CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF CIVIL ENGINEERING

DEPARTMENT OF MICROENVIRONMENTAL AND BUILDING SERVICES ENGINEERING

HEATING SYSTEM WITH RENEWABLE ENERGY SOURCES

BACHELOR PROJECT

ANETA BUREŠOVÁ

Bachelor thesis supervisor : **Ing. Daniel Adamovský, Ph.D.**

2015/2016

CZECH TECHNICAL UNIVERSITY IN PRAGUE
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BACHELOR'S THESIS PROPOSAL

study programme: Civil Engineering
study branch: Building structures
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Student's name and surname: Aneta Burešová
Assigning Department: Department of Microenvironmental and Building Services Engineering
Bachelor thesis supervisor: Ing. Daniel Adamovský, Ph.D.
Bachelor thesis title: Heating system with renewable energy sources
Bachelor thesis title in English Heating system with renewable energy sources

Framework content of Bachelor thesis: Design a heating system with renewable energy sources. Calculate heat losses of the building and design heating emitters. Define a suitable heat source, which use renewable energy. Design particular components of the heating systém and the plant room. Draw plans of the heating system in all building's floors and main sections (esp. room with the heat source), write technical report. Write a thesis focused on relation between underfloor heating and different types of heat sources.

Assignment date: 15.2.2016 Submission date: **20.5.2016**
(Fill in the last day of instruction in the respective semester)

If a student fails to submit the Bachelor thesis in the preset term, they are obliged to justify this fact in advance in writing, and if this request is granted by the Dean, the Dean will assign the student a substitute date for submitting the Bachelor thesis. If, however, this fact is not appropriately justified or if the request is not granted by the Dean, the student may register for the Bachelor thesis for the second time. A student who has failed to submit the Bachelor thesis in the preset term at the second registration and has not appropriately justified this fact in writing, or if the student's request has not been granted by the Dean, shall have their study terminated under § 56 of Act No. 111/1998 Coll. (University Act), (SEC CTU Art. 21, par. 4.).

The student takes notice of the obligation of working out the Bachelor thesis on their own, without any outside help, except for consultation. The list of references, other sources and names of consultants must be included in the Bachelor thesis.

Bachelor thesis supervisor

Head of department

Date of Bachelor thesis proposal take over: 15.2.2016

Student

This form must be completed in 3 copies – 1x department, 1x student, 1x Student Registrar (sent by department)

No later than by the end of the 2nd week of instruction in the semester the department shall send one copy of BT Proposal to the Student Registrar and enter data on BT into the Faculty KOS database. BT is assigned no later than in the 1st week of the semester in which the student has registered for BT. (Dean's Instruction for Implementation of Study Programmes and FGE at FCE CTU Art. 5, Par. 7)

Declaration

I do solemnly declare that I have written the presented research thesis by myself without undue help from a second person others and without using such tools other than that specified.

Prague, 16.5.2016 ……

Aneta Burešová

Acknowledgement

I would like to thank to my supervisor Ing. Daniel Adamovský, Ph.D. for the valuable advice he gave me during the consultations of my project. Special thanks go to my parents for their love and encouragement during my studies. And finally I would like to thank my friends and whole family for their continuous support and their tolerance during the writing of this thesis.

Content

Abstract

The topic of this bachelor project is the design of a heating system for a chosen administrative building. The aim is to design the most suitable heating system which provides thermal comfort to the users and also protects the environment and mitigates the impact on climate change by choosing an appropriate renewable source of energy. The main parts of this bachelor project are the calculations of heating system, drawings and the technical report with described final solution. The main part is supplemented by a research on radiant floor heating and how it works with different types of renewable sources of energy. The research shows that the radiant floor heating system is a good way to provide thermal comfort in living spaces and offices and in combination with a suitable source of energy it is a cost and energy efficient solution. The final solution for this project is a geothermal heat pump with horizontal collectors due to the favourable geological conditions in the area of construction and the size of the building plot, which is also in sole ownership of the building's owners.

