UNIVERSITY OF VALLADOLID

ESCUELA DE INGENIERIAS INDUSTRIALES

BACHELOR DEGREE

NEAR ZERO ENERGY BUILDINGS IN FINLAND

Autor:
Fazli Suka

Tutor:

Javier Maria Rey Hernandez

TAMPERE, May 2018.

ABSTRACT

Tampere University of Applied Sciences
Building Service engineering
HVAC

Suka Fazli
Near zero energy buildings in Finland.

Thesis of bachelor degree. 82 pages
May 2018

This thesis is about near zero energy buildings in Finland. In this thesis is also told energy technologies of near zero energy building and the use of renewable energy sources. The regulations of EU for near zero energy buildings are also part of the thesis.

TIIVISTELMÄ

Tampereen ammattikorkeakoulu
Talotekniikka
LVI

Suka Fazli
Lähes nollaenergiatalot suomessa

Opinnäytetyö, 82 sivua
Toukokuu 2018

Tässä opinnäytetyössä on käsitelty lähes nolla energia talot suomessa ja niihin liittyvää tekniikkaa. Opinnäytetyö sisältää tietoa lähes nolla energia talosta ja eri uusiutuvista energia lähteistä. Opinnäytetyö käsittelee myös lähes nolla-energiataloa koskevia lakeja ja säädöksiä, tärkeimpänä EU:n asettamia tavoitteita nolla energiatalojen suhteen.

CONTENTS

1 SUMMARY

I study building service engineering in Tampere university of applied sciences in Finland. During the autumn 2017 I was on exchange program in Spain at the university of Valladolid. The topic of my thesis was given by a professor in university of Valladolid.

The topic of this thesis is near zero energy buildings in Finland. The idea was to write, how near zero energy buildings are made in Finland. How they are designed and what kind of technique is used on near zero energy buildings in Finland.

The building service engineering in Finland is high-quality, however the conditions in Finland are challenging for near zero energy building. The challenges in Finland for near zero energy are the weather conditions and the regulations set by EU and Finland.

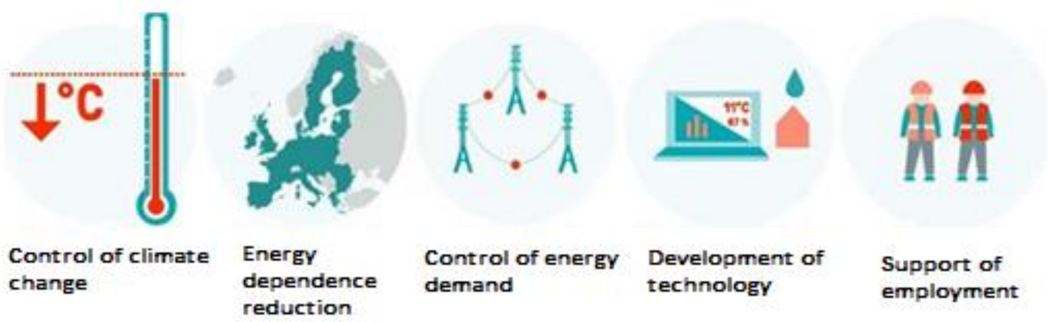
In this thesis is told, what near zero energy building means and in which ways this can be achieved. The regulations of EU and Finland set the goals of near zero energy buildings. The targets of near energy buildings to achieve more energy efficient constructions and to decrease the environmental impacts of building.

One of the biggest reason for near zero energy buildings is the target to reduction the use of fossil fuels and to slow down the climate change. The decrease of the greenhouse gas emissions is an important target that influence every country.

This thesis includes energy technology that can be used in near zero energy building. These energy technologies support the use of renewable energy sources and can replace fossil fuels.

2 WHAT IS A NEAR ZERO ENERGY BUILDING

Construction of buildings plays a big role on one of the five main targets of EU on calming the climate change and steady energy policy. The target is to decrease greenhouse gas emissions by 20% and to increase the use of renewable energy sources by 20%. The buildings cause 40% of EU`s total energy consumption and 35% of greenhouse gas emissions. Climate change, energy dependence reduction and control of energy demand are the main reasons for increasing the energy efficiency of buildings.



PICTURE 1. Targets of nZEB (ym.fi/fi)

NZE building is a building of which energy demand is covered scientifically from the building itself or with renewable energy sources. Renewable energy sources on nZEB for example can be photovoltaic energy, geothermal energy and biomass energy.

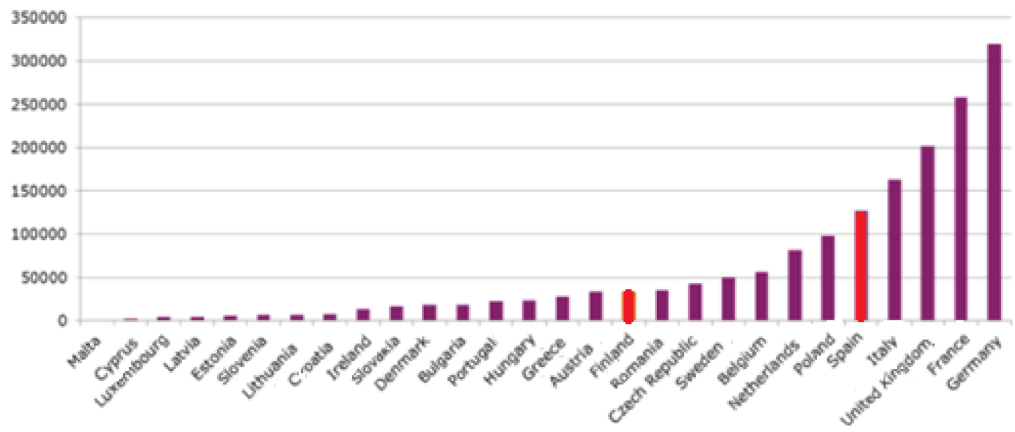
The nZEB construction is mainly directed by EU directives like energy efficiency directives EPDB (2010/31/EU) and EED (2012/27/EU) and renewable energy directive RES (2009/29/RE). EU`s targets and directives create a common goal for each country to pursue.

EU`s directives are ambiguous, for that reason in Finland is created FinZEB plan to determinate the directives in Finland. The purpose of FinZEB is to create a foundation for ambiguous national energy efficiency directive (EPDB) concerning the nZEB directives.

The aim is to find out how national requirements should be set in Finland sufficiently challenging and in a cost-effective way to meet the directives set for nZEB. With this, the different aspects of directives of the nZEB construction would be observed in the best possible way. The most concreate output of FinZEB is E- values published suggestion for nZEB.

2.1 FinZEB

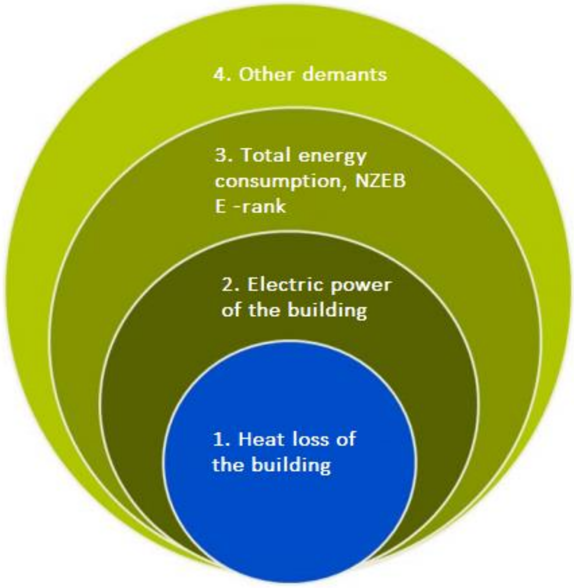
Even though Finland is the northernmost member of EU, Finland is not the EU`s top consumer of energy consumption, despite very challenging climate in Finland. Even in Finland the energy efficient construction has already obvious benefits on energy consumption. The EU`s energy consumption is 14% of the world’s total energy consumption and 12% of the world`s greenhouse gas emissions. With energy efficient construction improves energy self-sufficiency, creates new jobs and possibly improves economic growth with export opportunities. (Professor Jarek Kurnitski, 2012, slideshare.net)



PICTURE 2. Total energy consumption of EU in 2012 (Energia.fi)

The FinZEB -project revealed that different type of buildings requires different type of profitable energy saving methods, from which the most profitable methods are ventilation heat recovery, control of ventilation and lighting and improvement of the tightness of the building.

FinZEB instruct that the building must meet certain conditions to reach a level of near zero energy building. These conditions are examined step by step, some of the demands must be fulfilled when applying for building permit and the remaining must be fulfilled at commissioning inspections.



PICTURE 3. The required qualities for NZEB in Finland (FinZEB)

In step one, examination of heat losses of the building, will be examined building elements, tightness and the heat recovery of ventilation.

In step two the electrical power of the building is calculated, including electricity used for heating. The purpose of calculations is to limit the peak use with technology and automation.

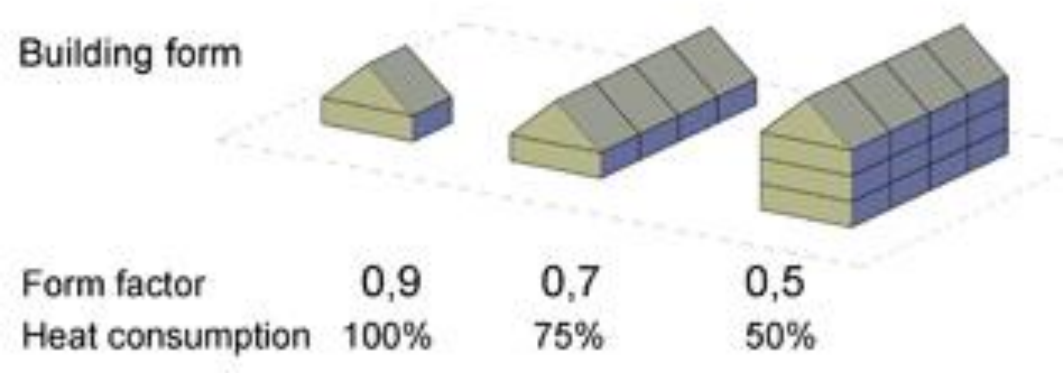
In step three is calculated the total energy consumption of the building and the E -value of the building. E -value for nZEB is determined in building regulations collection of Finland. It is important to understand that E -value is a calculated value of the building and it is not the actual energy consumption of the building.

In step four is included for example overheating inspection, efficiency of electric power of the ventilation, the renewable energy use and energy certification. Use and maintenance for energy efficiency instruction and demonstration of system operate may be required.

2.2 Structure of near zero-energy building

The construction and structure of nZEB must be designed carefully. The position, dimensions, shape and windows surface area of the building affects the energy consumption.

One of the most important design solutions for the energy demand of nZEB is the form of the building. Larger area of external envelope of the building and the complex of the buildings form weaken the energy efficiency of the building. However, the heat losses caused by complex form of the building can be compensated with other design solutions. NZEB should be adequate large to reduce the form factor of the building. The form factor A/V is a ratio of the heat insulation factor of external envelope and heated space volume.



PICTURE 4. Example of form factor (passiivi.info)

Windows should usually cover 15-20% of floor are, because the thermal insulation of windows is weaker than a wall structure. The windows should be directed to the sun and they can be shaded in the summer, with shading the windows the cooling demand can be decreased.

The structure of nZEB must be well insulated to achieve small thermal transmittance coefficient and heat losses. Thermal transmittance coefficient or U -value is planned specifically for each building. For nZEB has been recommended U -values, these are shown in Table 1.

TABLE 1. U -values of nZEB (ym.fi/rakentamismaaraykset/C3) (isover.fi)

Structural element	Normal Building (W/m²K)	nZEB (W/m²K)
Exterior wall	0,17	0,08
Roof	0,09	0,06
Base floor	0,16	0,09
Windows	1,0	0,7
Doors	1,0	0,7

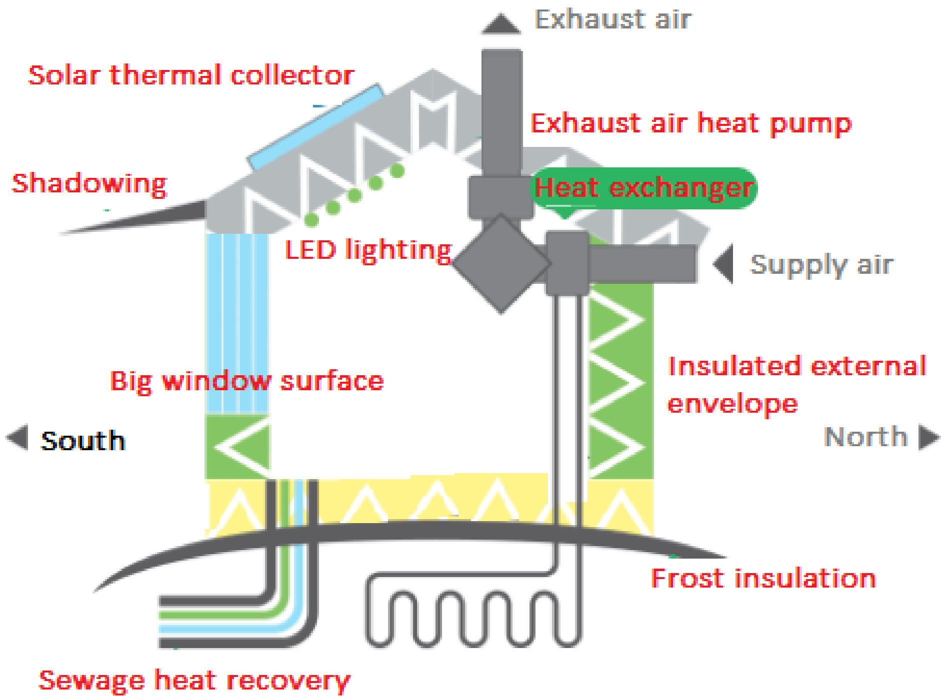
U -value indicates the heat transfer displacement trough one square meter of the structural element divided with the temperature difference between inside and outside temperature. The air moves from warm to cold until thermal equilibrium is achieved. The heat can be transferred by conduction, convection or radiation.

On nZEB the external envelope of the building must be air tight. When the external envelope of the building is ready, the air tightness of the building is measured. For airtightness of the building has been given the value for air leakage q_{50}, this tells the leakage air flow rate of the building in cubic meter per hour. The leakage air flow rate must not be over $4m^3/h$. The most challenging parts of the insulation of external envelope are thermal bridges. The insulation of thermal bridges must be carefully designed and installed.

2.3 Building service engineering in near zero-energy building

Near zero energy building is air tight, so it needs a well working and carefully dimensioned ventilation system. The ventilation system should have a good automation, variability and it must be energy efficient. The heat recovery from ventilation should be at least 70%. The purpose of the room area determines the target level for ventilation.

The energy consumption of the lighting in nZEB should be minimized without undermining the quality of lighting. This can be achieved with natural light, light surfaces and dimmers. With LED technology can be achieved a high energy efficiency on lighting. LED lights are long lasting and do not require a lot of maintenance.



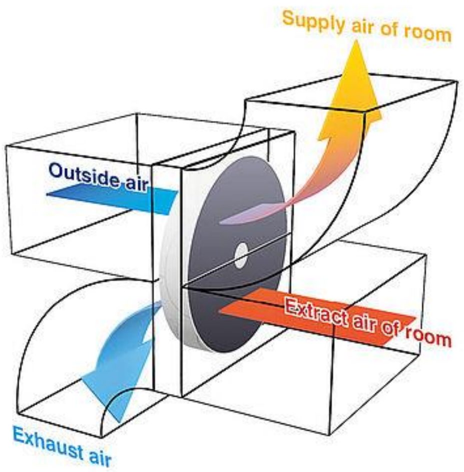
PICTURE 5. Example of nZEB technology (nollaenergiatalo.fi)

2.3.1 Ventilation

Ventilation is important for the building to achieve healthy and comfortable conditions for the building and the user. For the healthy and comfortable conditions, the purpose of the ventilation is to exchange the polluted inside air and to decrease the humidity in the building. With automation the energy losses of the ventilation can be decreased. With sensors measuring the temperature of the room, carbon dioxide and humidity in the room the ventilation can operate only when needed. Controlled ventilation saves energy significantly.

The efficient of ventilation is measured by temperature rate of heat recovery from ventilation and with electrical power of pump. The ventilation must be sufficient and mute. More expensive, however energy efficient air supply unit is more economical in long-term.

