Project ‘Installations’

Sustaining villa isover

Design of an energy system
Hanze University of Applied Sciences, Groningen
Mechanical Engineering
Project group 3

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Summary

The main function of this paper is to design an environmental friendly self-sufficient energy generating system for 'Villa Isover'. First of all the goal of 11000 Kwh of heating power is produced by Biomass and 4000 Kwh of electricity by Wind energy. Calculations on energy consumptions were done by each group member and submitted aside from the final report. However we would like to thank our tutor Tamizh for the enlightening conversations we had with him and guiding us.

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1. Introduction

Modern problems require modern solutions. It is well known nowadays that energy efficiency in houses is one of the major facts that should be developed for a sustainable world. Houses are complex systems constantly interacting with surroundings and inner components. The following report is a descriptive outline of the work conducted by group 3 for the project Installations offered by the Mechanical Engineering department of Hanze University of Applied sciences .The general main goal of this report is to design high energy efficient systems that preferably depend on renewable energies for villa isover which is located in Hyvinkaa, Finland. In order to plan a design and build a new home or do an extensive remodel on an existing house, optimizing home energy efficiency first requires to study the various factors influencing the design and installation of a (given) passive residential building, considering all the variables, details, and interactions that affect energy use in our home these include:

- Appliances and lighting electric energy consumption
- Heat loads consumed
- Space heating energy needed
- Water heating

So first each group member had his own task to discover and calculate the energy needed for each factor. Furthermore, information and discussions were given about all the renewable energy technologies we came up with and did research on. For every technology information were about the advantages of renewable energy components and how it works, the amount of energy that can be generated, the costs of the system needed and the environmental friendliness.

2. Design requirements

For this project we had to design an energy system that is self-sufficient. Before we will describe what it is needed in our system, a definition for self-sufficient energy system is firstly addressed . Having a self-sufficient energy system at house means no help is needed anymore from outside house to provide our energy needs. You are not reliant on getting electricity from electricity retailers or energy generated by other people. So, besides picking the energy generators we want to use to provide us with an energy amount that is enough, we also have to make sure you can use that energy whenever you want. First, almost all the energy was generated companies that supply energy. But lately, more and more houses also became suppliers, because of solar panels and wind turbines they have. Because nowadays still a small amount of energy is generated at houses, this does not cause a problem for our energy needs (it is for the grid that is not built for those amounts of energy in those places, but that is not the biggest problem here). If for example the solar panels generate more energy because there is more sunlight, they will let for example the coil power plants of a company generate less energy. In this case, the energy on our grid meets our needs and there is not an energy surplus. When in the evening solar panels produce less energy, they will let produce the coil power plants more energy and the grid fulfils us again with the energy we need. The energy supply should be reliable and also, even when putting energy and getting energy from the grid still works, like nowadays, that is not what we are looking for in this project. The energy that we would get from the grid, when our own system does not generate energy at that moment, is not our energy we put on the grid before. It is energy generated by someone else or by a company at that moment. Since you cannot store the energy on the grid, we have to come up with a system that can generate energy at every time of the day, every day of the year, whenever you want to use the energy. Otherwise, having a storage for energy ourselves is essential for our design.

Back to the design requirements for villa isover. First of all the house that will be designed should be safe. The goal of the power installed is to produce annually at least 11000 Kwh for heating house and hot water and 4000 Kwh of electricity. The new combined power installation should operate both during the day and night all year along, so the residents will have access to electricity twenty four hours a day. The house is based on the Biomass energy to provide energy needed for heating the house and hot water and Windmills installation to provide electricity.

2.1 Building size:

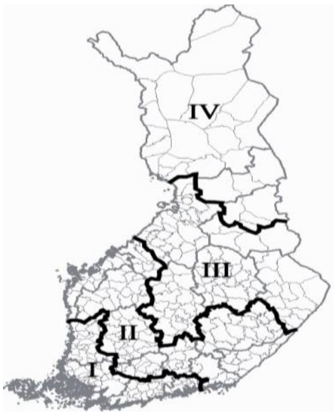
Space Name	**Frequency**	**Area per Frequency**
Floor size	1	195.5 m^2 + 21 m^2 storage space = 216.5 m^2
Air volume	1	507 m^3
Bedroom	2	15.6 m^2
Storage Room	2	20 m^2
Bathroom 1st floor	1	11.4 m^2
Bathroom 2nd floor	1	5 m^2
Laundry Facility	1	6 m^2
Hallway & Outside Spaces	1	27.53 m^2
Kitchen	1	12.27 m^2
Living Room	1	67.2 m^2
Garage	1	15.4 m^2

2.2 Building envelope U-values:

Wall	0.09 W/m^2*K
Window	0.75 W/m^2*K
Roof/ceiling to the attic	0.06 W/m^2*K
Cellar ceiling/ground slab	0.09 W/m^2*K
Doors	0.6-0.75 W/m^2*K

3. Calculations on energy needed for heating house and hot water in villa Isover:

Assuming the energy demand for heating depends on the time of the year. The energy consumption for heating depends on the time of the year because of the weather. So, first information was given about the weather in Hyvinkää during every month of the year.



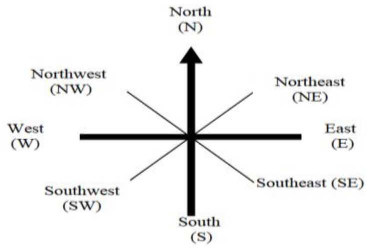


Figure 1: Weather zones in Finland

The city Hyvinkää is in weather zone 1. The following information belongs to weather zone 1

Month	**Mean outdoor air temperature, T_{out} ℃**
January	-3.97
February	-4.50
March	-2.58
April	4.50
May	10.76
June	14.23
July	17.30
August	16.05
September	10.53
October	6.20
November	0.50
December	-2.19

Table 1

Based on the average temperatures on monthly a basis that were given in (table 1), the values provided by the project description, the manual of calculations that was provided and assuming some values. The calculations for these monthly energy needed numbers for heating the house and HDW were calculated and done by Excel, and were sent in a file individually. As shown in the following table and diagram these were the resulted values for energy needed for heating the house on a monthly basis. As seen during the winter time we required much more energy than the summer times to provide the house with the heating needed.

Month	$Q_{conduction}$	$Q_{airleakge}$	$Q_{spaceair}$	$Q_{makeupair}$	$Q_{spaceair}$ (Total energy needed) KWh	$Q_{dhw,net}$
January	$5.275.10^9$	$3.646.10^5$	$8.284.10^6$	$8.284.10^6$	1470	140
February	$5.391.10^9$	$3.726.10^5$	$8.467.10^6$	$8.467.10^6$	1502	140
March	$4.969.10^9$	$3.434.10^5$	$7.804.10^6$	$7.804.10^6$	1385	140
April	$3.411.10^9$	$2.358.10^5$	$5.357.10^6$	$5.357.10^6$	951.5	84
May	$2.033.10^9$	$1.405.10^5$	$3.193.10^6$	$3.193.10^6$	566.6	84
June	$1.271.10^9$	$8.776.10^4$	$1.994.10^6$	$1.994.10^6$	353.8	84
July	$5.942.10^8$	$4.107.10^4$	$9.331.10^5$	$9.331.10^5$	165.6	84
August	$8.692.10^8$	$6.008.10^4$	$1.365.10^6$	$1.365.10^6$	242.2	84
September	$2.084.10^9$	$1.442.10^5$	$3.273.10^6$	$3.273.10^6$	580.7	84
October	$3.037.10^9$	$2.099.10^5$	$4.769.10^6$	$4.769.10^6$	846.3	140
November	$4.291.10^9$	$2.966.10^5$	$6.739.10^6$	$6.739.10^6$	1196	140
December	$4.883.10^9$	$3.375.10^5$	$7,669.10^6$	$7,669.10^6$	1361	140

