Heating Systems in Finland and China

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Bachelor's Thesis

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THESIS
Abstract

Field of Study Technology, Communication and Transport			
Degree Programme Degree Programme in Industrial Management			
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Title of Thesis Heating Systems in Finland and China			
Date	13.3.2013	Pages/Appendices	58
Supervisor(s) Harri Heikura			
Client Organisation/Partners None			

Abstract

This final thesis is mainly focused on the study of the heating systems in Finland and China. It aims of comparing systems and figuring out which one is the most suitable inside the house with cold climate conditions of Finland and China. The comparison is based on the economic criteria.

The study consists of theoretical part which describes the background, structure and different features of the heating systems, alternative energy sources and the heating systems for the house and practical part which includes comparison of the heating systems in Finland and China.

The results are shown in tables and appendices following the conclusions on the suitable heating system.

Keywords

Heating system, Finland, China, Energy, Environment, Comparison

CONTENTS

1 Introduction

Different kind of heating systems have already been experienced by the users for a long period of time, such as household heating systems, district heating systems and so on. In this report, we are just focusing on the district heating systems, which are more effective and well-known. District heating systems (DH systems) can not only play an important role in increasing the use of RES (Renewable Energy Resource) for heating purposes, but also in reducing total primary energy demand. According to the scale of economy, the DH systems provide an opportunity of using deep geothermal heat as well as unrefined biomass (e.g. waste wood, straw, forestry residues) and municipal solid waste (MSW).

The DH systems also enable the utilization of surplus heat in industries (industrial waste heat) and thermal power plants via Combined Heat and Power production (CHP), thus reducing primary energy demand. In Europe, DH systems are particularly common in Sweden, Finland, Denmark, the Baltic countries and Eastern Europe. This report is focused on Finland, where district heating accounts for 50% of the delivered energy for heating residential and non-industrial premises. Apart from the high penetration rate, the Finnish district heating sector is an interesting study object because of the transition from a near-complete reliance on oil to an energy supply with a high proportion of biomass.

The aim of this report is to describe the introduction and development of the DH systems and to identify which factors that have shaped this development. Elements which are described in my study include of the use of fuels and energy sources, CHP production, total DH supply, ownership and economics. Particularly attention is paid to different policy incentives and regulations that directly or indirectly have influenced the DH systems. Non-policy factors that have shaped the district heating development are, however, also discussed. The main questions that are addressed in this thesis are:

- How do the heating systems work?
- The heating systems in Finland.
- The heating systems in China.
- Comparing the heating systems in these two countries and developing them.

2 General information on the theory of heating systems

Hot water heating systems are built by the Centre on radiant heat. Water is heated by a boiler and then circulated throughout a series of pipes of a building. Apparently, the radiators distribute heat. There are three basic types of hot water heating systems: gravity flow, pumped and baseboard convection. But gravity flow is the oldest of the systems; baseboard convection is the newest of the hot water systems.

The Boiler

All of the water heating systems rely on a boiler to heat the water, which then circulates the water through the buildings, no matter how huge the building is. In this report, we will focus on the home heating systems, which is most relative to our life. The boiler can heat the water from many kinds of sources. In the most common method, gas or coal is burned in the boiler to heat an immersion coil. The coil, in return heats the water. Then the water will heat the homes.

Work Process

There are three water heating systems basically. Two are by the pumps one is by gravity. After the water is heated in the boiler, for the pump systems, the pump can circulate the water. The other one is circulated by gravity. In the pump systems, the circulating pumps force hot water through a network of pipes at a constant flow. In the pumped system, the pipes have joints to the radiators. In the convection baseboard system, the principle is the same, but the heat is delivered differently. Hot air is distributed with a fan and thin metal directional plates. In some systems, the resident turns off the pump when the house is hot enough. In other systems, the boiler shuts itself off when a thermostat shows that the water is warm enough. Gravity feed works on a slightly different principle. When the water is heated, cold water will go back to the piping system. So it forces the water upward, displaces the cooler water in the pipes, the cooler water is then forced back into the boiler on a return line to be heated. Through this way, it can reach cool and warm recycle.

Circulator Control

Thermostat runs the circulator control in the pump. It independently turns the boiler on and off when the water coming through the return line into the boiler hits the preset heat range. So, if there is no pump, the heated water goes nowhere.

Thermostat

Thermostat controlling circulator is used in systems. The water is maintained at a constant temperature in the boiler by an aquastat, which functions like a thermometer.

Last Method

A thermostat can also control the water temperature. On the wall that is usually run by a switch. We can turn the dial to the temperature we want. When the thermostat detects that the room temperature is not at the level you desire, it makes the boiler and pump work again. This automatic way to control the system is very easy and easy to operate. Nowadays, it is the most familiar method of controlling hot water system.

Tips

Two things should to be done at least once a year, usually at the beginning of the heating season. First, use the air vent valves on the radiators to remove air that has been trapped in the radiators. Since air rises through the water in the system, most air will collect at the highest level radiators. That includes the air pressure tank that allows for the expansion of the heated water.

Open the air vents beginning at the highest point in the system and work your way down. Air gets trapped in the radiators throughout the system, not just the top radiators. Second, the water should be drained and replaced throughout the system, particularly if it is unfiltered. Minerals will build up in the pipes restricting flow and diminishing heating efficiency.

2.1 The structure of a heating system

Radiant heating is an energy-efficient way to warming a space by heating the floor or ceiling. Floor radiant heating is the most popular and best choice in applications. A room with floor radiant heating is warmed quickly with low energy loss because heat permeates upward through the floor and rises, making the space more comfortable in cold weather.

Hydronic systems are heating and cooling systems. They use water pumping through pipes to warm or cool a space. Radiant heating is one example of a hydronic system, and also there are others, like hot water supply and return fan-coil systems. A few radiant systems use electrical heating, most of them use hot water circulated through pipe.

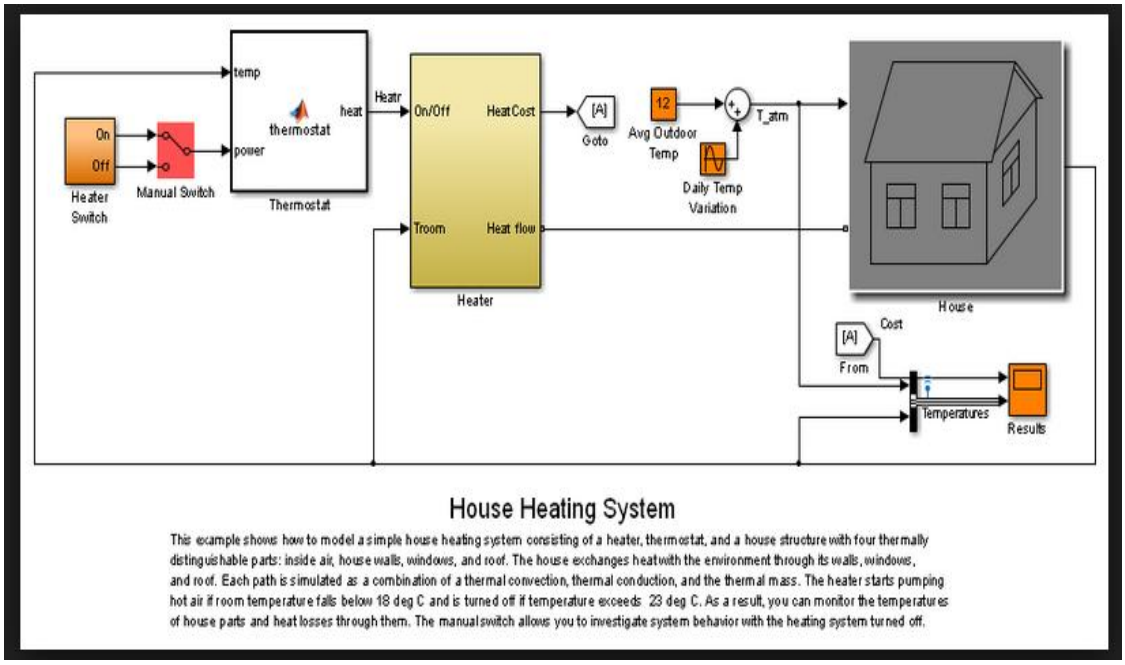


Figure 1: In this figure, we can see the outline of the heating system. If we want to know how it works, we must know its structure. So we continue as follows.

1. Boiler:

Figure2: Boiler in a heating system.

Boiler (a closed vessel) is energy exchanger equipment where the water or other fluid is heated. After energy transition, the heated water, steam or other organic heat carrier can be generated. The heated or vaporized fluid produced by the boiler will pro-

vide the industries and residents the energy to manufacture and live. The source of heat for a boiler is combustion of any of several fuels, such as wood, coal, oil, or natural gas and so on. Electric steam boilers use resistance or immersion-type heating elements. There are many kinds of ways to classify the boilers. The most common method is just classifying them into Life Boiler and Industrial Boiler.

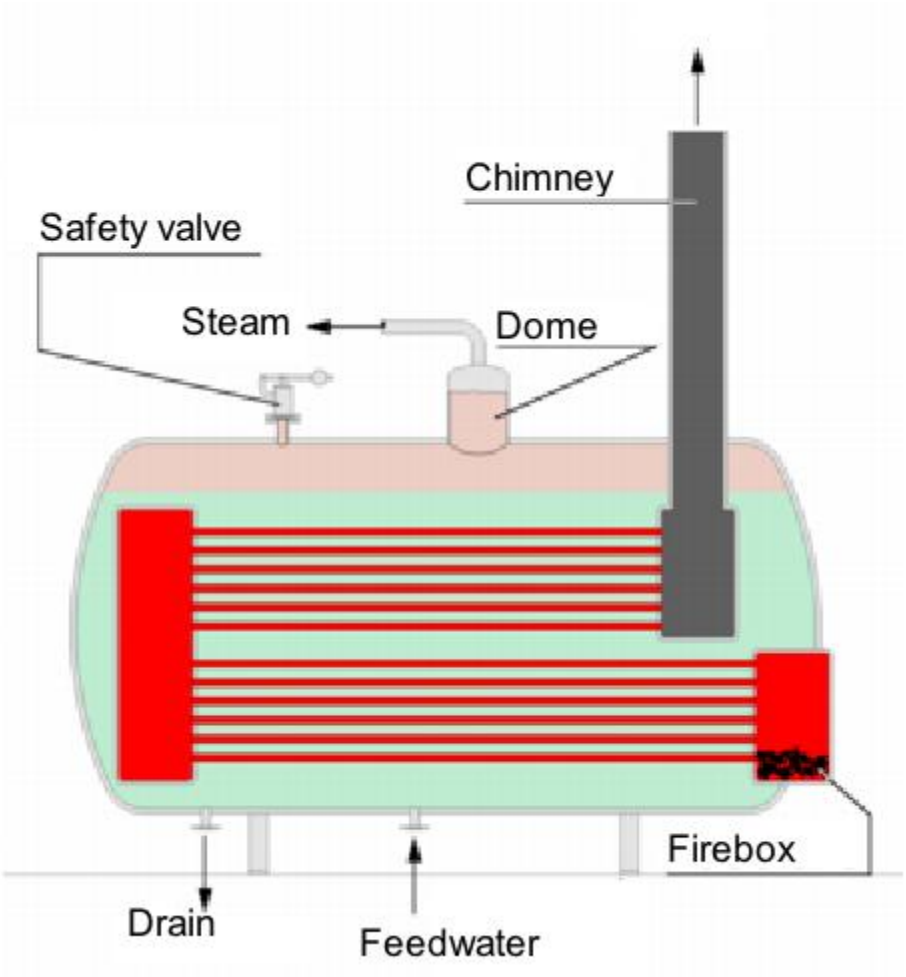


Figure3: Graph of the operation principle of the boiler.

We can see there are defined structures in the boiler. The cool water goes from the feedwater path, and then it gets heated by the coils. Fuels burn in the firebox. The chimney will discharge the gas. When the pressure exceeds the limit, the safety valve will open automatically. Otherwise, it will show faulty performance. When the water gets warmed enough, it goes by the drain path.

2. Expansion Tank

   As we all know, the boiler is a closed vessel. When the water is heated, the pressure will increase. Afterwards, we need to decrease the pressure and let the high pressure air out. So the expansion tank cannot be neglected.