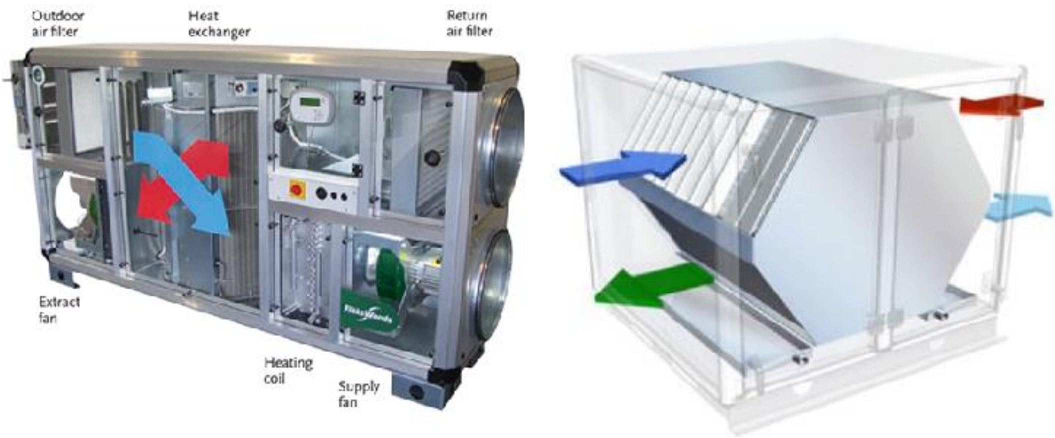
Heat recovery from ventilation usually means a thermal wheel or counterflow heat exchanger. Either of them has an efficient of 80%, this means that 80% of supply air heat energy demand is from exhaust air heat recovery. With this heat recovery efficient the needed heat energy for supply air is only 20%.



PICTURE 6. Thermal wheel heat exchanger (tecukltd.co.uk)

The thermal wheel collects the heat from exhaust air and rotates the heat to supply air. Thermal wheel is efficient and doesn't freeze easily. The thermal wheel exchanger is also easy to control for controlling the temperature in summer and winter. The exchanger also shifts humidity from exhaust air to supply air, which increases the air humidity in the winter.

Counterflow heat exchanger doesn't shift humidity and it can freeze easily. For preventing the exchanger from freezing, an air heater is needed in the unit. This heater requires electrical power which weaken the energy efficient. However, the air heater can be connected to ground energy, which will heat the air without electricity. Counterflow heat exchanger with a humidity shifting feature are available also, these exchangers do not freeze easily therefore they don't require an air heater in the unit.

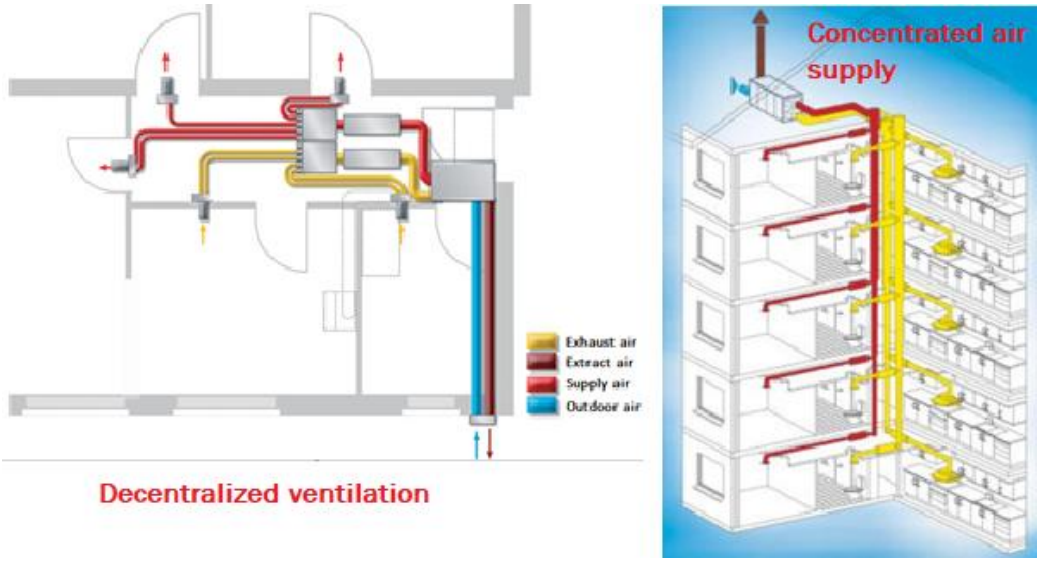


PICTURE 7. Counterflow heat exchanger (cibsejournal.com)

In residential apartment house the ventilation can be decentralized ventilation or concentrated air supply. Decentralized ventilation means that for every apartment there is an own air supply unit. The ventilation of the apartments is done by one smaller air supply unit that serves for one apartment only. The function of decentralized ventilation is similar to that of a single-family house`s.

Concentrated air supply is done by one bigger air supply unit serving the whole building. With concentrated air supply is more difficult to achieve 80% efficiency. The unit can be too big to use an counterflow air exchanger and thermal wheel is not allowed because of it shifts impurity from exhaust air to supply air. Thermal wheel is only allowed to be used with activated carbon filter.

Range hood of the kitchen cannot be connected to exhaust air. The range hood should have an own venting from the kitchen. In this way the impure air will not end up in to the supply air.



PICTURE 8. Decentralized ventilation and Concentrated air supply (Heikki Lamminaho 2012 & omataloyhtio.fi)

2.3.2 Heating

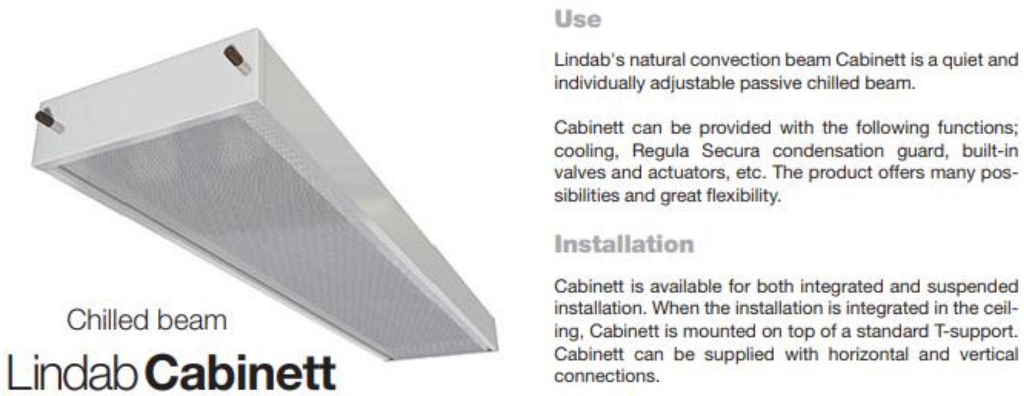
Radiation heating is a conventional heating system, however double-pipe connection used in old buildings can cause unnecessary heat loss when the thermostat is closed in one radiation. The new low temperature system allows to use manifold for the apartment where also the floor heating can be connected. The same heating water circulates radiators and floor heating. Manifolds allows to keep the floor heating warm during the summer for sanitary areas when in the same time the radiators are controlled by thermostats when heating is not needed. As well the water temperature is lower by using manifold when rated temperature for supply water can be 50/30 ˚C, 45/35 ˚C or only 40/30 ˚C.

2.3.3 Cooling

Cooling can be air cooling, room or apartment cooling. With air cooling the achieved cooling capacity can be low because of small air flow. With specified room or apartment can have high cooling capacity. Cooling alternatives can be chilled beam, floor cooling, sealing cooling or fan coil unit of air heat pump. The energy for cooling can be from borehole of ground heat, ground heat loop, air heat pump or district cooling.

Chilled beams and fan coil units have many alternatives for installation. They can be installed on the floor, ceiling or wall, which makes the installation easy to fit the needs of the room. The air flowing through the chilling beam induces the air achieving high cooling efficiency.

Air heat pumps can be used as well. This system includes outdoor unit from which the condense water must be sewer. The air heat pump work with free refrigerant circulation direct evaporation system, this makes the air heat pumps energy efficient. The cooling efficiency factor of air heat pump can be 5, this means with 1 kWh of electricity it produces 5 kWh of cooling energy. The indoor unit is the fan coil unit which allows an installation that suits the single-family houses and residential apartment houses very well.



PICTRUE 9. chilled beam product (lindab.com)

2.4 Challenges and problems of near zero-energy building

When designing near zero energy building, the whole complex of the building must be considered from the beginning. For achieving perfectly working building all the designers must work together from the beginning to make sure the constructions and the technology in the house works in the best possible way. Near zero energy building is more complicated, when the system includes more parts to consider.

Especially for Finnish conditions, the experience on near zero energy buildings is still narrow. Thick insulation decreases heat energy consumption, but in the summer the cooling of the building is more challenging. Increased thermal insulation increases the temperature of indoor air in the summer. Overheating of the building is a problem that decreases the indoor air quality and increases the humidity, that causes mould risk.

The external envelope of near zero energy building has a better airtightness, this increases the importance of ventilation for better indoor air. The automation of ventilation helps to control the indoor air and decrease the energy consumption when less air is needed in the room.

In near zero energy building the energy consumption and production often happen in a different time. In the summer the building produces more energy that needed, this energy should be stored which can be expensive. The energy could be sold, however the energy demand in the summer is low.

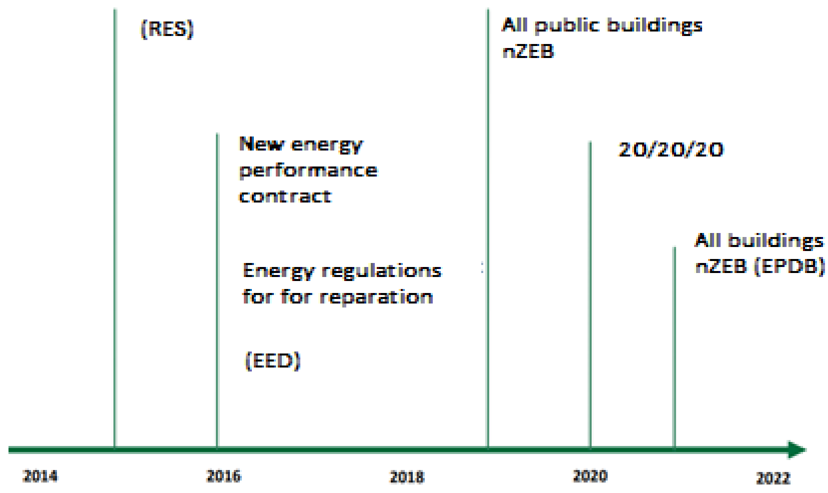
In the winter the demand of heat energy is very high in Finnish conditions, decreasing the heat losses of the building with structural solutions and technology is critical in Finnish conditions. Near zero energy building can have small energy demand, however the user has an important responsibly to make sure the building is used in energy efficiently.

The energy efficiency of the building should be monitored. If the actual energy consumption is different to the designed energy consumption the problem must be solved.

2.5 Legislation of near zero-energy building

Energy performance of building directive (EPDB 2010/31/EU) is coming into effect in 2019 and 2021. This directive determines that new residence buildings and municipal buildings must be near zero energy buildings. From 2019 all buildings controlled by authorities must be near zero energy buildings and after 2021 all buildings must be near zero energy buildings. (FinZEB)
Renewable energy directive RES (2009/29/RE) came into effect in 2015, this directive determines the minimum level of renewable energy in new buildings. With this came into effect also the recommendations for the technology of near zero-energy buildings. (FinZEB)

In 2009 the EU´s climate and energy policy gave the target called 20/20/20. according to this target by the end of 2020 the energy consumption of EU should be 20% from renewable energy sources, the greenhouse gas emissions reduced by 20% and the energy efficient should be increased by 20% as well. For Finland the target of renewable energy is 38% by the year 2020.



PICTURE 10. Timetable for energy performance improvement (Ville Reinikainen pdf, Granlund)

The Finnish building regulation collection D3 presents the demand of energy efficient in Finland. The most important regulations are about the total energy consumption of the building (E-value), control of room temperature and airtightness of the external envelope of the building.

The total energy consumption of the building, known as E-value, is the annual delivered energy of the building for heated net area. In the annual delivered energy is concluded the coefficient of energy source (Table 2.). The annual delivered energy is the delivered electricity, district heat or fossil fuel.

$$\text{E-value} = \frac{Delieved\ energy * coefficient\ of\ energy\ source}{heated\ net\ area}$$

In Finnish building regulation collection D3 is presented the E-values for each type of building depending the purpose of use.

TABLE 2. E-value demands for buildings (RakMK D3, 2012)

Purpose of use	E-value (kWh/m^2 per year)
Single-family house	by area
Residential building	130
Office building	170
Educational building	170
Hospital	450

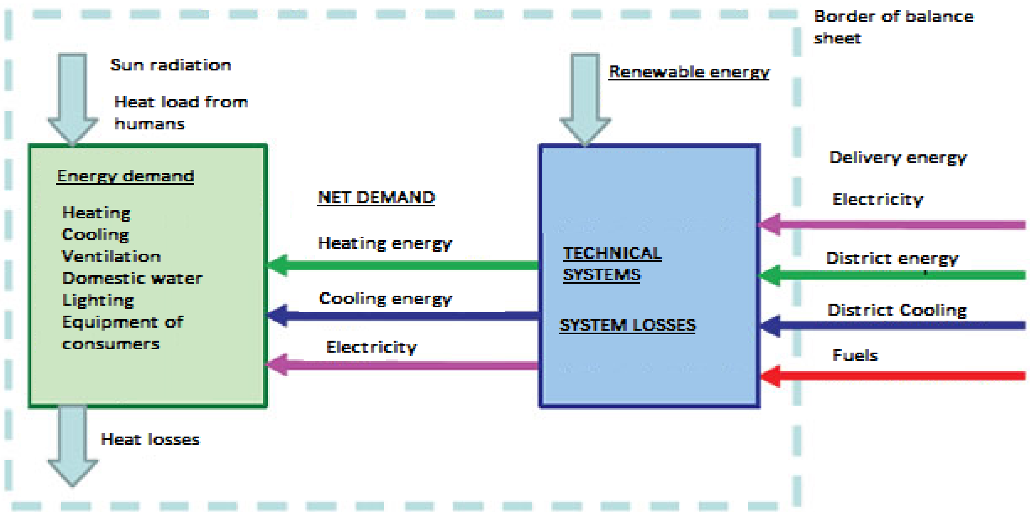
TABLE 3. The coefficient of energy sources (RakMK D3, 2012)

Energy source	The coefficient of energy source
Electricity	1,7
District heat	0,7
District cooling	0,4
Fossil fuel	1
Renewable energy sources	0,5

To determine the delivery energy, the Finnish building regulation collection gives so called balance sheet of demand energy (picture 10.). The balance sheet shows that all the energy produced inside the plot must be considered in calculations. The total energy consumption is determined by the amount of energy delivered outside the balance sheet.

The calculations show that is more economical to reduce the energy demand than increase the energy production. The Idea of balance sheet of delivery energy is to set all technical solutions in the same position, so the way to an energy efficient building is not unrestricted.

Self-sufficiency energy like solar energy is not multiplied with coefficient of energy source, however using renewable fuel must be calculated with the coefficient.



PICTURE 11. Balance sheet of delivery energy (finlex.fi)

The indoor temperature rises in spring and summer time considerably, therefore controlling the temperature rise during the summer must be considered.

For controlling the room temperature in summer, Finnish building regulation collection D2 and regulation for indoor climate 2008 of Finland (sisäilmastoluokitus 2008) gives the directions for better indoor climate conditions.

The indoor temperature limit is on residence building 27 ˚C and between 1st of June and 31st of august the indoor temperature should not go over 27 ˚C more than 150-degree hour. This means it is possible to cross the indoor temperature limit temporary. For example, if the indoor temperature is 30 ˚C for 3 hours the degree hour is 9-degree hour ((30-27) *3 = 9).

2.6 Calculation of Energy efficiency

The energy demand of the building includes the heating of domestic water and ventilation, cooling of rooms and ventilation and the electricity demand. The heat energy net demand can be calculated by calculating the difference between heat energy demand, energy production from solar energy, recovery energy and internal heat loads. (Rakennusmääräyskokoelma D5)

The energy consumption for heating systems is calculated from heat energy net demand by observing the heat losses of the system. The system losses are caused by delivery, distribution and storage of the heat energy. The efficiency of the system and the produced heat energy of the system must be observed as well. The electrical energy and heat energy of the heating system is specified in the calculations. (Rakennusmääräyskokoelma D5)

The Finnish building regulation collection D3 defines that the building must be designed that the temperature of the facilities does not rise harmfully. In priority the temperature rise of the facilities must be controlled by structural designing and passive way, however in the summer the cooling of building may be necessary. The energy consumption of cooling system is included to total energy consumption of the building.