Table 2

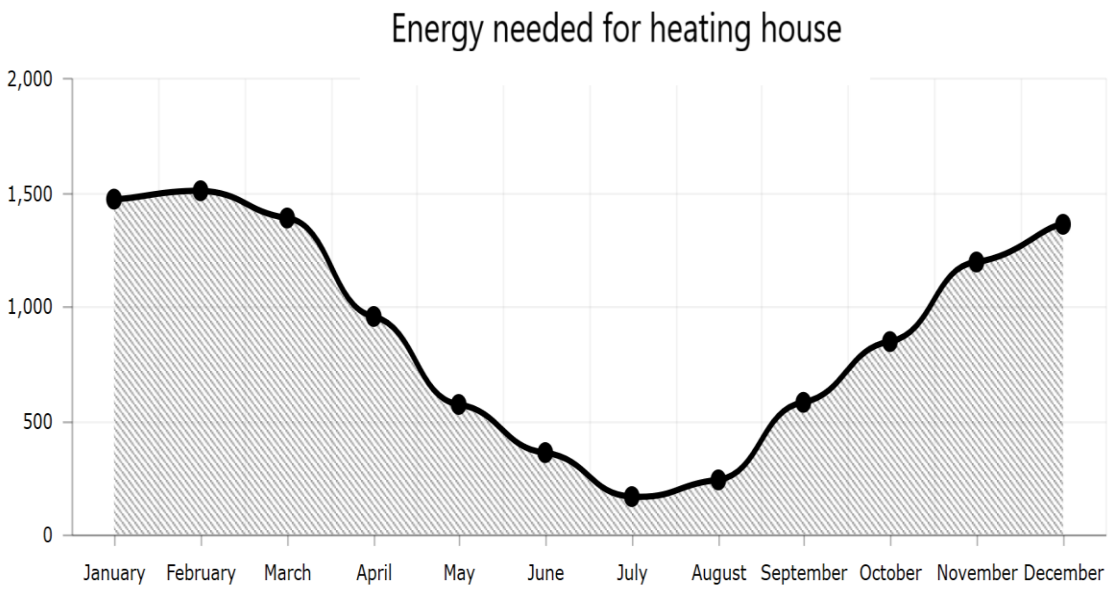


Figure 1

3.1 Renewable energy sources providing energy needed for heating the house

3.1.1 Geothermal Heat Pump

Wherever you live, Whether it’s a winter cold snap or a summer scorcher, the ground 3 meters below the surface maintains a constant temperature year round on a range of 10 °C - 16 °C. Probably anyone experienced this phenomenon at home without even realizing it. When you go into your basement on a hot day, it’s nice and cool down there because the earth on the other side of your foundation is. In the winter, even an unheated basement stays relatively warm because of that consistent stable temperature insulation from the surrounding earth. taking advantage of this naturally occurring constant underground temperature, Geothermal heat pump systems could be installed, where it uses this difference in temperature to transfer heat between the home and the earth. As shown in (figure 2) the Geothermal Heating and Cooling systems are made up of 2 components:

1. A heat pump, which is a mechanical device that can extract heat from air, water, or the earth. They are classified as “ground source”.
2. A serious underground heat exchanger loop pipes where water is mixed with antifreeze fluid and circulated in those pipes, where they act as a heat sink to store energy in the earth when cooling and to extract energy from the earth when heating.

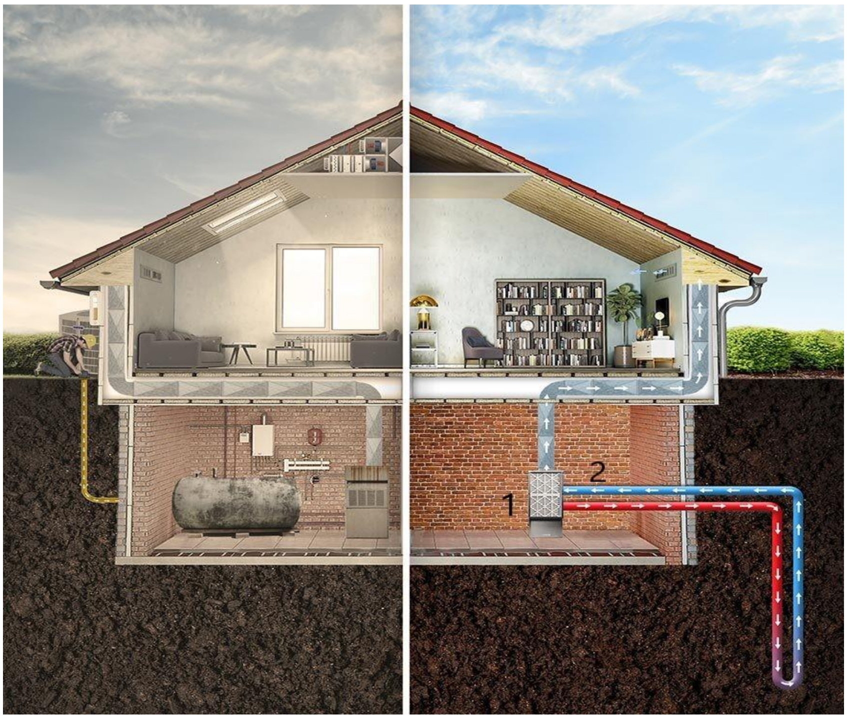


Figure 2

3.1.2 How does it works ?

So basically in the summer time, the heat pumps absorbs the heat from your home transfer it to the underground loop systems, where it is then absorbed by the cooler earth which later hits the heat away. While In the winter the heat is extracted from the ground using the same loop system and the heat pump compress it to much higher temperature and sent it as warm air in your home. Taking into consideration that we need to provide energy to heat our house and HDW, so the heating part is the one that will be addressed.

3.1.3 System Installation

The heat pump would be installed in the storage, connected to the underground loop pipes, For this pipe system there are a few options, either a horizontal or a vertical closed loop. Their both working principle is almost the same, only differs when space is limited, then the vertical is more preferred. The system has to be installed around 1.5 to 3 meters deep into the ground to reach the right temperature (here) there will be a constant temperature between 10 °C and 16 °C). The temperature must be 10 °C or more. The pipes are filled with an anti-freeze. This pipe system with antifreeze is a heat exchanger. The antifreeze will absorb the geothermal heat.

3.1.4 GSHP System cost

A geothermal heat pump needs electricity to pump around the liquid and gas and for the vapor-compressor refrigeration cycle. To calculate the electricity needed, the Coefficient of Performance (CoP). Is needed. Assuming the CoP is 4, and the ground source heat pump needs 1 unit (or kW) electricity to produce 4 units of energy (or 5 kW). As the pump will not always work at maximum efficiency rate, the CoP will be higher than the average efficiency rate of the heat pump. The CoP depends on for example the ground temperature, the energy efficiency of the property and the required room temperature. In most test conditions, a heat pump has a CoP of 4. Nevertheless, in an installations it is often less. So, for the calculations of the costs, a CoP of 3 will be considered. The energy needed for heating the house and DHW is around 12000 kWh annually. In order to generate this amount of energy needed for heating, the heat pump will require 3000 kWh of electricity for one year. Average price of a GSHP costs 15,000 euros. But in order to heat your house properly, underfloor heating. Will be needed as well. Taking into consideration that it is not already installed, that makes the costs higher.