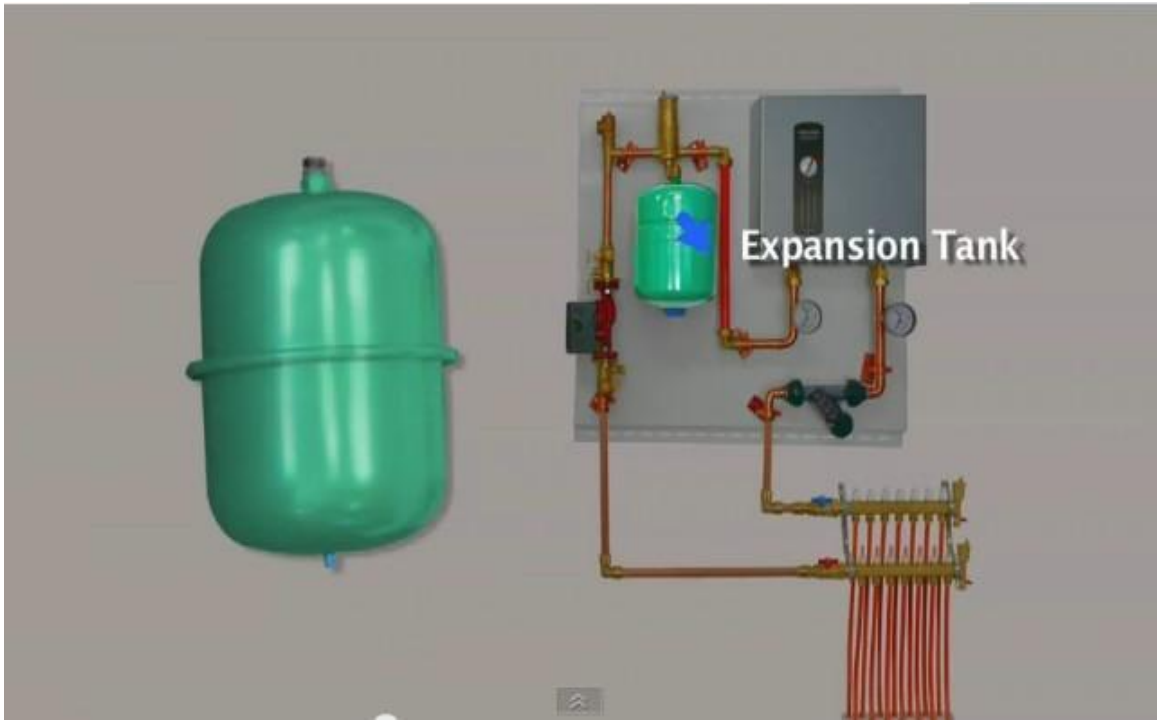


Figure4: Expansion Tank in a heating system.

The expansion tank is an important component in heating system. The function is to absorb and compensate the amount of expansion. Expansion tank or expansion vessel is a small tank used to protect closed water heating systems and domestic hot water systems from excessive pressure. The tank is partially filled with air. The water hammer can cause the compressibility cushions shocking and absorbs excess water pressure caused by thermal expansion.

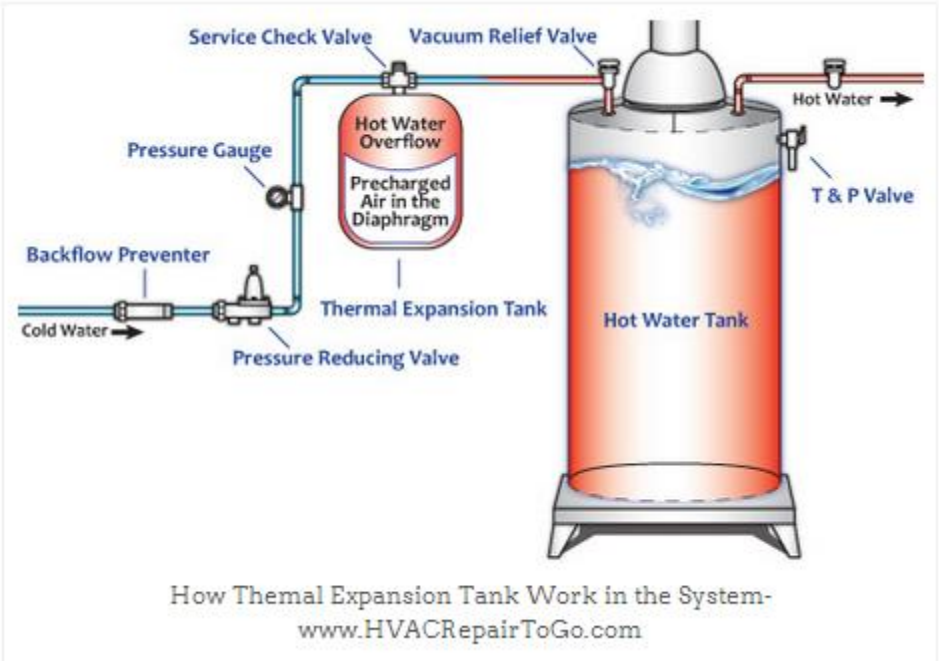


Figure5: The Expansion Tank's operation principle.

3. Fill Flange

Figure6: Fill Flange in a heating system.

Flange is a component which connects the pipes. It is an external or internal ridge to improve strength. The flange of an iron beam has I-beam and T-beam. It can be attached to another object. Thus flanged wheels are wheels with a flange on one side to keep the wheels from running off the rails. The term "flange" is also used for a kind of tool used to form flanges. Pipes with flanges can be assembled and disassembled easily.

4. Gauge

Figure7： Gauge in a heating system.

Pressure and Temperature gauge on hot water or hydronic heating boilers: this gauge displays the heating boiler's internal pressure and temperature.

Typical pressure for a residential boiler serving a two story home would show 82.74Kpa cold and less than 206.85Kpa hot. Over 206.85Kpa boiler pressure will cause the pressure relief valve to open.

Typical operating temperature settings on a boiler are called for a Low temperature (boiler cut-ins) between 120 and 160 ℃.

Typical operating temperatures on a hydronic boiler are called for a high temperature (boiler cuts off) of 180-200 ℃.

Over 200 degrees F. we're at risk of spilling at the pressure temperature relief-valve.

Typical operating temperature observed at the gauge will be below the high, and can be as low as night time room temperature in non-heating season if no tankless coil is in use.

The temperature/pressure gauge may help in checking normal conditions before and during boiler operation.

5. Air Eliminator

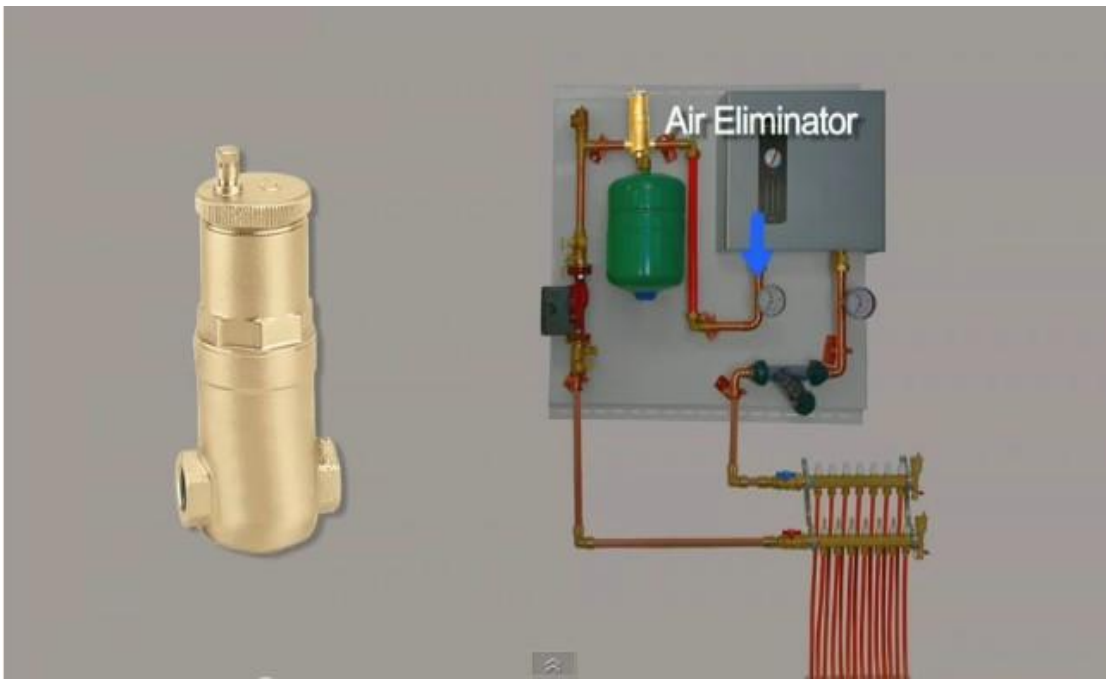


Figure8： Air Eliminator in a heating system.

An air eliminator is a segment of piping which is attached to a main piece of pipe to

trap and release air. In systems in which the flow of fluids is measured by a meter, the eliminator is usually attached ahead of the meter and on top of the main line. The main purpose of air eliminators is to prevent air from passing through the meter, which would cause inaccurate volume readings. Most piping systems used in the boilers and chillers in residential housing and manufacturing facilities utilize air eliminators.

Since air is generally lighter than liquids, air eliminators are attached above a stilling chamber at the highest part of the main pipe. Flow meters cannot differentiate between fluids and air, so air eliminators are installed ahead of the meters in a pipeline so that air will not be measured. This way the volumetric readings of the meters are more accurate. Excessive wear and unit failure or damage can also be reduced if the liquid flow is free from air.

A typical air eliminator is a circular piece of plumbing material made of a metal such as aluminum or steel. Some types are made of polyvinylchloride (PVC). Metal air eliminators are prone to corrosion caused by water, steam, or refrigerant flow, as well as by excessive air entrapment. PVCs do not rust, but can leak out harmful chemicals into the passing liquid.

6. Pump

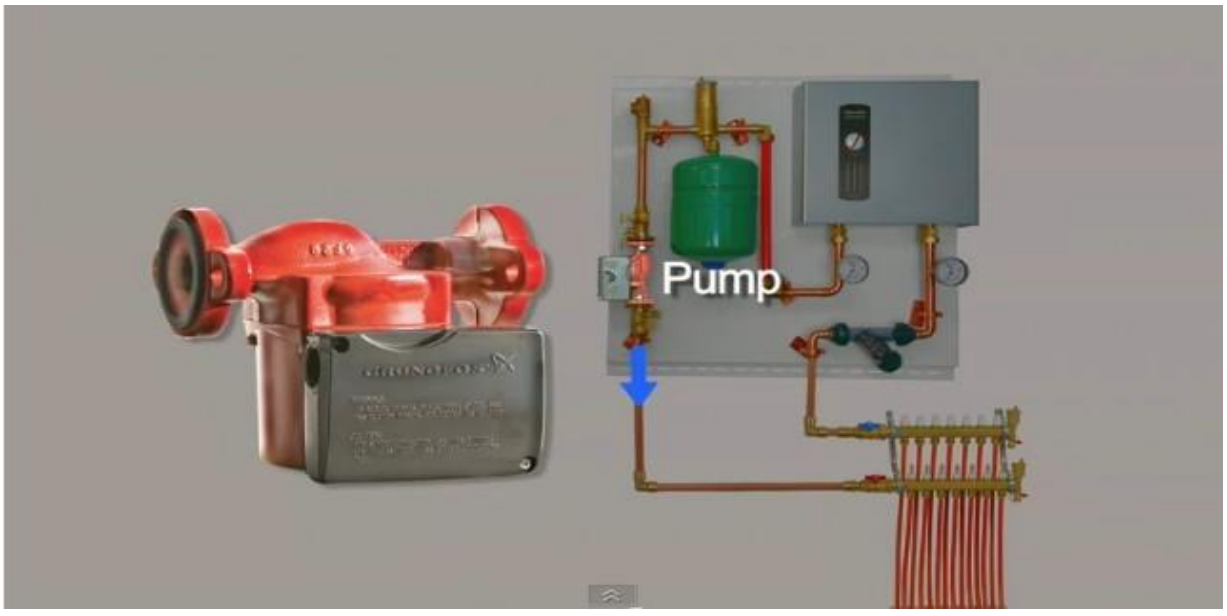


Figure9: Pump in a heating system.

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the

method they use to move the fluid: direct lift, displacement, and gravity pumps.

Pumps operate by some mechanism and they are typically reciprocating or rotary, and consume energy to perform mechanical work by moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power.

