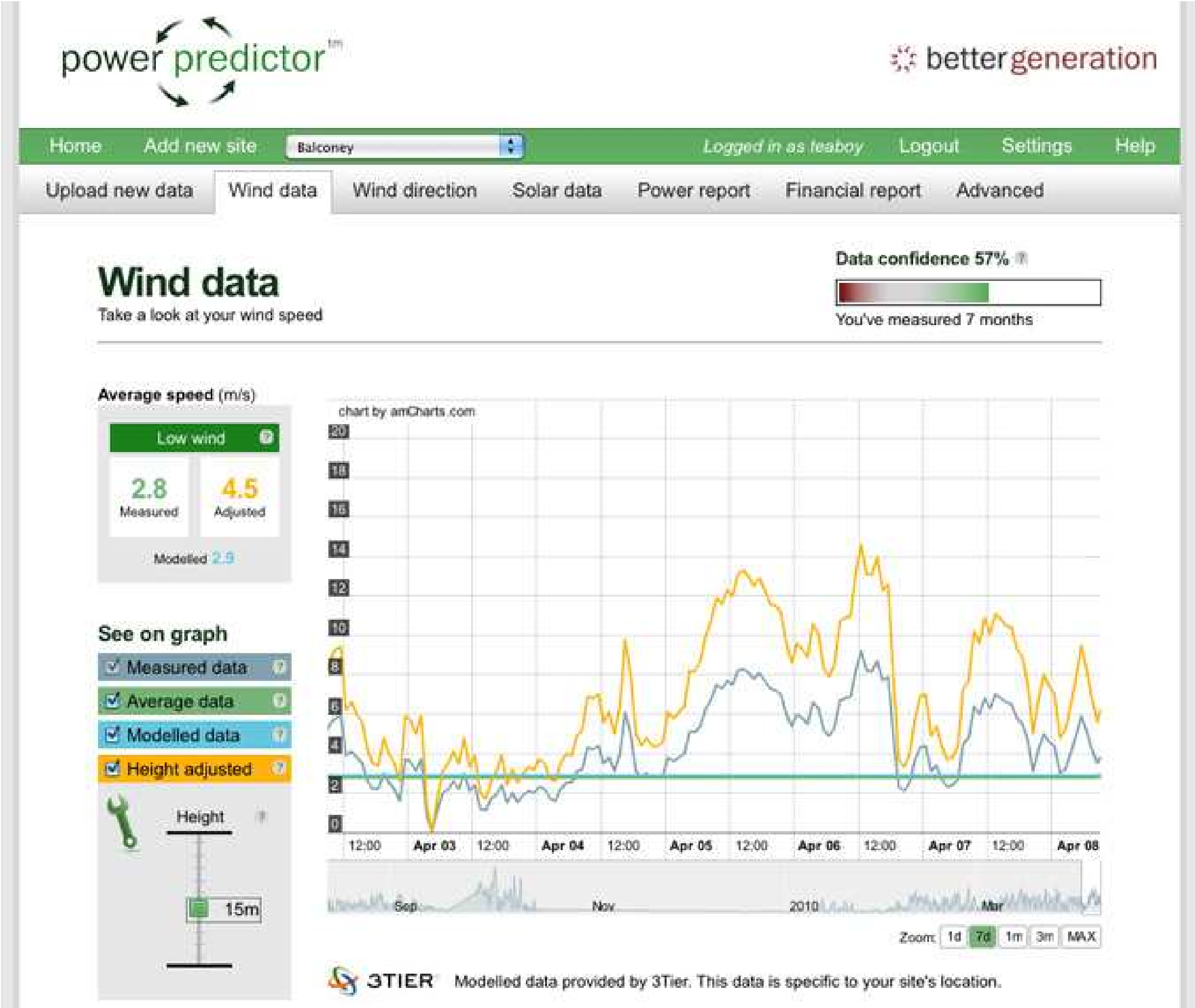
A.F.15. Roof direction and landscape type

Now you can upload your data on the website.

Exploitation of the data

A.F.16.Data studied by the website

Wind data study



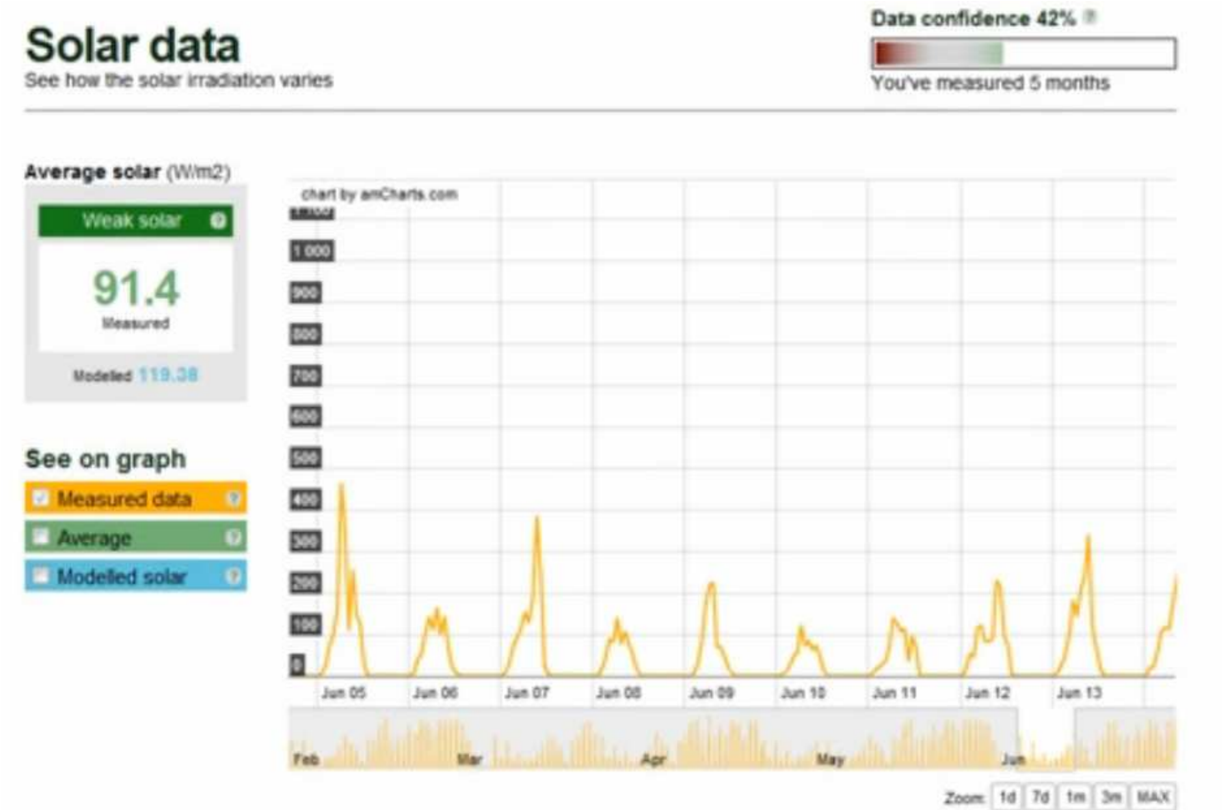
A.F.17. Wind data

In this data, you can find some information about the wind condition in your area like the average wind speed at different elevations. For example the blue curve shows the measured data and the yellow curve shows the estimated value at different elevations. The period of measurement can be changed with the zoom.

Wind Direction

This part is explained in the report Part 4.1.1: Wind direction.

Solar data



A.F.18. Solar data

This part works on the same principle as that of the wind data.

Power report

This part shows a study about the costs of different small wind turbines and heating solutions. It chooses for you the best wind turbine for the production of electricity. It gives details about the annual production, the general cost, the payback time and the capacity factor of your installation. It shows also different heating solutions like solar thermal, ground source heat pump and air source heat pump.

Electricity Options

Endurance E-3120 50kW

Sorted by

	Sort by kWh	Capital cost	kWh	Basic value	Capacity factor	$kgCO_2$ saved	Estimated Payback
1	Endurance E-3120 50kW	£240,000	1732	£208	3.9%	942.1kg	--yrs
2	Westwind 20kW	£69,000	410.0	£49.19	2.5%	223.0kg	--yrs
3	Gaia Wind 133 - 11kW	£50,600	338.4	£40.60	3.8%	184.1kg	--yrs
4	Westwind 10kW	£40,300	170.4	£20.45	2.1%	92.7kg	--yrs
5	Eoltec Scirocco 6kW	£23,000	166.1	£19.93	3.4%	90.3kg	--yrs
6	Evance Iskra R9000	£24,150	115.3	£13.83	2.7%	62.7kg	--yrs
7	Ampair 6kW	£15,000	112.7	£13.52	2.3%	61.3kg	--yrs
8	Westwind 5.5kW	£24,200	99.6	£11.95	2.2%	54.2kg	--yrs

Show more

Heating options

As well as telling you how well a wind turbine or solar PV panel would perform at your site, we can use the data you've collected to make some estimates about the performance of some renewable heat devices. Select your current heating solution from the list and we'll show you how much you could have saved below.

Gas
Gas
Electric
Oil

Solar Thermal

Capital Cost : €5900	Savings per year : €20	CO2 saved per year : 14.03kg	Payback time : 29

There's more than one type of solar thermal panel but we've assumed for these calculations that you'll have a 3.4m^2 installation on a typical family sized semi detatched house.

Ground Source Heat Pump

Capital Cost : €11200 - €21100	Savings per year : €0 - €161	CO2 saved per year : 350kg - 800kg	Payback time: 69.2+ yrs

Take care: These calculations are based on your location but they are just a guideline based on a typical 3 bedroom semi-detached property in your country.

Air Source Heat Pump

Capital Cost : €7400 - €12400	Savings per year : -€124 - €161	CO2 saved per year : -30kg - 800kg	Payback time: 46.2+ yrs

Negative savings mean that it could actually cost you more to use this technology than your current system. Also note that your payback time might be longer than the lifetime of the device.

A.F.19. Electricity option

A.4 | Chapter five

5. A.1 Calculations and sized of the different elements

The calculation process can be simplified into four steps:

1. Calculation of the maximum daily power need.
2. Calculating the type of inverter.
3. Calculation of the maximum daily consumption.
4. Calculating the number of PV modules.
5. Calculating the battery capacity.
6. Calculating the type of regulator.
7. Disposition of the installation

*All the calculations listed below are based in A.R.1 (Lopez, 2011)

1. Calculation of the maximum daily power

To determine the size of a PV isolated installation, it is necessary to know the energy demand by the user, the real solar energy available, and from these data determine the size of the various components of the installation.
There will be a detailed estimate of the average daily electricity consumption throughout the year for a detached home formed by 4 persons. The devices used in the housing are the following.

Consumption Elements	Number of units	Power per unit (W)	Power Installed (W)	Hours/day	Wh per day
Lamps	12	20	240	6	1440
TV	2	120	240	3	720
Music equipment	2	75	150	2	300
Computer	2	125	250	4	1000
Freezer	1	250	250	7	1750
Oven	1	1200	1200	0,5	600
microwave	1	800	800	0,5	400
Wash machine	1	1400	1400	2	2800
Dishwasher	1	1000	1000	1	1000
Oven	1	1500	1500	1,5	2250
Small households (hairdryer, toasted...)	1	1700	1700	0,5	850
Dryer	1	1600	1600	0,5	800
Water pump	1	400	400	3	1200
			10370 W	14660 Wh per day	

A.T.9 Estimated consumption of a family of 4 people (Own)

Average consumption per day depends on the month of the year. So the winter months the daily consumption will be higher due to the lack of light in most hours of the day, and in summer its change, consumption decreases because the people spend less time inside their because of the good weather, and less lighting is used, as there are more hours of sunshine.

The estimated consumption in the summer months is about 11 kWh and in winter about 16 kWh.

For the calculations a value close to the months of April and May is used, because if it is based the winter months, there will be overproduction in summer, and thereby wasting energy.

Average consumption per day is set to **12 kWh** per day, and with that value the installation will be sized for a full year.

The installed power is it 10370W, considering that consumer equipment is AC at 220 V. For calculations is estimated an average, each detached house has a power installation based on the devices of 10500 W.

2. Calculating the type of inverter

Theoretically, for choose the inverter it take in account the output power, and the total power installed in the home, because the output power of the inverter have to be above of the total power installed, but living in a 4 people house is very difficult that all the equipment are connected at the same time therefore estimated maximum usage per unit time of 4000 W.

Power nominal (W)	800	1000	1500	1800	2000	3600	5000	7000
Voltage nominal (V)	12	12	12	12/24	24	24	24/48	48
Overload 3'' (W)	1500	2000	2800	3300	3600	7000	7000	12000
Overload 50'' (W)	1200	1500	2250	2700	3000	5400	6000	10500
Overload 6' (W)	960	1200	1800	2160	2400	4320	5320	8400
Length (mm)	315	315	460	460	535	535	535	647
Height (mm)	118	118	157	157	178	178	178	210
Width (mm)	192	192	255	255	285	285	285	344
Net weight (kg)	9	12	20	22	24	36	36	68
Price (€)	710	760	960	1025	1330	1260	1640	3300

A. T.10. Different inverters of the Solener dealer. (Solener, 2011)

$$\textit{Power inverter} \geq 4000 \text{ W}$$

Inverters list given by the dealer Solener and respecting the constraint is chosen nominal power inverter 5000 W with a price of 1640 €.