The energy consumption of the cooling system is calculated from the net demand of cooling by observing the system losses caused by delivery and distribution of cooling. The output losses of the cooling system and variations must be observed as well, also the energy production of the cooling system. (Rakennusmääräyskokoelma D3)

2.7 Visions for Energy efficiency by the end of 2030

It is clear that the climate is changing. Climate researches anticipate that;

- Average temperature of year will rise.
- Temperatures in the winter are lower
- Temperatures in the summer rises
- Solar radiation decreases in the winter and spring.
- Relative humidity in the winter will rise
- The enthalpy will rise in temperature peak of the summer

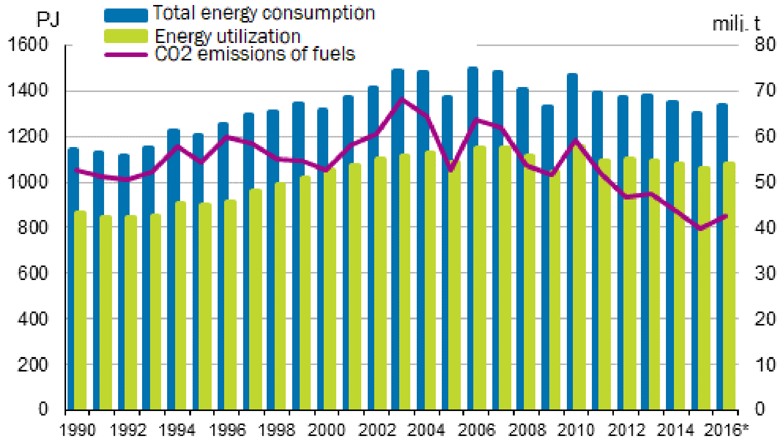
This means radical energy efficient improvement obligations and precautionary measures for climate changes. The changes in the winter are more significant, because of temperature rise, increase of rain, relative humidity of the air. In the summer the most significant changes are high temperature and increase of rainstorm. The use of renewable energy sources is critical for improving energy efficient. Other important matters are;

- Water saving
- Improved waste management
- Comprehensive energy saving development

For technologies and operation modes are given instructions like;

- Energy visions 2030 for Finland
- Energy industry 2010 /30/; From challenges to possibilities
- TEM /14/; Energy efficient demand and possibility 2050

In the picture 11. is shown the total energy consumption and emissions in Finland during 1990-2012.



PICTURE 12. Total energy consumption and emissions in Finland(Tilastokeskus)

Energy efficient buildings reduces greenhouse gas emissions of build-up environment and dependence on import energy.

In Finland are 270 milj. m^2 residence buildings and by the end of 2030 is required actions for improving energy efficient. Required actions in Finland on buildings by the end of 2030 are;

- 30-40 milj. m^2 near zero energy buildings
- 50-100 milj. m^2 of repair construction for increasing the energy efficient.
- 15-30 milj. m^2 of demolition of buildings.

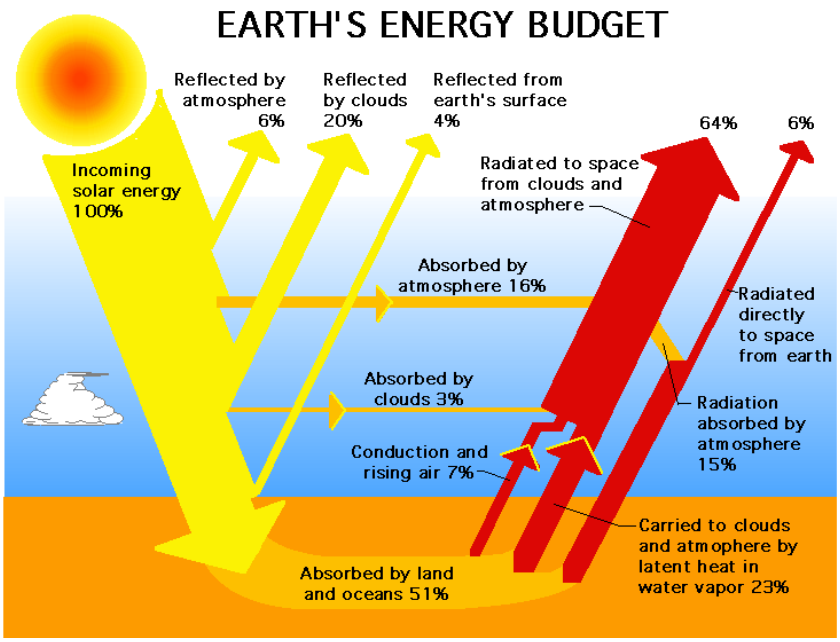
By the end of 2030 the energy consumption is predicted to decrease by 30% and the greenhouse emission by 44 %. The use of fossil fuels in heat energy production should be stopped. By the end of 2030 is predicted;

- Direct electric heating decreasing 89%
- Fuel oil heating decreasing 86%
- District heating decreasing 6%
- Geothermal heating increasing 78%
- Bioenergy consumption increasing 28%
- Solar energy and wind energy increasing 67%

3 PHOTOVOLTAIC ENERGY & SOLAR THERMAL ENERGY

The solar energy is generated in a fusion reaction, where two hydrogen atoms are combined to one helium atom. A large amount of energy is released from this reaction, which requires a high level of temperature. The fusion reaction of hydrogen atoms requires a temperature of 10 million degrees Celsius. From one helium kilo composing from hydrogen release 180 million kilowatt-hours. The same amount of energy can be obtained from 27 000 tonnes of coal.

The total radiation solar power or luminosity from the sun is 3,8 x 10^{23} kW. From this amount 1,7 x 10^{14} kW reaches the earth, which is 20 000 times the amount of power used by industry and heating in the world. Some of the incoming solar energy will be reflected to the space by atmosphere, clouds and earth`s surface. The solar energy will be also absorbed by atmosphere, clouds, land and oceans.



PICTURE 13. Earth`s energy budget from the sun (karvola.wordpress.com)

Solar constant is the radian energy of perpendicular insolation on the atmosphere of the earth on a $1m^2$ it is 1,35-1,39kW. This amount changes +/-3,5% because of distance change between the sun and the earth. The atmosphere decreases the solar constant by 40%, hence the instant solar constant, the amount of the energy that reaches the ground is 60%. In broad daylight instant solar constant is about 0,8-1,0 kW/m^2.

Because of the atmosphere there is three types of radiation coming to the ground: Beam radiation (I_B), diffuse radiation (I_D), Atmosphere radiation (I_A). Beam radiation is the direct solar radiation from the sun to the receiving surface, also referred to as direct radiation. Diffuse radiation is the solar radiation scattered by dust and molecules which the atmosphere contains. Atmosphere radiation is the radiation from ozone layer back to the ground, also known as greenhouse effect.

The total radiation I is the sum of these three radiations minus the radiation from the surface back to the space (I_U).

$$I = I_B + I_D + I_A - I_U \qquad (1)$$

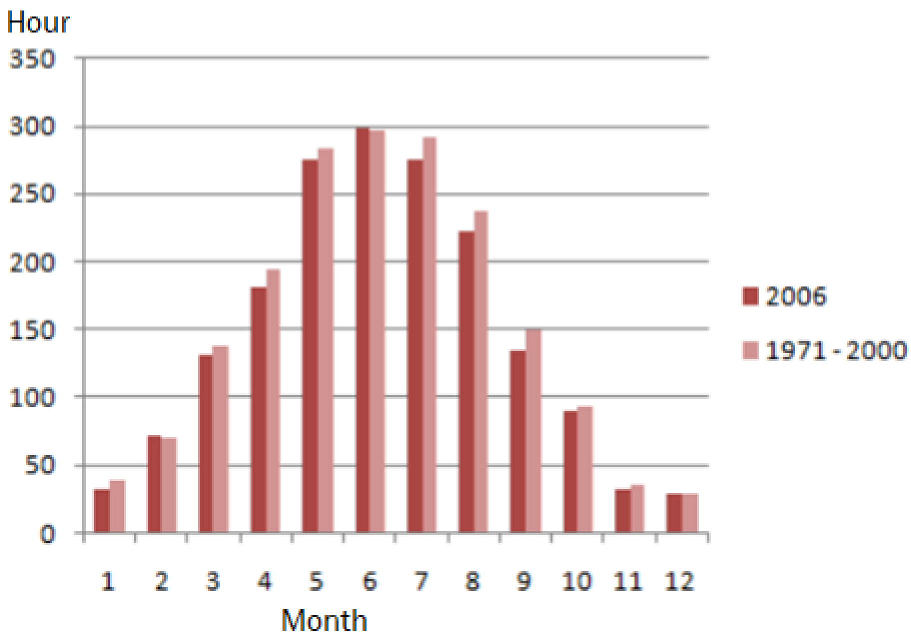
On a bright summer day 20% of the light is diffuse radiation and on a cloudy day it can be up to 80%. In Finland 50% of the light is diffuse radiation.

The global location and the time of the year also have an impact on the solar energy. The annual solar energy is higher closer to the Ecuador and the difference between seasons is smaller.

TABLE 4. The annual solar energy (Aurinko-opas aurinkoenergiaa rakennuksiin)

City	Latitude	kWh/m²/a
Helsinki	60˚ 12N	938
Rome	41˚ 48N	1435
Lisbon	38˚ 43N	1689
Paris	48˚ 49N	1032

Table 4. shows the annual solar energy difference between the city's located on different latitude. In Helsinki the annual solar energy is lower than for example in Lisbon. The latitude location of Helsinki is further from the Ecuador which means the difference of the solar energy between then months is bigger. This is shown in picture 14. In Helsinki the possibility to utilization of solar energy in the winter is much smaller than in the summer time. Therefore, in Finland the solar energy is used more for domestic water heating and less on heating purpose of the building.



PICTRURE 14. Solar hour in year in Helsinki

3.1 Utilization of photovoltaic energy

In Finland the heating of hot water consumes almost a third of a Finnish household electricity consumption. Hot water heating can be produced 60% by using solar panels. The heating of hot water in Finland can be done from march until the end of October.

By using the right building structure and trend of the building the heating of the house can be done by solar energy. For effective collection of solar energy, positioning, trending and windows are important. By building the buildings on north south direction will increase the possibility of higher solar energy utilization. With south placement of the windows enables the passive utilization of solar energy.

Active solar energy utilization is done with solar panels. For optimal energy yield the positioning, angle and trend of the solar panels are important. The positioning of solar panel should be south and on a shadowless place. Specially in the Finnish winter when the sun is much lower than during the summer. Higher positioning of solar panels will increase the efficiency. If the south direction is on shadow it is possible to trend the panels west or east, but this will decrease the efficiency of solar energy.

PICTURE 15. Solar panels on a building (puutarha.net/artikkeli14595)

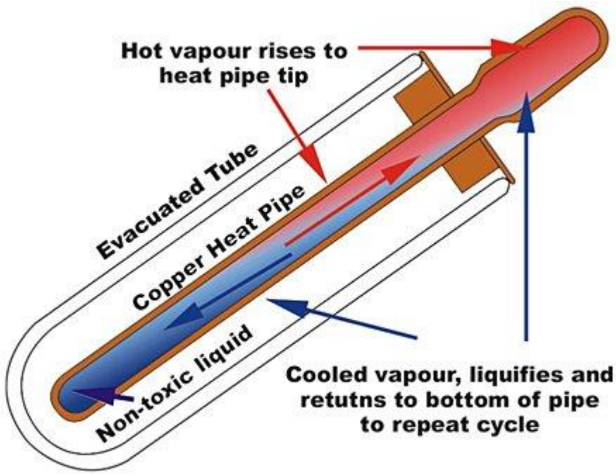
In picture 15. is shown the ideal way of trending the solar panels and windows. Large window surface area on the south increases the passive solar energy utilization. High location of the solar panels on the south side of the roof allow an efficient active solar energy utilization.

3.2 Solar collector systems

There are few solar energy collectors used, most commons are flat-plate collectors and vacuum tube collectors. The function of the collectors is to absorb solar heating to be reserved or to direct use.

3.2.1 Vacuum tube collector

Vacuum tube collectors can be divided to two types of collectors: heat-pipe collectors and U-pipe collectors. Heat-pipe collectors have vacuum tube pipe to absorb solar energy and another copper pipe to heat transfer. Inside the copper pipe the vapour will be heated and when evaporated the hot vapour rises on top of the tube. The heat will be transferred to heat transfer fluid in the system. After heat transfer the vapour liquefies and returns to the bottom of the heat pipe, to repeat the cycle.



PICTURE 16. Heat-pipe collector. (google.com/heatpipecollector)

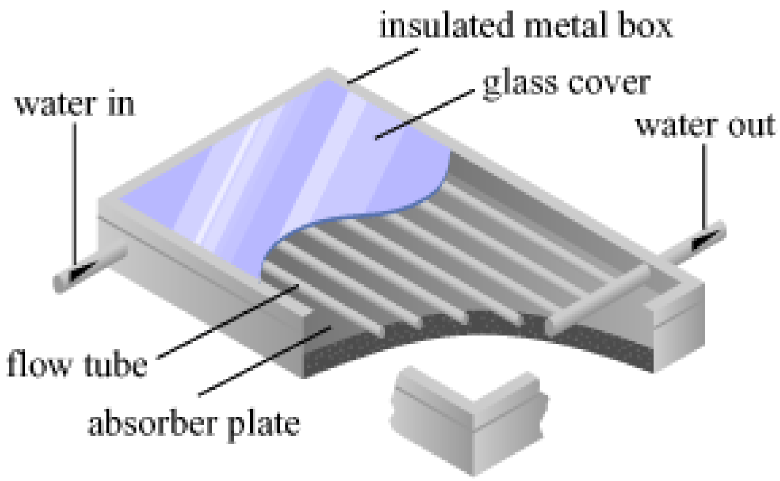
PICTURE 17. Installed heat-pipe collector. (sunpower-solar.com)

The function of U-pipe is similar to that of the heat-pipe system. On U-pipe collector the fluid will circulate in a U-shaped copper pipe. Due to slight amount of connection point in copper pipe and the thermal insulation of the vacuum between the pipes, the heat losses are very small.

3.2.2 Flat-plate collector

Flat-plate collectors are most common in Finland. They are economical and long-lasting. The operational reliability of flat-plate collectors is good for Finnish conditions. The principle of flat-plate collector is very simple. The collector collects solar radiation and transform it into heat in the absorber by using greenhouse effect. The flat-plate collector has a copper or aluminium large absorbing plate to reserve radiation from the sun. The surface is black to increase the efficiency of absorbing the solar energy. Under the plate there are copper pipes, which contains fluid for heat transferring.

The pipes are attached on the plate for heat transferring surface. When the plate is warmed by the sun, the fluid inside the copper pipes will absorb the heat. This heat can be used on domestic water heating.



PICTURE 18. Flat-plate collector (solartribune.com/solar-flat-plate-collector)

The vacuum tube collectors have a better efficient than flat-plate collectors. The vacuum tube collectors can store the heat in to the vacuum therefore it is better for diffuse radiation. In the winter when there is a lack of sunlight and more heat is needed vacuum tube collectors can collect diffuse radiation more efficient than flat-plate collectors. Flat-plate collectors in the other hand are economical, better for Finnish winter conditions, because they are less vulnerable of freezing and they last longer than vacuum tube collectors.

3.2.3 Efficiency of solar thermal collector

Not all solar radiation coming to the collectors can be utilized. The efficiency of the collectors is affected by some factors. These can be internal factors or external.