7. Pressure Relief Valve

Figure10: The pressure relief value in a heating system.

The relief valve (RV) is a type of valve used to control or limit the pressure in a system or vessel which can be built up by a process upset, instrument or equipment failure, or fire.

The pressure is relieved by allowing the pressurized fluid to flow from an auxiliary passage out of the system. The relief valve is designed or set to open at a predetermined set pressure to protect pressure vessels and other equipment from being subjected to pressures that exceed their design limits. When the set pressure is exceeded, the relief valve becomes the "path of least resistance" as the valve is forced open and a portion of the fluid is diverted through the auxiliary route.

The diverted fluid (liquid, gas or liquid–gas mixture) is usually routed through a piping system known as a flare header or relief header to a central, elevated gas flare where it is usually burned and the resulting combustion gases are released to the atmosphere. As the fluid is diverted, the pressure inside the vessel will drop.

Once it reaches the valve's reseating pressure, the valve will close. The blow-down is

usually stated as a percentage of set pressure and refers to how much the pressure needs to drop before the valve resets. The blow-down can vary from roughly 2–20%, and some valves have adjustable blow-downs.

Figure11: The manifold in a heating system.

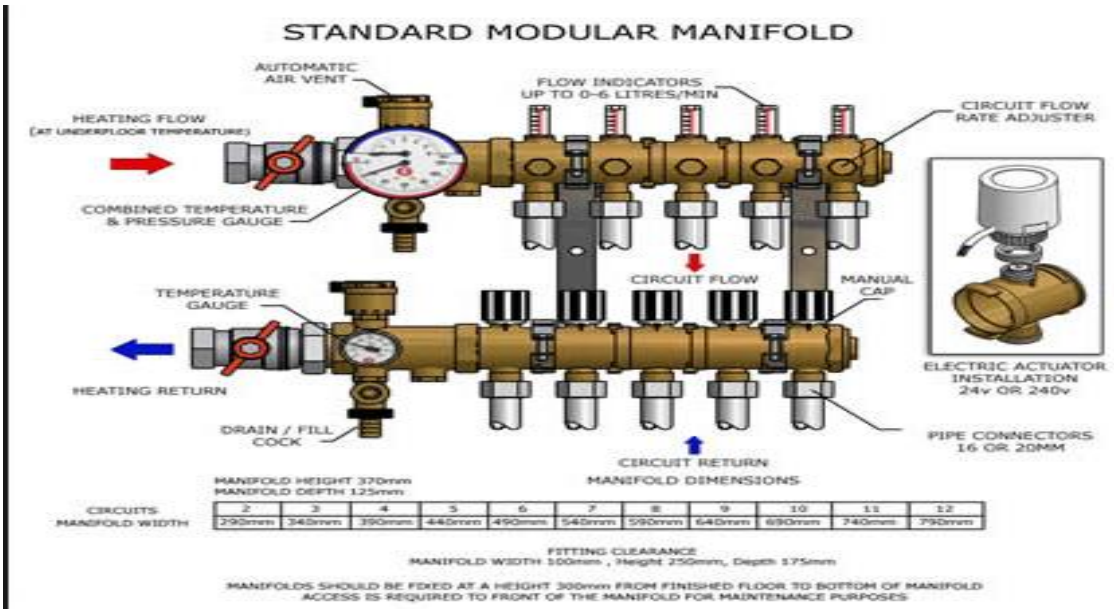


Figure12: The manifold's operation principle.

8. Manifold

Most of you know manifolds, particularly from under floor heating applications. This heating system is focusing on the increasing use of them in traditional wall hung radiator systems, with the advent of plastic piping.

Manifolds are revolutionizing installations in the same way as computer cabling did in the IT industry some years ago. They allow you to move away from the traditional ‘ring’ circuit system to a ‘star pattern’ system, giving significant advantages in the speed of installing a system, and commissioning it.

9. Thermostat

Figure13: The thermostat in a heating system.

A thermostat is a component of a control system which senses the temperature of a system so that the system's temperature is maintained near a desired set-point. The thermostat does this by switching heating or cooling devices on or off, or regulating the flow of a heat transfer fluid as needed, to maintain the correct temperature. The name is derived from the Greek words thermos "hot" and status "a standing".

A thermostat may be a control unit for a heating or cooling system or a component part of a heater or air conditioner. Thermostats can be constructed in many ways and may use a variety of sensors to measure the temperature. The output of the sensor then controls the heating or cooling apparatus. A thermostat may switch on and off at temperatures either side of the set-point. The extent of the difference is known as hysteresis and it prevents too frequent switching of the controlled equipment.

10. Radiator (heating)

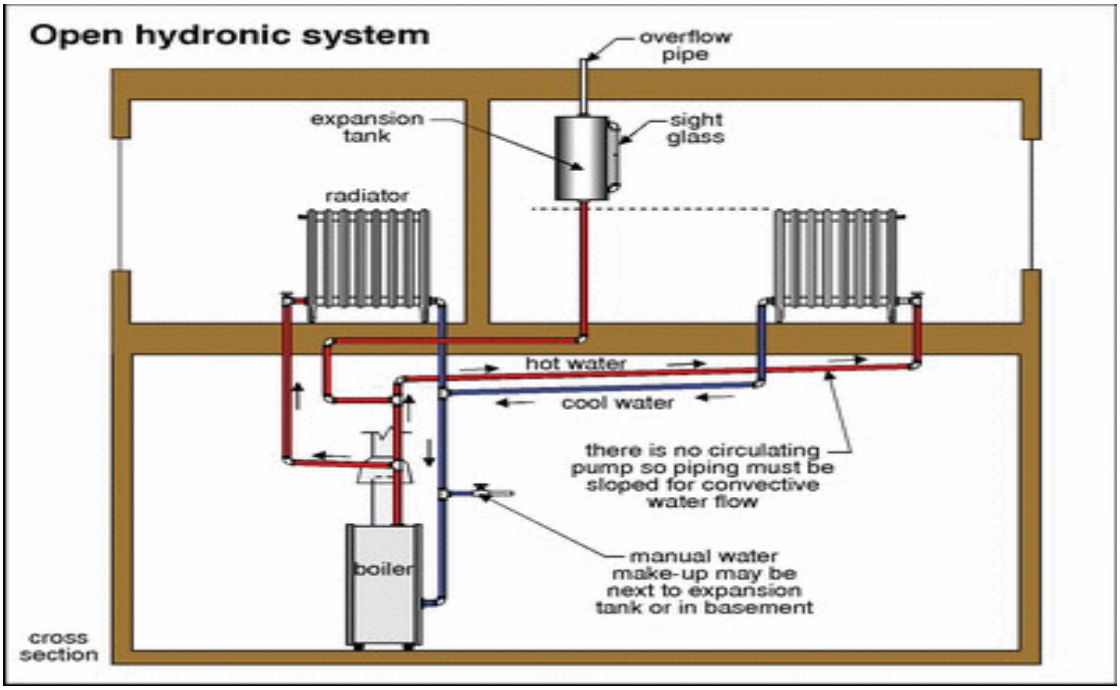


Figure14: The radiator in a heating system.

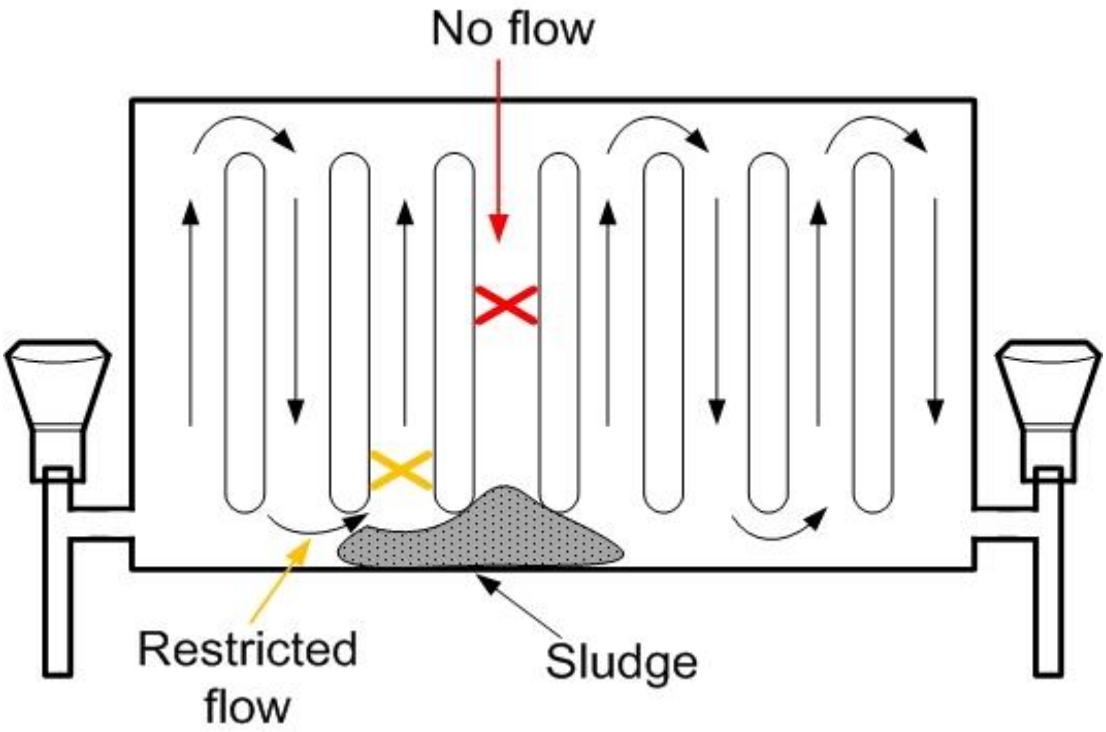


Figure15: The resistance of the flow

You can see from this picture, if the sludge generated in the bottom of the radiator, it

will restrict the water flow. Sometimes, it is caused by the water contain mineral subatance and impurities.When it happened, the radiator need to be dismantled and reinstall again after cleaning.

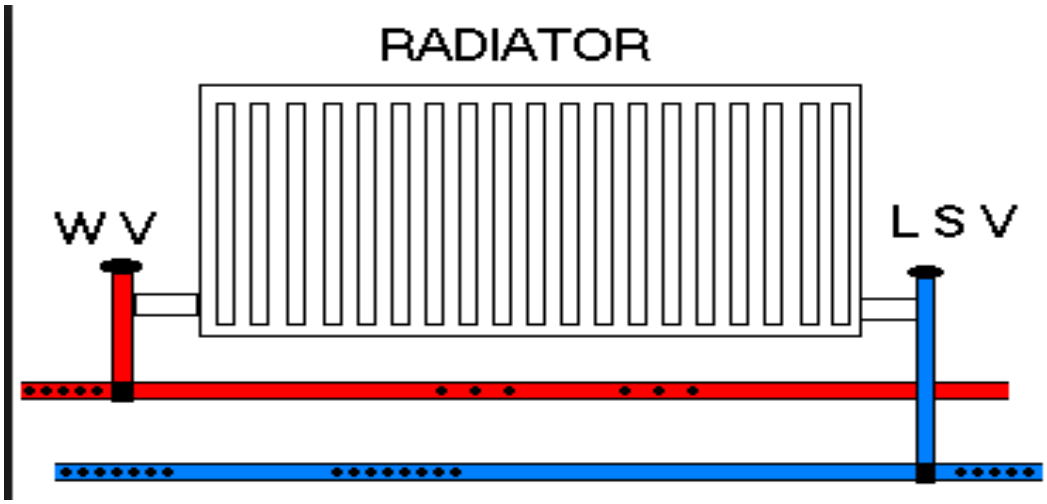


Figure16: The flow of hot water and cold water in the radiator.

Figure17: The radiator in a room.

Radiators are heat exchangers designed to transfer thermal energy from one

medium to another for the purpose of heating in spaces.

Normally, it can be used for heating our rooms. However, there are still some other functions. For instance, the radiators are installed in our cars. It used for cooling the engines.

2.2 The principle of the ground source heat pump

The ground source heat pump is one of the very important aspects of floor heating system. The floor heating can be easily divided into three aspects, which include the ground source heat pump, the electricity heating pump and the water circulated floor heating system. With respect to the electricity heating pump, the electrical energy is transformed to heat by the electric resistance. The electrical energy is produced by the heat, and then the electrical energy is transformed to heat again. So we lose more energy to complete the process than get the heat directly from burning or electricity.

What is more, the distribution lines are very expensive.