3. **Calculation of the maximum daily consumption.**

This chapter calculates the energy consumption of the installation, in that consumption will vary depending on the tension used, the higher the voltage the lower the current. But by contrast, will require more battery.

It uses a voltage value for the installation of 24 V, as it is used in high storage batteries and solar panels that generate high power, and they work with 24 V or more.

$$Energy\ installed\_max = \frac{E\ max\ daily}{V\ Battery} = \frac{12000\ wh}{24\ V} = 500\ Ah\ per\ day$$

The calculated value must be increased to maintain an acceptable consumption generating installation (photovoltaic panels). This increase is called safety margin or safety factor, the margin values ranging from 10%, 15% or 25%.

Apply a 15% margin:

$$Emax\_daily = Einst\_max + Einst\_max \cdot 15\% = 1,15 \cdot Einst\_max = 1,15 \cdot 500 = 575\ Ah\ per\ day$$

For maximal, we must take into account the lost, for it; calculate the total losses (Kt).

$$Kt = [1 - (Kb + Kc + Kr + Kx)] \cdot [1 - \frac{(Ka \cdot Daut)}{Pa}]$$

Ka: Losses because daily self-discharge of the battery, produced at 20 º C. This lost usually comes in the datasheets of this product provided by the manufacturer of the battery, its value default is 0.5%.

Kb: Loss because battery efficiency, usually, has a value of 5%, but can be chosen to a value of 10% for strong discharges old or accumulators or low temperatures. In this case value is used a 10% because of low temperatures in Komossa in the winter.

Kc: Losses because of the efficiency of the inverter used. The default values typically range between 8 % and 95%, so that losses oscillate between 20% and 5%. In this case be used a 10% because be a normal type of inverter is chosen.

Kc: Losses because regulator's job efficiency. Usually depends on the type used, but it is unknown if the default hosts efficiency of 90%, so the losses will be 10%.

KX: Other losses not contemplated (by the Joule effect, voltage losses, etc.). A default value of 10% is chosen.

Daut :Days of autonomy with little or no sunshine. In the Finnish winters in Finland there are few hours of sun, but the sky is clear, however in the autumn it is the rainy season, and days can be spent with the sky completely covered, so a value of 5 is chosen as days of autonomy for the installation.

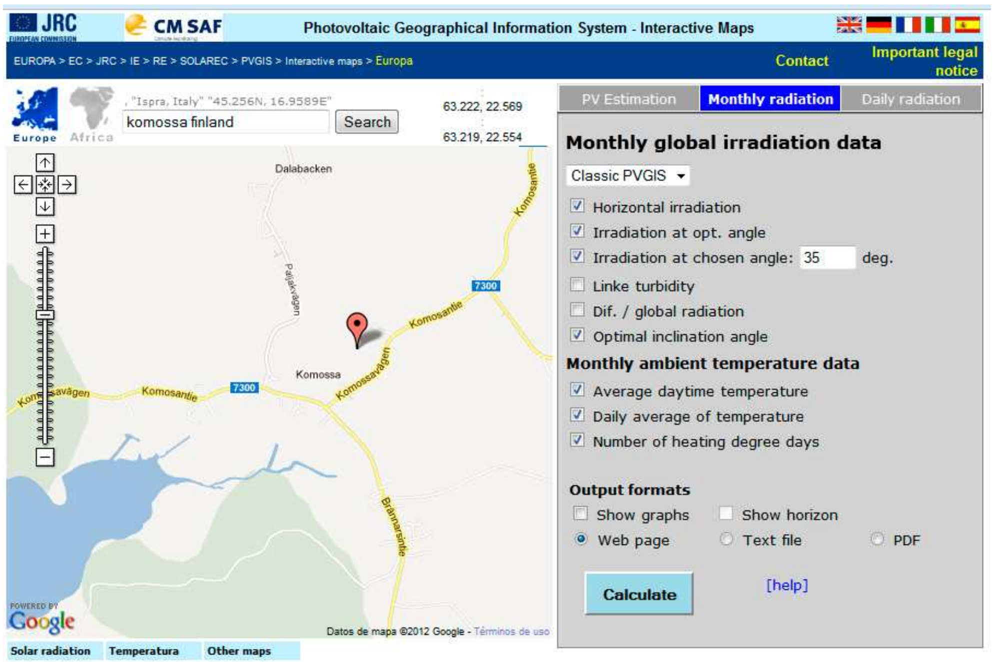
Pd: Depth of battery discharge, which is given by the battery manufacturer, choosing a default value of 60% or 70%.

$$Kt = [1 - (Kb + Kc + Kr + Kx)] \bullet [1 - \frac{(Ka \cdot Daut)}{Pa}] \quad Kt = [1 - (0{,}1 + 0{,}1 + 0{,}1 + 0{,}1)] \bullet [1 - \frac{(0{,}005 \cdot 5)}{0{,}6}] = 0{,}93$$

$$Emax = \frac{E\,max\,daily}{Kt} = \frac{575}{0{,}93} = 618{,}28 \text{ Ah daily}$$

4. Calculating the number of PV modules

A PVGIS estimation tool is used, with the following considerations can establish the estimated solar radiation for the project location, Komossa can be established.



A. F. 20. *Screenshot of PVGIS* tools website. (PVGIS, 2011)

Komossa, location: 63º13'8" North, 22º33'15" East, Elevation: 44 m a.s.l.

Solar radiation database used: PVGIS-classic

Optimal inclination angle is: 45 degrees

Annual irradiation deficit due to shadowing (horizontal): 0.0 %

Month	H_h	H_{opt}	H(35)	I_{opt}	T_D	T_{24h}	N_{DD}
Jan	170	635	552	82	-4.5	-4.7	728
Feb	759	1980	1780	75	-5.3	-5.8	693
Mar	1810	3000	2840	61	-2.7	-3.5	602
Apr	3610	4710	4640	46	2.6	2.0	433
May	5060	5510	5610	32	7.5	7.0	270
Jun	5580	5600	5770	24	13.0	12.7	114
Jul	5160	5340	5490	27	16.8	16.4	41
Aug	3600	4110	4140	37	16.4	15.7	106
Sep	2030	2860	2770	53	11.6	11.0	299
Oct	859	1580	1480	67	6.0	5.5	471
Nov	245	634	568	77	0.7	0.5	595
Dec	73.5	316	272	84	-3.1	-3.3	719
Year	2420	3030	3000	45	4.9	4.5	5071

A. T.11. Solar irradiance values of Komossa. (PVGIS, 2011)

H_h: Irradiation on horizontal plane (Wh/m^2/day)

H_{opt}: Irradiation on optimally inclined plane (Wh/m^2/day)

H(35): Irradiation on plane at angle: 35 deg. (Wh/m^2/day)

I_{opt}: Optimal inclination (deg.)

T_D: Average daytime temperature (deg.)

T_{24h}: 24 hour average of temperature (deg.)

Knowing the energy that the facility is going to consume, (Emax), and the characteristics of the panel, number of PV modules required is calculated.

That is, the software will calculate the amount of amps it can supply to the installation and that value fits the amps needed to run the installation completely autonomously, the calculation must take into account the energy generated by a panel (Epanel) for one day to do this using the following equation:

Epanel = I_panel · SHP · η panel [Ahd]

η panel is the panel's performance.

In panel performance typical values can be chosen between 85% and 95%. As a general rule selects a 90% overall performance therefore is multiplied by 0.9, and the equation being:

Epanel =0,9 · I_panel · SHP [Ahd] = 0,9 · Im · SHP [Ahd]

So to obtain the SHP value (Solar hour's peak), divide the value of irradiation with an optimal inclination, 45º, of 1 Kilowatt per square meter, so it shows that the value of SHP is obtained dividing by 1000.

The calculation will take months for the use to be applied, one year, 12 months, divided by the days of autonomy, in this case are five days.

$$SHP = \frac{Jan+Feb+Mar+Apr+May+Jun+Jul+Aug+Sep+Oct+Nov+Dec}{5\ days} = \frac{0,64+1,98+3,00+4,71+5,51+5,60+5,34+4,11+2,86+1,58+,63+0,32}{5} = 7,26$$

Below is a table with different solar panels from the same manufacturer LDK:

TYPE		AB190M	AB195M	AB200M
Nominal Output (Pmax) [W]		**190**	195	200
Voltage at Pmax [Vmp] [V]		**37.7**	37.9	38.1
Current al Pmax (Imp) [A]		**5.18**	5.30	5.41
Open Circuit Voltage (Voc) [V]		**42.8**	45.0	45.2
Short Circuit Current (Isc)		**5.51**	5.59	5.68
Cell Efficiency		**18.25**	18.73	19.21
Module Efficiency		**14.88**	15.27	16.67

A.T.12. Different manufacturers of solar panels. (Aibo, 2010)

The power tolerance is +/- 3% referred to the Nominal Output

Maximum System Voltage

STC (Standard Test Conditions): Irradiance 1000W/m2. Module Temperature 25ºC, Air Mass 1.5*

AB 190 M a model from Solar Aibo dealer of photovoltaic panel is chosen, with a price of 250 € for each panel.

$$Epanel = 0{,}9 \cdot Ipanel \cdot SHP = 0{,}9 \cdot 5{,}18 \cdot 7{,}26 = 33{,}72 \text{ Ah per day}$$

To calculate the number of parallel branches:

$$\frac{Emax}{Epanel} = \frac{618{,}28}{33{,}72} = 18{,}33$$

Parallel panels = 19 panels

Total Installation kWp:

21 · 190w = 3,610 kWp

5. Calculating the battery capacity

To calculate the number of batteries needed, the capacity of the battery bank installation must be known using the same value of depth of discharge as for the battery used for the calculation of losses. Field capacity of batteries is:

$$\frac{E\,max \cdot D\,aut}{Pd} = \frac{618{,}28 \cdot 5}{0{,}93} = 3324{,}09 \text{ Ah}$$

Type Battery	Ah. Ah. C10	C100	Length mm.	Width mm.	Height mm	Weight Kg. Without/Acid	Weight Kg. With/Acid
6 OPzS 600	600	900	147	208	791	36,9	49,8
8 OPzS 800	800	1.200	212	193	791	48,1	65
10 OPzS 1.000	1.000	1.500	212	235	791	58,9	80
12 OPzS 1.200	1.200	1.800	212	277	791	67,8	93
12 OPzS 1.500	1.500	2.232	212	277	941	80,8	115
16 OPzS 2.000	2.000	3.000	212	397	920	107,7	165,7
20 OPzS 2.500	2.600	3720	212	487	920	134,7	202,7
24 OPzS 3.000	3.120	4.464	212	576	920	161,6	237,6

A.T.13. Different types of batteries. (Batterien, 2012)

Battery 20 OPzS 2,500 is selected with a storage capacity of 3720 Ah, checked above the restriction. Above is a table of the dealer HOPPECKE Batteries. The price is 6100

6. Calculating the type of regulator

The last item to be chosen is the regulator. To calculate the current regulator, to do this, see the short circuit current of the photovoltaic module AB 190 M

From the following regulators, will take the most suitable for installation as required.

Ifield_ photovoltaic = Isc · nº of branches =5,51 ·19 = 104,69 A

Iregulator = 105 A

MODELO	SS-30C	SS-45C	SS-60C
ELECTRICAS			
Indices voltage systems	12, 24, 48 VCC		
Current Indices - Controller Battery Charge	30A	45A	60A
Indices Current - DC Charge Controller	30A	45A	60A
Current Indices - diversion load controller	30A diversion load	45A diversion load	60A diversion load
Precision	12/24V: ≤0.1% ± 50mV 48V: ≤0.1% ± 100mV		
Minimum voltage for current	9V		
Max. the PV field open circuit (Voc)	140V		
Max. operating voltage	68V		
Total current consumption	During operation, 25mA, Stand-3mA		

A. T.14. Different types of regulators. (Xantrex, 2012)

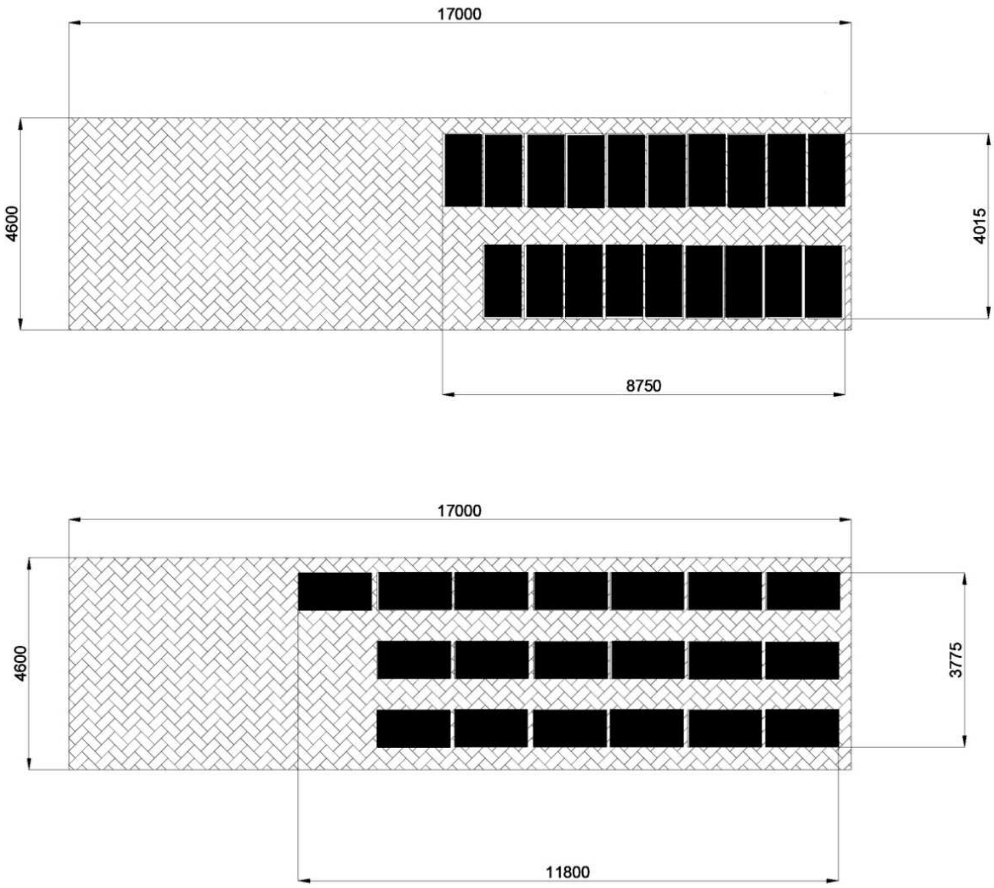
2 regulators are chosen, one SS - 60C of 60A and SS – 45 C of 45 A to cover the 105 A that the 19 solar panels are providing. They are priced at € 280 and 219 €, for a total of 499 €.