Keywords: radiant floor heating system, renewable energy source, thermal comfort, geothermal heat pump

Abstrakt

Předmětem této bakalářské práce je návrh vytápění pro vybranou administrativní budovu. Cílem této práce je návrh optimálního vytápěcího systému, který zajišťuje tepelnou pohodu uživatelům budovy a zároveň chrání životní prostřední a snaží se předcházet změnám klimatu díky volbě vhodného obnovitelného zdroje energie. Hlavní částí této bakalářské práce jsou výpočty, výkresy a technická zpráva popisující finální řešení. Hlavní část je doplněna o rešerši zaměřenou na podlahové vytápění, a jak funguje s různými obnovitelnými a zdroji energie. Výsledky rešerše ukazují, že volba podlahového vytápění jako otopné plochy výrazně přispívá k tepelné pohodě v obytných místnostech a kancelářích a spolu s vhodným zdrojem obnovitelného zdroje energie je výhodným řešením z hlediska úspory energie a nákladů na vytápění. Vhodným řešením pro tento projekt se ukázalo být tepelné čerpadlo s plošnými kolektory vzhledem k nadstandardním geologickým podmínkám z hlediska čerpání geotermální energie a také s přihlédnutím k velikosti pozemku, na kterém se budova nachází a který je ve vlastnictví majitelů budovy.

Klíčová slova: podlahové vytápění, obnovitelné zdroje energie, teplená pohoda, tepelné čerpadlo

Introduction

The topic of my bachelor project is the design of the heating system for the administrative building. Nowadays people spend most of their life inside so the responsibility of the engineers and designers while working on a new project is to create an environment which is comfortable and not harmful for the people who spend their time there. The office environment is one of the crucial ones because people spend there approximately 8 hours a day (which is one-third of the whole day). The quality of the internal environment in the workplace also influences the productivity of the employees. In order to provide thermal comfort in the internal environment, I decided to use the radiant floor heating system as heat emitters for the offices and meeting room in the administrative building in my bachelor project. Another reason to use the radiant floor heating system is the fact, that it works with a lower temperature of the heating medium within the system, and so it decreases the energy consumption. As a part of my bachelor project, I research the radiant floor heating system and the way it works with different types of renewable energy sources. The purpose of this research is to find the ideal source of energy for the chosen administrative building, taking into account that in most rooms there is the radiant floor heating system.

The first part of this thesis is focused in general on the radiant floor heating system. It describes the history of this type of heating system, how the system works and what the types of radiant heating floor system are. This part of the work should give an idea why I chose a radiant floor heating system and what advantages of such a system are.

The second part of this thesis characterizes four renewable sources of energy which were a possible solution for the chosen administrative building. These four renewable sources are generally described and also, there is the part which specifies how these sources work with the radiant floor heating system.

Introduction to the radiant floor heating system

History

The idea to design radiant floor heating system is not an innovation. The system of heating of buildings with the use of radiant floor heating was already used by the ancient Romans. At the time, the radiant floor heating system was created by constructing a gap under the floor. The gap would be filled with warm air and combustion products from a nearby furnace. The hot air would flow through the gap, heating up the surrounding masonry and the floor above it, thus heating up the space above. One example of such a building is the ancient Rome Hypokaustum which was built in 80 BC. [1] Although the history of radiant floor heating is that ancient it started to be more popular recently and it is becoming to be frequently used in the modern construction. Heating system with water used as heat transfer medium started to be used in the 18th century in France. The combination of water as a heat transfer medium and radiators as heat emitters was commonly used at the beginning of 20th century. British company Crittal started to insert piping into the construction (mostly floors and ceilings) in 1926. [2]

General description

There are three ways of heat transfer: convection, conduction, and radiation. The radiant floor heating system transfer 55% of heat by radiation (remaining 45% of heat is transferred by convection) which means that firstly surface of other constructions and objects are heated and after that the air is heated from these constructions and objects. This is the reason why the surface temperature is higher than the temperature of ambient air. Nevertheless, the surface temperature is still quite low compared to the other types of heat emitters. The surface temperature of a radiant floor heating emitter is between 25 to 34°C. [1]

The radiant floor heating system is considered to be a low-temperature heating system.