For the water circulated floor heating system. The water is heated by the boiler, it goes everywhere including where we do not need it. It means that the efficiency is worse than in the electricity heating pump. The water circulated heating system could make some troubles. The binding between the boiler and the pipes perhaps could leak, and the valve between the boilers may be broken. Due to the pipes are all buried in the ground, so when it happens, all of the floor structure will be reinstalled. It can be a very expensive and complex work.

After introducing the other two kinds of floor heating systems, we would like to highlight the ground heating system.

The heat pump is a mechanical device which enables the transfer of heat from low energy to high energy. In order to achieve the refrigeration or heating of buildings, the water source heat pumps will extract energy form the geothermal source. The groundwater and subsurface soil compose the geothermal source which will generate or release the energy to the buildings. This kind of heating system is an energy exchange between the home and environment.

There are two different ways to transfer the energy for heating and cooling. The working process is displaying in the following pictures.

In the summer, the heat pump unit absorbs heat from indoors and releases it into the ground.

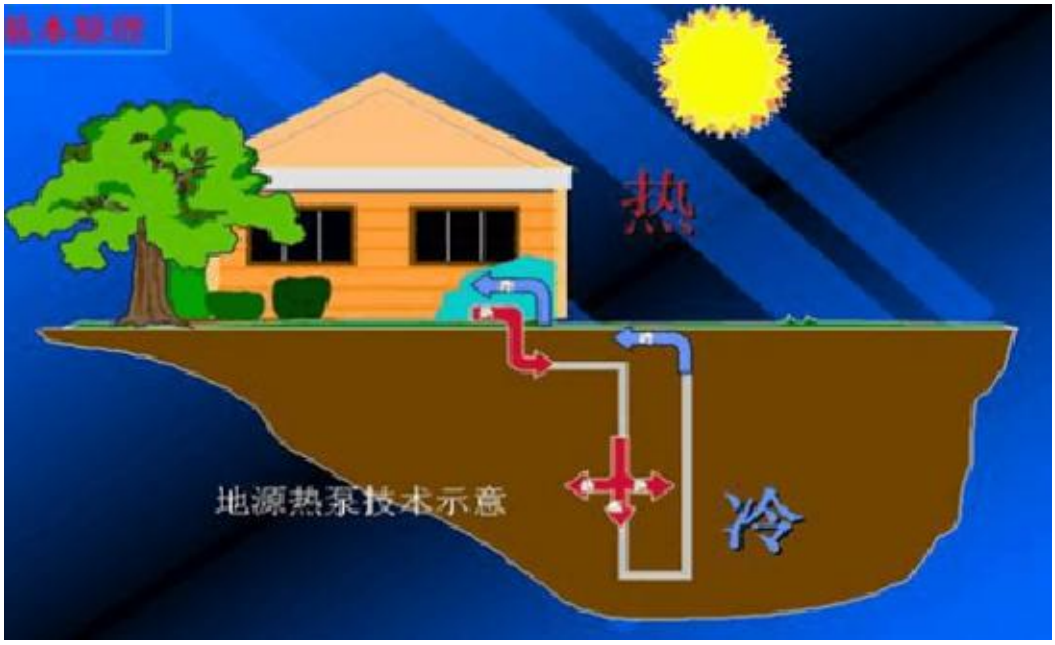


Figure18: Ground source heat pump technology schematic diagram in the winter.

In the winter, the heat pump unit absorbs heat from the ground source (shallow water or rock and soil) to the building heating.

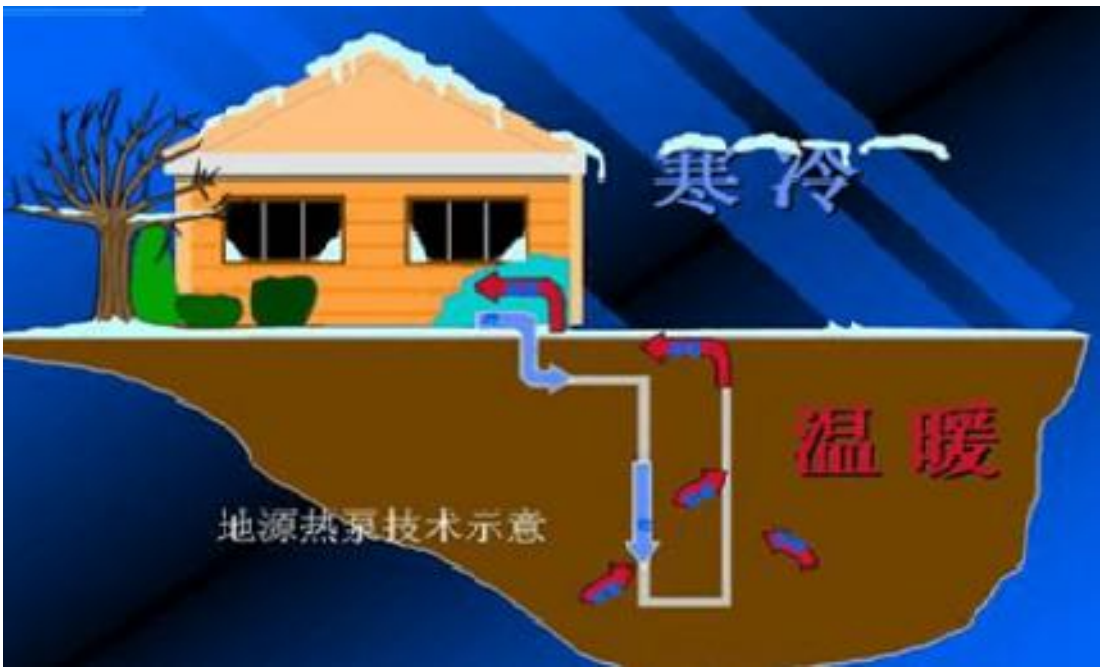


Figure19: Ground source heat pump technology schematic diagram in the winter.

2.3 The structure of the ground source heat pump

The main parts of a heat pump unit are: a compressor, condenser, evaporator and an expansion valve. It allows the liquid refrigerant (refrigerant or cooling media) to do the process recycle such as: evaporation (absorbing heat from the environment) → compression → condensation (heat release) → throttle → the thermodynamic cycle of re-evaporation process, so that the heat is transferred to water in the environment.

Basically, according to refrigeration theory, the compressor makes the working substance to transfer from low-temperature low-pressure gas to high-temperature high-pressure gas. Then it goes to condenser, which makes it into low-temperature high-pressure liquid. After throttled by the throttle valve, it becomes low-temperature low-pressure liquid. This liquid working substance enters the evaporator, which makes that substance lower-pressure steam. At the same time, the evaporation process absorbs heat. That is the cold recycle process.

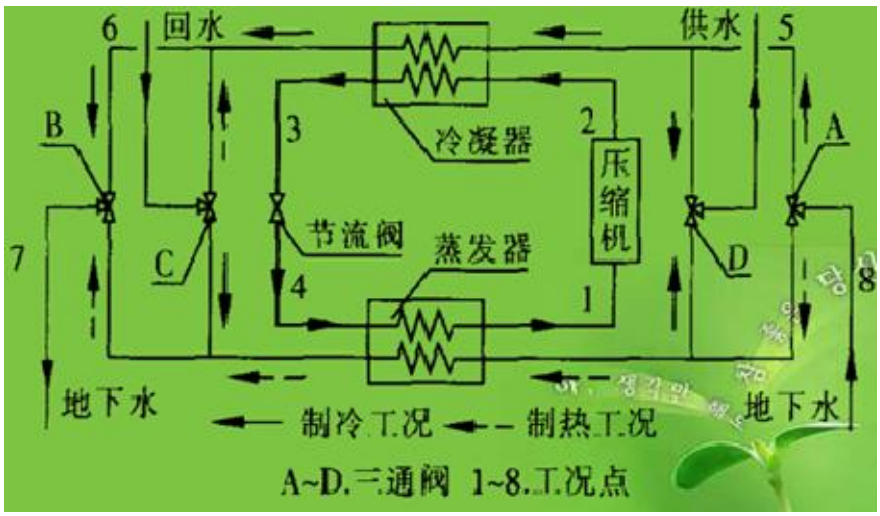


Figure20: The structure of the ground source heat pump.

2.4 Horizontal ground source heat pump

The horizontal ground source heat pump is a closed heat exchanger system, which is buried in the 2 to 4 meters below the ground surface. In that place it can exchange the cold and heat inside the soil. Such a system is suitable for refrigerating small area building, such as villas or small single room. Also it has relatively small initial investment and the construction is easy, but it occupies a large area.

Figure21: Horizontal ground source heat pump.

2.5 Vertical ground source heat pump

In this heating system, hot and cold exchange pumps are embedded into 50M-400M deep in the ground. Then the pump gets heated and cooled through the soil by vertical drilling holes. It is also a closed heating system. Such kind of cooling and heating systems are suitable for huge buildings, surrounded by open space, such as villas, office buildings, etc. The system requires a higher initial investment, and the construction is difficult, but it occupies a small area.

Figure22: Vertical ground source heat pump.

2.6 Surface water ground source heat pump

In this heating system, the heat pump is arranged in the bottom of rivers, lakes, and other water sources. Such kind of system is suitable for small or medium area, which is close to the waterside. It can take advantage of ponds or lakes under stable temperature and it is not allowed to drill holes. But there must be a flowing deep lake or river around. So this system is limited because of geographical position.

Figure23: Surface water ground source heat pump.

2.7 Advantages and disadvantages of the systems

Hot water heating pump

Many kinds of sources can be used in hot water heating pump. Such as Solar, natural gas, LPG, wood, briquettes, coal, and electricity. Obviously, every kind of heating system has its advantages and disadvantages. In general, hot water heating system:
Advantages:

1) It has many choices, including the price of equipment.
2) Hot water heating system can heat your home very fast. It is safe to work for a very long time.
3) Because of efficiency, it saves a lot of fuel. And the heat loss is small.
4) It is healthy and clean to use water as heat medium.

Disadvantages:

1）Some fuels will produce greenhouse gas.
2）It costs a lot of money to pay it and fix it.
3）The consumption of electricity is huge for this heating system.

Ground source heat pump

Advantages:

1) Using renewable energy

Ground source heat pump is using shallow geothermal resources of the Earth's surface as a heat source and air-conditioning systems for energy conversion. This is almost unlimited renewable energy stored in the surface of shallow ground source, which is clean and friendly to our environment.

2) Energy-efficient and stable operation

As the ground source temperature is relatively stable throughout the year, higher than the air temperature in winter, however that temperature is lower than the air temperature in the summer. The diversification of temperature in the ground is much smaller than the it in the air. The ground source temperature is relatively constant, which makes the ground source heat pump's efficiency 40% higher than the conventional air conditioning system. There is no problem of defrosting in winter, while the heat pump unit runs in a more reliable and stable way.

3) Green and good for environment

Ground source heat pump runs without any pollution and can be built in a residential area. There is no burning, no smoke, no exhaust material, and we do not need a site to pile up the fuel, and do not have to transfer heat in long distance.

4) Flexibility

The heat pump units can be placed anywhere. It is flexible, safe, and reliable. It also can save space. Ground source heat pump can also be used in the buildings to provide heating and cooling for air conditioning system, and at the same time provide domestic hot water.

Disadvantages:

1) The initial investment is too large. It needs a large area of land.
2) The heat pump is not a strict closed system. So oxygen will cause the oxidation water.
3) Currently, there are no specialized evaluation criteria of ground source heat pump system, so we need to establish effective evaluation criteria.
4) It strongly relies on the local geological and climatic conditions.

2.8 Some problems related to the pump

Hot water heating system

Even though the hot water heating system is an efficient and effective way to heat, it still has many advantages.

1) A direct hot water heating system provides no ventilation.
2) The size of the radiator is proportionally big.

3) It is dangerous when the water system is freezing, although keeping the boiler on can prevent it.
4) There are too many junctions in this system, and thus more parts can leak. These breakable parts include pump, valve, a circulator etc.

Ground source heat pump

1) The operating characteristics and technical parameters of ground source heat pump are directly related to the annual normal operation and energy consumption. But in China there are still no specific standard references.

2) Whether the match of the compressor and the heat exchanger is suitable or not is the main problem we face. It is the most important issue of heat pump unit. If it is not suitable, not only the unit cannot achieve the desired effect, but also cannot be able to achieve energy saving.

3) The quality of heat pump needs to be improved.

4) More professional workers who know how to design and install the system are needed.