Internal factors are:

- Features of the solar collector
- The orientation and inclination of the solar collector
- Absorption capacity and heat transfer capability of fluids
- Thermal insulation
- The feature of the collector and the pipes.
- The required temperature and energy
- Distance from collector to boiler
- Temperature of the boiler

external factors are:

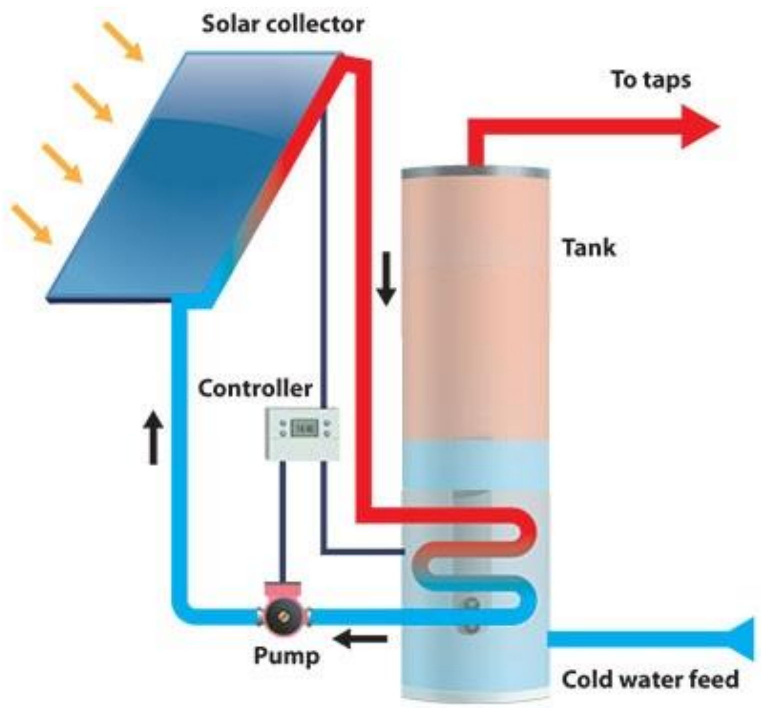
- The angle of sunlight, this depends on season and time.
- Shadows
- Temperature
- Windiness

To improve the efficiency of the collectors, it is important to choose the right system and to install the collectors in the best way possible.

PICTURE 19. Installation of solar collectors (https://yle.fi/uutiset/3-9831045)

3.3 Solar thermal collector system and devices

The solar thermal collector system consists of many devices and components. The devices and components included in the solar thermal collectors are solar collector, piping, pump and control unit, heat exchanger and safety devices.



PICTURE 20. Solar thermal system. (greenfieldspenrith.com)

Picture 20. shows the solar thermal system and the way the components are installed. The solar thermal system is controlled by control unit, the control unit regulates the pump unit. When the heat on the collectors is higher than the heat in the hot water tank, the automation will activate the fluid flow by starting the pump. The control unit also monitors the overheating of the hot water boiler, by shutting down the pump when the temperature rises excessively in the hot water boiler. With pump the fluid start flowing and collects the heat from the collector bringing it into the hot water boiler where the heat can be stored. The domestic water will be heated in the hot water boiler and will continue to the taps.

The pipes contain the heat transfer fluid, the pipes are copper to sustain the high temperature. The system contains expansion tank, which keeps the pressure of the system stable.

Due to temperature changes the volume in the pipes changes also, the expansion tank is needed to stable this. Excessive air and pressure is controlled with overpressure valve and air extraction valve. These valves release pressure or air from the system. The one-way valve prevents the fluid flow on opposite way.

3.4 Energy yield of photovoltaic energy system

The photovoltaic energy revenue of solar thermal system can be calculated with equation 2. For calculating the revenue at least, the area of the panels, orientation and inclination of the collectors, maximum power coefficient and installation method information of solar panels must be known. This method is used only on the building or its immediate vicinity. This information is from Finnish building specification collection D5 (Rakennusmääräyskokoelma D5).

$$W_a = \frac{G_{sun} \cdot P_{max} \cdot F_{use}}{I_{ref}} \quad (2)$$

where,

W_a	photovoltaic cell annual energy yield kWh/a
G_{sun}	annual solar radiation energy on panel kWh/m^2
P_{max}	largest electric power of photovoltaic cell kW (reference radiation)
F_{use}	operability factor of usage
I_{ref}	reference radiation situation

3.5 Standards

For solar thermal collector systems are se these standards;

- ISO 9806: Testing methods of solar thermal collectors
- SFS-EN 12975-1: Solar thermal collectors
- SFS-EN 12976: Manufactured solar systems
- SFS-EN 12977: Other than manufactured solar systems

In Finland there is not actual regulations for solar systems, however solar system must fulfil the qualification of standard SFS-EN 12975-1 to achieve Nordic eco label.

From 2016 the installation of solar system has required a permission from city administration. The requirements of permissions various depending on the city.

4 BIOMASS ENERGY

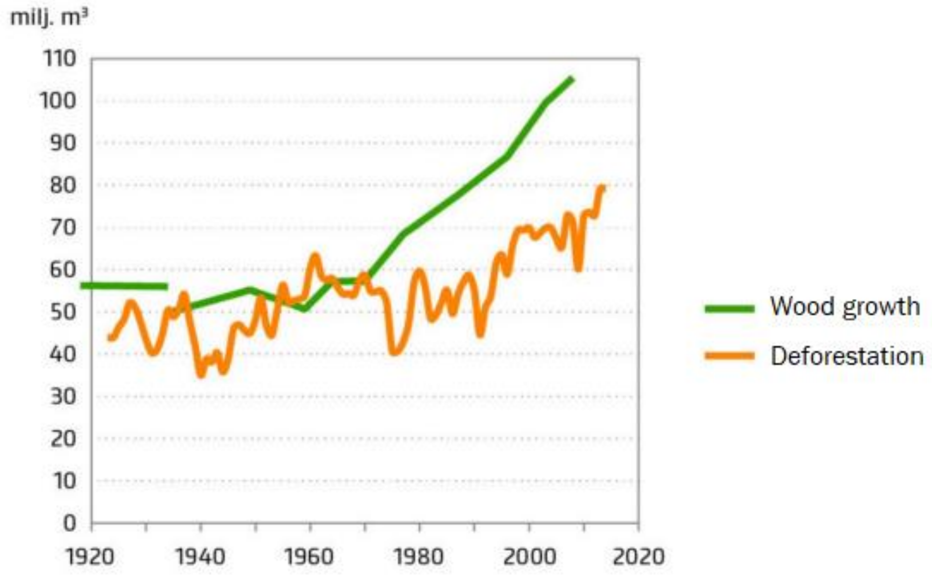
Biomass energy is pure and environmentally friendly renewable energy produced from different sources such as wood, agrobiomass or bio waste. Biomass is carbon dioxide -neutral therefore it does not increase carbon dioxide emissions. The carbon released from biomass energy bonds back to the nature in the long term.

Biomass energy can replace fossil fuels and decrease greenhouse gas emissions that slows down climate change. Using biomass energy can reduce also sulphur dioxide emissions. Utilization of domestic biomass increases the self-sufficiency and employment.

Biomass energy means the energy produced by combustion of biofuels. Most of the bioenergy in Finland is wood based fuels. Composition of biofuels can be solid, liquid or gaseous. Biomass energy is one of renewable energy sources together with geothermal energy, solar energy and wind power.

Availability of biomass energy in Finland is good, as 75% of the surface are of Finland is covered by forest, which is the most in Europe. This means 22,8 million hectares of wood, which is 2400 cubic meter of wood area. Wood fuels are 26% of total energy consumption of Finland. Finland`s forest growth in 2016 was 105,5 million cubic meter and deforestation was 65,3 million cubic meters. Picture 20 shows the growth of forest and deforestation in Finland, this shows that the source is long lasting. (Metsäyhdistys 2016)

In 2015 wood fuels were the most significant energy source of Finland with the quarter share of total energy consumption. In energy content, wood was used up to 93 TWh. (Tilastokeskus 2016)

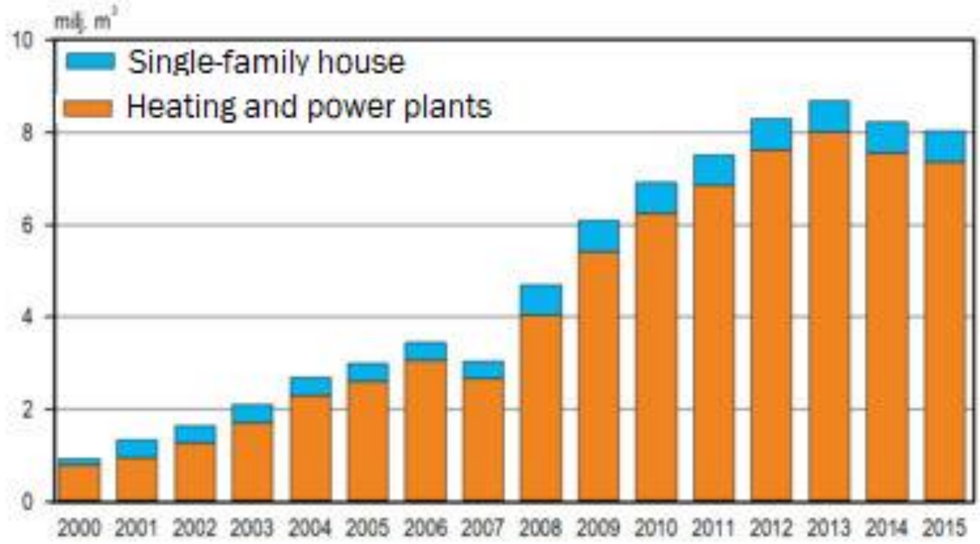


PICTURE 21. Wood growth and deforestation in Finland (Luke 2016.)

Biomass energy produced from recycled fuel, bio-based fuels and biogas has been low on total energy production until now, however the importance of biomass produced from these sources has been growing. The reason for growing interest on biomass is the purpose to find different alternatives to replace fossil fuels. (motiva.fi)

4.1 Biomass fuels

Forest converted chips is wood-chip made from forest trees. It is the most important wood fuel used by urbans and industrial heat and power plants in Finland. The forest converted chip is used for district heating and building heating. Forest converted chip is mostly accumulated from forestry of young forest, dozy trees and regeneration cutting.



PICTURE 22. The use and quantity of forest converted chip in 2000-2015 (Luke.fi)

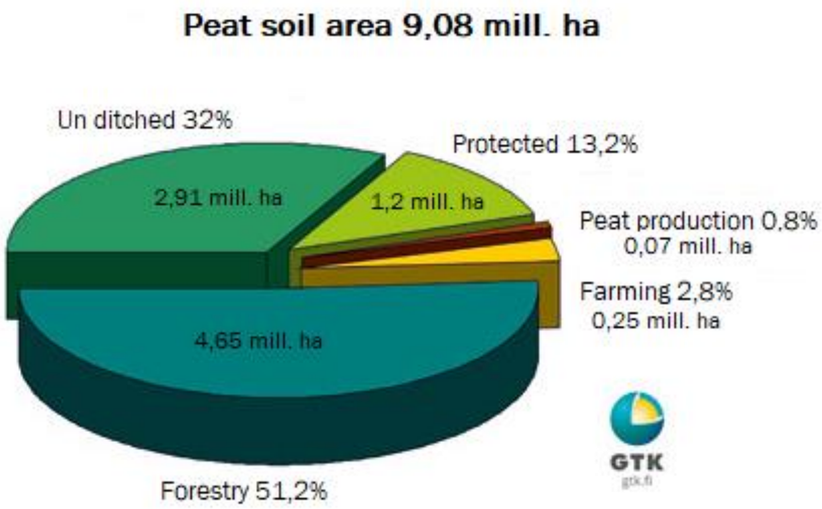
Another wood fuel is sawdust. It can be utilized in forest industry and heating plants or it can be used for pellets and briquette. Sawdust is usually wed and airy, a by-product of sawing, however the humidity of sawdust can vary.

4.1.1 Peat

One of the most important biomass fuel in Finland is peat. Peat is an organic soil formed because of incomplete disintegration of bog plants. It is formed when dead parts of the plant are humified in humid conditions. Due the lack of water and oxygen the dead plants do not disintegrate properly, therefore they are compressed in peat bed. The conditions of Finland are favourable for peak formation. (turveinfo.fi)

Almost the third of Finnish ground surface area is bog and peat soil. This means 9,08 million hectares of bog and peak soil from which 13,2 % is protected peak soil area. Over half of Finnish peak soil area is afforested and 2,8% is used for farming. (turveinfo.fi)

The use of bog and peat soil areas is controlled by many acts, agreements and directives to management the harms caused by using bog and peat soil.
In picture 23. is showed the use of peat soil areas.



PICTURE 23. The use of peat soil areas in Finland (GTK.fi)

Near 20% of domestic district heat energy and 7% of electricity is produced from peat used for energy. Peat used for energy can be divided to milling peat and sod peat. Milling peat is milled from the surface of the peat bog and then solar desiccated. It is used at district heat plants and industrial power plants. Sod peat is raised from peat bog and modified mechanically in to pieces after solar desiccation. Peak is often used as a mixed fuel with wood and recycled fuels. (turveinfo.fi)

4.1.2 Pellet

Wood pellet fuels is a wood fuel compressed from by-products of forest industry. These by-products are sawdust and cutter shaving. Wood pellets can be produced from biomass, forest converted chips and bark.

Wood pellets are used in heat and power plants, as well in single-family houses, farms and large real estates for fuel. For utilization of wood pellet an equipment for burning wood pellets is requires. In Finland 300 000 tons of wood pellet is produced per year, when the maximum capacity of production is 630 000 tons per year. (VTT)

When raw material is produced from bark, forest converted chips or wood chips it must be dried and crushed before grinding and pelletizing.
Moisture and lignin content of raw material affects the quality and production. Moisture of raw material affects the strength of pellets, device capacity and power demand. Lignin content is a natural adhesive of wood fibre and therefore it is also adhesive of pellets. (VTT)

The production of one ton of pellet requires 7 i-m^3 of sawdust as raw material when the humidity is 50-55% and 10 i-m^3 cutter shaving when humidity is 10-15%. Dry sawdust and cutter shaving doesn’t require drying, however rotary drum dryer can be used for drying the raw material.

4.1.3 Biogas

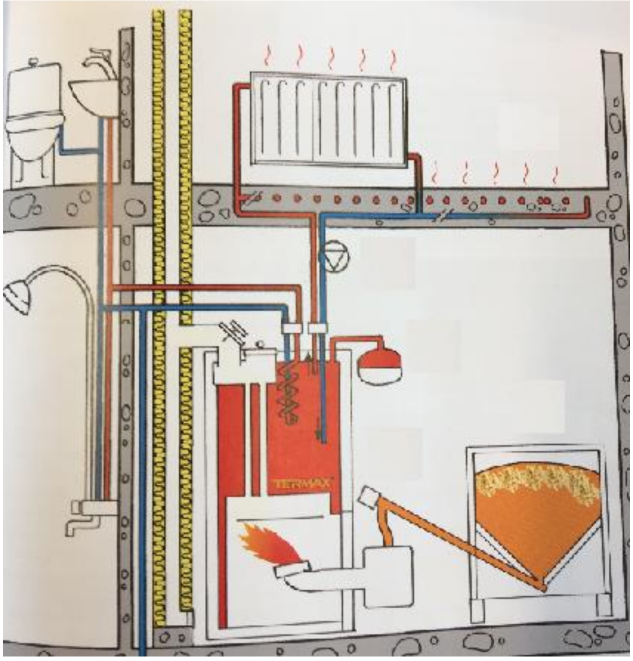
Biogas is gas mixture that is originated from decomposition of organic substances. Biogas consist methane (CH_4) 60%, carbon dioxide (CO_2) 38% and 2% of oxygen (O_2), Nitrogen (N_2) and hydrogen (H_2). Most important biogas sources are sewage treatment plants, controlled gas collection of landfill farming manure and field plants. (Suomalainen kaukolämmitys, 2015)

In 2015 350 GWh of heat energy and electricity was produced in Finland. This amount covers heat energy demand of 18 000 single-family houses. In Finland is possible to produce 10 TWh of biogas per year, however only 4% of Finland`s production potential is used. (gasum.com)

4.2 Utilization of bioenergy in buildings

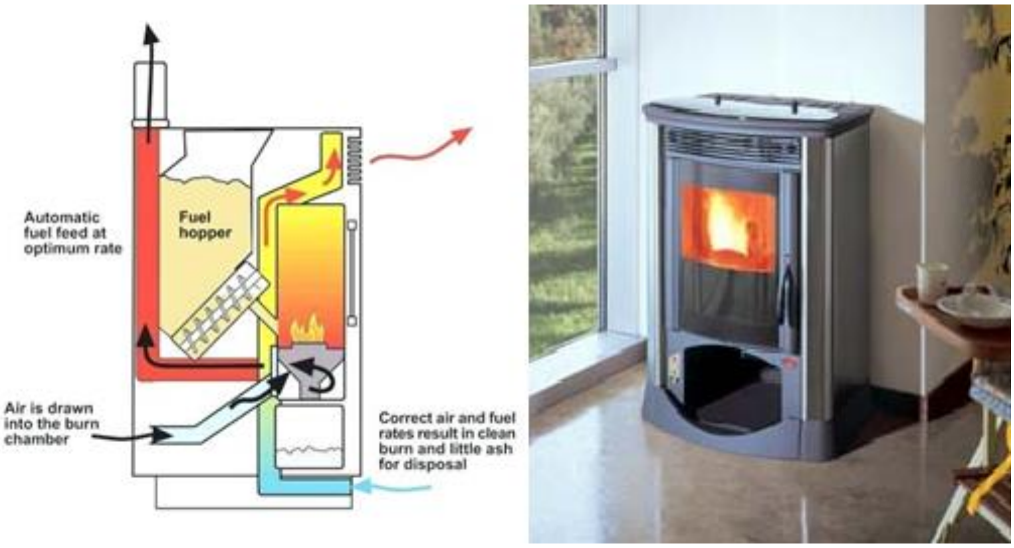
Bioenergy is produced for heat energy by burning chopped wood, wood-based pellets and briquettes in heating boilers and fireplaces. These heat energy sources can be used in farms, single-family houses and in bigger building as well. Wood based heat energy can be used as primary heating or it can support other heating system. Wood based heating is inexpensive and they are usually replacing oil heating.