7. Disposition of the installation

The panels will be on the roof of the house, the area occupied will be:

- Module AB 190 M = 1,586 m (height) · 0,808 m (width) = 1,281 m^2
- Total area occupied = 1,281 m2· 19 (panels) = 24.34 m

Different solutions to the placement of the panels on the roof:



A. F.21. Two versions of how placing the solar panels. (Own)

5. A.2. Estimated the production of a solar panel installation

Fixed system: inclination=44º, orientation=0º (Optimum at given orientation)				
Month	E_d	E_m	H_d	H_m
Jan	2.12	65.6	0.64	19.8
Feb	6.46	181	1.98	55.3
Mar	9.37	291	2.99	92.7
Apr	14.10	423	4.71	141
May	16.10	499	5.53	171
Jun	15.80	475	5.62	169
Jul	14.90	462	5.36	166
Aug	11.50	357	4.12	128
Sep	8.40	252	2.85	85.6
Oct	4.85	150	1.57	48.7
Nov	2.05	61.5	0.64	19.1
Dec	0.99	30.7	0.30	9.32
Yearly average	**8.90**	**271**	**3.03**	**92.1**
Total for year		**3250**		**1110**

A. T. 15. Production each month in Komossa. (PVGIS, 2011)

Nominal power of the PV system: 3.6 kW (crystalline silicon)

Estimated losses due to temperature: 6.4% (using local ambient temperature)

Estimated loss due to angular reflectance effects: 2.9%

Other losses (cables, inverter etc.): 10.0%

Combined PV system losses: 18.2%

E_d: Average daily electricity production from the given system (kWh)

E_m: Average monthly electricity production from the given system (kWh)

H_d: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

H_m: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

5. A.3. Payback calculations

1	2	3	4	5	6	7
Year	Initial Cost	Maintenance Cost 4%	Costs Totals 2+3	Saving 4%	Net flow 4+5	Accumulated 7+5
1	-14 289		-14 289	570,43	-13718,57	-13718,57
2		-40	-40	587,54	547,54	-13171,03
3		-41,2	-41,2	605,16	563,96	-12607,07
4		-42,43	-42,43	623.32	580,89	-12043,11
5		-43,70	-43,70	642,02	598,32	-11444,79
6		-45,02	-45,02	661,28	616,26	-10828,53
7		-46,37	-46,37	681,12	634,75	-10193,78
8		-47,76	-47,76	701,56	653,8	-9539,98
9		-49,19	-49,19	722,60	673,41	-8866,57
10		-50,67	-50,67	744,28	693,61	-8172,96
11		-52,19	-52,19	766,61	714,42	-7458,54
12		-53,75	-53,75	789,60	735,85	-6722,69
13		-55,36	-55,36	813,29	757,93	-5964,76
14		-57,03	-57,03	837,69	780,66	-5184,10
15		-58,74	-58,74	862,82	804,08	-4380,02
16		-60,50	-60,50	888,71	828,21	-35518,1
17		-62,31	-62,31	915,37	853,06	-2698,75
18		-64,19	-64,19	942,83	878,64	-1820,11
19		-66,11	-66,11	971,11	905	-915,11
20		-68,09	-68,09	1000,25	932,16	**17,05**
21		-70,14	-70,14	1030,26	960,12	977,17
22		-72,24	-72,24	1060,17	987,93	1,965.1
23		-74,40	-74,40	1093,01	1018,61	2,983,71
24		-76,63	-76,63	1125,79	1049,16	4032,87
25		-78,94	-78,94	1159,56	1080,62	5113,49
26		-81,30	-81,30	1194,35	1113,05	6226,54
27		-83,74	-83,74	1230,18	1146,44	7372,98
28		-86,25	-86,25	1267,08	1180,83	8713,60
29		-88,84	-88,84	1305,10	1216,26	8914,82
30		-91,51	-91,51	1344,25	1252,74	10167,56
Total	-14289	-1808,6	-16097,6	26514,02	9848,74	

A. T.16. Payback time calculations. *NPV, net present value.* (Done, 2012)

5. A.4 Data about small user installation

Total fuel and/or electrical energy consumption of the system [Etot]	13,866.8 kWh
Total energy consumption [Quse]	14,830.7 kWh
System performance (Quse / Etot)	1,07
Comfort demand	Energy demand covered

A. T.17. System overview for small users (annual values) (Solaris, 2012)

Collector area	8,6
Solar fraction total	18,1%
Solar fraction hot water	48,3%
Solar fraction building	10,1%
Total annual field yield	2,892.6 kWh
Collector field yield relating to gross area	334.6 kWh/m²/Year
Collector field yield relating to aperture area	510.5 kWh/m²/Year
Max. energy savings	3,044.9 kWh

A. T.18. Overview solar thermal energy for small users (annual values) (Solaris, 2012)

Collector	Genersys HP 58/30	
Data Source	SPF	
Number of collectors	2	
Number of arrays	1	
Total gross area	m²	8.64
Total aperture area	m²	5.666
Total absorber area	m²	4.96
Tilt angle (hor.=0°, vert.=90°)	°	40
Orientation (E=+90°, S=0°, W=-90°)	°	0
Collector field yield [Qsol]	kWh	2,892.6
Irradiation onto collector area [Esol]	kWh	7,070
Collector efficiency [Qsol / Esol]	%	40.9
Direct irradiation after IAM	kWh	3,704.2

A. T.19. Specifications of solar collector small users (Solaris, 2012)

Building	Single family house, normal building	
Heated/air-conditioned living area	m²	99
Heating setpoint temperature	°C	21.1
Heating energy demand excluding DHW [Qdem]	kWh	12,994.6
Specific heating energy demand excluding DHW [Qdem]	kWh/m²	131.3
Solar gain through windows	kWh	11,906.1
Total energy losses	kWh	28,679.3

A. T.20. Type of Building and specifications for small users (Solaris, 2012)

Hot water demand	constant	
Volume withdrawal/daily consumption	l/d	121.2
Temperature setting	°C	45
Energy demand [Qdem]	kWh	1,796.5

A. T.21. Demand of hot water for small users (Solaris, 2012)

Storage tank	200gal US universal tank	
Volume	l	757.1
Height	m	2.2
Material		Enameled steel
Insulation		Flexible polyurethane foam
Thickness of insulation	mm	101.6
Heat loss	kWh	533
Connection losses	kWh	512.3

A. T.22. Specifications of Storage tank for small users (Solaris, 2012)

	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar thermal energy to the system [Qsol]													
kWh	2893	154	181	278	307	341	293	312	303	271	206	134	111
Heat generator energy to the system (solar thermal energy not included) [Qaux]													
kWh	13131	2744	2135	1411	769	196	0	0	0	192	777	2153	2754
Heat generator fuel and electrical energy consumption [Eaux]													
kWh	13822	2889	2247	1485	809	206	0	0	0	203	818	2267	2899
Solar fraction: fraction of solar energy to system [SFn]													
%	18.1	5.3	7.8	16.4	28.5	63.5	100	100	100	58.5	20.9	5.9	3.9
Total fuel and/or electrical energy consumption of the system [Etot]													
kWh	13867	2897	2254	1490	812	208	1	1	1	204	820	2273	2907
Irradiation onto collector area [Esol]													
kWh	7070	312	401	627	728	817	801	877	843	676	477	284	228
Electrical energy consumption of pumps [Epar]													
kWh	45	8	6	5	3	2	1	1	1	1	3	6	8
Heat loss to indoor room (including heat generator losses) [Qint]													
kWh	1936	215	181	156	135	131	144	158	157	128	133	184	213
Heat loss to surroundings (without collector losses) [Qext]													
kWh	50	2	3	4	5	6	6	7	6	5	3	2	2
Total energy consumption [Quse]													
kWh	14831	2835	2252	1604	992	387	156	151	148	354	924	2225	2803

A. F.22. Summary of the performance of installation small users (Solaris, 2012)

5. A.5 Data about medium user installation

Total fuel and/or electrical energy consumption of the system [Etot]	26,180.5 kWh
Total energy consumption [Quse]	29,270.3 kWh
System performance (Quse / Etot)	1.12
Comfort demand	Energy demand covered

A. T.23. System overview for medium users (annual values) (Solaris, 2012)

Collector area	17,3 m^2
Solar fraction total	18.6%
Solar fraction hot water	47.6%
Solar fraction building	12.5%
Total annual field yield	5,663.7 kWh
Collector field yield relating to gross area	327.6 kWh/m²/Year
Collector field yield relating to aperture area	499.8 kWh/m²/Year
Max. energy savings	5,961.7 kWh/m²/Year

A. T.24. Overview solar thermal energy for medium users (annual values) (Solaris, 2012)

Collector	Genersys HP 58/30	
Data Source	SPF	
Number of collectors	4	
Number of arrays	1	
Total gross area	m²	17.29
Total aperture area	m²	11.332
Total absorber area	m²	9.92
Tilt angle (hor.=0°, vert.=90°)	°	40
Orientation (E=+90°, S=0°, W=-90°)	°	0
Collector field yield [Qsol]	kWh	5,663.7
Irradiation onto collector area [Esol]	kWh	14,140
Collector efficiency [Qsol / Esol]	%	40.1
Direct irradiation after IAM	kWh	7,408.4

A. T.25. Specifications of solar collector medium users (Solaris, 2012)

Building	Single family house, normal building	
Heated/air-conditioned living area	m²	187
Heating setpoint temperature	°C	21.1
Heating energy demand excluding DHW [Qdem]	kWh	26,222
Specific heating energy demand excluding DHW [Qdem]	kWh/m²	140.2
Solar gain through windows	kWh	16,837
Total energy losses	kWh	48,037.8

A. T.26. Type of Building and specifications for medium users (Solaris, 2012)

Hot water demand	constant	
Volume withdrawal/daily consumption	l/d	202.1
Temperature setting	°C	45
Energy demand [Qdem]	kWh	2,994.6

A. T.27. Demand of hot water for medium users (Solaris, 2012)

Storage tank	1500l buffer universal tank	
Volume	l	1,500
Height	m	2
Material		Steel
Insulation		Rigid PU foam
Thickness of insulation	mm	80
Heat loss	kWh	814.8
Connection losses	kWh	605.7

A. T.28. Specifications of Storage tank for medium users (Solaris, 2012)

	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar thermal energy to the system [Qsol]													
kWh	5664	327	388	596	663	700	545	493	491	508	435	285	233
Heat generator energy to the system (solar thermal energy not included) [Qaux]													
kWh	24829	5008	3960	2776	1623	463	52	0	0	410	1550	3972	5018
Heat generator fuel and electrical energy consumption [Eaux]													
kWh	26136	5272	4169	2922	1708	487	54	0	0	431	1631	4181	5282
Solar fraction: fraction of solar energy to system [SFn]													
%	18.6	6.1	8.9	17.7	29	60.2	91.3	100	100	55.4	21.9	6.7	4.4
Total fuel and/or electrical energy consumption of the system [Etot]													
kWh	26181	5280	4175	2927	1712	489	55	1	1	433	1634	4186	5289
Irradiation onto collector area [Esol]													
kWh	14140	623	802	1255	1455	1634	1602	1754	1686	1352	953	569	455
Electrical energy consumption of pumps [Epar]													
kWh	44	8	6	5	4	2	1	1	1	1	3	6	7
Heat loss to indoor room (including heat generator losses) [Qint]													
kWh	2925	332	278	236	196	182	207	242	244	198	192	284	333
Heat loss to surroundings (without collector losses) [Qext]													
kWh	46	2	3	4	4	5	6	6	6	4	3	2	2
Total energy consumption [Quse]													
kWh	29270	5375	4339	3293	2204	937	411	251	247	786	1959	4228	5240