3 Heating systems in Finland and China

In the following, we will introduce the situation of the heating systems in Finland. It includes the background, energy used, source fuels, and the environmental aspects.

3.1 Background

Lying approximately between latitudes 60° and 70° N, and longitudes 20° and 32° E, Finland is one of the world's northernmost countries. Winter in Finland lasts roughly from December to March. The mid-winter temperatures might drop as low as -30 ℃. So people need heating almost everywhere in the houses.

In Finland, the heating time is quite long, from the beginning of September to the middle of May next year. Nearly 80 % of the energy use of households was spent on heating in 2008-2011.

By the end of 2009, almost 200 local heating industries have been established around Finland, which means some 400 local heating schemes.

Figure24: Finland Map.

3.2 Energy and energy policy in Finland

Here is a table comparing the energy usage with different aspects from 2004 and 2010.

TABLE 1: Finland's Energy Usage from 2004 to 2010.

Energy in Finland						
	Capita	Prim. energy	Production	Import	Electricity	CO_2-emission
	Million	TWh	TWh	TWh	TWh	Mt
2004	5.23	443	185	247	87.7	68.9
2007	5.29	424	185	232	90.8	64.4
2008	5.31	410	193	230	86.9	56.6
2009	5.34	386	192	213	81.4	55.0
2010	5.36	423	201	210	88.4	62.9
Change 2004-10	2.5 %	-4.4 %	8.9 %	-15.0 %	0.8 %	-8.7 %
(Mtoe = 11.63 TWh, Prim. energy includes energy losses that are 2/3 for nuclear power)						

(Note: 1 w.h = 3600J; 1 Kw.h = 10^3 w.h; 1 Mw.h = 10^6 w.h; 1 Gw.h = 10^9 w.h; 1 Tw.h = 10^{12} w.h)

(Reference: http://en.wikipedia.org/wiki/Energy_in_Finland)

According to Statistics Finland, energy consumption in households amounted to 61,884 GWh in 2011. Eighty-four per cent of energy consumption concerned heating of residential buildings and 16 per cent household appliances. The most common energy source for heating of residential buildings was district heat between 2008 and 2011. Wood and electricity were the next most consumed sources. These three energy sources accounted for over 80 per cent of the consumption of heating energy for residential buildings. A total of 17,313 GWh of district heat was used for heating residential buildings in 2011.

The objective of RE (2005) of electricity was 35% (1997–2010). However,(2006) the Finnish objective dropped to 31.5% (1997–2010).According to 'Renewables Global Status Report' Finland aims to increase RE only by 2% in 13 years. This objective to add the RE use by 2% in 13 years is among the most modest of all the EU countries.

3.3 Heating fuel/ source of heat

Fuels (such like coal, oil, gas etc.) are materials where store the energy, which can be released by combustion. It is harmful to the environment. We can also use environmentally friendly-energy source, such as solar, ground source etc. In the following, we will introduce the majority of the heating fuels, which provide the energy for residents and industries in Finland.

Solar power

- A solar hot water system, which requires an additional investment of 1,200 to 1,700 euros above the price of a conventional hot water, but it can pay back the additional cost in energy savings in approximately 5-10 years.
- All systems come with a gas, off-peak electric or solid fuel booster to supply hot water during the periods of low sunshine.
- Generally, the collector panels are located on the roof, with a storage tank either on the roof or at ground level.
- Solar hot water systems have a low impact on the environment.

Natural gas

- Both storage and continuous flow systems are available.
- Both internal and external models are available.

LPG

- The running costs are average around one and a half to three times the price of natural gas or off-peak electricity.
- Storage and continuous units are available.

Solid fuels (wood, briquettes, coal, etc.)

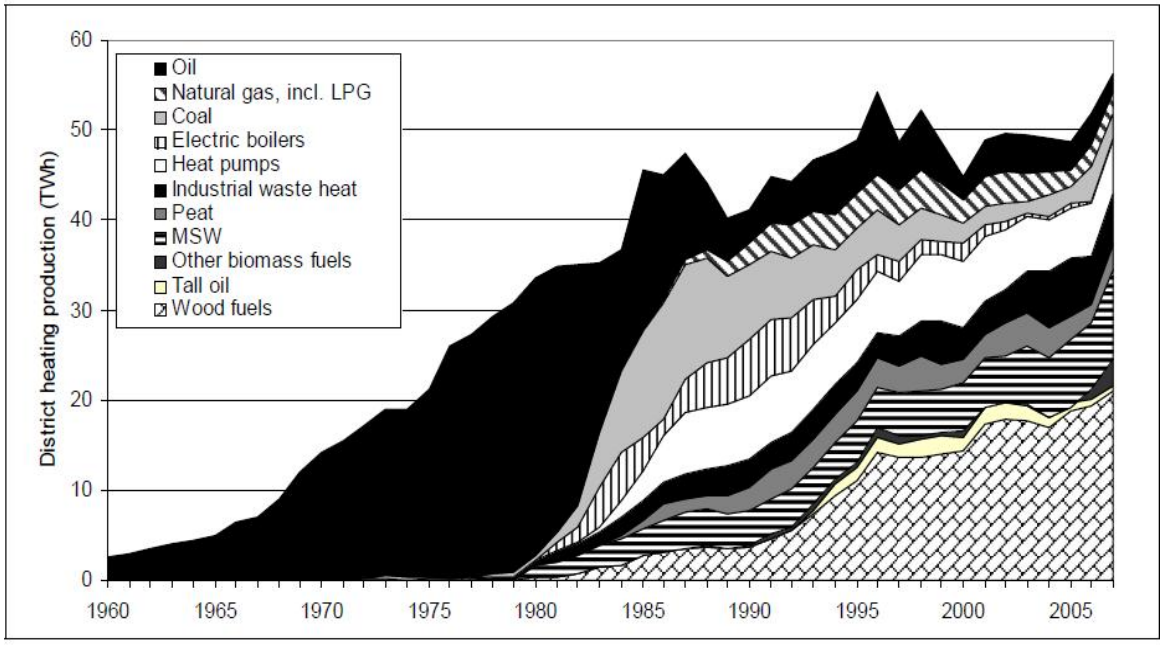
- Cost of fuels varies greatly.
- Can be used alone, or in conjunction with off-peak electricity and/or solar in constant pressure storage units.
- Water can be heated using a 'wetback' attached to a slow combustion wood heater, or a stand-alone water heater powered by solid fuel.
- The mains pressure systems cannot be used, unless using a heat exchanger.
- Not available for constant flow systems.

Off-peak electricity

- The running costs are similar to those of natural gas.
- It can only be used in storage systems of 160 litres capacity or greater.
- Water is heated overnight to provide adequate hot water during the day.
- Twin element units can operate with a 24-hour off-peak boost (if hot water runs out, water is reheated automatically on the off-peak tariff). Check with your electricity supplier for more information.
- Internal and external models are available.

Peak electricity

- Used for electricity constant flow units, storage water heaters with a capacity of less than 160 litres and heat pump type storage systems.
- With the exception of heat pumps, these systems can be very expensive to run, so should only be used when other options are not suitable.



Source: 1960-69: approximations from DHA (2001); 1970-2007: SEA (2008a)

Figure25: The source usage to make the heat energy in Finland from 1960 to 2007.

In the past decades there has also been a continuous increase in the utilization of industrial waste heat which increased from 0.6 to 5.8 TWh/y between 1980 and 2007(SEA, 2008a). A significant part of the industrial waste heat is supplied by pulp and paper mills which is the dominant process industry in Finland. Apart from the pulp and paper mills, industrial waste heat is also supplied by some chemical and food processing plants, steelworks, refineries and one sugar mill. Industrial waste

heat often plays a prominent role in the DH systems where it is used, especially in some small towns. Industrial waste heat is, however, also important in some larger towns.

3.4 Distribution of district heat

In Finland, heating systems are built as closed systems that are separated from the heating systems of the buildings by an intermediate heat exchanger (substation).
The district heat is distributed in the form of hot water which circulates through the pipelines in the DH systems and is returned to the plant for reheating and redistribution. It is also possible to use steam as heat carrier.

The heat losses are greater when using steam as heat carrier, and the temperature of the forwarded water should in general be as low as possible in order to minimize heat losses. The temperature of the forwarded water in the Finland DH systems varies between 70 and 120°C depending on the heat load demands. The highest temperature is used in winter and the lowest during summer. The temperature of the return water varies between 40 and 65°C.

The size of DH systems varies greatly with an annual heat load that ranges from a few GWh to more than 8 TWh.

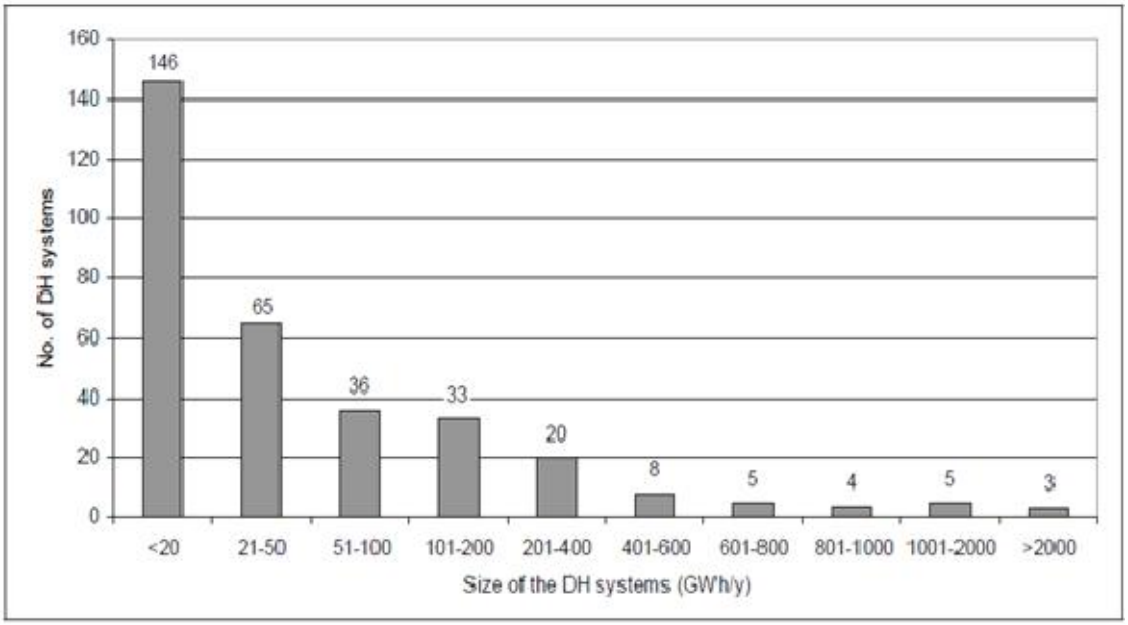


Figure26: Distribution of the number of DH systems between different size ranges

based on the annual deliveries of district heat in 2005.
(Reference: www.stat.fi)

We can figure from this picture that with the increasing size of DH systems, the number of DH systems decreased. Especially, when the size of the DH system is less than 20 GWh/y, the number of DH system can reach 146. When it goes to 21-50, the number of DH system decreases rapidly.

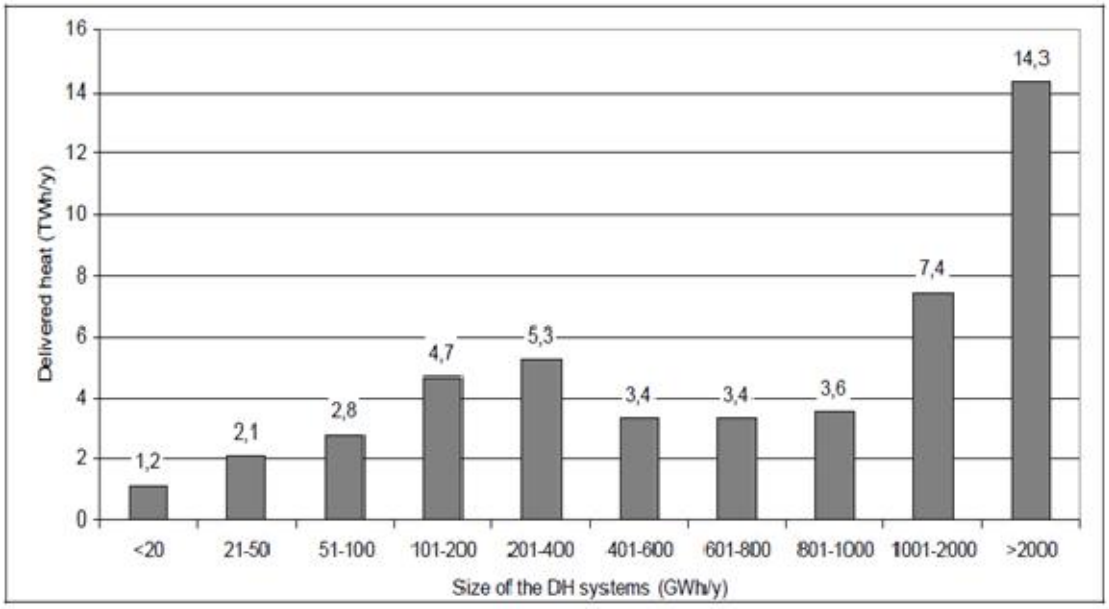


Figure27: Distribution of the DH production between different size ranges of the DH systems based on the annual deliveries of district heat in 2005.
(Reference: www.stat.fi)

3.4 Environmental aspects

Greenhouse effect

The greenhouse effect is a process by which thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases, and is re-radiated in all directions. Since part of this re-radiation is back towards the surface and the lower atmosphere, it results in an elevation of the average surface temperature above what it would be in the absence of the gases. It always makes our temperature rising.