There are many advantages connected with the radiant floor heating system. For example, it does not produce any noise, it operates with low-temperature water and it consumes a low amount of energy. [3] The very important advantage of radiant floor heating is its ability to create thermal comfort in the room. This is the main goal of any heating system in general. Thermal comfort means that the system has to create such conditions that a person in the room feels neither too cold nor too warm. The amount of energy received by a human has to be in equilibrium with the amount of energy produced by the metabolic heat flow. The human

factors affecting thermal comforts are: metabolic rate and clothing insulation. The indoor environment factors affecting thermal comfort are: internal temperature, mean radiant temperature, internal air velocity and humidity of ambient air. To create thermal comfort is necessary to eliminate the situation of local discomfort, such as is the case when a barefoot person steps on the heated surface. The knowledge of the surface material and the purpose of the room is crucial for the design of the radiant floor heating system. For example, the optimal surface temperature of the room with surface material – cork where stands a person with barefoot for 10 minutes is 26°C. The very important attribute of the room to provide thermal comfort for its occupants is the spatial distribution of temperature. The ideal state of heating is the moment when there is a slight difference between temperatures at the level of the floor and between the temperatures under the ceiling. Figure 1 shows the ideal heating curve and the heating curve of radiant floor heating system. It can be seen in Figure 1 that these two curves are very similar which is one of the advantages of the radiant floor heating system. [1]