3.1.5 GSHP pros and cons

Geothermal energy is considered as environmentally friendly, not a significant source of pollution. Geothermal energy is a renewable resource as long as the Earth exists. In comparison to other renewable sources of energy like solar, wind or biomass. It is an exceptionally constant source of energy, meaning that it is not dependent on neither wind nor sun, and available all year long. However The high capital cost for the start-up and the annually to run it, are not the only cons about Geothermal. The main disadvantages of Geothermal are the environmental issues. Below the surface of the earth there are an abundance of greenhouse gasses, which some of them are flowing to the surface and then into the atmosphere. With a geothermal heat source water is pumped from a underground reservoir, with this pumping some of these underground gasses from the reservoir are emitted to the atmosphere. The gasses that are damaging the environment are hydrogen sulphide, carbon dioxide, ammonia, methane, and boron. Once in the atmosphere hydrogen sulphide changes into sulphur dioxide. Sulphur dioxide causes acid rain, which damages crops, forests, and soils, and acidified lakes and streams.

3.2 Biomass

One of the second best alternatives to provide our house with the energy needed for heating our house and heating the HDW is by using biomass as a source of renewable energy. Not only does this give us a renewable source of energy to heat our homes, power our vehicles, and produce electricity, but it also helps us eliminate some of the waste we are throwing out there, in other terms they also allow us to cut down on the amount of trash placed in the landfills each year, such as agricultural waste, these waste use the heat energy to create steam, which is then used to either heat buildings or create electricity.

3.2.1 How it works ?

As shown in the following (figure 3), pellets or wood chips are stored in the storage room, where later are automatically or manually fed into the biomass boiler. As the fuel enters the boiler, the material is ignited either by elements or an electric blower on the initial start-up. The hot gases are then passed through a heat exchanger and the heat is transferred to the water used in your central heating system. These heat could be also stored in a buffer storage, which basically can store heating water for long periods due to their thermal efficiency and layering properties. When used in conjunction with effective mixing and loading valves, they can help to get the best use out of your biomass boiler.

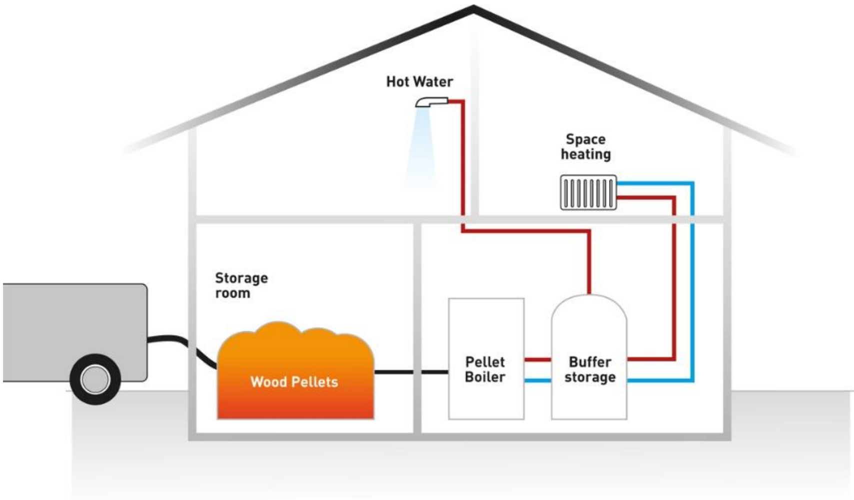


Figure 3

3.2.2 Biomass costs

Based on some research it was found out that as a general guide for domestic installations the price per installed kW (including flue, fuel storage, fuel feed, commissioning and design) is around €750 - €1000. So a 15kW pellet boiler would cost approximately €11,000.

Log boilers tend to be cheaper than both wood chip and wood pellet boilers; for example a 20kW system suitable for a 3 or 4 bed property would cost in the region of €500-750 per kW installed (€2,000). Larger boilers (>20kW) tend to be cheaper.

Additional costs include housing for fuel storage and, for larger installations with multiple buildings, a heat main to distribute hot water to where it is needed. A general rule of thumb for the installation of heat mains is approximately €150 per metre.

In terms of running costs these will vary depending on the type of wood fuel used. For example, wood pellets are currently more expensive than wood chips and logs. The table below (3) is based on current fuel prices and shows the cost (in cents) per unit of energy (kWh). One tonne of wood pellets is currently selling for approximately €200 (5,000kWh), a tonne of wood chip approx. €45 to €75 (2,000-4,000kWh) and a tonne of logs approx. €50-€60 (4,200kWh).

Fuel Type	**Price per unit**	**KWh per unit**	**Cent per KWh**	**Density Kg/m^3**
Wood chips	€100 / tonne	3,500kWh/ tonne	2.9c/ kWh	275
Wood pellets	€200 / tonne	4,800kWh/ tonne	4.2c / kWh	650
Wood logs	€80 / tonne	4000KWh / tonne	3.2c / kwh	400

Table 3

3.2.3 Basic calculations

This section looks at various basic calculations to find out what size boiler our project will require; the quantity and volume of wood fuel you needed, as well as what carbon dioxide savings can be expected by installing a biomass boiler.

3. 2.3.1 Boiler sizing

Calculating required boiler capacity (typically stated in kilowatts, kW) is not as straightforward as it should be. Fortunately there are some rules of thumb could be used to work out approximate figures. Two methods are used could be used for calculating the kW capacity or size of boiler you might need:

Method 1: assuming the house with Using a large detached 2 or 3 bed property as an example in our case. Multiply the volume of the building by 0.035. so in this case the house volume is considered to be 507 m^3. So 600 x 0.035 ≈ 20 kW

Method 2: based on the results of the calculations on energy needed for heating the house and hot water, we know the house needs an average of 15000 kWh, so we want to remove the hours to leave us with kilowatts. So dividing our heating consumption in kWh by the number of full load hours the boiler will be running for. Since boiler use varies daily, weekly and seasonally, a simplification called Full Load Heating Hours Equivalent or FLHE is used. For a domestic property we expect about 1000 FLHE. 17,630kWh ÷ 1,200hrs = 15 kW. This is what would be expect for a 3 bed property.

3.2.4 Annual biomass consumption and storage space

Step 1 – Convert the heating demand into biomass quantities

Therefore converting 15,000kWh into biomass quantities is straightforward. In order to do this we need to know the energy densities of biomass fuels,(see table 3). Before calculating biomass quantities though, it is important to make another boiler efficiency adjustment. If we install a wood boiler it will be 90% efficient, 15,000 kWh ÷ 90% = 17,000 kwh. So in order to generate 15,000 kWh, a 90% efficient biomass boiler will require an input of 17,000 kWh.