TABLE2: Comparing the CO_2 emission in four different types of tanks.

Tank types	**Est. Annual C02 Emissions Based on Standard Home and Family of Four**	**Comments**
Solar water heater	Marginal	Emissions increase if a backup tank or pump is part of the system
Tankless gas water heater	1 ton CO_2	Assumes usage does not increase with increased hot water capacity
Conventional gas water heater	2 tons CO_2	Assumes similar energy usage as conventional electric tank
Conventional electric water heater	8 tons CO_2	Assumes 6,400 kwh hours required to heat water for one year for a family of four

Currently, solar water heaters are the best option for those who are environmentally conscious. However, solar water heaters will still produce some carbon emissions in most cases. As most solar systems are “active” systems, which require a pump and a backup conventional tank to ensure adequate hot water supply.

For normal home owners, tankless hot water heating systems offer the best of both in terms of least energy consumption and convenience. However, in order to realize energy and greenhouse gas emission savings, a new tankless hot water heater user must keep their energy use constant.

For those who are both environmentally and budget conscious, the best choice is to stick with their conventional natural gas (oil or propane) water heater, as this is still four times better than a standard electric tank.

Renewable energy in Finland

The source of renewable energy in Finland of electricity was (in 2005): Water 60%, forest industry black liquor 22%, other wood residues 16%, wind power 0.2% and other RE 1%.

- Wind power

  In the end of 2011 wind power capacity in Finland was 197 MW and the wind energy share of total electricity consumption was 0.5%.

- Biomass power

  Finland uses a lot of wood as energy source because of the abundant forest source. Its volume has increased in the industrial use. As the energy consumption has increased, the share of RE is constant.

- Photovoltaic power

  Photovoltaic power generation employs solar panels composed of a number of solar cells containing photovoltaic material.

- Solar power

  The solar heating has not been competitive due to cheap alternatives (electricity, fuel oil and district heating) and the lack of support systems. Companies and public organizations may receive 40% percentage investment subsidies, but private houses do not receive subsidies yet.

- Biofuels

  It has been decided that the public transportation in the Helsinki metropolitan area will use the palm oil biodiesel of Nest Oil. In 2010 half of the busses used it already. Finnish government is supporting the biodiesel use financially. Nest Oil biodiesel will be tax free for the public transportation from 2010.

- Peat

  According to European Union and IPCC peat is not a biofuel as it is claimed but has equal CO2 emissions to coal. Many peat energy plants can use coal as alternative energy source.

Fuels in Finland

- Petroleum

  Most of petroleum is used in vehicles, but about 260,000 homes are heated by heating oil.

- Natural gas

  In 2010 the share of gas in TPES was about 10%. Finland was 100% dependent on a single supplier in gas, namely Russia.

- Coal

  Finland is a peat-producing nation. Peat is classified as coal by the IEA. There is no coal mining or coal tar in Finland.

- Nuclear power

  As of 2008, Finland's nuclear power program has four nuclear reactors in two power plants. The first of these came into operation in 1977. In 2007 they provided 28.4% of Finland's electricity. And the fifth reactors in under construction, it is planned to finish in 2015 or later.

- Peat

Peat and hard coal are the most harmful energy sources for global warming all over the world. Peat is widely used in Finland for energy investments from 2005.

4 Heating systems in China

With the development of the construction industry and the defects of the traditional way of heating, the new heating ways are constantly on the rise. The environmental governance in heating areas are facing a big problem, which includes adjusting the energy structure, reducing the pollution caused by burning coal, and solving the contradiction between power supply and demand.

Currently, the heating systems are mainly relying on fuel (including coal, oil, gas) energy, water, air, ground etc. The scale and the end of the form of the different heating system are determined by the different heat source. With a huge amount of building energy consumption in China, we have to formulate relevant energy policy which is based on the actual state of nation.

4.1The background of Chinese heating systems

Chinese northeast region is a huge market for heating systems. The northeast region includes Liaoning, Jilin, Heilongjiang province and four cities in Inner Mongolia which owns jurisdiction area of 626,000 square kilometers and the population is 150 million, is the most important area of the heating systems in China. In winter, the lowest temperature is -40. The northeast people need to use the heating system for a long period every year which last 4 and 6 months. So protection of the residents of these areas is a very important thing for the government. In recent years with the rapid and stable development of China's economy, people's living standard has improved. The heating system requires a higher level, and these have opened up a vast market for the heating industry. Not so long ago, Liaoning province has held the 16th Northeast International air conditioning and heat pump technology equipment exhibition. From 1998, this exhibition has been held for 15 sessions. The well-known enterprises, famous brands of the heating system at home and abroad will appear every year in this exhibition, the buyer’s purchase and decision-makers have increased year by year, known as the “The No.1 Northeast heating exhibition”.

4.2 Different types of heating systems

In the different types of heating systems, the use of fuel as energy resource systems is widely applied in some areas of China. They almost include some ways, such as: household heating, domestic gas boiler heating and low temperature and hot water radiant floor heating.

4.2.1 Domestic heating system

The specific way of the household heating is divided into three aspects:

1) Heat and power cogeneration: Power plants produce electrical energy, and use steam which is produced by turbine generators to provide heating to customers. It means producing the electricity and heating at the same time. Comparing with producing them separately, it will save fuel.

Advantages:
Economical
Energy-saving
High performance environmental protection
Disadvantages:
High investment
Long construction period
Heating is not flexible
Accidents and maintenance impact a lot
Management costs high

2) Centralized heating of regional boilers and small boilers: This system supplies the lives and manufacturing of the city or one region by using steam or hot water as a medium. The steam and hot water are delivered by pipes. It is also known as district heat supply. It is an infrastructure of energy construction.

Advantages:
1. Regional central heating boiler is equipped with a complete water source system
2. Smoke and dust removal devices are needed.
3. Good energy saving, environmental protection and operational efficiency.
4. Small investment
5. Construction period is short.

Disadvantages:
1. Low thermal efficiency of dispersed coal-fired boilers
2. Smoke and dust removal efficiency are not good

3) Centralized hot water for household heating

Advantages:

Easy to control and adjust the average heat for every house.

The consumption of heat is separate for every house.

Disadvantages:

The lock valve and the regulator valve should be installed which increases investment.

4.2.2 Domestic gas boiler heating

The specific ways of domestic gas boiler heating can be divided into two aspects:

1) Heating water system.

Advantages:

Clean and green, flexible adjustment, Energy saving

The equipment is small and exquisite

Easy to install and easy to operate

Ease of measurement

Disadvantages:

High cost compared with coal-fired heating system

2) Heating gas system

This system has the same advantages and disadvantages with the hot water heating system.

4.2.3 Low-temperature and hot-water radiant floor heating

Low-temperature and hot-water radiant floor heating system uses hot water (less than 60□)as heat medium which is circulated in the plates to heat floors. So the radiation and convection of heat in the ground is transferred to the rooms.

Advantages:

The thermal performance makes people comfortable

Energy saving

Ensures better air quality indoor

Convenient measurement

Disadvantages:

Increases the rooms of building

Increases the costs of construction

4.2.4 Electric film

When the electric film is heated, the carbon molecules will have a ‘Brownian motion’ in the electric field. Strongly friction and collision will be happened between the carbon molecules, which generate high heat energy. The generated energy is delivered outside through infrared radiation and convection. The rate of thermal energy convection can reach 98%. The electric film becomes warm rapidly because of the function of carbon molecules. When it is installed in the wall or ground surface, heat will be delivered to every corner of the room evenly.

Advantages:

Can work in high temperature;

Having the common advantages of the radiant heating;

Comfort and safety;

Saving water and area

Disadvantages:

High health and comfortable conditions

High operating costs;

The utilization rate is lower.

4.2.5 Air source heat pump

An air source heat pump can provide heating and cooling in your rooms, especially in the warm regions. It extracts heat from the outside air in the same way as a fridge extracts heat from its inside. It can get heat from the air even when the temperature is as low as -10° C. But these heat pumps also have some impact on the environment as they need electricity to run, but the heat they extract from the ground, air, or water is constantly renewed naturally.

Advantages:

High thermal efficiency;

Saving costs

Disadvantages:

Heating efficiency decreases as the outdoor temperature decreases, and should not be used in cold regions.

4.2.6 Water source pump

The principle is transferring the low level heat energy to high places by entering a small amount of high-grade energy (e.g. electricity). Water is respectively used as heating source in the winter and the cooling source of the air conditioning in the summer. In the summer the heat in the building is taken out and then released into

water. It can carry away heat effectively, making the room cool. In the winter, water source delivers heat to rooms by the pumps.

Advantages:

The heat capacity of water is big and it is easy to transfer heat.

Generally water source heat pump is heating performance is better than that of air source heat pump system.

Disadvantages

Restricted by the water source.

4.2.7 Ground-source heat pump

We have strongly introduced this heating system in the beginning of this thesis. Even though it is not widely used in our country currently, this can become a popular system for middle class and rich people. It is good for the decoration of the houses, and it is friendly for the environment.

4.2.8 Conclusions

Through the introduction of the different heating systems, it can be said that: Central heating is the preferred way of heating our homes for quite a long time. The utilization of heat pump technology is a new direction of applications in the future. Energy is the key of the heating systems, include heaters, electric heating, electric film etc. If the nuclear and electricity power is enough, the radiator and electric film is more suitable because of the high efficiency.

4.3 The background of the ground source heat pumps in China

With emphasis on the problem of energy crisis and environmental pollution, ground source heat pump is developing fast. There were 121 ground source heat pump enterprises in 2009, but there were only 80 enterprises in 2007. The following diagram shows Chinese ground heat pump station maps, covering almost every province. The ground source heating pump is also the most widely used in home heating system.

Figure28: The distribution of ground source heat pumps in China.
(Reference: http://www.dyrbw.com/)

4.4 Environmental aspects

Comparing these several Chinese heating systems, they all created energy by the fuels and electricity except the ground heating system. In China, people always use coal and gas as fuel. As we all know, the burning of the coal will create CO_2, which is an important gas, absorbing heat radiation form earth's surface which otherwise would have left the atmosphere. What is worse, the coal contains many impurities, for example, it contains sulphur, which reacts with oxygen and will generate SO_2. The SO_2 will generate Acid Rain. In addition, due to the insufficient burning, it generates CO. CO is toxic gas.

With the environmental aspect, the gas is better than the coal. Gas always burns more sufficiently than the coal, so the CO could be avoided. Currently, most of the gas is non-sulphur gas, so the SO_2 cannot be generated. Furthermore, the energy generated by the gas is greater than the coal.

Above all, gas is a better choice. When we talk about the electrical energy, which cannot be neglected, it can pollute the environment. Because in China, the most widely used heating equipment is thermal stoves. The coal is used for producing the energy

There is no doubt that the ground heating systems are incredibly environmentally friendly as they use the nature heat of the Earth with no emissions or toxicity involved.

So is it the perfect environmental heating system? Now, we would like to introduce the possible pollution of the ground heating systems.

1) The discharge of the hot abandoned water impacts the surface water environment
It means the abandoned water goes into the rivers and lakes, which causes the water quality to changes. Thereby the original function is changed.

2) Impacting the groundwater environment
If the abandoned water could not get into the sewer directly, it will pollute the underground water.