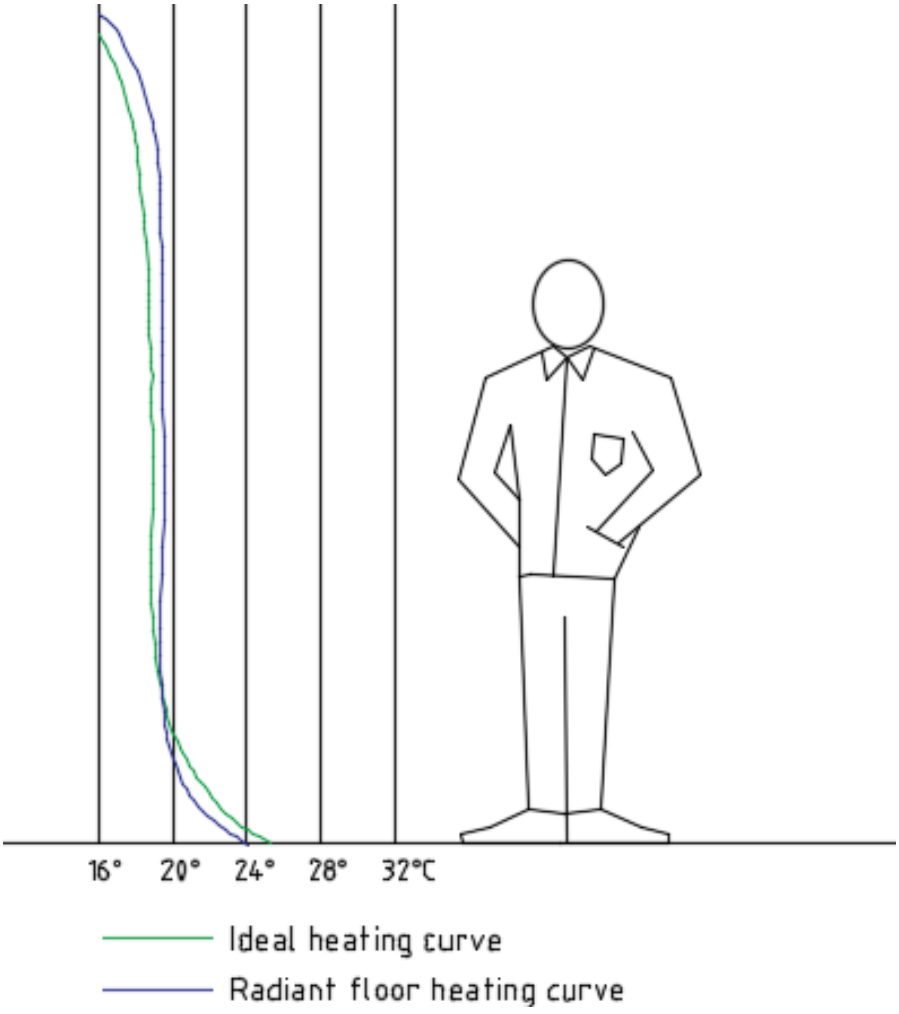

Figure 1: *Ideal heating curve and radiant floor heating curve*

The way the room is heated up while using radiant floor heating system is quite different from the traditional system with radiators. Figure 2 shows the scheme of the heat transfer while using convectional heating system with radiators as heat emitters.

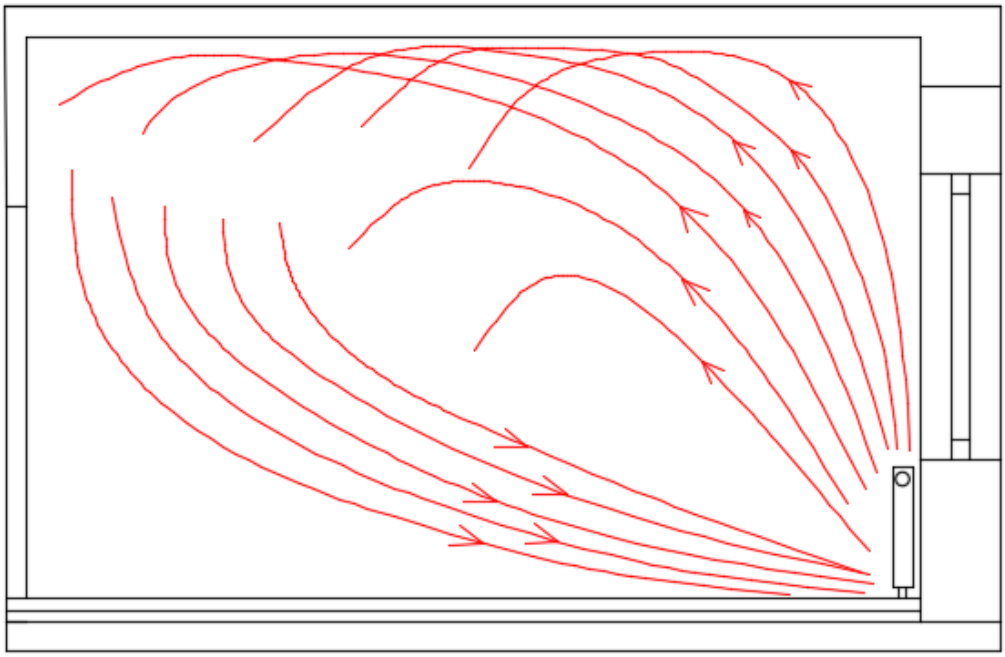

Figure 2: *The heating transfer while using convectional heating system with radiators*

Figure 3 shows the scheme of heat transfer in the room while using the radiant floor heating system. [2]