Pellet heating system is one way to produce heat energy in buildings. The heat system has same elements than in oil heating system. The heat energy is produces by burning pellets in the burning pot. The system has a pellet container, which are dosed automatically for burning. Fixed installed detonator will start the fire for burning pellets. Domestic water is circulated in to the boiler and circulated for heat distribution.



PICTURE 24. Pellet heating system (Pellettikirja)

The heat can be distributed with pellet fireplace as well. Pellet fireplaces are easy to use and suitable for single-family houses. The fireplace has an integrated container with automatic fuel feed. Convector fan ensures more heat distribution and flames are visible through window, which also makes the are more comfortable.



PICTURE 25. Pellet fireplace. (rakentaja.fi)

4.3 Regulations

The EU Commission published a proposal for a new renewable energy directive (RED II) in November 2016. The directive will come in to effect in the beginning of 2021.

The directive contains binding EU-level sustainability criteria for biomass used for energy production. Sustainability criteria aim to ensure that the increasing use of bioenergy in the EU produces significant reductions in greenhouse gas emissions compared to fossil fuels. In addition, sustainability criteria include requirements to produce biomass in forests, fields and grasslands. As the current directive only applies to sustainability criteria for liquid biofuels, the REDII directive proposes expanding the scope of sustainability criteria to fixed energy biomasses as well.

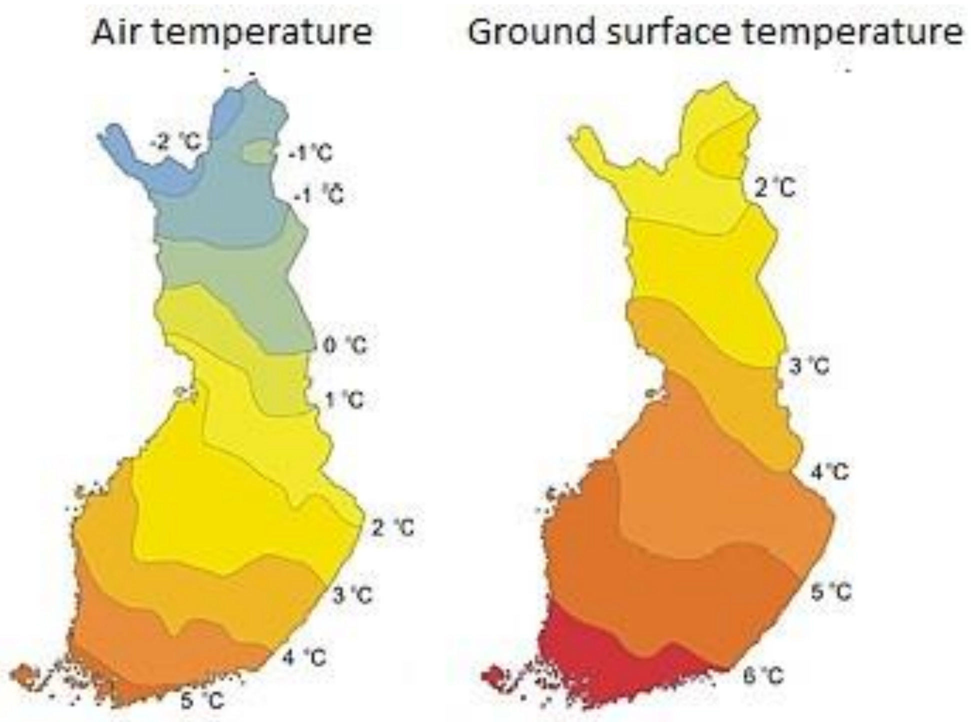
In addition to the sustainability criteria for producing biomass, sustainable bio-energy must also meet the greenhouse gas emission criterion. This means that at least a certain reduction in greenhouse gas emissions compared to fossil fuel will be required during the life cycle of a bioenergy.

According to the Commission's bottom-line, for fixed and gaseous biomasses for electricity and heat production, the khk emission requirement would be 80% / 85% compared to fossil fuel. This requirement would come to effect from the beginning of 2021

5 GEOTHERMAL ENERGY

The surface of the earth and bedrock has thermal energy stored, this energy is mostly from the sun. Deeper in the bedrock the thermal energy is from radioactive decay in the ground. The surface of the earth contains thermal energy that can be collected with ground loop and geothermal heat pump for heating and cooling.

The average temperature of underground is about two degrees above the average air temperature of the year. The temperature is variant on geographical location and locally. In Finland the ground temperature is a constant of 5-6 degrees at depth of 15 meters and deeper in the bedrock geothermal temperature raises about 0,5-1 degrees per 100 meters.



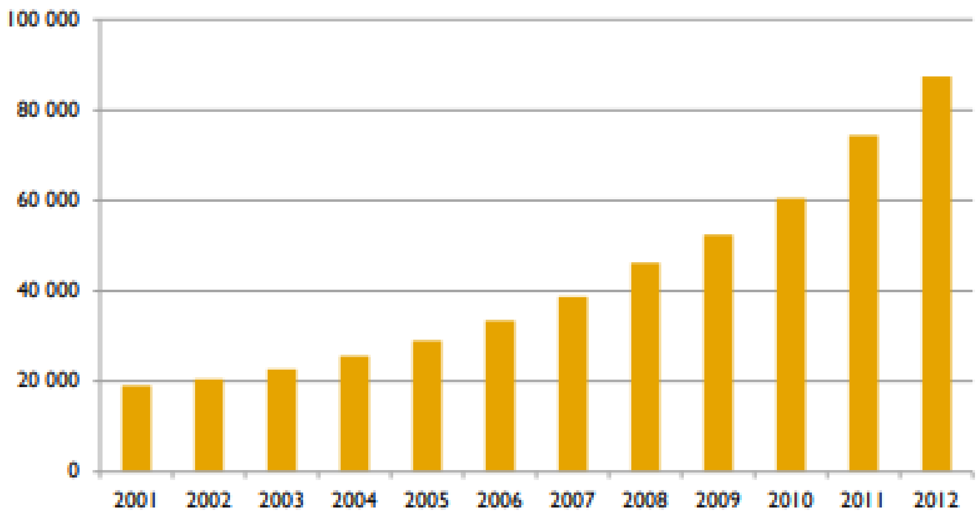
PICTURE 26. Average air and ground surface temperatures in Finland (gtk.fi)

Geothermal energy in Finland and the world

The use of geothermal energy has been increasing worldwide as a renewable energy source. In 30 counties the use of geothermal energy has increased 10% a year. The increase of the use of geothermal energy has been the most in Europe, where Sweden has the most geothermal heat pumps installed for geothermal energy.

Geothermal wells are more common than the closed loop in the ground. The principle of geothermal wells is the same around the world, however the installation methods are different for geologic and regulation reasons. In Finland the geothermal wells are drilled usually in the bedrock, however in the south country's the bedrock is much deeper. Therefore, in the southern countries the geothermal wells are drilled in the soil and the space between the loop and soil is usually filled with bentonite.

In Finland the geothermal energy started to increase in 1990s with an average sales growth of 20-30% per year. By the end of 2012 there were 80 000 geothermal heat pumps installed in Finland and 80-90% of them had geothermal well as an energy source. (sulpu.fi)

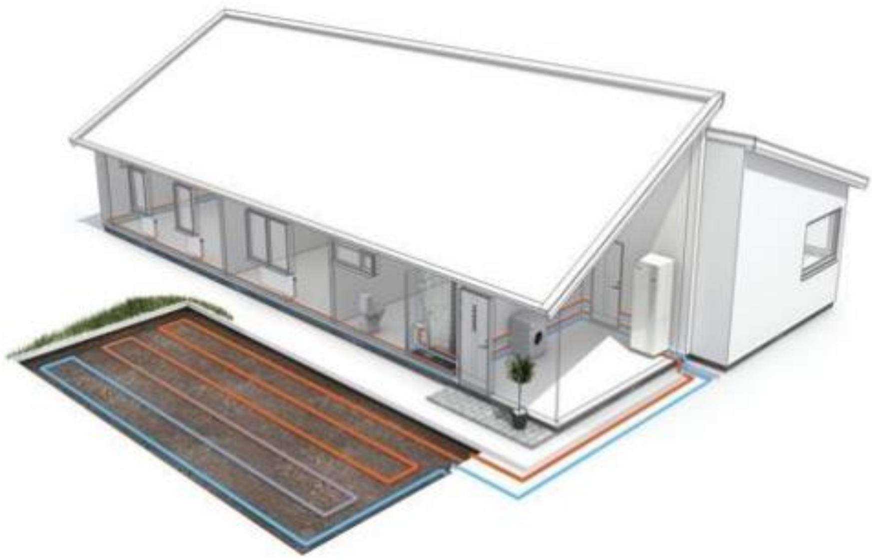


PICTURE 27. Installed geothermal heat pumps in Finland

5.1 Geothermal energy collecting systems

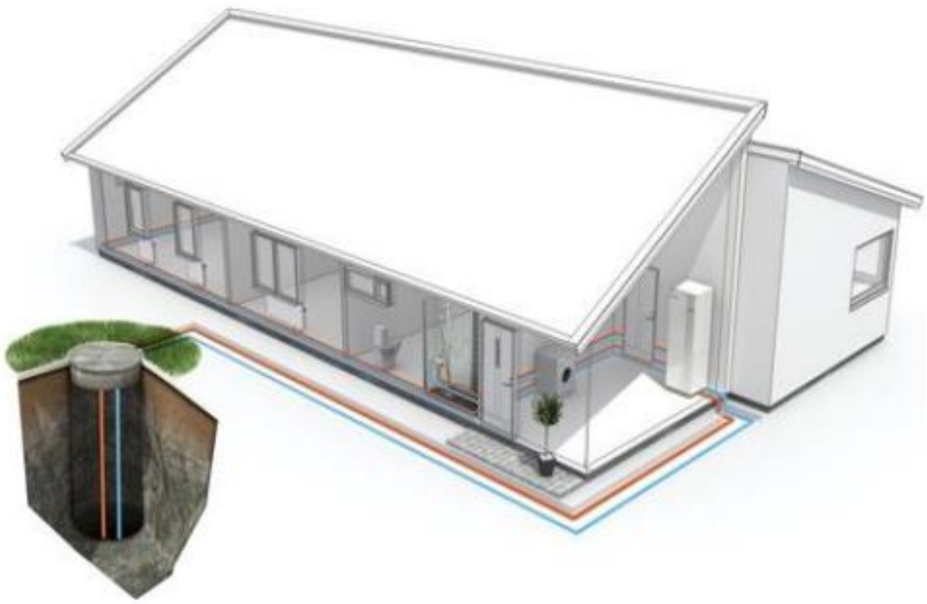
With heat pump technology the thermal ground and bedrock energy can be used for heating and cooling all over the year. Geothermal energy can be also used for domestic water heating. Geothermal energy is the most efficient energy among heat pump technologies. Acquisition and installation cost of geothermal heat pump system are higher than other heat pump technology's however the operation cost of geothermal energy is lower. The geothermal system includes components like heat pump, heat exchangers (transfer pipeline) and ground loop.

Geothermal energy is collected from the surface of the ground with ground loop, which is a pipeline buried about 1-2 meters deep. The length of the pipeline is at least 500 meters and will require an area of 1,5m^2 for one meter. The pipes will be installed horizontally. This will require a large surface area, yet it is cheaper to install the pipeline just 1-2 meters in to the ground than drilling a borehole. Ground should be loam, rather than sand or rocky soil. The heat transfer is better on a loam soil than sand and the rocks can damage the pipes. This method is a closed loop system.



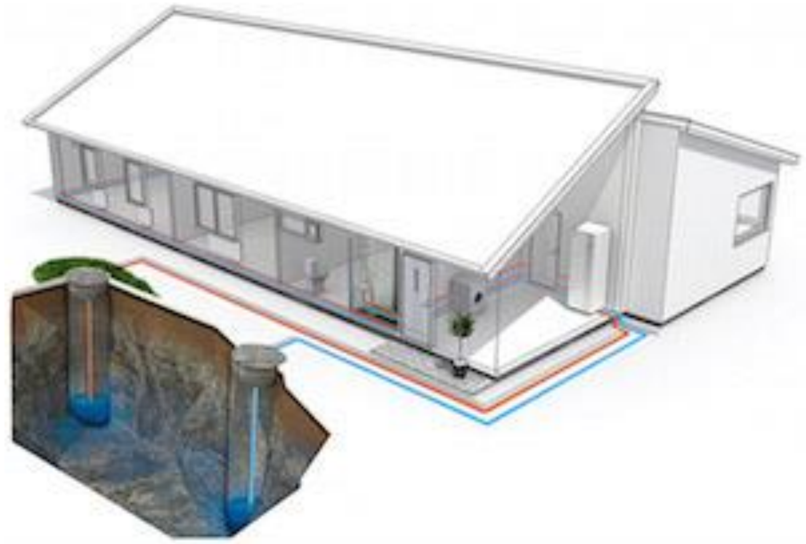
PICTURE 28. Geothermal energy from surface of the ground. (ekolampo.fi)

From the bedrock the geothermal energy is collected with collecting pipe installed in a borehole. The depth of a borehole is less than 300m. This method doesn’t require a large area and can be done without harming the property with digging. The heat in the borehole is constant even during the seasons, this allows to collect heat also in the winter. The heat demand of the building and the location affects the depth of the borehole. The temperature is different in the south of Finland than in the north, therefore the location matters for the depth. Drilling in to a rock ground is easier and cheaper, in the rock ground a protective tube is not necessary. In the south ground the protective tube must be installed for ground collapse protection.



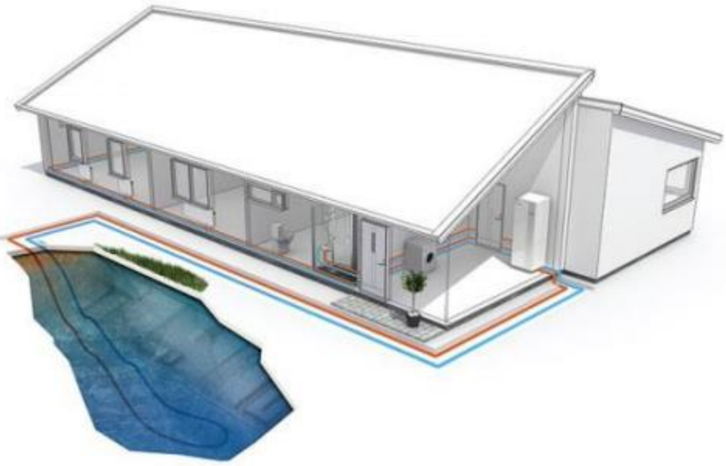
PICTURE 29. Geothermal energy from bedrock (puurkaev.eu)

Also, groundwater can be used as a geothermal energy source and exchanger. The groundwater will be pumped from the ground in a transfer pipe to the surface. The heat pump will use the heat of the water and after the utilization the groundwater will be channelled back into the ground or into a lake. This is an example of an open loop system.