3) Impacting the soil environment
The disposable water which contains minerals is discharged into the open ditches. It increases the soil salinity. And the harmful substances cause the pollution of soil.

4) Impacting the geological subsidence
Excessive development of ground resources will result in sinking of land.

5 Development and comparison

After describing the different kinds of heating systems, and highlighting the basic two kinds of heating system, we would like to come up with some ideas to develop these two systems. After all, they are not perfect in efficiency. In addition, we want to compare these two heating systems in household structure, regional restrictions and which is better for our health.

5.1 Zero Energy Building in Finland

The amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building.

The locations of zero energy buildings in Finland: Kuopio, Järvenpää, Mäntyharju,Luukku/Aalto-Yliopisto

5.1.1 Eight things that unite all these buildings

1 Windows facing rather north than south.

In autumn and spring northern latitudes, the sun is shining very low which can easily overheat the building. (Hard to protect the windows) Extra energy is only needed during coldest winter days but facing windows directly to south causes more cooling than benefits from heating during the year.

2 Window type 2+2.

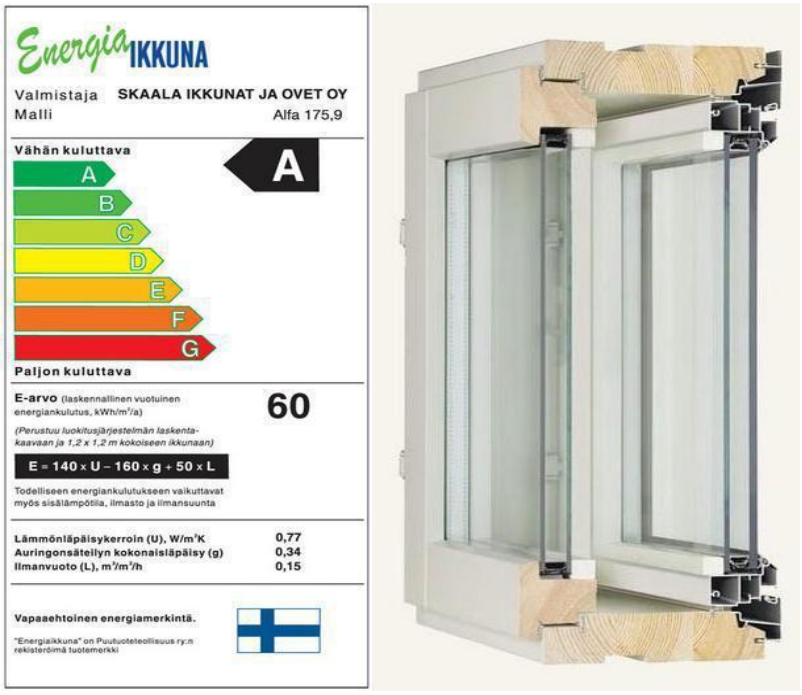


Figure29: Window type 2+2.

Big windows are used instead of many small ones due to avoiding cold bridges of the frames.

3 Floor area and competitiveness.

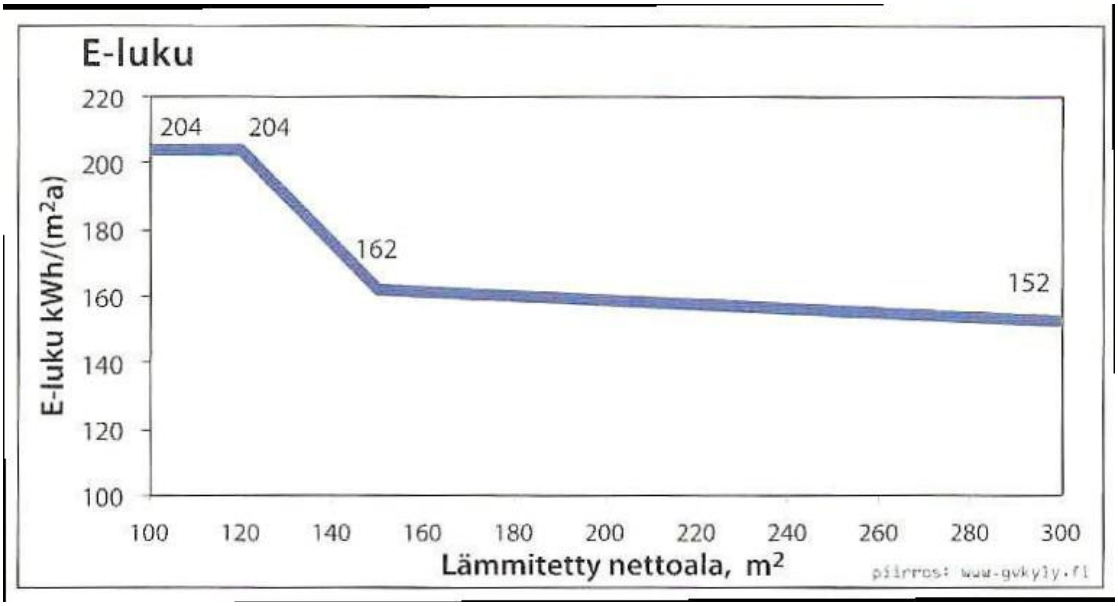


Figure30: Floor area with energy usage.
(Maaria Laukkanen, Zero Energy Building Technologies in Finland, 21.8.2012.
Area of the building is today taken in account also in building codes.)

4 Mechanical exhaust and intake air with effective heat-recovery demand based exchange rates, insulated air ducts.

Figure31: Mechanical exhaust.
(Maaria Laukkanen, Zero Energy Building Technologies in Finland, 21.8.2012.)

5 Wood and solar good combination: can provide all needed energy.

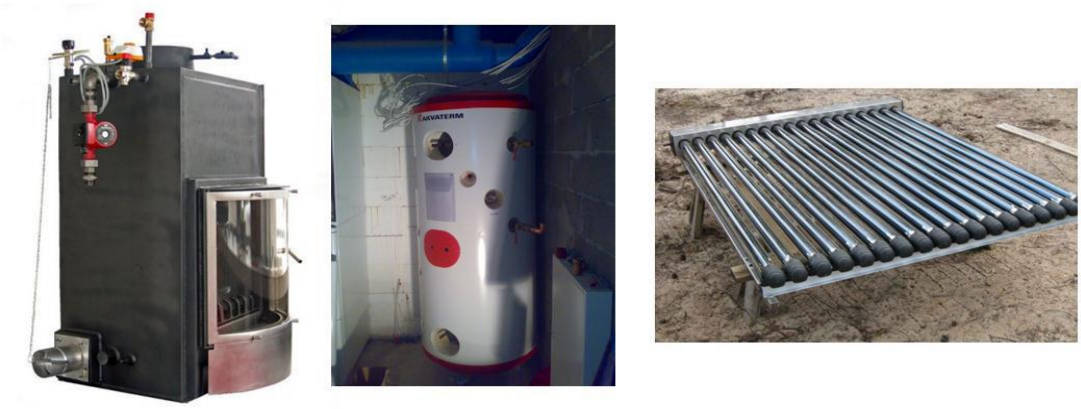


Figure32： Wood and solar energy combination.
(Maaria Laukkanen, Zero Energy Building Technologies in Finland, 21.8.2012.)

On the right Savumax chimney / warm water accumulator combination restores heat from the flue gases (from sauna stove, fire place). Below water circuited fire-place, warm water storage and solar heat collectors.

6 Low temperature ground-floor heating.

Figure33: Ground floor heating structure.
(Maaria Laukkanen, Zero Energy Building Technologies in Finland, 21.8.2012.)

For heating and cooling, each room can be separately adjusted. It can be done by many different energy sources.

7 Pre-heating and pre-cooling intake-air.

8 Smart HVAC automation and friendly user interface.

Figure34： Automation interface in family.
(Maaria Laukkanen, Zero Energy Building Technologies in Finland, 21.8.2012.)

Figure35: Smart interface of heating system.
(Maaria Laukkanen, Zero Energy Building Technologies in Finland, 21.8.2012.)

5.2 Improving the Chinese ground heating system

1) In order to develop conditions and technical standards, we must conduct in-depth analysis and research.
2) Ground source heat pump system is a central air conditioning system which combines the functions of cooling and heating. The conversion of heating and cooling is using the four-way valve to change the flow direction by refrigerants. In order not to change the normal operation of the system in the future, when we choose the exchanger, we use the same specifications to the condenser and the evaporator as the heat exchanger. However, in the practical application of the system, its heat absorption should be less than the heat release, which means that the number of pieces of the condenser should be more than the pieces of evaporator.

If we use the electric three-way valve to control the water circulation, in the winter and summer conversion, we just change the flow direction of the water without changing the flow of refrigerant. If we design the system in that way, the four-way valve could not be used. For that reason the pieces of the condenser and evaporator could be matched correspondingly, which does not affect the normal operation of the system. Comparing with original system, the performance is better.

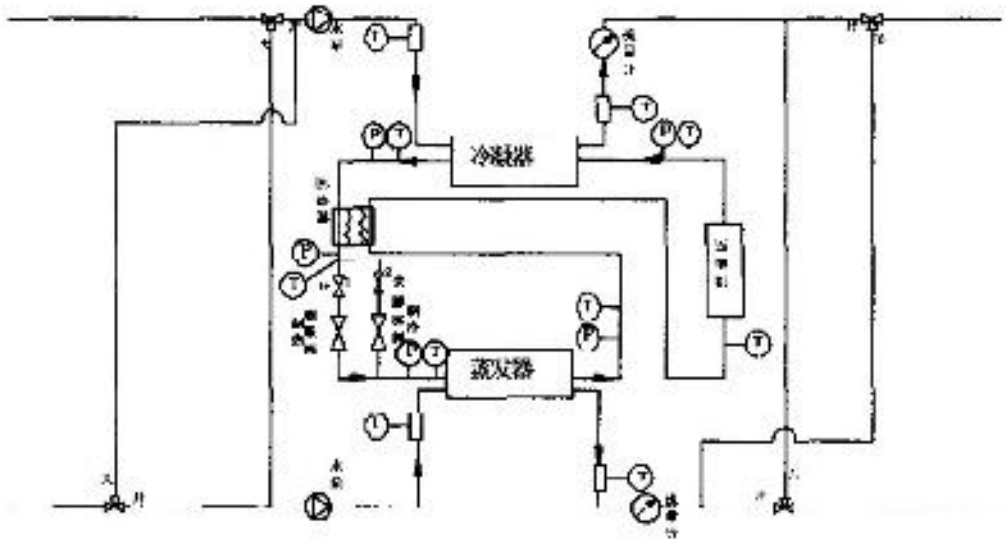


Figure36: The structure of China ground heating.

The thermal expansion valve is relying on the size of the degree of superheat of the refrigerant at the outlet of the evaporator to adjust the opening degree of the valve, then it can adjust the cooling capacity of the unit automatically, which in order to require the change of external heat load. The capacity of the thermal expansion valve is related to the flow of refrigerant, cooling condition, the differential pressure in the valve. When the capacity is too small, it will cause heat transfer area in evaporation is not fully utilized, refrigeration is declined. On the other hand, when the capacity is too large, it impacts the regular performance, it will increase the evaporator fluctuations in temperature and the efficiency of superheat refrigeration system will decline. In some severe cases the fluid hammer phenomenon will be created.

Due to the fact that the heating capacity and cooling capacity are respectively different in the winter and summer. The flows of refrigeration are different, but the range of adjustment in the thermal expansion valve is not big. If we take a compromise on selection of the expansion valve, it must affect the operation of the system effect. But if we use the double-way expansion valve in the system (winter and summer, respectively), so the demand of the heating in the winter and cooling in the summer can be reached. In the design, we can get parallel connection to the two expansion valves in the pipeline, using the solenoid valve to control the conversion so that it can greatly improve the performance of operation of the system.

3) Currently, in China, some businessmen want to catch this opportunity to manufacture heat pumps. But there is still not a strict regime to supervise these products. So the customers always buy the low level quality products. I suggest the quality administration could inspect the products more strictly.

4) In the heating pump system, China has started latter than western countries. Though it is a fast developing project, the operators still do not know much about that. We need to get the workers trained well. Also the government can motivate the companies to develop this project well.

5.3 The comparison between the water heating systems and ground heating systems

We will compare these two heating systems in 4 aspects: housing structure, regional restrictions, health, and carbon emission.

5.3.1 Housing structure

Houses and apartments in Finland are of high quality and with a good heating system, and have all modern conveniences. Houses are always made of wood, and heated by hot water. And also in apartments the hot water heating system is often used. The advantage is that it is energy efficient, quiet and easy temperature control.