• Wood chips = 17,000 kWh ÷ 3,500 kWh/tonne = 5 tonnes (at 30% moisture content)
• Wood pellets = 17,000 kWh ÷ 4,800 kWh/tonne = 3.5 tonnes
• Logs = 17,000 ÷ 4,000 kWh/tonne = 4.2 tonnes (20% air dried stacked logs)

Step 2 – Convert the biomass quantities into required storage space

Each type of biomass has a different bulk density (see table 3),

• Wood chip = 5 tonnes = 5000 kg ÷ 275 kg/m^3 = 18 m^3
• Wood pellets = 3.5 tonnes = 3,000 kg ÷ 650 kg/m^3 = 4.6 m^3
• Logs = 4.25 = 4,250 kg ÷ 400 kg/m^3 = 10 m^3

For a 3 bedroom property, storage space is likely to be a major constraint and therefore a biomass storage space larger than 5 m^3 is likely to be unfeasible. In our case we have a storage room of around 17 m^2 This means by using wood pellets as our source of fuel, we would only need 1 delivery a year to store 3.5 tonnes.

3.2.5 Buying wood

The first step was to made a decision about the type of wood that is best for burning. A good quality wood has to have higher density so that it burn slower and generates more heat. another factor to consider is the minimal ash to be remained after burning and also preferably least amount of smell. The other factor to be considered is the need to thread or season the wood before burning. Based on all these requirements it was found out the wood pellets is the best fuel source for the biomass boiler since:

- Wood pellets are the easiest to handle of the wood fuel types.
- They are much more controllable than logs.
- Pellets also take up less space in a fuel store than wood chips or logs.
- Pellets produce less ash than wood chips or logs.

3.2.6 Producing wood

As long as the wood is managed sustainably, where appropriate and fuel is processed properly, this option will reduce running costs and improve the financial viability of the project. Processing your own wood for fuel may also open up the opportunity to sell surplus wood chip to other biomass heating installations in the vicinity. So the first step is to be able to find the best species of trees that can grow with minimal maintenance in the Scandinavian forests. According to the Economy of trees in Scandinavian and Russian continent, Birch trees has always been a choice, since it can be grown in acidic soils. they are very resistant toward icy environment. Birch is categorized as Hard wood and Grade quality is marked as good.
The second step is to find a sweet spot for tree's age and research the information about the weight and height of wood that can be produced over the period. since the sole reason to grow trees are to burn them and large slabs of wood are not needed. In order to calculate the body mass of trees, the following table is used (4)

Property	Unit	Birch SB1 slow-grown	Birch SB2 medium-grown	Birch SB3 fast-grown
Wood density	kg/m^3	709	604	605
Diameter growth	mm/y	2,78	4,52	8,24
Height growth	m/y	0,27	0,33	0,83
Volume growth	m^3/y	0,0031	0,0030	0,0059
Biomass growth	kg/y	2,52	2,61	4,06

Figure 4

On average we need to produce 3.5 Kg of wood per year, and in 20 years a tree is going to weight around 70 kg green, but we have to air these woods and up to 20 % of the body mass is lost during the process. So in order to produce 15000 kwh, and energy of 1Kg wood is 3.5 kwh, so weight of 1 tree would be around 4285 Kg.

3.2.7 Biomass pros and cons:

On the pros side, biomass is a widely available, reliable type of renewable energy. Biomass materials are considered to be a low carbon source of energy because, despite producing carbon dioxide when burnt, they only release roughly the same amount they absorb while growing. Although, biomass combustion is CO2 neutral, the transportation and harvesting of the biomass still runs on diesel or petrol. Thus exhausting CO2 and other harmful gases. While biomass heating is suitable for any type of building, you need to have space to store the fuel and to access the system for loading. There are also building regulation considerations that affect where a boiler can be placed, what needs to be done to the chimney and how much room it needs surrounding it, which can all impact on the cost of installation.

3.3 Final heating energy system

For providing the energy needed for heating the house and water, two possibilities were addressed: the geothermal heat pump and biomass boiler. Heat pump is an absolute champion when it comes to CO2 emissions, and can deliver a superior efficiency rate compared to a boiler. Given the high initial costs and the limited heating output of a heat pump, having a gas boiler might prove to be cheaper and to a certain extent more efficient, especially during the cold days of the winter, when a higher heat yield IS needed. After voting within the group members, we decided to choose the biomass boiler. Since the biggest con of the heat pump was that it needed electrical energy to generate heat for our house. This was a big con for us, as we found out that it is really difficult to come up with solutions to generate electrical energy in Finland, in a self-sufficient and sustainable way. If we would cut the trees by hand (you only have to do a small amount at a time), the burning wood option is CO2-neutral.

4. Electric Energy Consumption of Appliances & Lightning

4.1 Electric energy consumption of appliances ($W_{appliances}$)

The electric energy consumption of appliances in a building is the sum of appliance electric energy consumed, less electric energy consumed by lighting and ventilation systems, or electricity used in heating air and cooling spaces. All electric appliances are considered to be of A+ grade in terms of efficiency. The following are considered when calculating $W_{appliances}$, Appliances

- Stove
- Microwave Oven
- Coffeemaker
- Dishwasher
- Refrigerator/Freezer combo
- Ice Box
- Upright freezer
- Washing Machine
- Clothes Dryer
- TV
- Video
- PC
- Laundry Facility

Locations

- Home Sauna
- Car Parking Spaces
- Outside Lighting

After carrying out the appropriate calculations, $W_{appliances}$ turns out to be 5230 kWh/each time used.

4.2 Electric energy consumption of lighting ($W_{lighting}$)

The total area of the house is divided into several sections as shown in the following table:

Space Name	Frequency	Area per Frequency
Bedroom	2	15.6 m^2
Storage Room	2	20 m^2
Bathroom 1	1	11.4 m^2
Bathroom 2	1	5 m^2
Laundry Facility	1	6 m^2
Car Parking	1	15.4 m^2
Hallway & Outside Spaces	1	27.53 m^2
Kitchen	1	12.27 m^2
Living Room	1	67.2 m^2

Table 4

For all the lighting of the house, **room specific switches** are chosen from the following list of choices:

-presence sensor and daylight timer
-daylight timer
-presence sensor
-room-specific switch
-room-specific switch, separate one for window wall
-central ON/OFF

As this is a family house, the Luminaire Maintenance Factor is chosen to be **clean environment** from the following list of choices:

Luminaire Maintenance Factor:
-clean environment
-average environment
- filthy environment

Finally, **direct lighting** is selected for the coefficient of utilisation from the following list of choices:

coefficient of utilisation:
-direct lighting
-combined direct/indirect lighting
- indirect lighting

In terms of the number of lights throughout the whole house, they are chosen as:

- 2x 300 W LED lamps for Hallway
- 3x 300 W LED lamps for Living Room
- 1x 300 W LED lamp for every other room

After carrying out the appropriate calculations, $W_{lighting}$ turns out to be 13.54 kWh.

Important mathematical values derived from Chapter 4:

- Electric energy consumption of appliances, $W_{appliances}$ = 5230 kWh/each time used
- Electric energy consumption of lighting, $W_{lighting}$ = 13.54 kWh/year

5. Heat Loads

5.1 Heat Load from People (Q_{person})

The building's utilisation level during operation, representing the average time people stay in the building is considered to be 16 hours/day. It is also considered that the house has 4 residents. The length of stay in the house is calculated on a 24-hour counting cycle.

After carrying out the appropriate calculations, Q_{person} turns out to be 6.85 kWh.

5.2 Heat Load of Lighting & Electrical Appliances ($Q_{electric}$)

The electric energy consumption of lighting and appliances as a whole goes into the building as a heat load.