A. F.23. Summary of the performance of installation medium users (Solaris, 2012)

5. A.5 Data about large user installation

Total fuel and/or electrical energy consumption of the system [Etot]	41,519.4 kWh
Total energy consumption [Quse]	47,050.5 kWh
System performance (Quse / Etot)	1.13
Comfort demand	Energy demand covered

A. T.29. System overview for large users (annual values) (Solaris, 2012)

Collector area	30.3 m^2
Solar fraction total	18.4%
Solar fraction hot water	49.1%
Solar fraction building	12.8%
Total annual field yield	8,857.6 kWh
Collector field yield relating to gross area	292.8 kWh/m²/Year
Collector field yield relating to aperture area	446 .7 kWh/m²/Year
Max. energy savings	9,323.8 kWh/m²/Year

A. T.30. Overview solar thermal energy for large users (annual values) (Solaris, 2012)

Collector	Genersys HP 58/30	
Data Source	SPF	
Number of collectors	7	
Number of arrays	1	
Total gross area	m²	30.25
Total aperture area	m²	19.831
Total absorber area	m²	17.37
Tilt angle (hor.=0°, vert.=90°)	°	40
Orientation (E=+90°, S=0°, W=-90°)	°	0
Collector field yield [Qsol]	kWh	8,857.6
Irradiation onto collector area [Esol]	kWh	24,745.1
Collector efficiency [Qsol / Esol]	%	35.8
Direct irradiation after IAM	kWh	12,964.7

A. T.31. Specifications of solar collector large users (Solaris, 2012)

Building	Single family house, normal building	
Heated/air-conditioned living area	m²	306
Heating setpoint temperature	°C	21.1
Heating energy demand excluding DHW [Qdem]	kWh	41,703
Specific heating energy demand excluding DHW [Qdem]	kWh/m²	136.3
Solar gain through windows	kWh	31,524.4
Total energy losses	kWh	82,268.8

A. T.32. Type of Building and specifications for large users (Solaris, 2012)

Hot water demand	constant	
Volume withdrawal/daily consumption	l/d	351.5
Temperature setting	°C	45
Energy demand [Qdem]	kWh	5,207.8

A. T.33. Demand of hot water for large users (Solaris, 2012)

Storage tank	750gal US universal tank	
Volume	l	2,839.1
Height	m	2.2
Material		Enameled steel
Insulation		Flexible polyurethane foam
Thickness of insulation	mm	101.6
Heat loss	kWh	1,032.3
Connection losses	kWh	480.1

A. T.34. Specifications of Storage tank for large users (Solaris, 2012)

	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Solar thermal energy to the system [Qsol]													
kWh	8858	544	645	1000	1107	1080	799	679	666	778	692	477	390
Heat generator energy to the system (solar thermal energy not included) [Qaux]													
kWh	39402	8190	6386	4302	2350	617	0	0	0	562	2338	6438	8217
Heat generator fuel and electrical energy consumption [Eaux]													
kWh	41476	8621	6722	4529	2474	650	0	0	0	591	2461	6777	8650
Solar fraction: fraction of solar energy to system [SFn]													
%	18.4	6.2	9.2	18.9	32	63.6	100	100	100	58.1	22.8	6.9	4.5
Total fuel and/or electrical energy consumption of the system [Etot]													
kWh	41519	8629	6728	4534	2478	652	1	1	1	593	2464	6783	8657
Irradiation onto collector area [Esol]													
kWh	24745	1091	1404	2196	2546	2859	2804	3069	2950	2366	1668	995	797
Electrical energy consumption of pumps [Epar]													
kWh	44	7	6	5	4	2	1	1	1	1	3	6	7
Heat loss to indoor room (including heat generator losses) [Qint]													
kWh	3798	512	414	322	238	206	217	248	248	216	245	421	511
Heat loss to surroundings (without collector losses) [Qext]													
kWh	57	2	3	4	5	7	7	8	7	5	4	2	2
Total energy consumption [Quse]													
kWh	47050	8733	7024	5209	3425	1401	606	435	424	1214	3057	6913	8608

A. F.24. Summary of the performance of installation large users (Solaris, 2012)

A.5 | Chapter six

6.A. 1: Forest and Wood data

Forest data of Komossa:

- Average growth per year: 5,6 m^3/ha
- Forest area estimation ≈ 500 ha
- Tree species composition in Komossa
  - Pine - 32,8%
  - Spruce - 44,2%
  - Birch - 19,2%
  - Other - 3,8%

- Estimated average of wood used for energy today in whole Vörå municipality: 0,74 m3/ha/ year

Data for wood fuel:

- Energy content at 30 % moisture:
  - Pine and spruce: 2,0 MWh/m3
    Bbirch: 2,5 MWh/m3

- Average energy content per m3 wood, calculated from the species composition:
  - 2,1 MWh/m3

- Average potential energy/ha/year, calculated from average growth and average energy content:
  - 11,8 MWh/ha/ year

- 1 m3 wood ≈ 2,5 m3 wood chips

- 1 m3 wood chips ≈ 0,9 MWh

6.A. 2: Fuel data

Fuel	Effective heat value MJ/kg DM	Moisture %	Effective heat value MJ/kg	Effective heat value MWh/ton	Ash %	Sulphur %
Forest waste (rejected tops and branches)	19.2	45	9.5	2.6	1.5	0.05
Dry wood chips	19.2	12	16.6	4.6	0.8	0.03
Willow chips	18.3	50	7.9	2.2	1.5	0.02
Fire wood	19.2	25	13.8		3.8	1.0
Straw	17.4	15	14.4	4.0	7.0	0.15
Rörflen	17.2	14	14.3	4.0	5.5	0.1
Fuel oil	35.9 GJ/m³	0.01	42.7	11.9	0.005	0.1

A.T.35. Fuel data

6.A. 3: General fuel prices in Finland today

Wood pellets: 36 € / MWh (Ref 6.R.19)

Wood chips: 18 € / MWh (Ref 6.R.19)

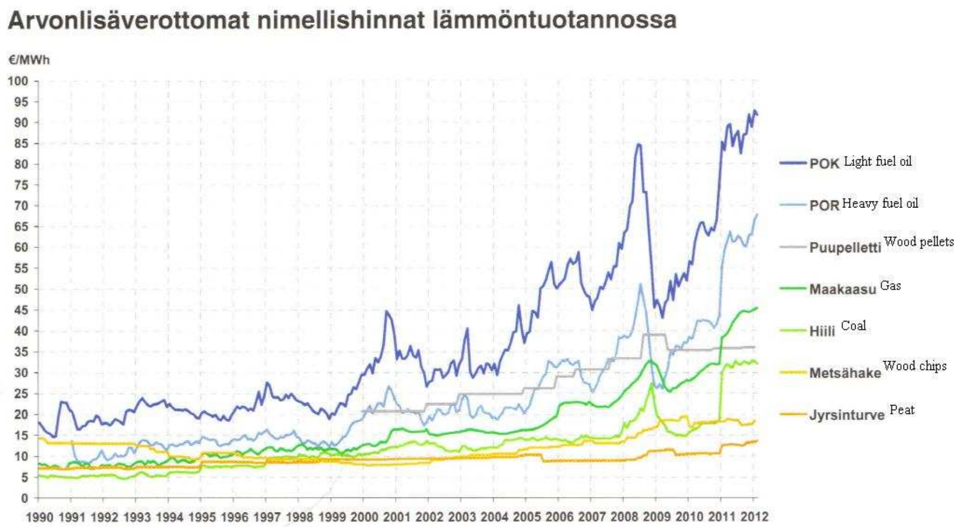
Reeds canary grass: Production cost: 22 – 25 € / MWh (Ref 6.R.18)

Salix: 18 – 21 € / MWh (Ref 6.R.19)

Light fuel oil: 1,10 €/l = 1,1 €/kWh = 110 €/MWh

Electricity: 12,0 c/kWh = 120 €/MWh

6.A. 4: Price trends of fuels



A.F.25. Price trends of fuels

6.A. 5: Heating systems when building a new home

The Equivalent annual cost for the investment has been calculated using the following formulas:

$$k = \frac{p}{1-(1+p)^{-n}}$$

$$A = \mathrm{NNV} \cdot k = \frac{\mathrm{NNV} \cdot p}{1-(1+p)^{-n}}$$

- *p* = interest, 4% used in calculations
- *k* = annuity factor
- *A* = Equivalent annual cost
- NNV = Net present value, cost of investment
- *n* = economic lifetime, 15 years used in calculations

Option 1. Direct electrical heating:

- Heating cost: Price Total
  - o 20 000 kWh/year 12,0 c/kWh 2400 €/year

- Investment cost:
  - Radiators and thermostats 1 600 €
  - Hot water heater 670 €
  - Installation 1400 €
  - Equivalent annual cost 330 €/year
- Total energy cost + equivalent annual cost: 2730 €/year

Option 2. Oil burning boiler:

The efficiency of an oil burning boiler is calculated to be around 85 %. This means that amount of fuel needed is 20 000 kWh / 0,85 = 22 222 kWh/year. The price of fuel oil in the calculations: 1,10 €/l

- Heating cost: Price Total
  - 22 222kWh/year 11,0 c/kWh 2444 €/year
  - Maintenance 200 €/year
- Investment cost:
  - Boiler + burner + installation 3500 €
  - Chimney 1000 €
  - Oil tank 800 €
  - Other installation material 1500 €
  - Waterborne floor heating 4 000 €
  - Equivalent annual cost 970 €/year
- Total heating cost + equivalent annual cost: 3614 €/year

Option 3. Wood pellet heating:

The efficiency of the wood pellet burner is calculated to be around 85 %. This means that amount of fuel needed is 20 000 kWh / 0,85 = 22 222 kWh/year. The price of wood pellets in the calculations: 36 € / MWh

- Heating cost: Price
  Total
  - 22 222kWh/year 3,6 c/kWh 800 €/year
  - Maintenance 300 €/year

- Investment cost:
  - Boiler + burner + installation 7000 €
  - Chimney 1000 €
  - Pellet storage 2000 €
  - Other installation material 1000 €
  - Waterborne floor heating 4 000 €
  - Equivalent annual cost 1350 €/year
- Total heating cost + equivalent annual cost: 2450 €/year

Option 4. Fire wood heating:

The efficiency of the fire wood boiler is calculated to be around 80 %. This means that amount of fuel needed is 20 000 kWh / 0.80 = 25 000 kWh/year. The price of fire wood in the calculations: 2,0 c/kWh

- Heating cost: Price Total
  - 25 000 kWh/year 2,0 c/kWh 500 €/year
  - Maintenance 300 €/year
- Investment cost:
  - Boiler + installation 3500 €
  - Chimney 1000 €
  - Other installation material 1000 €
  - Waterborne floor heating 4 000 €
  - Equivalent annual cost 855 €/year
- Total heating cost + equivalent annual cost: 1655 €/year

Note that these are only estimated costs. Prices may vary between different installations.

6.A. 6: Different groups of energy users in Komossa

Group 1: Small users

- Homes < 120m2
- Electricity use: <5 000 kWh/year
- Heating need: 5 000 – 15 000 kWh/year
- Approximately 48% of all buildings

Group 2: Medium users

- Homes 120m2 – 200m2
- Electricity use: 5 000 – 10 000 kWh/year
- Heating need: 15 000 – 30 000 kWh/year
- Approximately 36% of all buildings

Group 3: Large users

- Homes >200 m2
- Homes + garage/workshop/farm buildings
- Electricity use: > 10 000 kWh/year
- Heating need: > 30 000 kWh/year
- Approximately 16% of all buildings

6.A. 7: Heating costs for different heating systems

	Energy user:	Group 1: Small		Group 2: Medium		Group 3: Large	
		Low	High	Low	High	Low	High
	Heating need [kWh/year]:	5000	15000	15000	30000	30000	60000
Direct electrical heating:							
Energy price [c/kWh]:	15						
Total efficiency [%]:	100						
	Energy cost [€/year]:	750	2250	2250	4500	4500	9000
	Maintainance [€/year]:	0	0	0	0	0	0
	Total [€/year]:	750	2250	2250	4500	4500	9000
Oil burning boiler:							
Energy price [c/kWh]:	12						
Total efficiency [%]:	85						
	Energy cost [€/year]:	706	2118	2118	4235	4235	8471
	Maintainance [€/year]:	100	150	150	300	300	600
	Total [€/year]:	806	2268	2268	4535	4535	9071
Firewood burning boiler:							
Energy price [c/kWh]:	2						
Total efficiency [%]:	80						
	Energy cost [€/year]:	125	375	375	750	750	1500
	Maintainance [€/year]:	100	200	200	400	400	800
	Total [€/year]:	225	575	575	1150	1150	2300
Savings compared to	Oil heating [€/year]:	581	1693	1693	3385	3385	6771
Wood pellet heating:							
Energy price [c/kWh]:	3,6						
Total efficiency [%]:	85						
	Energy cost [€/year]:	212	635	635	1271	1271	2541
	Maintainance [€/year]:	100	200	200	400	400	800
	Total [€/year]:	312	835	835	1671	1671	3341
Savings compared to	Oil heating [€/year]:	494	1432	1432	2865	2865	5729
Wood chip heating:							
Energy price [c/kWh]:	1,8						
Total efficiency [%]:	85						
	Energy cost [€/year]:	106	318	318	635	635	1271
	Maintainance [€/year]:	100	200	200	400	400	800
	Total [€/year]:	206	518	518	1035	1035	2071
Savings compared to	Oil heating [€/year]:	600	1750	1750	3500	3500	7000