PICTURE 30. Geothermal energy from groundwater (puurkaev.eu)

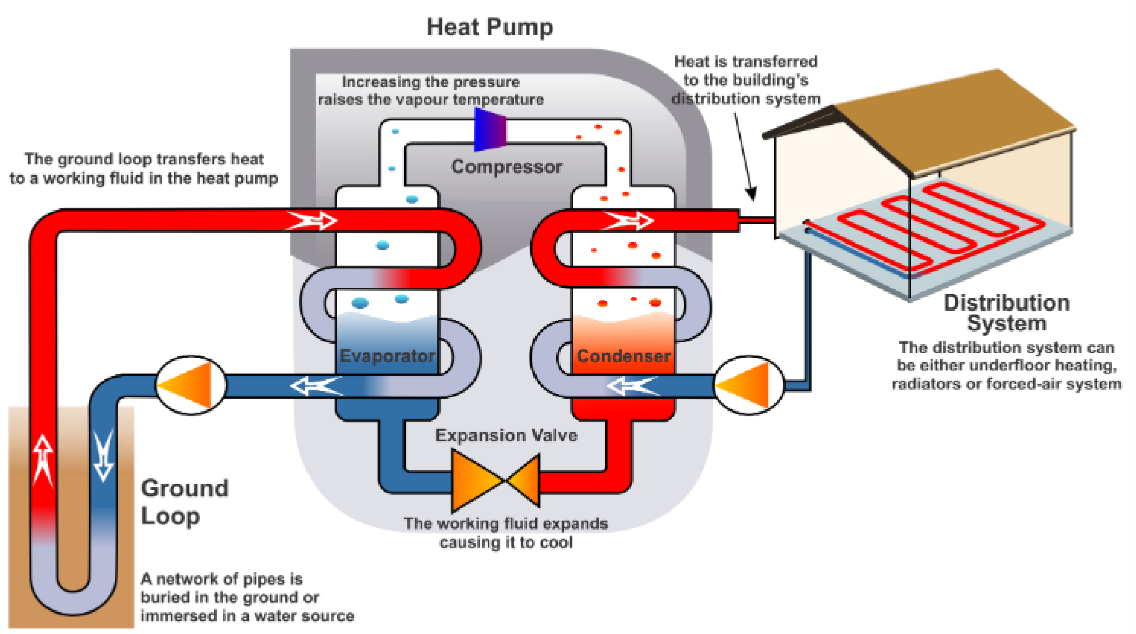
Geothermal energy can be collected from surface waters also. The collection pipeline will be installed under the water surface collecting the heat from the water. The heat will then be transferred to the building where it can be used by heat pump. The pipes installed in the water must be set down with enough weight to avoid damage and to keep them well impacted. The water should have a depth of 2 meters at least, to get heat energy also in the winters. On the shore the pipes must be at least one meter deep to avoid heat loss and damage in the winter. For heat source a flowing water is not preferred, because it will cool down to the bottom and there will not be enough heat energy in the winter.



PICTURE 31. Geothermal energy from surface water (ekolampo.fi)

5.2 The geothermal heat pumps

The geothermal heat pump transfers the energy collected from the ground, bedrock or water with electricity. The energy collected by the ground loop is transferred to the evaporator of the heat pump. From the evaporator the heat will be transferred to the refrigerant circuit of the heat pump. The refrigerant is recycled by the heat pump compressor to a condenser where the heat from refrigerant is transferred to the heating circuit. The circulation of the energy is explained in picture 32.



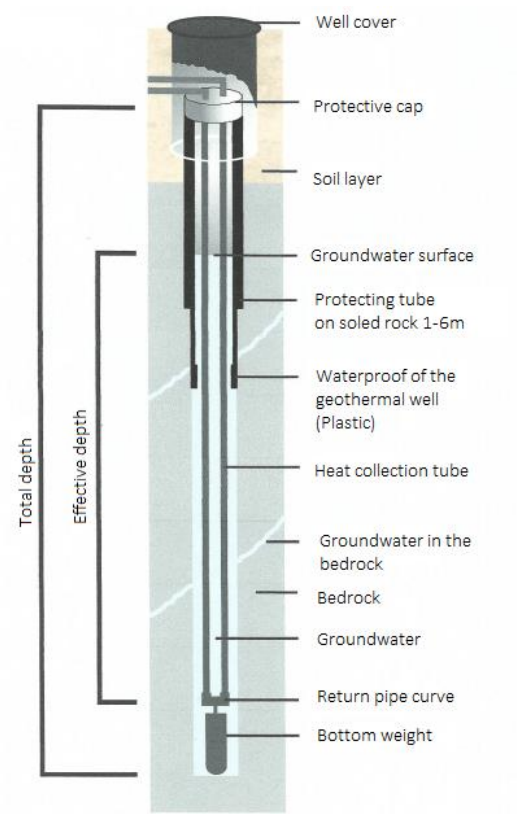
PICTURE 32. The circulation of the heat pump. (nzgeothermal.org.nz)

Geothermal heat pump is applicable for low temperature heat distribution systems such as water based underfloor heating systems and warm air heating systems. The geothermal heat pump is also applicable for radiation heating and cooling in the summer. When the room air is cooled in the summer, the heat of the air is transferred to the bedrock, this can improve the output of the geothermal energy for the winter.

5.3 Geothermal well and the structure.

The depth and number of geothermal wells depends on energy demand of the building. The depth of one borehole can be 120-300m. If the energy demand is higher, the borehole can be deeper, however it may be cheaper to drill more holes. The diameter of a hole in the bedrock is usually in Finland 105-165mm. On the top of the well a protective tube is required to prevent loose soil accessing the geothermal hole.

The well is also waterproofed six meters from the ground surface with a plastic insulation tube or concrete. In few days the well usually fills itself with water, if not it has to be filled and the water surface will be documented. The plastic tube and the heat collecting fluid is lighter than water, the tube will not stay down without weighting. The well will be protected from drainage water and loose soil with protective cap. If the pressure is too high it may be necessary to extract groundwater from overflow.



PICTURE 33. Structure of geothermal well (oulunporakaivot.fi)

5.4 Dimensioning

Energy demand of the building is the most important factor when dimensioning the geothermal energy system. The energy demand is affected by insulation of building, other heat sources in the building, ventilation, hot water demand and geological location.

Composition and structure of bedrock and ground as well as groundwater conditions have a significant effect on dimensioning of geothermal loop. The temperature of heat distribution system also affects the efficiency of the system and on the length of the ground loop. The switchboard of the building can also affect on dimensioning the geothermal system. This dimensioning is a responsibility of geothermal system designer.

When heating and cooling demand of the building is known, the size of heat pump is chosen. Then the other components of the geothermal system can be dimensioned. For these dimensions the length and number of collection pipes, energy well`s depth, number of drilled energy wells and the distance between the wells must be considered. The use of ground energy on cooling and heating of domestic water affect the dimensioning. The length of the pipes depends on total and effective depth of energy well and the transfer pipe length from the well to the building.

Heat pump is optimized for operational and investment costs. With full capacity the heat pump produces all the energy demand of the building and with part power it usually produces 60-85% of the power, this can cover 90-98% of energy demand. The efficiency of the heat pump is described with coefficient of performance (COP). COP tells how much heat energy the heat pump produces with consummated electricity. In Finnish circumstances the annual average coefficient of ground heat pump is three. This means the heat pump produces three kilowatt-hours of heat energy from one kilowatt-hour of electricity.

When comparing coefficient of performance, the measurement conditions of the coefficient number must be considered. Seasonal performance factor (SPF) describes this better.

For determining some of the necessary variables needed on geothermal energy designing, a thermal response test (TRT) is needed. This test measures property of the bedrock and ground, most important is the average temperature of the bedrock and thermal conductivity of bedrock. Capacity of thermal conductivity of the bedrock from the borehole is affected of the conductivity and thermal resistance of the bedrock and groundwater flow in the hole. The thermal resistance determines how well the energy flows from the bedrock to the collection loop.

5.5 Risks of ground heat systems

The environment risks of ground heat systems are mainly related to groundwater. The groundwater can be deteriorated for example from soil contamination. The deteriorating of groundwater can result from few factors.

- The storm water accessing the groundwater due the poor well structure or protective pipes,
- Excavation work on a contaminated land
- The mix of different layers of groundwater in the bedrock
- The influence of drilling on the groundwater.
- Leak of the heat collecting fluid.
- Ground water temperature change

When drilling throw ground layers into bedrock, a deteriorated soil and poor-quality surface water can be mixed with quality groundwater. This can deteriorate the groundwater. The information for deteriorated territory can be verified from Finland`s environmental administration.
The leak of heat collection fluid can harm the quality of groundwater. The heat collection fluid contains substances that increases the quantity of microbes and oxygen consumption. This affects the quality of groundwater.

5.6 Laws and regulations of geothermal energy

Construction of geothermal energy system in Finland requires a permission for land use and building act and water act. For geothermal energy system is also required following permissions;

- Licensing requirements on geothermal energy construction
- verification of classified groundwater areas,
- historical sites that limits the drilling of energy wells
- underground constructions that limits the drilling of energy wells

If the project may change the quality or quantity of groundwater, a water act permission is required. A change on groundwater can affect the deposit of groundwater resource and cause damages on the quality or use of groundwater resource.

The environment protection act prohibits the pollution of groundwater resources by regulations. Substances or energy is not allowed to be treaded in a way that can harm the quality or the use of important groundwater resource. It must not harm the quality or the use of a groundwater on the next property. Action that can harm the quality or the use of groundwater for any public or private interest is forbitten. (Environmental protection act 86/2000, finlex.fi)

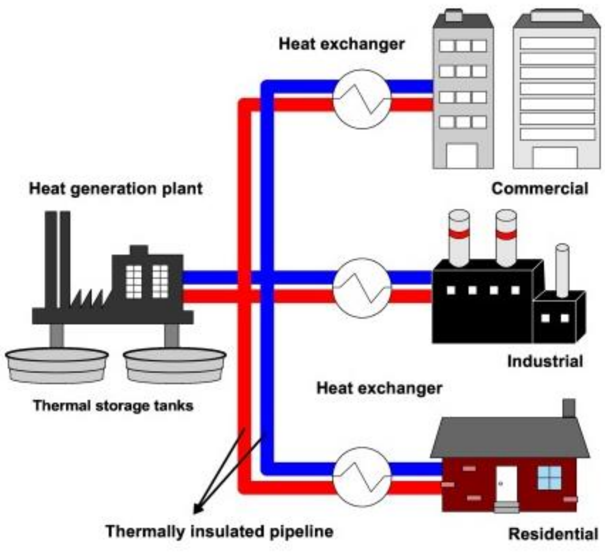
In the case of pollution, the purification of groundwater is a responsibility of the one who's intentional or unintentional actions causes the pollution. If the person responsible is not able to abide the obligation, the property owner can be held responsible for purification. (Environmental protection act 86/2000, finlex.fi)

The chemical act is authoritative on chemicals used in the heat collection fluid. The quantity and dangerousness of chemicals must be considered for preventing health and environmental hazards and harms. In the case of pollution, the one who's actions cause the pollution is responsible for purification of building or environment so the pollution does not cause health or environmental hazards. (Chemical act 599/2013, finlex.fi)

6 DISTRICT HEAT ENERGY

District heat energy is used as an energy system for large areas or cities. In 2013 about 46% of Finland`s population were living in buildings that used district heat energy as heat energy source. The heat energy is produced in concentrated heat generation plants of district heating centre. The heat is transferred to customers by district heating network. In 2014 34.5 TWh of district heat energy was produced in Finland.

The circulation water of district heat is warmed in a boiler of district heating centre. The hot water of district heat energy is mainly produced together with electricity generation (CHP). First the electricity is generated with hot steam and the remaining energy from the steam is used to heat circulation water of district heat on required temperature. Producing district heat energy together with electricity generation is the most energy-efficient way of producing district heat energy. The hot circulation water of district heat energy is pumped in to district heating network to customers. Heat energy is transferred to customers` heat distribution centre from where the heat energy is used for building. The circulation water of district heat is then circulated back to the district heating centre to be warmed again. (Suomalainen kaukolämmitys, 2015)

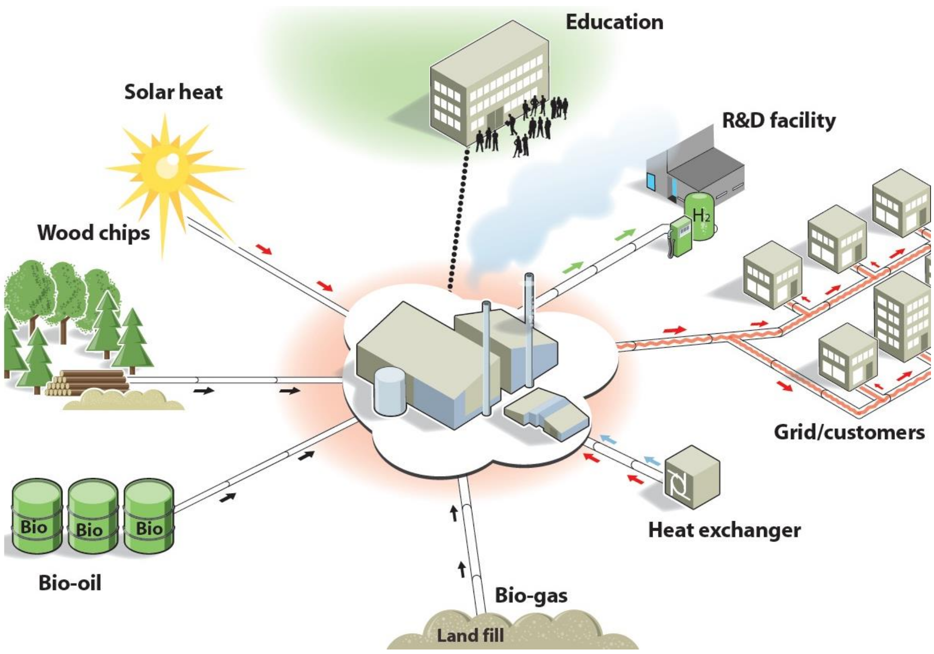


PICTURE 34. District heat energy network (sciencedirect.com)

The benefits of district heat energy are energy efficiency, environmentally friendly, economical and reliability. District heat energy and especially heat and electricity cogeneration are energy efficiently and environmentally friendly energy production techniques.

By using cogeneration of heat energy and electricity (CHP) it is possible to produce heat energy and electricity with less fuel load and therefore also CO2 emissions will be smaller. Increasing the cogeneration of energy in the future, CO2 emissions can be decreased. The energy source of district heat can be renewable energy source for example biomass energy. This way energy production of district heat is efficient and environmentally friendly.

Concentrated heat generation plant operates with less chimneys that can be equipped with chimney gas cleaning devices. This keeps the air cleaner and for example the air of Helsinki has been improved since district heat. In 1990 Helsinki received environmental price for promoting cogeneration.



PICTURE 35. District heat energy can be produced from renewable energy sources (solar-district-heating.eu)

6.1 Main parts of district heat energy

The main parts of district heat energy system are heat generation plant, distribution network and equipment's of costumers. Customer equipment's are district heat measurement centre and heat distribution centre of the building, located in the building.

The heat is generated in the heat generation plant and supply temperature of circulation water is between 120 ˚C and 70 ˚C, depending on season and demand. In Finland the energy source is usually biomass fuel like wood or peat, however also fossil fuels are used. The use of fossil fuels is decreasing and the target is to replace them with renewable energy sources. Hot supply water is distributed to customers with thermally insulated pipeline. The heat is used in heat distribution centre of building, where the water will get colder. The cooled water will be returned to the heat generation plant through return pipe, temperature of the water being between 40 ˚C – 25 ˚C. (Suomalainen kaukolämmitys, 2015)

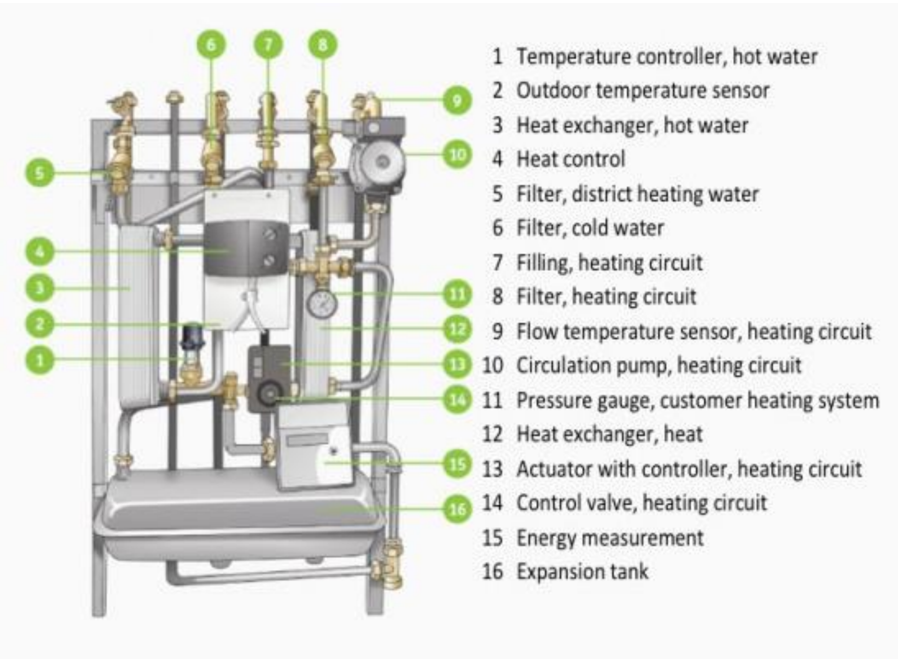
The equipment's of customers are in heat distribution room of building, usually including measurement centre and heat distribution centre. Measurement centre includes temperature sensors for supply and return water, flow sensor and heat volume indicator.