After carrying out the appropriate calculations, $Q_{electric}$ turns out to be 5243.54 kWh/each time used

5.3 Solar radiant energy entering the building through windows (Q_{solar})

Solar radiant energy includes energy entering the building directly through windows and indirectly as heat absorbed by windows.
It is considered that the building faces south. The building is located in Weather Zone 1. It is also assumed that no curtains are hanged behind the windows. Finally, no evidence of any sort of obstacle which could cause shade inside the house has been found.
The total solar radiant energy on a horizontal surface per area unit ($G_{radiant, horizontal}$), total solar radiant energy on a vertical surface per area unit ($G_{radiant, vertical}$), & the conversion factor for converting the total solar radiant energy on a horizontal surface to total radiant energy on a vertical surface by compass direction ($F_{direction}$) change every month and thus, individual calculations are done for Q_{solar} for every month and they are added to find the total Q_{solar}.
Since no curtains were considered for the windows, the total correction factor for radiation transmittance ($F_{transmittance}$) is taken as 0.75. The surface area of a window opening (including frame and casing) is taken as 20 m^2.
After carrying out the appropriate calculations, Q_{solar} turns out to be $12.23 * 10^3$ kWh/month.

5.4 cannot be done because of absence of required data from 6.3.

5.5 Energy Recovered from Heat Loads ($Q_{int.heat}$)

Heat loads in buildings occur from activities performed in them, especially from lighting and people as well as solar radiant energy coming in through windows; these heat loads can be recovered for heating the buildings. Heat loads can only be recovered on the condition that there is a simultaneous need for heating and that the regulating devices will reduce the generation of other heat by the corresponding amount.

The loss from domestic hot water circulation ($Q_{DHW\ circ}$), & loss from domestic hot water being stored in tank ($Q_{DHW\ tank}$) are not considered because of their absence from chapter 6.
The building's specific heat loss (H) is calculated on a 24-hour time period length. The building's interior effective thermal capacity (C_{build}) is chosen as heavy construction from the following list of choices:

	Multi-storey apartment buildings
Light-weight construction	EW, PW, IF light-weight stick-built structures, F concrete
Medium	EW light-weight stick-built structures, PW light-weight stick-built structures or concrete, IW concrete, F concrete,
Heavy construction	EW concrete, PW cinder block or concrete, IW concrete, F concrete

Figure 5

The indoor air temperature (T_{ind}) is chosen as 25 °C, & the outside air temperature (T_{out}) is taken as 15 °C. The heat loss of a building's spaces (Q_{space}) is obtained to be 987.375 kW from a different chapter.

After carrying out the appropriate calculations, $Q_{int.heat}$ turns out to be 874 kWh.

Important mathematical values derived from Chapter 5:

- Heat Load from people, Q_{person} = 6.85 * 30 = 205.5 kWh/month
- Heat Load of Lighting & Electrical Appliances, $Q_{electric}$ = 5243.54 kWh/each time used
- Solar radiant energy entering the building through the windows, Q_{solar} = 12.23 * 10^3 /month
- Heat load energy recovered for heating, ($Q_{int.heat}$) = 26220 kWh/month

6. Hydroelectricity

Hydroelectricity is a viable option for providing energy needed for heating & electric purposes in a household. Hydroelectric power, also called hydropower, is electricity produced from generators driven by turbines that convert the potential energy of falling or fast-flowing water into mechanical energy. In 2019, it accounted for more than 18% of the world's total power generation capacity.

However, since the only source of hydroelectric power near Hyvinkaa, Finland is a river, a non-conventional type of hydro-electric generation called Run-of-the-river (ROR) hydroelectricity has to be considered. It is a type of hydroelectric generation plant whereby little or no water storage is provided. Run-of-the-river power plants may have no water storage at all or a limited amount of storage, in which case the storage reservoir is referred to as pondage. A plant without pondage is subject to seasonal river flows, thus the plant will operate as an intermittent energy source. A system that has pondage can regulate water flow to some extent and can serve either as a base-load source or can be used as a peaking power plant, which means it produces power when the demand is highest.

6.1 How it Works

Run-of-the-river or ROR hydroelectricity is considered ideal for rivers that can sustain a minimum flow or those regulated by a lake or reservoir upstream. A small dam is built to create a head pond ensuring that there is enough water entering the penstock pipes that lead to the turbines which are at a lower elevation. At the end of the penstock there is a turbine propeller, which is turned by the moving water. The shaft from the turbine goes up into the generator, which produces the power. Power lines are connected to the generator that carry electricity to residential houses. Up to 95% of mean annual discharge of a river is diverted through a pipe and/or tunnel leading to electricity-generating turbines, then return the water back to the river downstream.

6.2 ROR Hydroelectricity costs

According to a 2009 Navigant Study, the instalment cost of an ROR system that delivers approximately 10 MW power annually ranges from €1300 to €5000 per kW. As the electricity need of the house is 4000 kWh, the instalment cost of an appropriate ROR hydroelectric system would be from €5.2 million to €20 million.

6.3 ROR Advantages

1. Eco friendly: Similar all hydro-electric power, ROR hydro harnesses the natural potential energy of water, eliminating the need to burn coal or natural gas to generate the electricity needed by consumers. Moreover, ROR hydro-electric plants do not have reservoirs, thus eliminating the methane and carbon dioxide emissions caused by the decomposition of organic matter in the reservoir of a conventional hydro-electric dam.
2. Fewer flooding/reservoirs: Flooding of the upper part of the river does not happen without a reservoir. As a result, people remain living at or near the river and existing habitats are not flooded.

6.4 ROR Disadvantages

1. Unreliable: ROR is considered unreliable because it has little or no capacity for energy storage and hence cannot co-ordinate the output of electricity generation to match consumer demand. It thus generates much more power during times when seasonal river flows are high, and depending on location, much less during drier summer months or frozen winter months.

7. Wind Energy

Wind turbine are devices used for converting kinetic energy from wind into mechanical energy. The blades of wind turbines are designed to create a pressure difference when the wind strikes them. This pressure difference makes the blades to rotate. Wind turbines fabricate power to abuse the moderate intensity of the breeze to drive a generator. The breeze could be a clean property supply of fuel, it does not create discharges and it will never run out since it is interminably restored with the vitality of the sun. In some ways wind turbines zone unit, the character advancement of old windmills anyway presently they here and there have three cutting edges that spin around a flat shape at the most elevated of a steel tower. One in all the chief usual and vogue turbine styles could be a metal pinnacle with a three-sharp edge rotor.

Rising oil costs feature the abuse of sustainable power source applications. Wind vitality is a standout amongst the most appealing sustainable power source advancements on account of its high proficiency and low contamination.