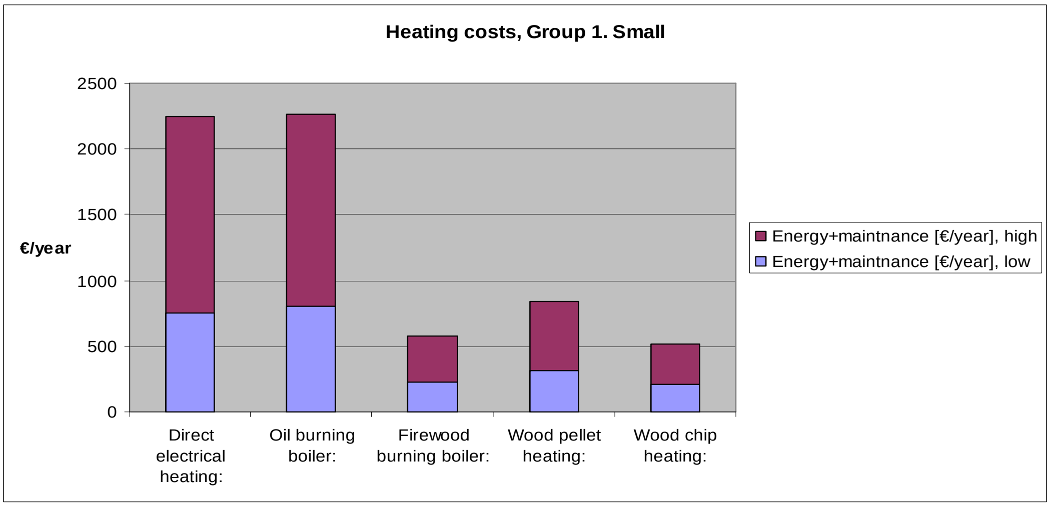
A.T.36. Heating costs for different heating systems

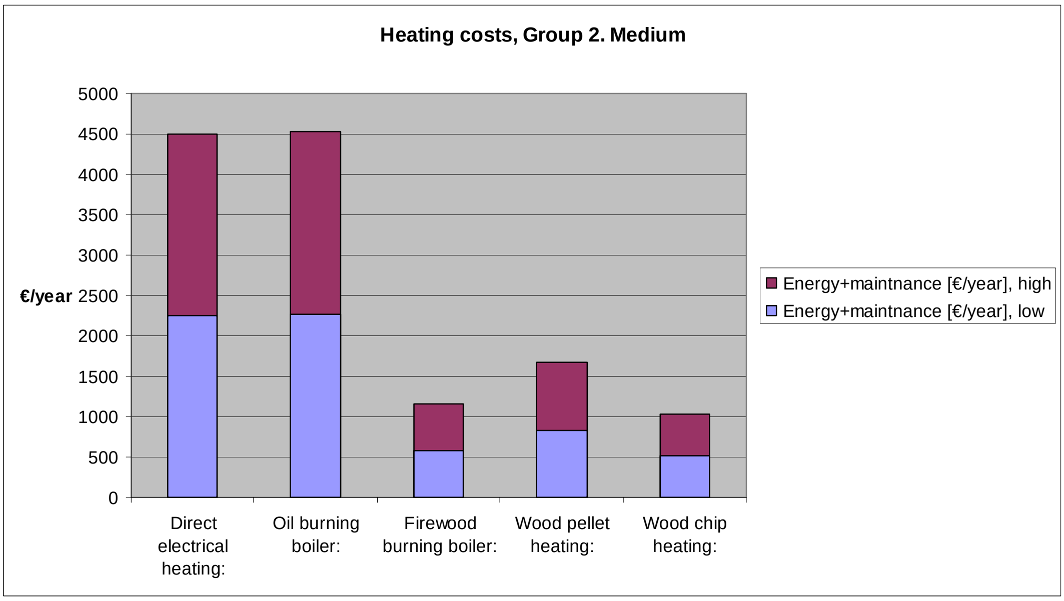
6.A. 8: Investment size for different heating systems

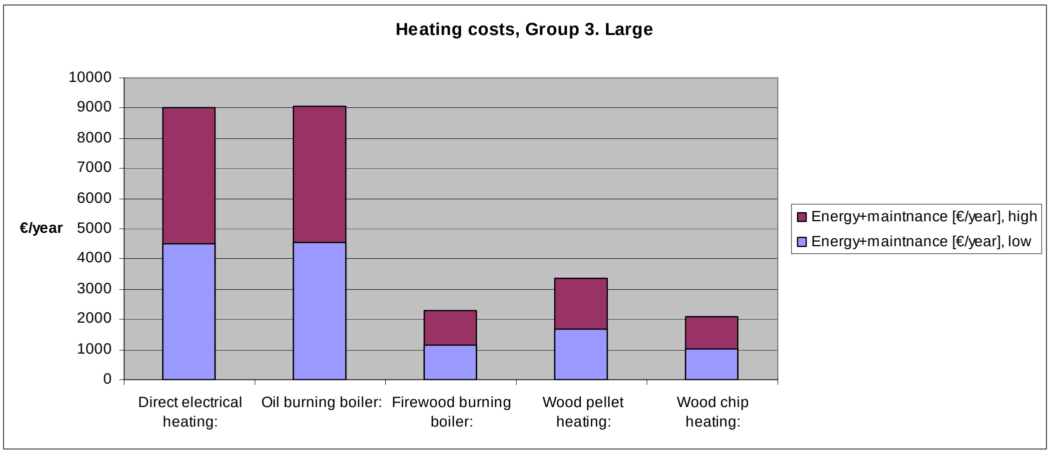
		Energy user:	Group 1:	Small	Group 2:	Medium	Group 3:	Large
		Heating need [kWh/year]:	5000	15000	15000	30000	30000	60000
Direct electrical heating:	**Existing system # 1.**		Existing	Existing	Existing	Existing	Existing	Existing
Oil burning boiler:	**Existing system # 2.**		Existing	Existing	Existing	Existing	Existing	Existing
Firewood burning boiler:	Uppgrading from Oil burning boiler:							
System cost calculated for	Investments	Firewood burning boiler	2500	2500	3500	3500	5000	5000
one system of suitable	needed:	Larger heat storage tank	800	800	1000	1000	2000	2000
dimensions for each		Installation material and work	1200	1200	1500	1500	2000	2000
energyuser group		Total:	4500	4500	6000	6000	9000	9000
		Paybacktime [years]:	20	6	8	5	6	4
Wood pellet heating:	Uppgrading from Oil burning boiler:							
System cost calculated for	Investments	Wood pellet burner	2300	2300	3500	3500	5000	5000
one system of suitable	needed:	Boiler	2500	2500	4000	4000	5500	5500
dimensions for each		Pellet storage and transfer sys.	800	800	1500	1500	2000	2000
energyuser group		Installation material and work	1000	1000	1500	1500	2000	2000
		Total:	6600	6600	10500	10500	14500	14500
		Paybacktime [years]:	-	17	-	13	18	9
Wood chip heating:	Uppgrading from Oil burning boiler:							
System cost calculated for	Investments	Wood chip burner + tank	10000	10000	13000	13000	17000	17000
one system of suitable	needed:	Wood chip boiler	2500	2500	3500	3500	6000	6000
dimensions for each		Installation material and work	1500	1500	1800	1800	2500	2500
energyuser group		Total:	14000	14000	18300	18300	25500	25500
		Paybacktime [years]:	-	17	24	10	15	7

A.T.37. Heating costs for different heating systems

6.A. 9: Graphs of energy of maintenance costs for different heating options

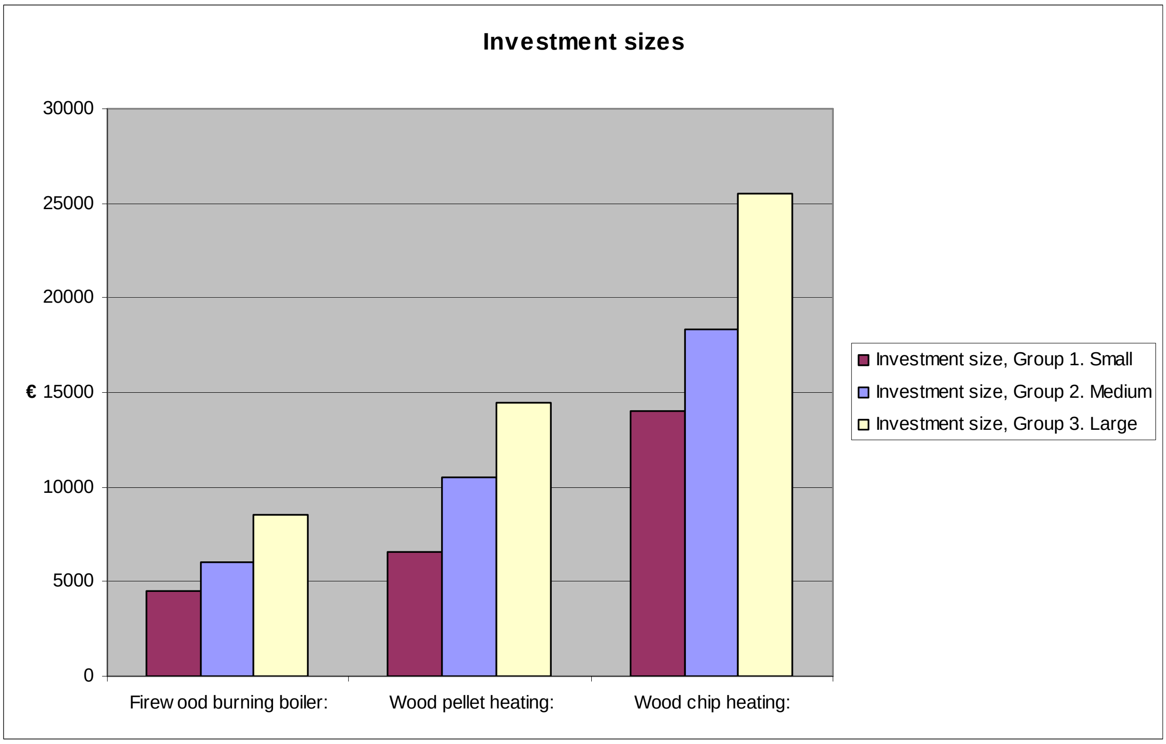






A.F.27. Graphs of energy of maintenance costs for different heating options

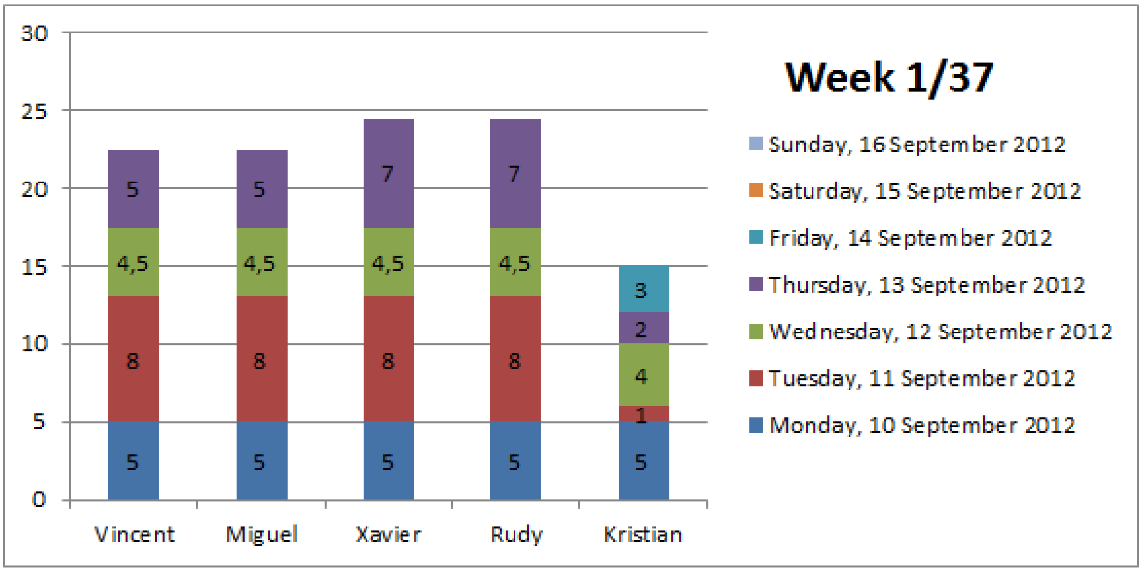
6. A. 10: Graphs of size of investment for different heating options