PICTURE 36. Measuring centre unit (docplayer.fi)

Heat distribution centre includes heat exchangers, pumps and control automation. Usually at least two heat exchangers are required, one for heating and one for hot domestic water production. Heat distribution centre includes components required to distribute the heat for all heating systems of the building. Heat distribution centres are usually manufactured and designed for heat demand of the building. Manufactured heat distribution centre includes following equipment;

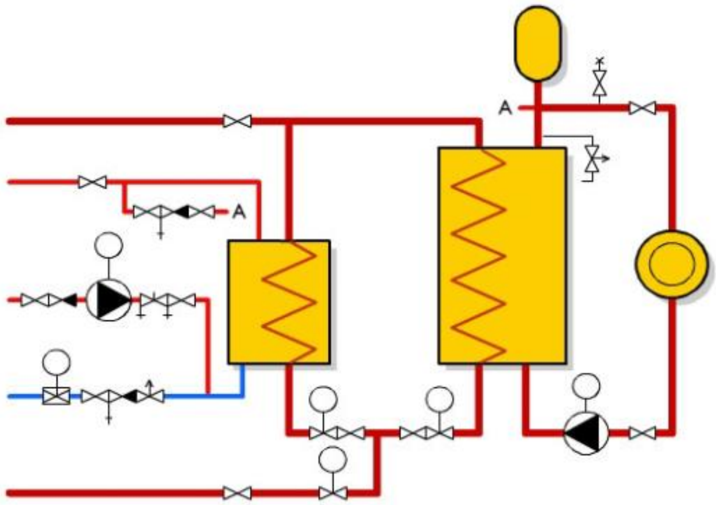
- Thermal insulated heat exchangers
- Heat regulation system
- Alarm system for temperature
- Pressure and other functions
- Installed circulation pump
- Installed sensors
- Temperature detectors

These are connected mechanically and electrically together forming one complex. (Suomalainen kaukolämmitys, 2015)



PICTURE 37. Heat distribution centre. (ecomatic.fi)

These devices are connected according connecting pattern which includes valve values, rated temperature, rated temperature power, design flow and design pressure drop for each heat circuit.



PICTURE 38. Connecting pattern of district heating

6.2 District heat distribution

Distribution pipeline includes transmission pipeline, main pipeline and service connection pipes. District heat network enable district heat distribution and the district heat network must be dimensioned considering prospects of city planning and land use planning. District heat network is the most expensive part of direct heat energy system therefore, the durability of the pipeline must be at least 30-50 years to avoid maintenance and reparational costs. At best durability of the district heat network in Finland can be from 70 years to 100 years. (Suomalainen kaukolämmitys, 2015)

In Finland district heat network consist supply pipe and return pipe, usually installed under the ground. Two separated pipes are installed under the ground and these pipes are thermally insulated with polyurethane. Sometimes the material of pipes can be copper, usually used for low temperature network.
Supply pipe and return pipe are same size and principally made of steel. Main pipeline distributes district heat energy from transmission pipeline to service connection pipes.

6.3 Pipes of district heat network

Designed temperature of district heat network in Finland is 120 ˚C.
When the material of pipes is copper the maximum supply water temperature can be 80 ˚C. In exception the temperature of supply water can be 90 ˚C.
Operating pressure of the network can be 1,6 MPa at most. In some district heat network is used 1,0 MPa operating pressure. The operating pressure for low temperature network is between 4-10 MPa. (Suomalainen kaukolämmitys, 2015)

In Finland 90% of district heat network pipes are steel. Steel is preferred for lower cost price and conventional installation of the steel pipes. However, the problem of steel is underground water, that causes corrosion and damages on pipe structure. (Suomalainen kaukolämmitys, 2015)

Majority of district heat network are constructed with factory-made steel pipe system. Factory- made pipes includes polyurethane thermally insulated pipe and protective shell made from polyurethane. Pipe system types are 2Mpuk, Mpuk and concrete element duct. 2mpuk and Mpuk are both thermally insulated with polyurethane at the factory. In Mpuk system supply pipe and return pipe are both in the same shell, when in 2Mpuk the pipes are separated.

PICTURE 39. 2mpuk and Mpuk pipes of district heat network. (helsinginuutiset.fi)

6.4 Dimensioning of district heat network

Dimensioning of district heat pipes is always done according to the needs of respective parts of district heat network. In addition of transferable power, most significant factors in dimensioning is the temperature difference between supply water and return water of district heat and the changes on hot domestic water demand.

$$\Phi = p \cdot q_v \cdot c_p \cdot \Delta t \qquad (3)$$

Where,

ϕ	District heat power, kW
p	Density of district heat water, kg/dm^3
q_v	District heat water flow rate, dm^3/s
C_p	Specific capacity of district heat water, kJ/kg K
Δt	Temperature difference between supply and return water, K

Required pipe size is calculated based on water stream and flow velocity of district water. Calculated pipe diameter is obtained with equation 4.

$$d = \sqrt{\frac{4\mathrm{qv}}{\pi\ vcal}} \qquad (4)$$

Where,

d	Calculated pipe diameter, m
q_v	District heat water flow rate, dm^3/s
v_{cal}	Flow velocity of district water used on dimensioning, m/s

District water flow velocity used on dimensioning depend on pipe material and permitted pressure loss of pipe. Accuracy of initial data and possible changes on power demand in the future must be considered when deciding the size of pipes. (Suomalainen kaukolämmitys, 2015)

The demand of hot domestic water is not continuous, it varies occasionally and by different day and week rhythm. Domestic water power demand of one costumer affects differently the amount of total power to be distributed in different part of the network. This is taken into consideration by a coefficient. This coefficient takes into consideration the impact of intersections of domestic water power on total power. (Suomalainen kaukolämmitys, 2015)

Service connections must be dimensioned by actual power demand and operating temperatures. For service connections is allowed 1-2 bar/km of pressure loss, this means 100-200 Pa/m. Summer and winter situations must be considered separated on dimensioning of service connection. The demands are different on the summer and winter. (Suomalainen kaukolämmitys, 2015)

Domestic water power demand must be considered on dimensioning the distribution pipeline. The permitted pressure loss on distribution pipeline is about 1 bar/km and used temperature difference between supply and return water is 45-55 ˚C. The permitted pressure loss of transmission pipeline is 0,5-1 bar/km and used temperature pressure loss is 30-40 ˚C. (Suomalainen kaukolämmitys, 2015)

6.5 Dimensioning of Heat distribution centre

Dimensioning of heat distribution centre of district heat is instructed on regulations and instructions of energiateollisuus oy (energy industry oy). In district heat regulations and instructions K1/2013 is instructed the dimensioning, planning and installation of heat distribution centre. Dimensioning is done by HVAC engineer and installation by installer. The goal is to choose a system that works the best for customer and supplier. (Suomalainen kaukolämmitys, 2015)

The heat distribution centre is designed to be energy efficient and to achieve quality inside air in every area and circumstances. According to K1/2013 regulations and instructions, following matters must be considered on dimensioning of the heat distribution centre;

- Control system should be able to adapt the energy consumption in the way that the heat loads from humans, sun and lighting can be utilized in each area.
- Temperatures in different heat circuits can be regulated according to demand and kept as low as possible.
- Equipment must work well in the case of pressure changes.
- Optimization of energy and power demand is possible.

Every heat circuit is designed with the own heat exchanger and control unit. This way power need can be controlled according secondary heat power demand of the heat circuit. Specific heat exchanger and control unit of heat circuits increases the operation of district heat system and the quality of heat energy for customers. (K1/2013)

For new buildings the power demand of heat and ventilation, as well the design flow of domestic water is calculated according the Finnish building regulation collections. The regulation and instruction K1 is used on dimensioning the heat distribution centre. (K1/2013)

Every heat circuit is dimensioned singly. First the heat losses of the building, the power demand of ventilation and heat demand of domestic water is calculated. These shows the heat power required from district heat network. After this the heat exchanger and other devises of the primary side must be chosen according to the total pressure loss. The pressure losses of secondary side depend on pressure losses caused by friction losses of the pipes and single resistance. Single resistances are pipe fittings like valves and pipe bends. The pump of secondary side is chosen according to pressure losses and water stream of the secondary side. (K1/2013)

TABLE 5 Design temperatures for new buildings in Finland (K1/2013)

Heat exchnager for;	Design temperatures of heat exchanger, ˚C			
	Primary		Secondary	
	Supply	Return	Return	Supply
radiator heating	**115**	**33 (max)**	**30 (max)**	**45 (max)**
radiator heating (exception)	**115**	**33 (max)**	**30 (max)**	**60 (max)**
floor heating	**115**	**33 (max)**	**30 (max)**	**35 (max)**
humid room floor heating	**70**	**28 (max)**	**25 (max)**	**30 (max)**
ventilation	**115**	**33 (max)**	**30 (max)**	**60 (max)**
Note;	Return temperature of primary side can be max 3 ˚C higher than the return temperature of secondary side			

The maximum pressure loss for heat exchanger can be 20 kPa on primary and secondary sides. Only for domestic water heat exchanger is allowed 50 kPa pressure loss on secondary side.

TABLE 6. Design temperatures for old buildings in Finland (K1/2013)

(old buildings) Heat exchnager for;	Design temperatures of heat exchanger, ˚C			
	Primary		Secondary	
	Supply	Return	Return	Supply
radiator heating	115	43 (max)	40 (max)	70 (max)
Radiator heating (Old buildings)	115	63 (max)	60 (max)	80 (max)
floor heating	115	33 (max)	30 (max)	40 (max)
humid room floor heating	70	28 (max)	25 (max)	70 (max)
ventilation	115	43 (max)	40 (max)	70 (max)
Note;	Return temperature of primary side can be max 3 ˚C higher than the return temperature of secondary side			

Radiator heating

These values shown in table 5. and 6. are used on dimensioning of heat exchanger of the heat distribution centre. Additional to primary and secondary side temperatures, also wanted inside air temperature and rated temperature of location is taken into account. Heat exchanger of the radiation heating is dimensioned by the Finnish building regulation collection D5 (RaMk D5). The emission of radiator is dimensioned by room area and the total heat power of radiators is the heat power of the heat exchanger.

The maximum district heat water temperature in Finland is 120 ˚C, therefore the rated temperature of radiation heat is 115 ˚C. The heat demand peak of radiator heating is in the winter. With this 5 ˚C difference is ensured the heat demand is achieved in every part of the district heat network.

For new buildings the secondary temperature is 45 ˚C for supply water and 30˚C for return water. The primary side temperature for return water is 3 ˚C at most. The required water stream of radiators is the total stream of secondary side of the exchangers.

$$q_{v,s} = \frac{\phi}{p \cdot cp \cdot \Delta t} \quad (4)$$

Where,

$q_{v,s}$	Secondary side water flow rate, dm^3/s
ϕ	Power, kW
p	Density of water, kg/dm^3
Δt	Temperature difference, K

For primary side is used temperatures of 115 ˚C – 33 ˚C, therefore the temperature difference is 82K. This is used to calculate the water stream of primary side.

Heat distribution centre equipment

Properly chosen and well dimensioned equipment of heat distribution centre is critical for a working system. One wrongly dimensioned equipment can ruin the entire heat distribution centre. This is important for quality of the heat distributed to the customer.

PUMP

Pumps are needed in heating circuit and domestic water to produce the required water flow. In heat distribution centre is use centrifugal pump. For dimensioning of pump is necessary to know the required water flow and total pressure loss of the most difficult heat circuit.

The pump must be chosen to produce the required water flow and lifting height with this water flow. Operation point of pump must be near coefficient of efficiency of the pump. Type and manufacturer of the pump must be labelled on the pump. In some cases, the heat distribution centre can be equipped with relay pump.

Control system

With control system the resident of the building can control the living environment by controlling inside air temperature and steady domestic water heat. The control unit can produce economic benefits with the possibility of controlling the heating cost.

The target of control system is good inside air quality in every room and energy efficient utilization of district heat energy. The main function of control unit is to control;

- Supply water of heating systems
- Supply water of ventilation heating.
- Temperature of domestic water.

The control system must consider heat dynamics of the building and exploitable heat loads in the best possible way for inside air quality and healthiness.

Other equipment's are;

- Shut-off valve
- Relief valve
- Sanitary trap
- Well of sensors
- Pressure difference controller

6.6 Agreement of district heat energy

District heat energy requires large amount of investments on energy production and district heat energy network. However, district heat energy is economically profitable competitive, especially in the Nordic countries.

Finnish law requires heat agreement between the customer and supplier. In this agreement must be at least;

- Contracting parties
- Supply service
- Measuring centre unit
- Invoicing heat power
- Connection fee
- Period of validity
- Heat billing agreement

The agreement must include also following attachment;

- Conditions of sale of the district heat energy
- Conditions of connection
- Price list of heat energy
- Price list of services

Measuring law regulation of Finland is a regulation for district heat energy measurement systems. In Finland the measurement equipment is owned by district heat energy supplier. The supplier is also responsible of installation and maintenance. The measurement data is generally collected for every hour.

7 SOME CASES OF NZEB IN FINLAND

In this chapter are two examples of zero energy buildings and one near zero energy building in Finland. These buildings are examined by design solutions, designed energy consumption and actual energy consumption. These examples are based on the report of financial and development 2016. (Asumisen rahoitus- ja kehittämiskeskuksen raportteja 2016)

7.1 Case 1 – Service Flats of Onnelanpolku

Onnelanpolku service flats are in Lahti, Finland. Old Service flats where not in condition for reconstruction therefore the old buildings where demolished and a new building build. This new building was designed to be near zero energy building.

Architecture has a significant role in the energy efficient. The form of building is kept compact and different solutions and materials has been used to support the energy efficient.

TABLE 7. Basic Information of the building

Building type	Service flats, New building
Location	Lahti, Finland
Size	16 335 brm^2, 228 apartments
Year	2014
Developer	LVAS
Architecture	Architecture Boman, Lindström, Vesanen, Virtanen oy
Heating system	District heat, Solar energy
Energy production of the building	Photovoltaic energy, Solar energy
Energy classification	Designed: A Realized: A
Net delivered energy	1 006 MWh/a (62kWh/brm2) (7/2014-6/2015)
Carbon footprint	201 tnCO2/a (12 kg/brm2/a) (7/2014-6/2015)

PICTURE 40. The building of Onnelanpolku in Lahti. (report of financial and development 2016)

Design solutions

Structural body of the building is mostly concrete and the external envelope is insulated with wool. On the roof has been used expanded clay and EPS insulation. At patio there is a class atrium that works as a heat charger. with carefully designing, the building has 40% smaller relative wall surface area than ordinary multi-storey apartment block.

The building has two parts that are connected with atrium. Eight story buildings protect the atrium from overheating. Placing of the buildings is designer for optimal solar energy utilization and using the atrium as a heat charger increases the use of passive energy. The atrium is used to preheat the supply air with the heat that the atrium collects and it also decreases the heat loss through the wall. In case of overheating the air can be released from the top of atrium through windows or with heat recovery system. The windows of atrium operate automatically controlling the inside temperature.