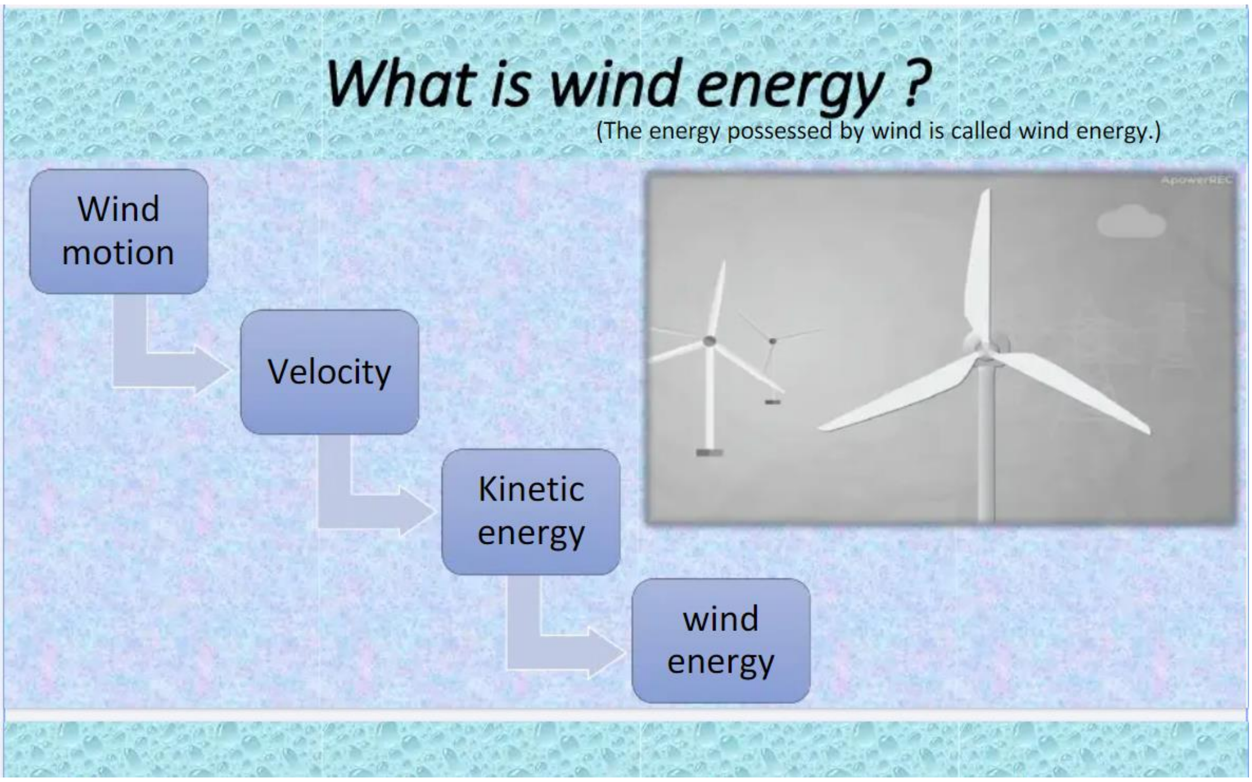


Figure 6

7.1 Wind speed

Wind speed is one in everything about chief basic qualities in elective energy generation. Wind speed changes in each time and house, controlled by a few components equal geographic and climatic conditions. The measure of vitality in the breeze shifts with the solid shape of the breeze speed, at the end of the day if the breeze speed copies there is eight times more vitality in the breeze. Little varieties in wind speed mostly affect the measure of energy accessible in the breeze.

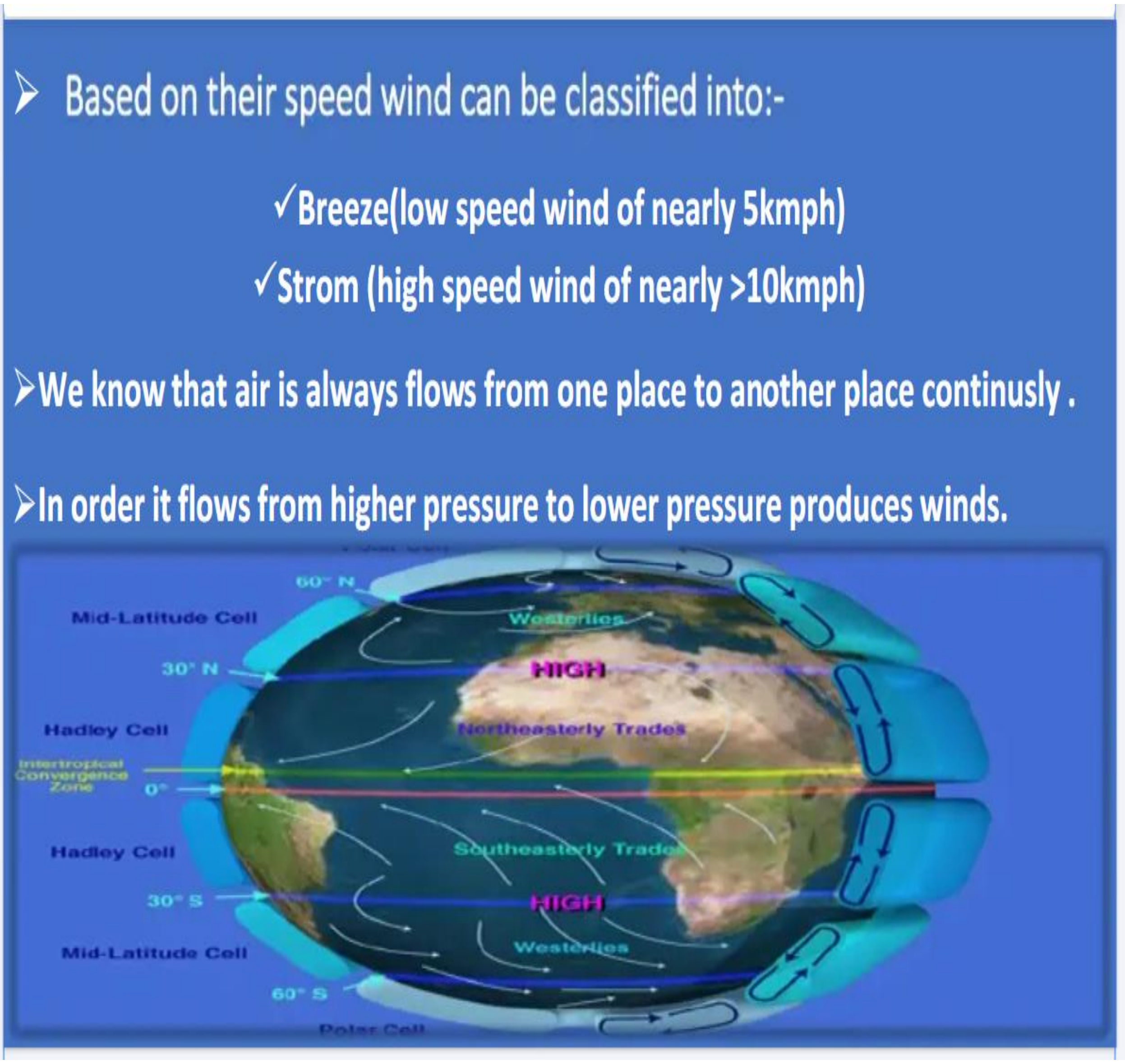


Figure 7

7.2 Density of the air

The denser the sky the more vitality the turbine gets. The thickness of air shifts with height and temperature. The atmosphere is less thick at high altitude than adrift level and warm air is less compressed than chilly air. Every single other thing being equivalent turbines will deliver more power at bringing down heights and in places where average temperatures are colder.