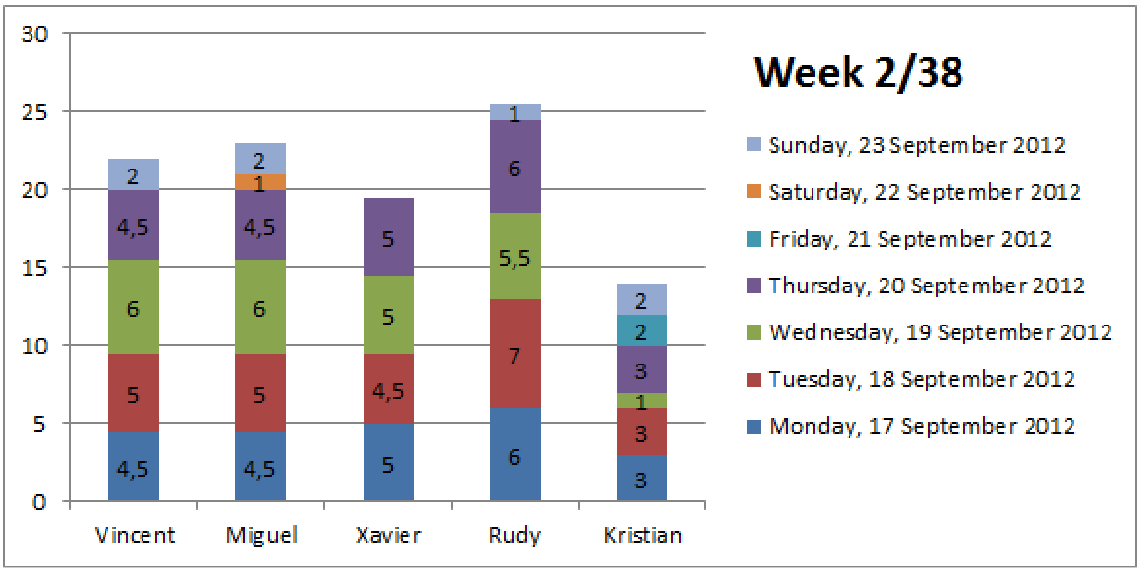


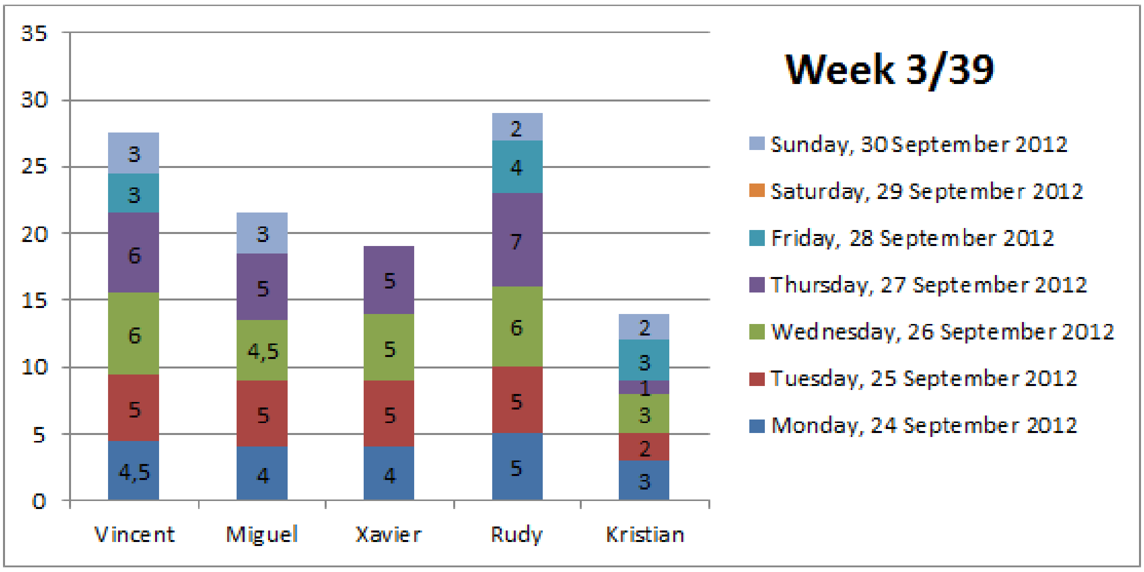
A.F.28. Graphs of size of investment for different heating options

Project hours

Per week







Week 3/39
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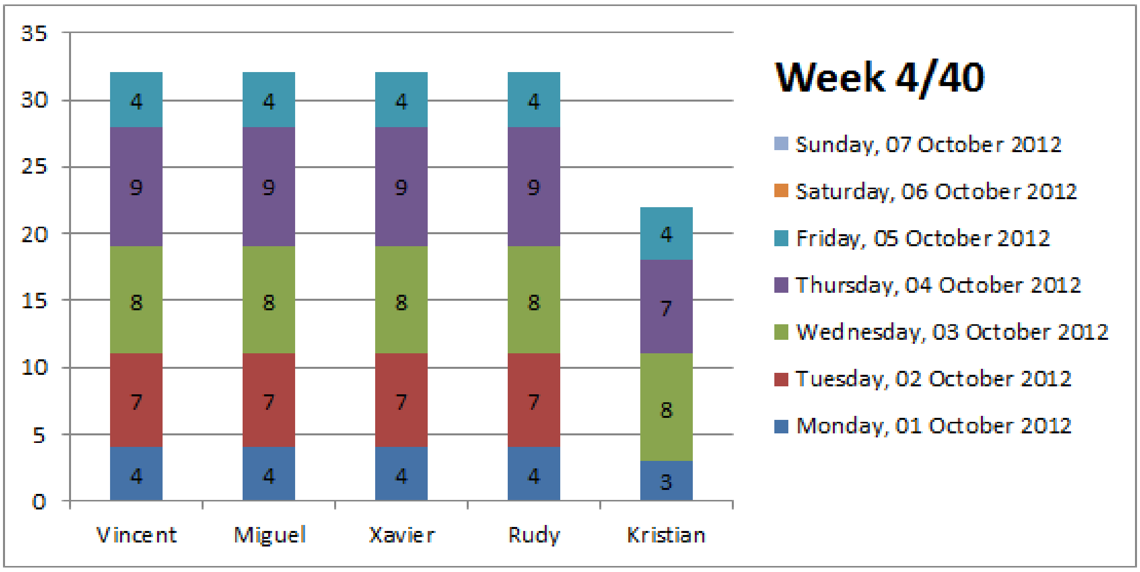
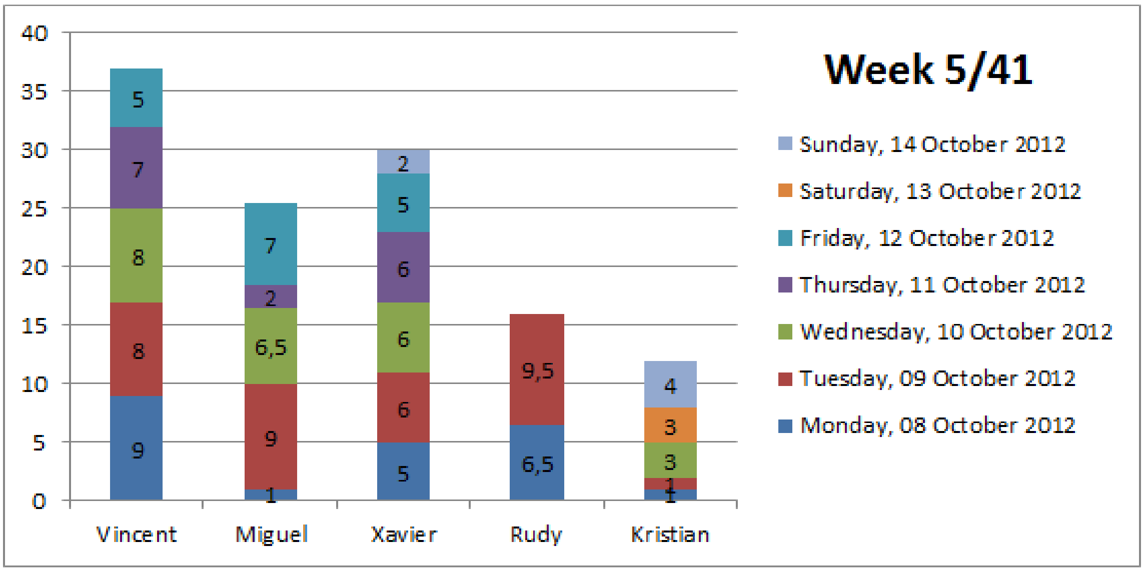
Saturday, 29 September 2012
Friday, 28 September 2012
Thursday, 27 September 2012
Wednesday, 26 September 2012
Tuesday, 25 September 2012
Monday, 24 September 2012
Vincent
Miguel
Xavier
Rudy
Kristian



Week 4/40
Sunday, 07 October 2012
Saturday, 06 October 2012
Friday, 05 October 2012
Thursday, 04 October 2012
Wednesday, 03 October 2012
Tuesday, 02 October 2012
Monday, 01 October 2012
Vincent
Miguel
Xavier
Rudy
Kristian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Saturday, 13 October 2012
Friday, 12 October 2012
Thursday, 11 October 2012
Wednesday, 10 October 2012
Tuesday, 09 October 2012
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Miguel
Xavier
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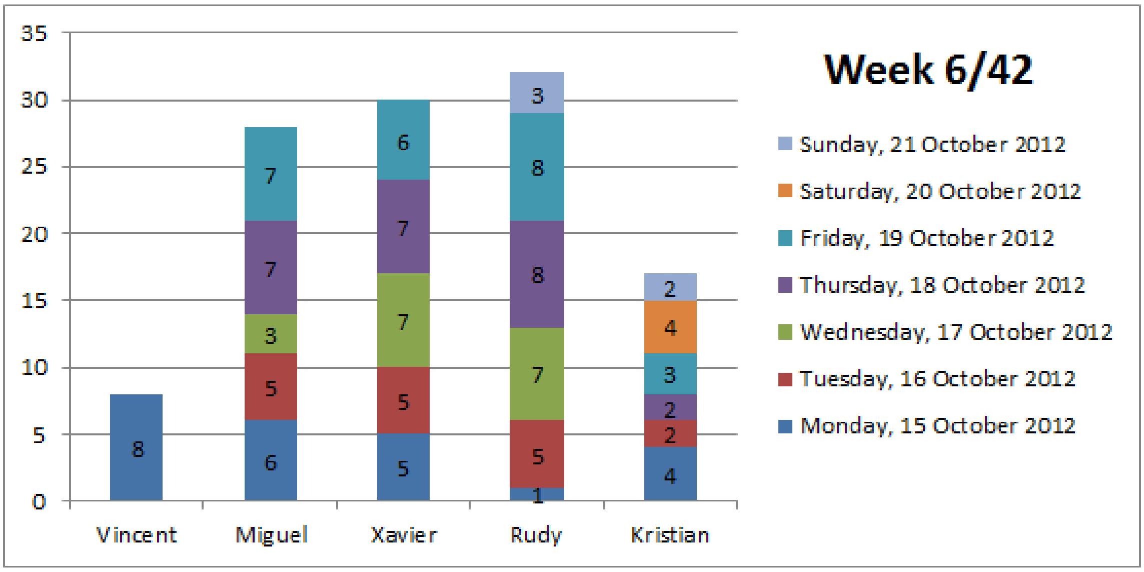
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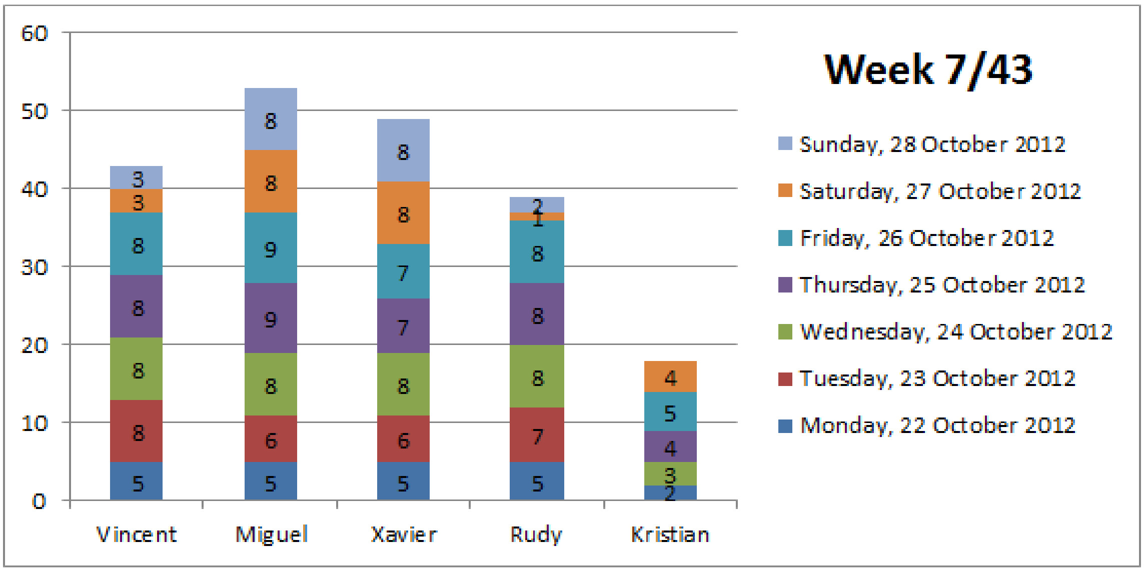