PICTURE 41. Atrium of the building (report of financial and development 2016)

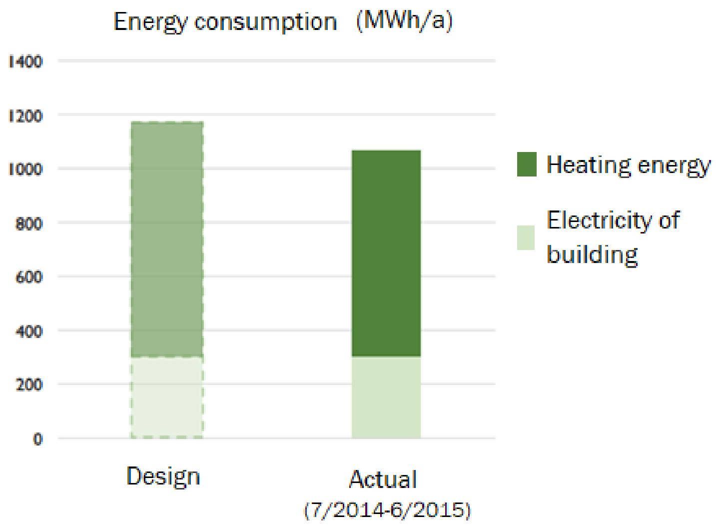
Heat demand is covered with district heat and Solar energy. These two energy sources are connected in the same heat exchanger from where the heat is distributed with floor heating, using water. Mixed use street is kept melted in the winter with return water of district heat. Solar panels and solar thermal collectors are installed on the roof of the building. The electricity produced with solar panels is used in the building and additional electricity is supplied to the electric power network. Electrical compressors are used for cooling apartments and building, the cooling is done through ventilation.

Ventilation is designed with three sectional concentrated air supplies and every section has the own heat recovery. The ventilation is controlled with timed automation. Residents of the building can also control the ventilation from apartments.

All lights in the building are LED lights and common areas are controlled with motion detectors. Domestic water consumption is monitored with water flow meters in apartments. Authorized person can monitor the system of the building with network connection.

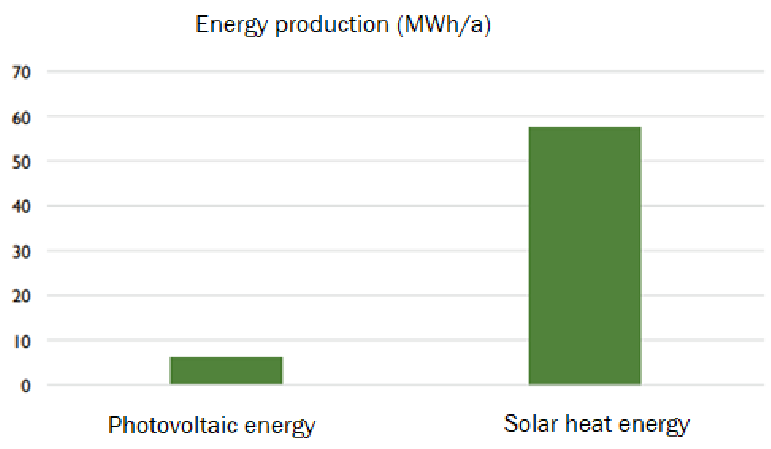
Energy consumption

Designed energy consumption of the building is achieved according on results got from monitoring. The maximum hot water demand in this building is during the day when also solar energy production is high. This is favourable for achieving the designed energy consumption. Also, the atrium used as a heat charger facilitate to reach ideal values.



PICTURE 42. Energy consumption (report of financial and development 2016)

The building has a large enough energy demand, therefore it is easier to utilize produced energy and to achieve better energy efficient. Photovoltaic energy and solar energy has been utilized well allowing to achieve design energy consumption. However, the building is still new therefore the results are from a short part of time.



PICTURE 43. Energy production (report of financial and development 2016)

7.2 Case 2 – Lantti-house

Lantti-house is in Tampere, Finland. It is the first zero energy house designed in Finland. The idea was to build a small-family house to fulfil EU directives. Energy saving was the target on every design solutions.

TABLE 8. Basic information of the building

Building type	Single-family house
Location	Tampere, Finland
Size	246 brm^2, 4-5 Rooms, kitchen and sauna
Year	2012
Developer	TA-yhtymä OY
Architecture	University of Aalto/ Heikkinen Pekka, Maftei Iona, Sutinen Einari, Tulamo Tomi
Heating system	District heat, Solar energy
Energy production of the building	Photovoltaic energy, Solar energy
Energy classification	Designed: A Actual: A
Net delivered energy	18 MWh/a (74kWh/brm2) (2013-2014)
Carbon footprint	4 tnCO2/a (15 kg/brm2/a) (2013-2014)

Design solutions

In the area where Lantti-house was build, the planning regulations restricted the model of the house. Therefore, the model of the house was chosen to be curb roof. The structural body is wood, insulated with wool and cellulose insulation.

The house is designed as square to decrease the surface are of external envelope, which is designed to be very air tight. These design solutions and small windows surface increases the energy efficient.

The primary heating energy of the house is district heat energy, supported with solar heat energy. The distribution of heat is done with water circulated floor heating. The solar thermal collectors are installed on the roof directed west for maximize solar thermal energy in afternoon, when the demand is the biggest. The house is designed to utilize solar thermal energy before using district heat energy.

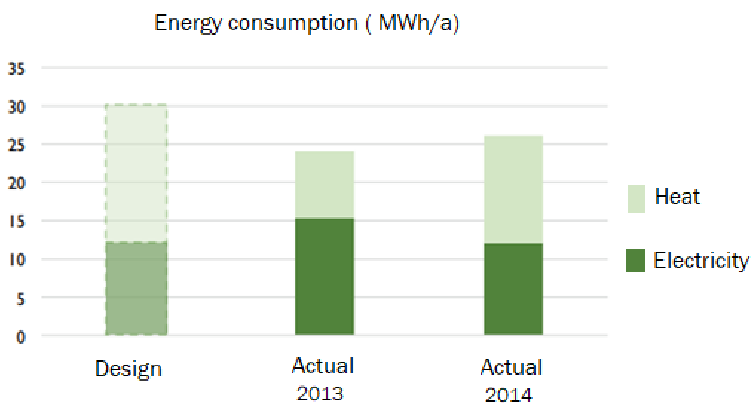
Photovoltaic energy is collected with solar panels installed on the roof and on the south wall. The house utilizes electricity produced with solar panels and additional electricity is supplied to the electric power network.

Cooling energy demand is decreased by shadowing the windows with outside grid. The lights in the house are LED lights. House automation system produces extensively measurements to monitor the system. Temperature and ventilation can be controlled by the residents. The ventilation is mechanical ventilation controlled with a switcher. Energy recovery from ventilation is done with thermal wheel.

PICTURE 44. Lantti-house (report of financial and development 2016)

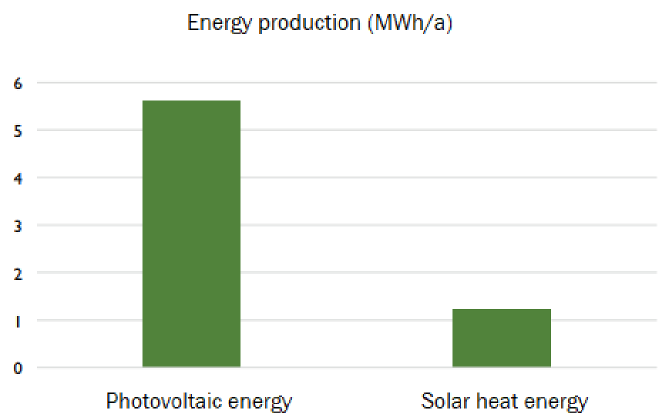
Energy consumption

Lantti-house was developed as energy project, therefore the house has been monitored and analysed all the time. These studies show that the energy consumption has been corresponding to designed energy consumption. Due the constant monitoring and analysing the adjustments of the system in the house has been managed to control very well.



PICTURE 45. Energy consumption (report of financial and development 2016)

Photovoltaic energy has been produced more than solar heat energy. With the produced photovoltaic energy 40% of total consumed electricity was covered in 2013 and 2014. Total heat energy consumption was covered 10% with solar heat energy.



PICTURE 46. Energy production (report of financial and development 2016)

The feedback from residents of the house has been good. Notable detail has been the temperature difference between rooms, however luminosity and ventilation of the house has been pleasant.

7.3 Case 3 – Near zero energy buildings of Soininen

In the city of Naantali, the Idea was to build an entire energy efficient block of houses. Naantali is in the west of Finland near Turku and the city of Naantali was committed on the project as well as the owner of the plot. The buildings of Soininen was built in 2013 and the project included 10 houses build as semi-detached houses and row houses. These 10 buildings include 38 apartments.

The energy efficient was most important detail from the beginning of the project. The energy efficient was a big part of land use planning and with this all the buildings was easy to direct on south for efficient solar energy collecting.

All the changes of land use planning and others was made considering the goals of the project.

TABLE 9. Basic information of the buildings.

Building type	semi-detached houses and row houses.
Location	Naantali, Finland
Size	3 938 brm^2, 10 buildings, 38 apartments
Year	2013
Developer	VASO
Architecture	Architecture office Kimmo Lylykangas oy
Heating system	Electricity, Solar heat energy
Energy production of the building	Solar heat energy
Energy classification	Designed: A Realized: A
Net delivered energy	146 MWh/a (37 kWh/brm2) (2014)
Carbon footprint	33 tnCO2/a (8 kg/brm2/a) (2014)

Design solutions

Timber construction was favoured on the project therefore, the structural body of the buildings is mainly wood. Building envelope and the roof is insulated with glass wool made from recycling glass. Surface area of external envelope and windows, as well as windows location, was considered in planning carefully. The windows are quadruple with selective plating. The big windows are shadowed from the direct light with terrace.

For solar energy collection, there is solar thermal collectors on the roof of buildings. The Solar energy system is controlled individually from each apartment, however the system is automated to close and open the circulation according the temperature of solar thermal collectors. The heat is transferred from solar thermal collectors to heat exchanger and further to individual boiler of each apartment.

If the heat collected with solar thermal panels do not cover the heat demand, the domestic water is heated in the boiler with electric resistance. Domestic water use is measured by dial flow meter in the apartments. Electrical heaters are used to support inside air heating in cold moths. The energy efficient is improved with energy recovery.

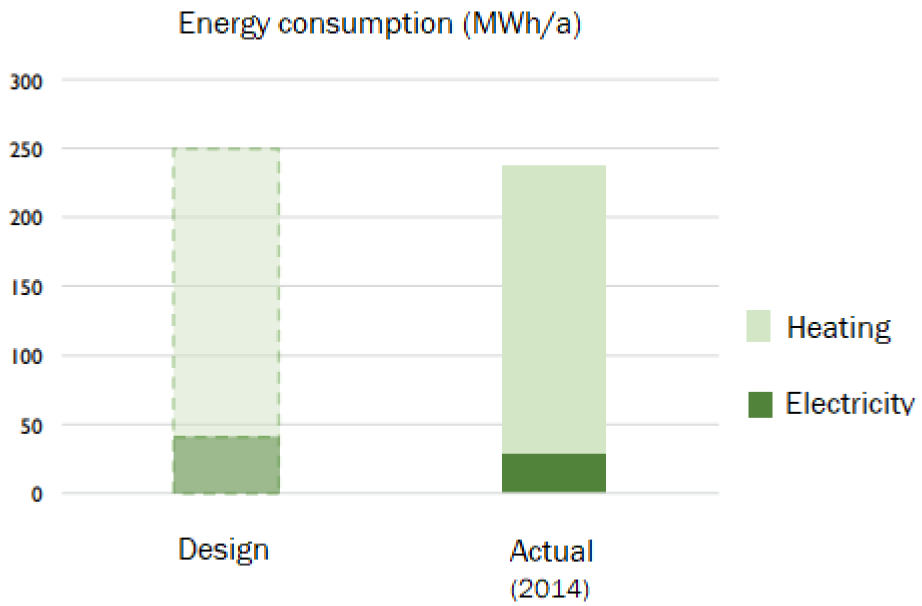
PICTURE 47. Buildings of Soininen (report of financial and development 2016)

In the buildings of Soininen for lighting is used LED lights. Outdoor lighting is controlled by time and motion detectors. Monitoring apparatus on apartments shows the electricity consumption and data of boiler in each apartment. The ventilation is controlled with a switcher with the possibility to control the inside air temperature. The building of Soininen do not have cooling system.

Energy consumption

The energy consumption of Soininen buildings has been slightly less than planned, however this is measured just by one year. The measurements show that this project has been successful. In 2014 the inside air temperature has been changing from planned temperature, the reason for that has been the weather.

When apartment is empty for longer time, the individual solar system is left unused, this is a problem of the individual solar system of each apartment.



PICTURE 48. Energy consumption of the buildings. (report of financial and development 2016)

According of residents there has been problems about floors being too cold and air draft in apartments. Also, the electricity of the buildings was too high in cold winter when the heat demand couldn't be covered by solar heat energy. Residents have also said that solar energy system has worked without problems and without need of maintenance of the solar system.

8 CONCLUSION

Near zero energy buildings are an important part to slow down the climate change and reduce greenhouse gas emissions. This is because the impact of construction on environment is very significant.

The regulations set by EU have set challenging targets for every country and they affect the way of construction in Finland very much. For reaching these goals the way of construction must be energy efficient.

The use of renewable energy sources decreases the use of fossil fuels or they can replace fossil fuels overall. At this moment the renewable energy sources are not used in the maximum potential that they have. When the use of renewable energy source like solar energy, biomass energy and geothermal energy is increased, only then the fossil fuels can be replaced. With these energy technologies the impact of construction on environment and climate change will be improved significantly.

The example cases of near zero energy building in Finland shows that the targets of near zero energy building can be achieved also in challenging conditions of Finland. The importance of structure and energy efficient can be seen from these examples.

The goals of near zero energy buildings has been taken very seriously in Finland. Finland has taken a good direction to achieve the targets of energy efficient construction, however there is still a lot of work and improvement to be done. The energy efficient construction must be improved all the time to be able to achieve the construction that has the minimum impact on environment.

This thesis was done during twelve weeks in the spring of 2018. I learned a lot about near zero energy buildings, however I also got to understand the amount of work that is still to be done for achieving the targets of near zero energy building.

9 BIBLIOGRAPHY

Ekolampo.fi/maalammon-keruupiiri-osa-1-lampokaivo

Ekolampo.fi/maalammon-keruupiiri-osa-3-keruupiiri-vesistoon/

Erat B., Erkkilä V., Nyman C., Peippo K., Peltola S., Suokivi H.
Aurinko-opas aurinkoenergiaa rakennuksiin,

finlex.fi/fi/laki/kaannokset/1999/en19990132.pdf
finlex.fi/en/laki/kaannokset/1961/en19610264
finlex.fi/fi/laki/kaannokset/2013/en20130599.pdf

Gasum.com/kaasusta/biokaasu/biokaasu/

Gtk.fi/geologia/luonnonvarat/turve/turvemaat.html

Greenfieldspenrith.com/renewable-energy-cumbria/solar-thermal

Insinoorikuusinen.com/2011/06/13/kohti-nollaenergiataloja/

Isover.fi/suunnittelijalle/mita-nollaenergiatalo-tarkoittaa

Kurnitksi, Jarek. Energiamääräykset 2012

Kurnitksi, Jarek.
slideshare.net/SitraEnergia/sitra-jarek-kurnitski-201267.

Luonnonvarakeskus. 2016.
Luke.fi/uutiset/metsahakkeen-kaytto-supistui-2015/

Metsä yhdistys 2016.
smy.fi/forest-fi/metsatietopaketti/suomen-metsavarat/

Motiva
www.motiva.fi/ratkaisut/uusiutuva_energia/bioenergia/bioenergian_kaytto

Mäkelä Veli-matti, Tuunanen Jarmo
District heat energy. Suomalainen kaukolämpö. 2015. MAMK

Pesola, A. Autio, M. Alam, J. Ylimäki, L. Descombes, L. Vehviläinen, I. Vanhanen, J.
Asumisen rahoitus- ja kehittämiskeskuksen raportteja 1, 2016

Tilastokeskus 2016

Tiwari G.N. Solar energy

Turveinfo.fi

Sepponen Mari – Nieminen Jyri – Tuominen Pekka – Kouhia Ilpo – Shemeikka Jari – Viikari Meri – Hemmilä Kari – Nykänen Veijo 2013. Lähes nollaenergia-talon suunnitteluohjeet. 2013, Lahti

Sulpu.fi

Suomen rakennusmääräyskokoelma D3
finlex.fi/data/normit/37188/D3-2012_Suomi.pdf

Suomen rakennusmääräyskokoelma D5

Vapo. Pellettikirja, ajatuksia ja ohjeita taloudelliseen puulämmitykseen.

Ympäristöministeriöopas 2013

www.rakennuslehti.fi/2015/02/487051/