In China ground heating system is always used in villas. Because the radiator uses hot and cold air circulation, it exchanges in the interior space. So it is more suitable to occupy a small area of the room.

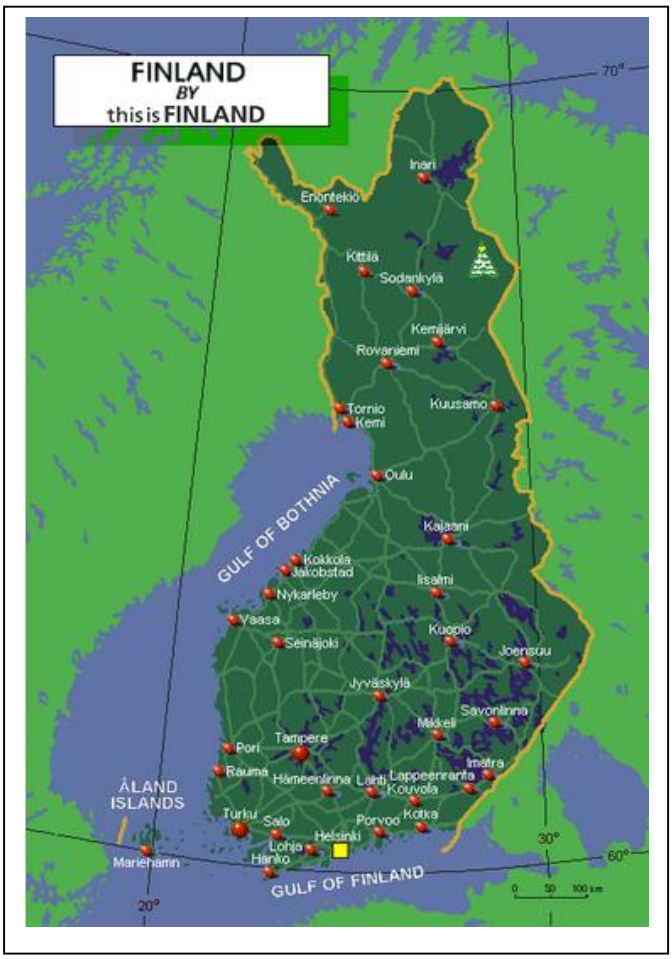
In a villa, radiator needs to occupy large flat area, and will affect the beauty of Villa. Floor heating is currently the most popular villa heating method.

5.3.2 Regional restrictions

The area of application of ground source heat pump is basically unrestricted. But if you build a ground heating system in the mountains, then drilling wells will increase the cost, because of the rocks.

In cold regions, taking the lower equipment investment and scientific reasons into consideration, it is better to use radiator system. For example if we choose a ground source heat pump for saving fuels. We cannot get the applicable temperature as we want. The underground temperature is not warm enough to get the whole house warm. So this area is recommended to use radiator heating system, such as water or gas radiator heating system.

In the hot summer and cold winter area, it is recommended to choose solar water heaters.



In the southern area of Finland, the heat pump is in use most of the year (90%-100%).

In the middle and north area of Finland, there is a combination of heat pump and electric heating elements.

Heat pump water heaters are most useful in hot-or-warm climates.

In cold climates, heat pump efficiency drops when back-up heat elements are used to heat water

During winter, the furnace heats the air that heat pump uses to heat water.

Figure37: Map of Finland.

5.3.3 Health

On the basis of the heat demand of the human body, the ideal temperature is ‘warm feet and head cool’ (Chinese traditional medical science). It is also proved by the western medical science that when the feet are not warm, we feel cold. If it happens for a long period, the blood pressure will increase correspondingly. People can get sick. Scattered radiant heating is the best heating system; it can make the indoor surface temperature uniform. The temperature decreases from the bottom to up gradually. And it also does not cause dirty air convection, the interior is very clean.

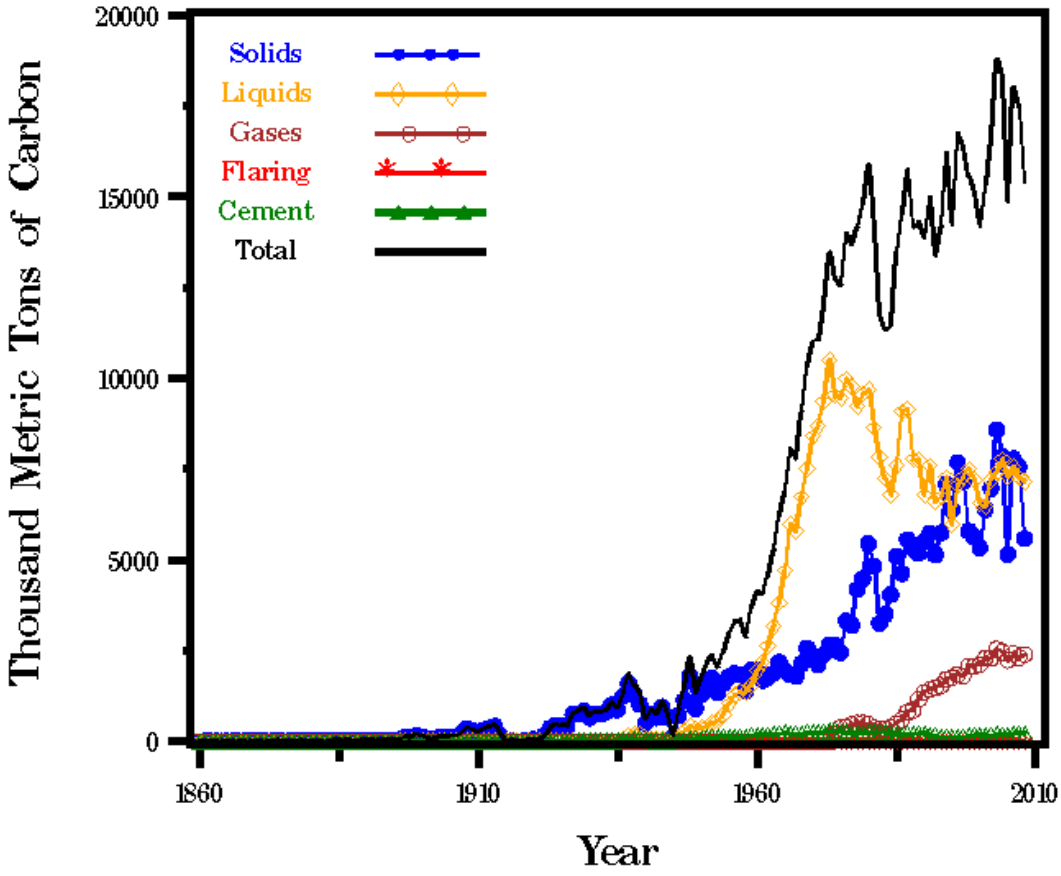
Generally, the temperature created by ground heating system is less than the temperature in the water radiant heating system. So the water in the room cannot be evaporated and people would not feel dry. It is the most common phenomenon in Finnish apartments. Especially in a small room where a water heating system is installed.

6 Conclusions

6.1 Carbon emissions between Finland and China

Nowadays, the issue of carbon emissions is the most popular social phenomenon. Between the government of Finland and China, all take responsibilities of environmental protection. In the following, we will introduce the carbon emissions between Finland and China. It will be better to choose the heating system when take environmental protection into consideration.

Table38: CO_2 Emissions from Finland.



This picture provides the CO_2 emissions in Finland from 1860-2010. We can figure out that the emissions of CO_2 rapidly increased from 1960-1985. After that they fluctuated from 1985 until now. It means that when Finnish people pay attention to the environment protection, the CO_2 emission will get well controlled. Solid and liquid fuels were used more than others. CO_2 emissions from gaseous fuel consumption (% of total) in Finland were 14.90 as of 2009. Its highest value over the past 49 years was 15.73 in 2008, while its lowest value was 0.00 in 1960. CO_2 emissions from other sectors, excluding residential buildings and commercial and public services (% of

total fuel combustion) in Finland was 4.07 as of 2010. Its highest value over the past 50 years was 7.35 in 1961, while its lowest value was 2.74 in 1994.

CO_2 emissions from other sectors, less residential buildings and commercial and public services contains the emissions from commercial/institutional activities, residential, agriculture/forestry, fishing and other emissions not specified elsewhere that are included in the IPCC Source/Sink Categories 1 A 4 and 1 A 5. In the 1996 IPCC Guidelines, the category also includes emissions from autoproducers in the commercial/residential/agricultural sectors that generate electricity and/or heat. The IEA data are not collected in a way that allows the energy consumption to be split by specific end-use and therefore, autoproducers are shown as a separate item (Unallocated Autoproducers).

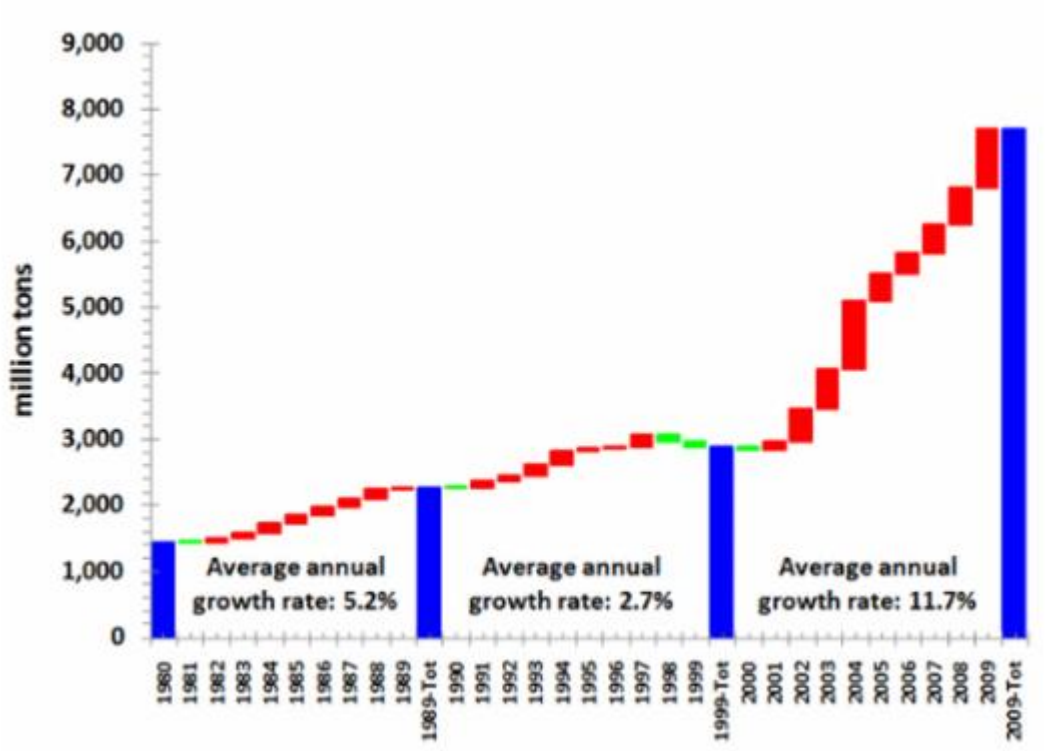


Table39: China CO_2 Emission produced by Energy Use.

Before 2002, the capita carbon emission in China was below the level of world average. Due to the development of the industry, the carbon emission was increasing rapidly from 1999. Until 2010, it came to the same level with Europe. Because of having a large population of 1.3 billion people, the amount of carbon emission is in the first position nowadays in comparison with America.

6.2 Choosing a heating system

Some of the Finnish families use the radiator heating system. But in different areas in China, people use different heating systems. In the north of China, the temperature in the winter is similar to Finland; people always use the same heating system which is used in Finland. Therefore, the carbon emissions are almost the same because of the same heating system. But in the middle of the China, people use air conditioners to adjust the temperature. In the south of China, people do not need to use the heating system. For decreasing carbon emissions, we suggest the north people to use the radiator heating system and the people who live in the middle of China, to use the ground source heating system. In the middle of China, people are normally living next to the yellow and Yangtze River, the abundant water results in using the ground source heating pump.

7 Symbol

CHP = Combined Heat and Power

IEA = International Energy Agency

IPCC = Intergovernmental Panel on Climate Change

LPG = Liquid Petroleum Gas

MSW = Municipal Solid Waste

RES = Renewable Energy Resource

RV = Relief Valve

TPES = Total Primary Energy Supply

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