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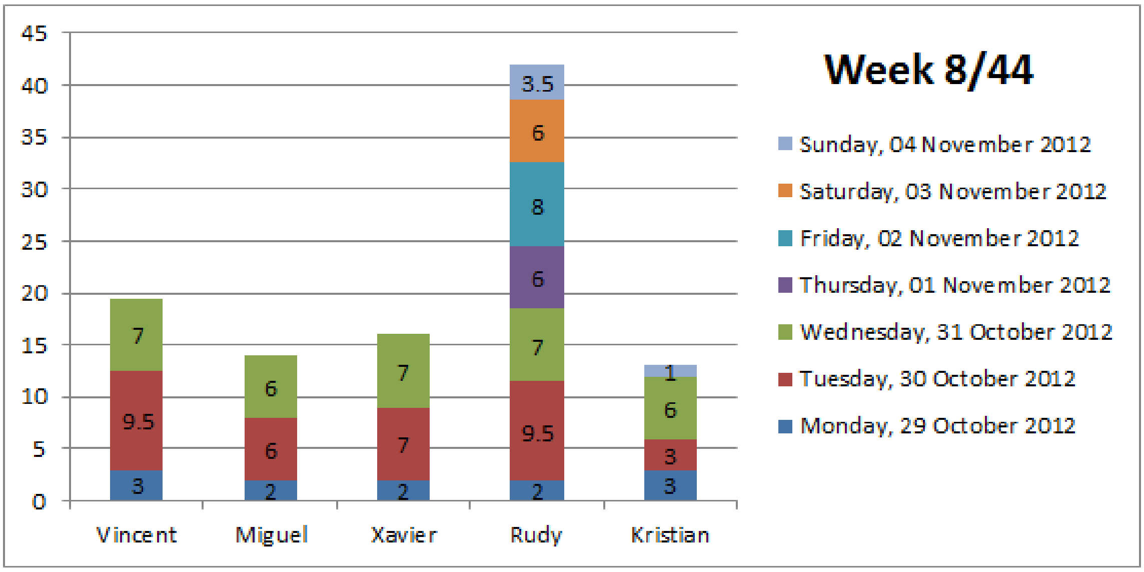

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Wednesday, 31 October 2012
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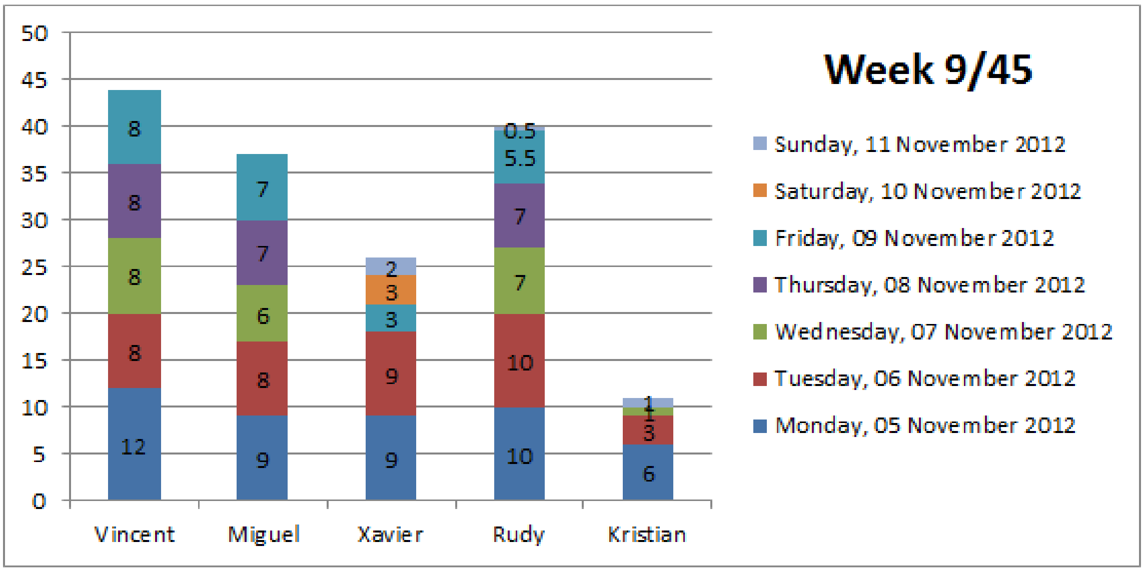
Xavier
Rudy
Kristian



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Kristian
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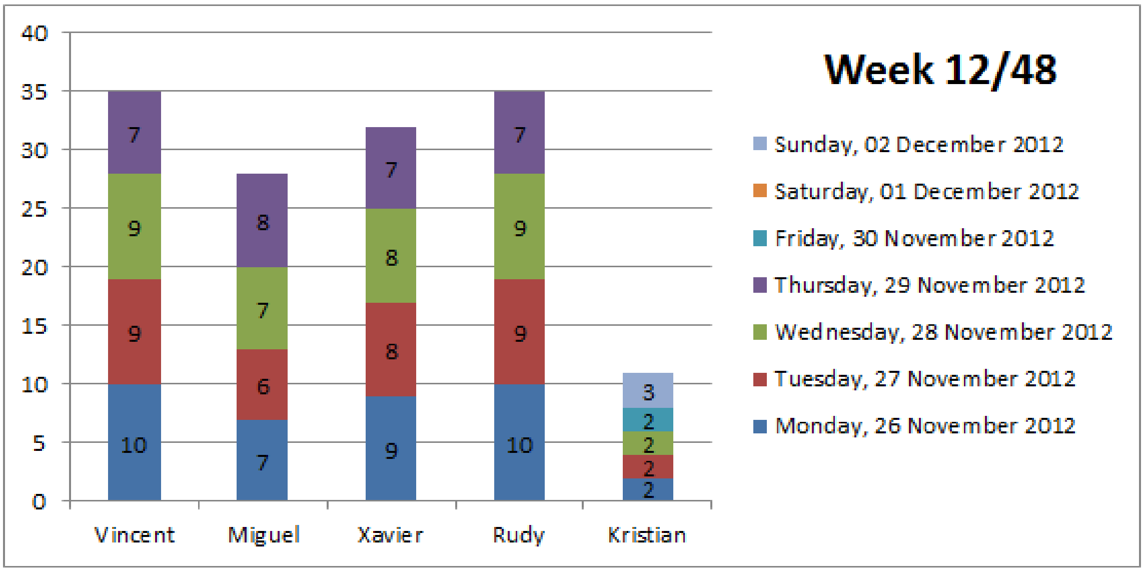

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Miguel
Xavier
Rudy
Kristian
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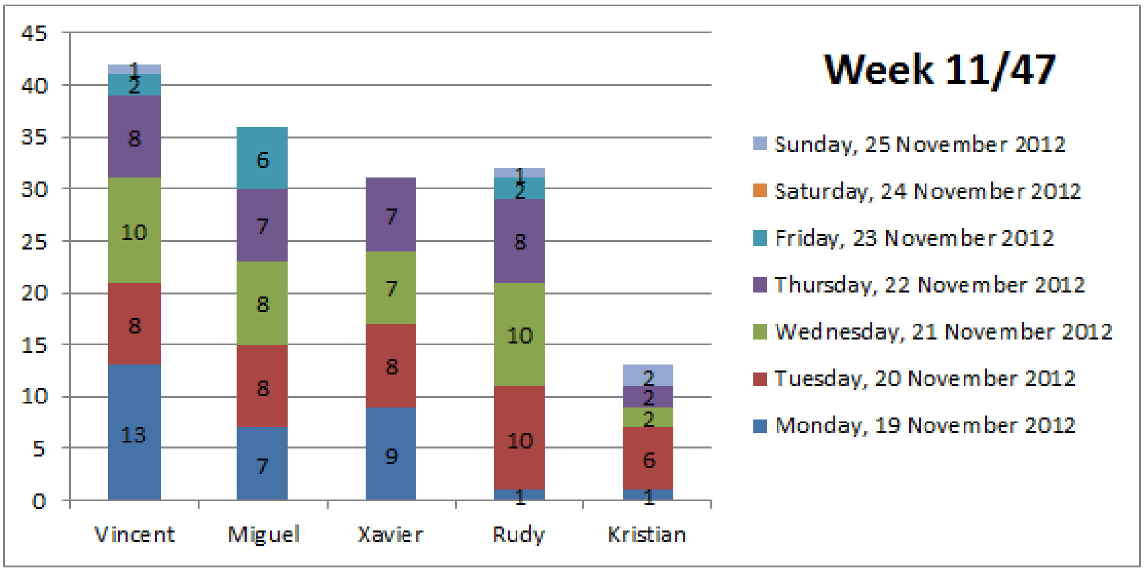
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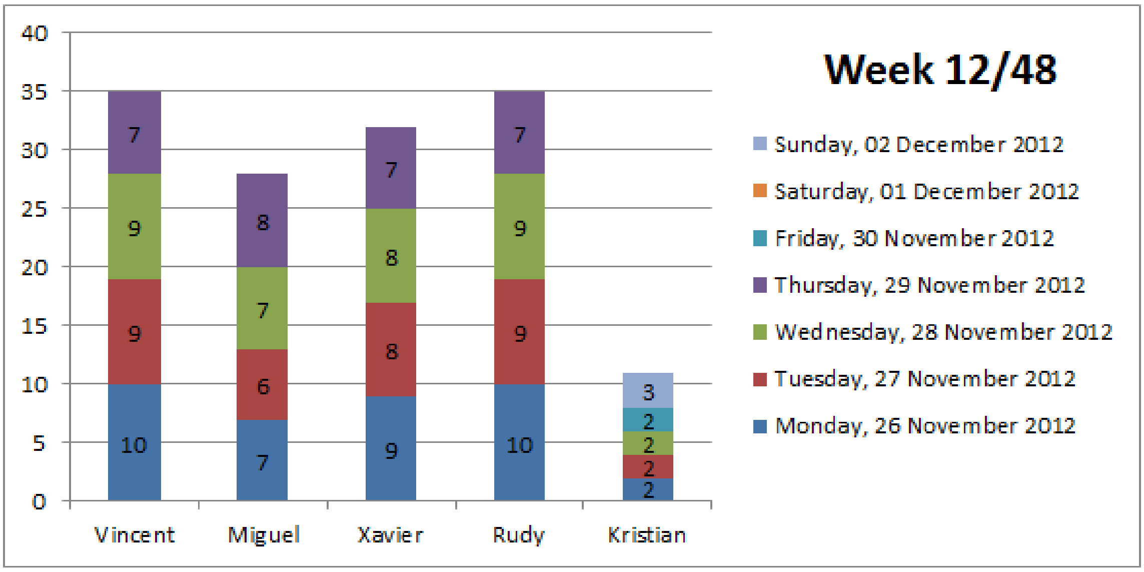
Kristian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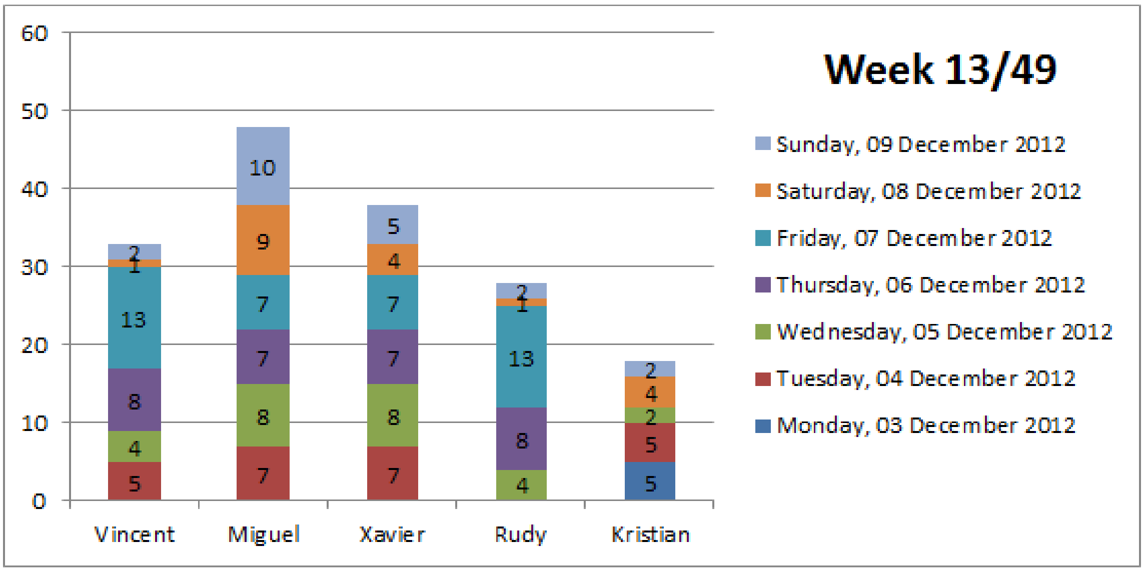
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Miguel
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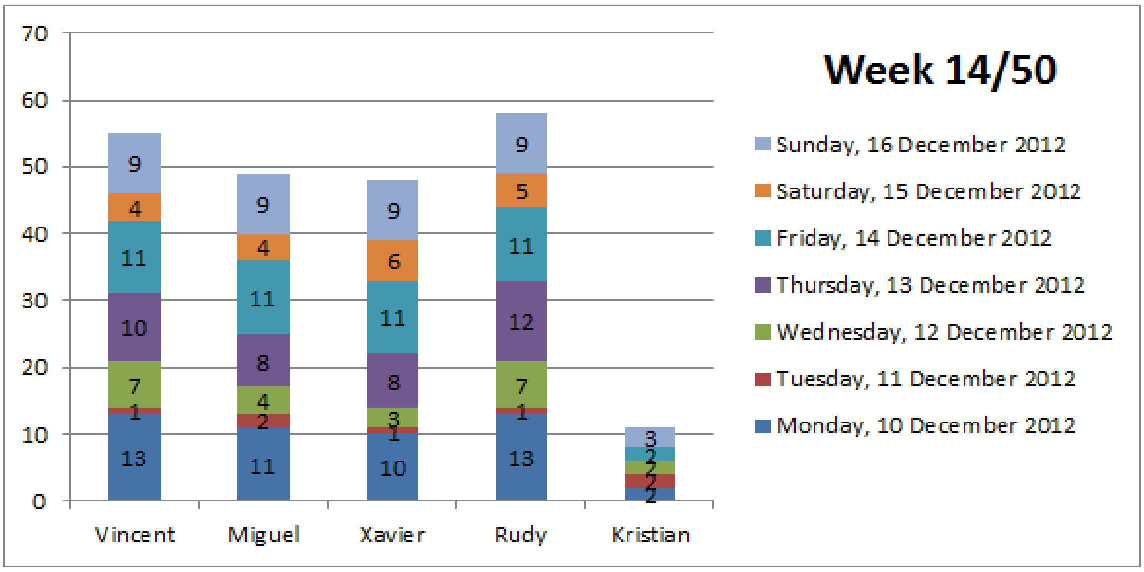
Kristian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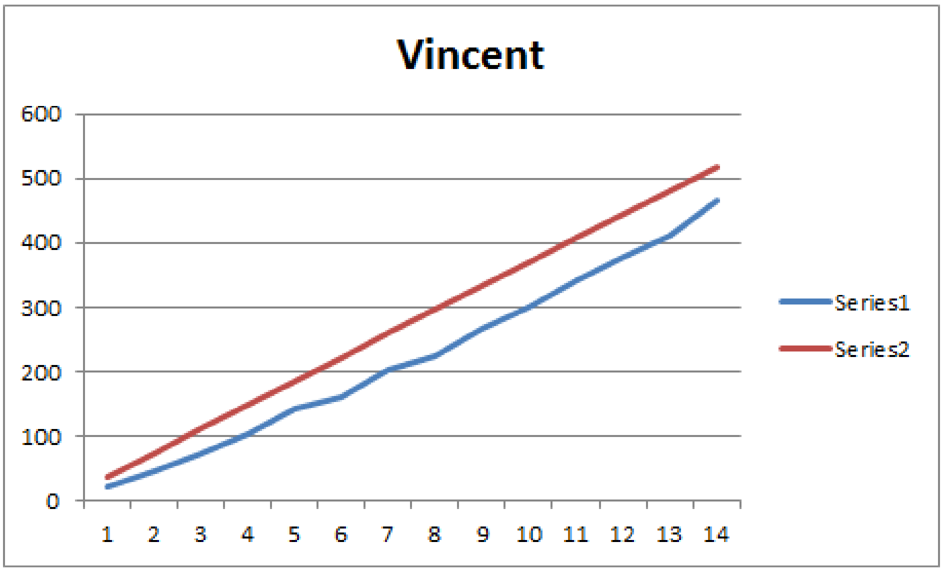
Miguel
Xavier
Rudy
Kristian