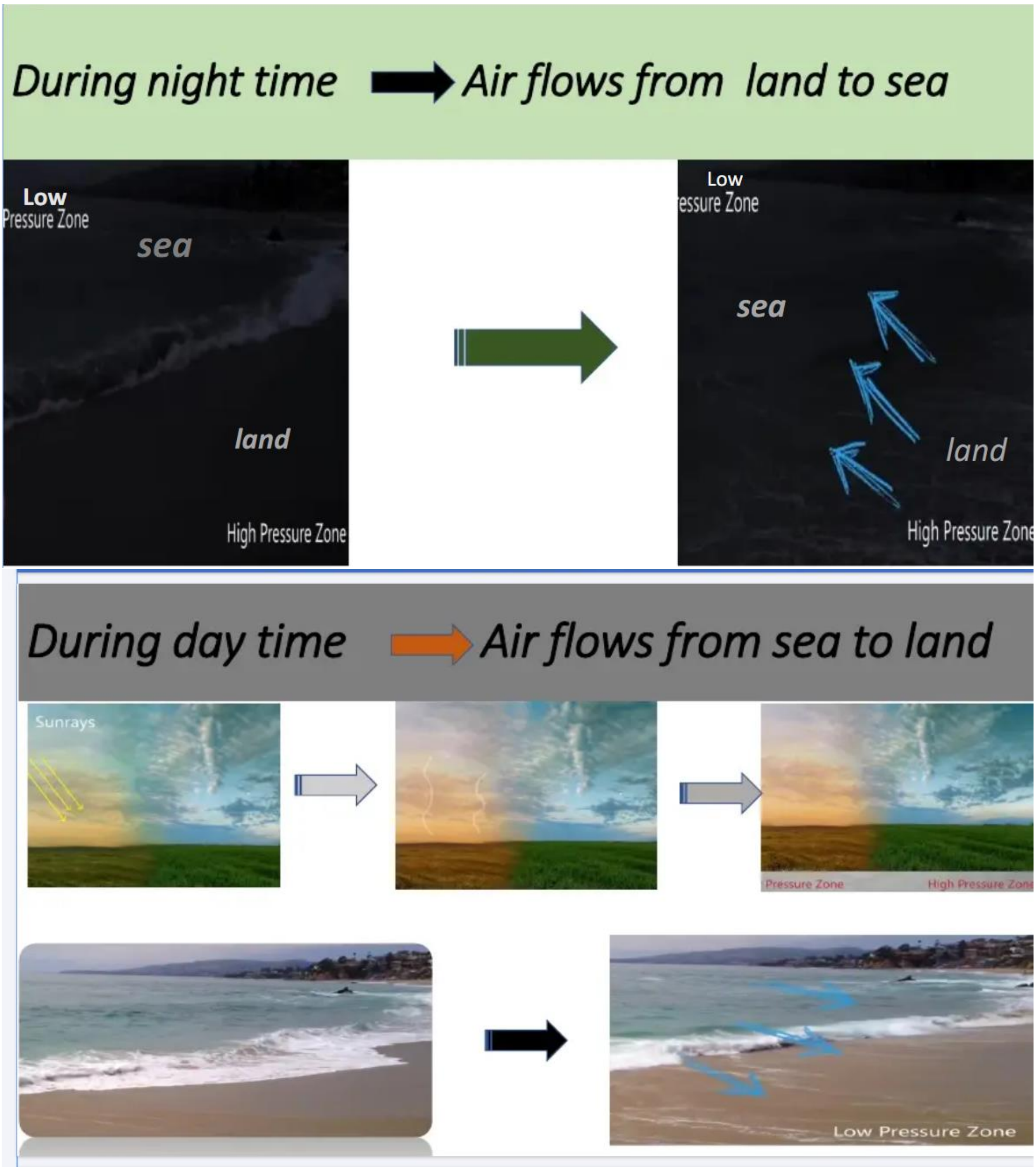


Figure 8

7.3 The swept area of the turbine

The bigger the region cleared the measure of the rotational part of the rotor the more noteworthy the power that the turbine can get from the breeze. Since the cleared territory is the place span of the rotor a little increment in edge length brings about a more significant increase in the accessible power for the turbine.

7.4 Advantages and disadvantages of wind turbines

Advantages	**Disadvantages**
No fuel pollution	Produces more sound pollution
Displaces 2365 tons of CO_2 every year	It is not available at all times
Each wind turbine saves 174.000 bathtubs of water every year	Turbine setup is very expensive
Saves a lot of money	Blades need higher maintenance

Table 5

7.5 Choosing a suitable wind turbine

The wind turbine should be mounted 10 meters above the ground in order to be more efficient as the air is denser and the wind speeds are higher. A diameter for the rotor is chosen to be 0.7 meters and an average wind speed of 8 m/s is desired for a wind turbine to produce 900 kWh/year with a turbine efficiency of 55%.

If we want to improve the amount of energy produced, we would need to use a windmill with a bigger rotor diameter. Also, the rotational speed of a turbine depends on how many blades it has: more blades means les RPM.

8. Heating power needs of a building

The first passive house was invented in 1991 by Dr. Wolfgang Feist in Darmstadt, Germany with the purpose of saving and reusing almost all the energy and heat produced inside the house. A passive house needs 90% less energy than a normal house and it is supplied by the heat from the sun, body heat or from the appliances: lights, oven, TV, fridge etc. and can be built in any type of climate. Every passive house has a ventilation system for a permanently fresh air supply and must be oriented south.

8.1 Thermal bridges

However, a house like this is 20-25% more expensive, and harder to build because it requires much more attention when building it and more material for insulation to prevent thermal bridges. Thermal bridges are created when materials with low thermal insulating characteristics come in contact and create a ‘highway of heat losses’, most of them appearing at the joints between walls, floor or roof and can account for up to 30% of heat losses. These thermal bridges must be lowered until they reach a value close to zero. For being able to achieve that, the house must be raised up so that the floor is not in direct contact with the ground and must be insulated with expanded polystyrene with a heat conduction coefficient of 0.18 kW/m^2K. Another method of lowering the thermal bridges is to use triple glazed windows (thermal conductivity between 0.5 - 0.8 kW/m^2K) and wood on the exterior walls of the building (U = 0.65 kW/m^2K).

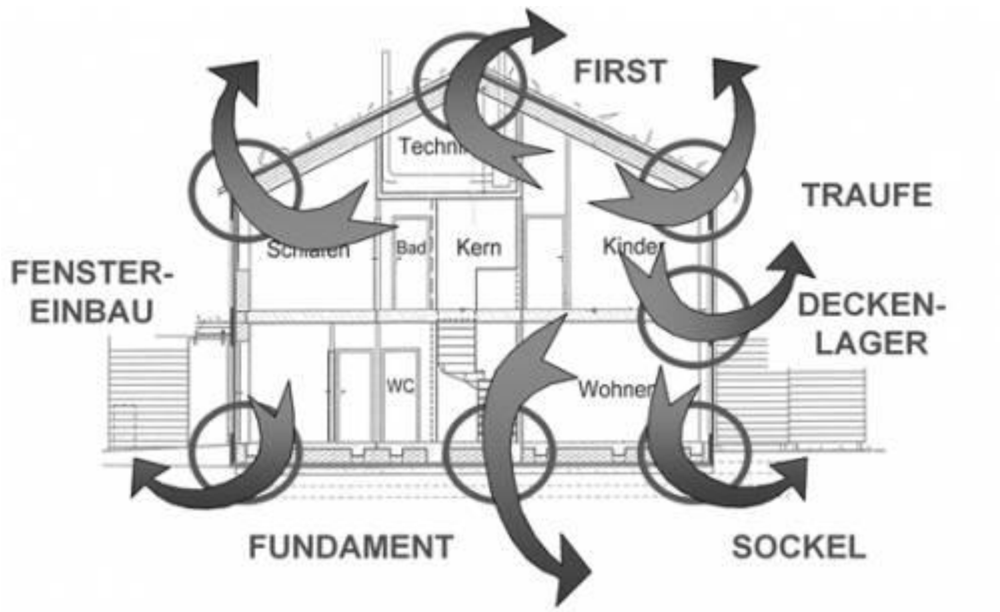


Figure 9

8.2 Power required for heating

8.2.1 Space heating

Now that we know what to do to avoid most of the heat losses, we can start calculating the amount of power needed to heat up a 2-story building along one full year. In order to do that, we first need to find the following values:

- Conduction heat losses through building's shell (Q.conduction)
- Air leakage heat losses (Q.air leakage)
- Power for heating supply air in a space (Q.supply air)
- Power for heating make-up air in a space (Q.make-up air)

Conduction heat losses can take place through walls (U=0.09 W/m^2K), floor (U=0.09 W/m^2K), roof (U=0.06 W/m^2K), windows (U=0.76 W/m^2K) and doors (U=0.7 W/m^2K). Thus, the overall conduction heat loss can be calculated by adding up heat losses through each component:
Q.conduction = $\sum UA * \Delta T$ = 1.7176 kW

In order to be able to find the air leakage heat losses, we must first determine the value of the air leakage flow escaping the house and for that, the air leakage number must be calculated:

q.50 =n.50 $\frac{V}{A}$ $\frac{m^3}{h*m^2}$ -> q.air leakage = q.50*$\frac{A}{3600*x}$ $\frac{m^3}{s}$ -> Q.air leakage = 0.353 kW
air leakage number air leakage flow air leakage heat loss

The same calculation is being done to find the value of supply air and make-up air heat losses, the only difference between them being n.50 (value of a building with 50 Pa pressure difference); the number for 'air leakage' was given in the table 3.2 from the book, but for finding the other 2 values, research had been done :

n.50_air leakage = 3 $\frac{1}{hr}$ n.50_supply air = 0.4 $\frac{1}{hr}$ n.50_make-up air = 0.5 $\frac{1}{hr}$

After adding up all the values of heat loss, we get:

Q.space = Q.conduction + Q.air leakage + Q.supply air + Q.make-up air = 2.77 kW/year

8.2.2 Power needed for ventilation supply air after-heater battery

The next value to be obtained is the heat power need for a ventilation supply air after-heater battery, so the flow of supply air from the system (q.vent_supply) is chosen to be 0.02 $m^3/_s$. If this value is known, Q.supply_air_battery can be easily determined using the formula given in the book:

Q.supply_air_battery = ρ.air*Cp.air*q.vent_supply*(T.ib – T.recov) = 0.00362 kW/year

where T.recov was calculated by adding up the mean annual outdoor temperature and the product between the difference in temperature from inside & outside and the heat recovery efficiency:

T.recov = T.outd + (T.ind – T.outd) * η_t = 17.85 ℃

8.2.3 Power required to heat domestic hot water

Heating domestic hot water requires the most power and to demonstrate it, we computed it using the following formula:

Q.dhw = ρ.water * Cp.water * q.dhw * (T.dhw – T.cw) + q.dhw_circloss * L.pipes = 6.567 kW/year

where q.dhw and q.dhw_circloss were found to be 20 $L/_{hr}$ and 40 $W/_m$ respectively; the length of water pipes was assumed to be 135 m and the difference in temperature between cold and hot water is usually around 50 ℃.

8.2.4 Total heat power required for heating

Now that all the values have been found, we can easily sum them up:

Q.heating = $\frac{Q_{space}}{\eta_{space}} + \frac{Q_{air\_supply\_battery}}{\eta_{air\_supply\_battery}} + \frac{Q_{dhw}}{\eta_{dhw}}$ = 13.42 $kW/_{year}$

where efficiencies were also researched and found out to be 80% , 72% and 66% respectively.

9. Energy storage

We have to take in consideration that we can generate more energy during day-time, but use more energy during the evening. We will use batteries, so we can store the energy generated during the day and use it in the evening.

By looking at the cycle of standard 21th. century households, the family members do leave their house for 9-5 work or study and the energy consumption is at the lowest. in fact the energy consumption is at its peak while all the family members do arrive until they sleep around 22:00 to 00:00. But the sun is still shining, and the electrical energy being produced but to store this energy is something we want to focus. Back in the days the cost effective way to store electrical energy was to use Lead-acid batteries which was widely used in the cars.

CONS of Lead-acid battery:

- Constant need for maintenance
- expensive
- Heavy

Now thanks to the new technology in batteries the Li-ion batteries :

- Cheap
- Lightweight
- Minimal to No maintenance
- Since it is modular, any repair or damaged cell packs can be replaced easily.
- Environmentally friendlier than counterpart lead batteries

The Li-ion batteries comes in different sizes, but the 18650 size format seems to be at the sweet spot and it is the format that the electric car giant is using for its cars and also for power walls.

The main companies that are producing 18650 batteries are Panasonic, Samsung, and LG. LG and Samsung are making more cost effective batteries, and in fact the model that I have chosen is Samsung 25R 18650 Li-ion batteries, it can be purchased as low as 2.4 Euros per cell.

Figure 10 Battery

The number and architecture of connecting these batteries are based on the current (A) and Voltage (V) we need.
The packs that I am introducing for these packs 20 batteries connected in parallel which each pack and generate 72V @ 2.5 Ah of energy.

Battery energy Supply				
Battery Packs	Numbers in parallel	Number in Series	Total Number of Battery	cost [2]
72 V @ 2.5 Ah	6	3	360	864 €

Table 6

The end result will 216 V @ 15A which is enough for most electrical appliances with max power output of 3.240Kwh.
The charging voltage will be power need is as follows:

- Nominal capacity: 2500 mAh
- Nominal voltage: 3.6 V
- Discharge end voltage: 2.5 V
- Charging voltage: 4.20 +/- 0.05 V
- Standard charging current: 1.25 A

So by considering the Power needed to charge 1 cell is : 5.25 W
so for our total power storage needs 1890 W to charge for the best performance. please do consider that the slower the batteries are charged the better will be the performance.

10. References

1. Hanze university of applied science. Module 4: Installation, mechanical engineering bachelor program, project description, 2020.
2. “Ground Source Heat Pumps.” Ground Source Heat Pumps | Centre for Sustainable Energy, www.cse.org.uk/advice/renewable-energy/ground-source-heat-pumps.
3. “Home Heating with Wood.” NASD, nasdonline.org/1435/d001235/home-heating-with-wood.html.
4. “Home Heating with Wood.” NASD, nasdonline.org/1435/d001235/home-heating-with-wood.html
5. “Air-Source Heat Pumps.” Energy.gov, www.energy.gov/energysaver/heat-pump-systems/air-source-heat-pumps.
6. “Heat Logs.” Bioenex OÜ, Lieferant Von Holzbriketts Rindenbriketts Und Anfeuerholz, www.bioenex.com/en/component/content/article/6.html.
7. Firewood, S.Y.: Different Types of Wood for Burning and their Characteristics, https://www.southyorkshirefirewood.com/wood-burning-characteristics.html.
8. https://www.britannica.com/science/hydroelectric-power
9. https://en.wikipedia.org/wiki/Run-of-the-river_hydroelectricity
10. https://electricalacademia.com/renewable-energy/hydroelectric-power-plant-working-types-hydroelectric-power-plants/
11. https://www.hydro.org/waterpower/why-hydro/affordable/
12. “Samsung INR18650-25R.” 18650 Battery | BATTERY BRO, batterybro.com/products/samsung-25r-inr1865025r-2500mah-20a.