Per person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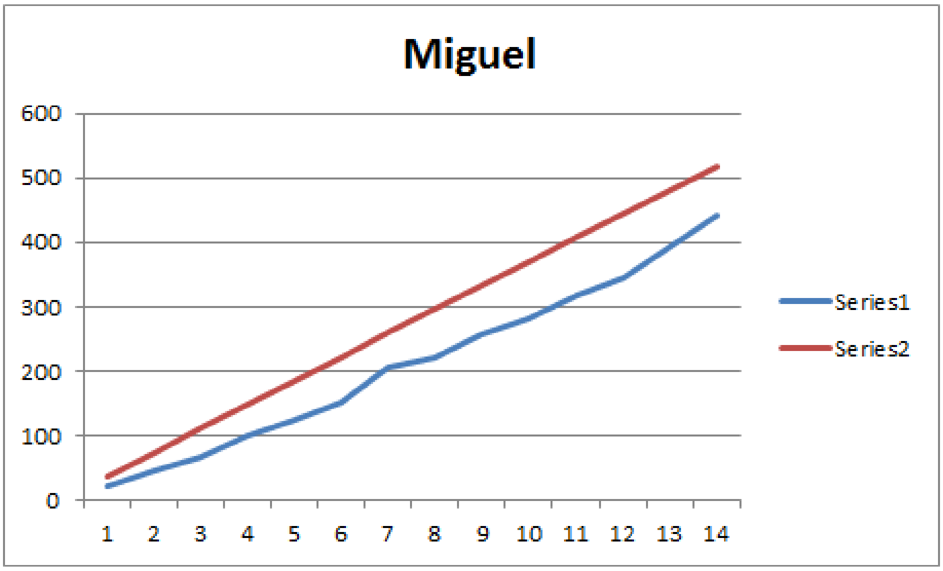
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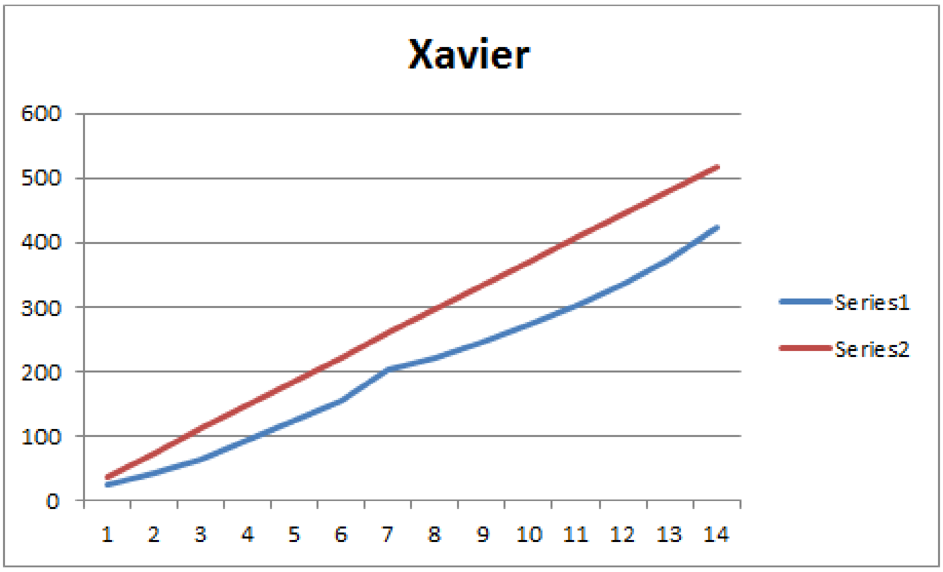
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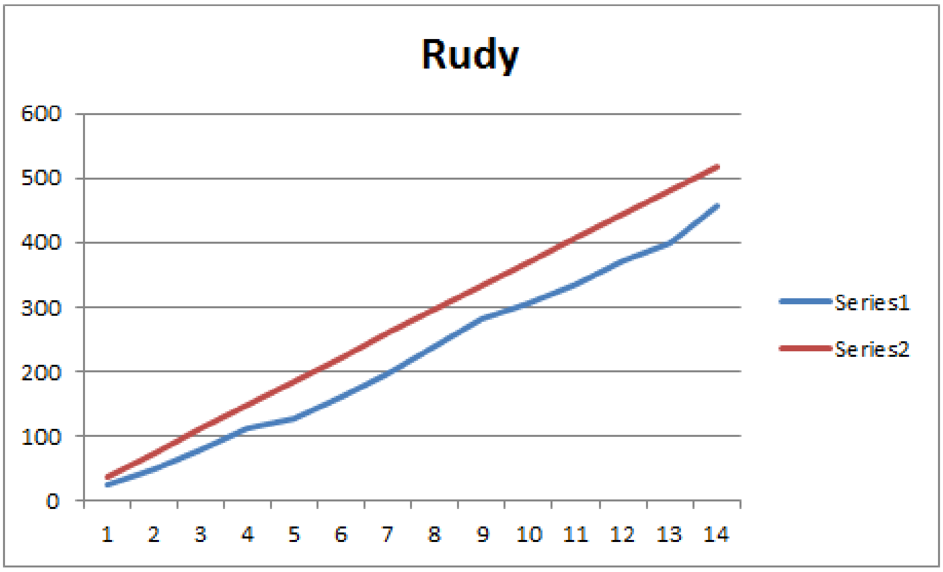
Series2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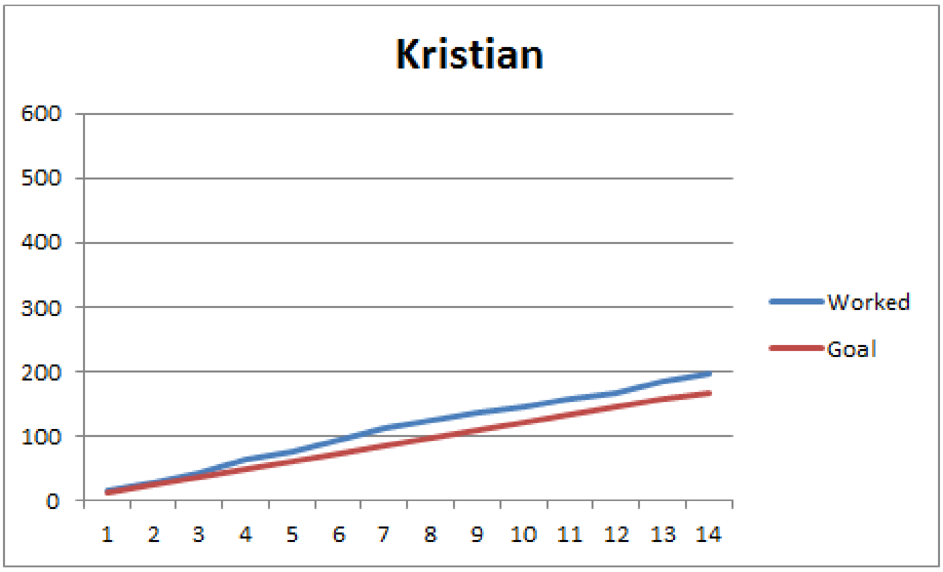
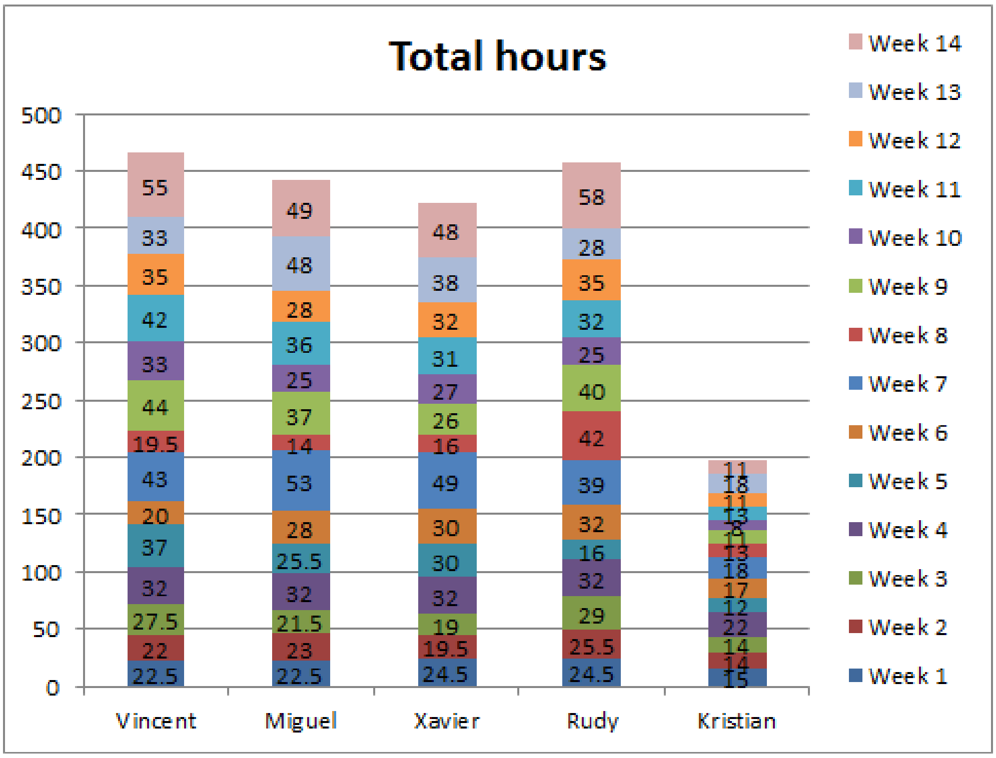
Series1
Series2



Kristian
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14
Worked
Goal

Total hours



Total hours
500
450
400
350
300
250
200
150
100
50
0
Vincent
Miguel
Xavier
Rudy
Kristian
Week 14
Week 13
Week 12
Week 11
Week 10
Week 9
Week 8
Week 7
Week 6
Week 5
Week 4
Week 3
Week 2
Week 1
22.5 22 27.5 32 37 20 43 19.5 44 33 42 35 33 55
22.5 23 21.5 32 25.5 28 53 14 37 25 36 28 48 49
24.5 19.5 19 32 30 30 49 16 26 27 31 32 38 48
24.5 25.5 29 32 16 32 39 42 40 25 32 35 28 58

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