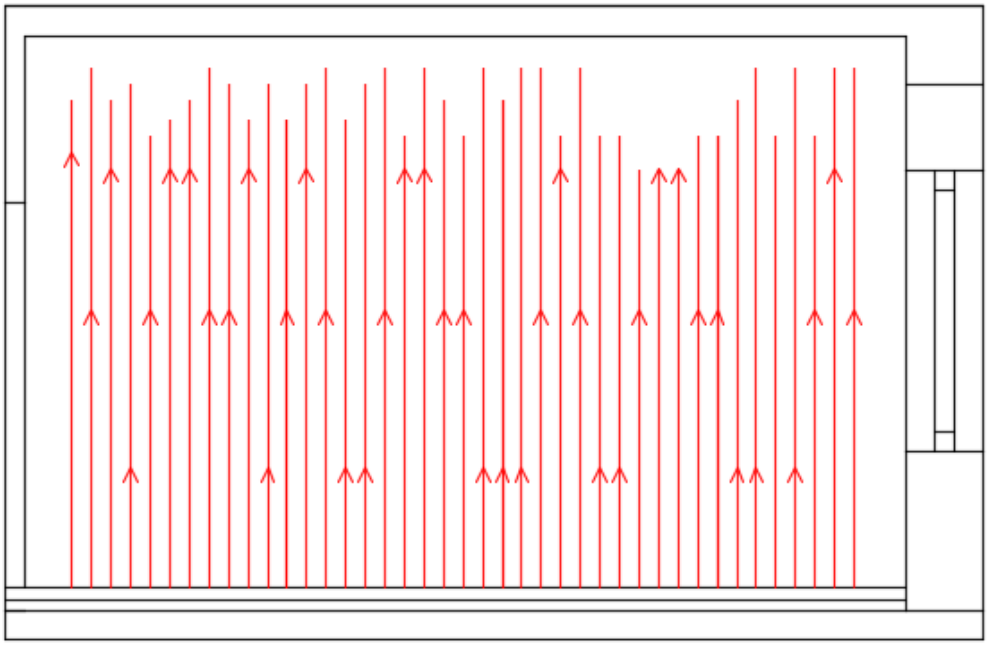

Figure 3: *The heating transfer while using the radiant floor heating system*

The possibility to use radiant floor heating system is determined by the building itself. It has to fulfil a set of requirements to ensure that the system is suitable for the building. The average heat loss should not be lower than 20 W/m^3or the average annual consumption of energy should not be lower than 80 kWh/m^2. [2]

Radiant floor heating types

There are different ways to divide radiant floor heating. It can be divided according to:

- Heat transfer medium
- Method of assembly
- Heating tubing layout
- Piping material
- Embedding of pipes

Heat transfer medium

The heat transfer medium can be water, electricity or air. The most common heat transfer medium is water because it has very good properties regarding transferring heat. While designing the hot water heating system attention should be paid to oxygen diffusion, which is a chemical reaction that can easily destroy pipes. Such a failure can lead to water leakage into the construction. The moisture in the construction can cause varieties of problems, for example, occurrence of moulds, or deterioration of material and its loss of strength. Nowadays the resilience of materials is very good so the oxygen diffusion is not the reason to be worried. One of the easy ways to prevent oxygen diffusion is to install pipes with an oxygen diffusion barrier. Another way is to design the system where the presence of ferrous materials is eliminated. [3] Electricity as a heat transfer medium is used in a way that it creates electric resistance. The electric radiant floor heating area can be divided according to its working mode into a fully accumulated, a partially accumulated and a convector heater. The depth and the construction of the floor are the main determinants of how the heat flows divide in the upward or downward direction. Air as a heat transfer medium is the very oldest method of heat transfer that is not used at the present time. Air as heat transfer medium was used for example in ancient Rome Hypokaustum for 80 BC. [1]

Method of assembly

The method of assembly is divided into a wet process, a dry process, a usage of module climate board or other similar components and a usage of the capillary mat. The wet process is when the piping is assembled inside a concrete layer. Firstly the piping is laid and then the

concrete is poured over it. It works with the water heated from 35 to 55°C. The dry process is when the piping is placed in an insulation layer under a concrete slab. This setup allows the water to be heated in the range from 40 to 70°C. The module climate boards are hollow profiles produced exactly for this purpose. It works with the water heated to low temperatures in the range from 25 to 35°C. The last possible method of assembly is the usage of the capillary mat which is very rarely used for radiant floor heating and more often it is used for wall and ceiling heating system. [1]

Heating tubing layout

There are two types of layouts. One of them is called the meander and it can be seen in Figure 4. This system works in a way that the warmest water is lead firstly to an area near a window, because that is the location with the biggest heat losses, and after that the water flows in the direction of an internal wall. As water flows through the pipes, it is decreasing its temperature. Space is not heated symmetrically, but the difference is in balance with the local heat loss of the room, so it does not influence thermal comfort of the room.

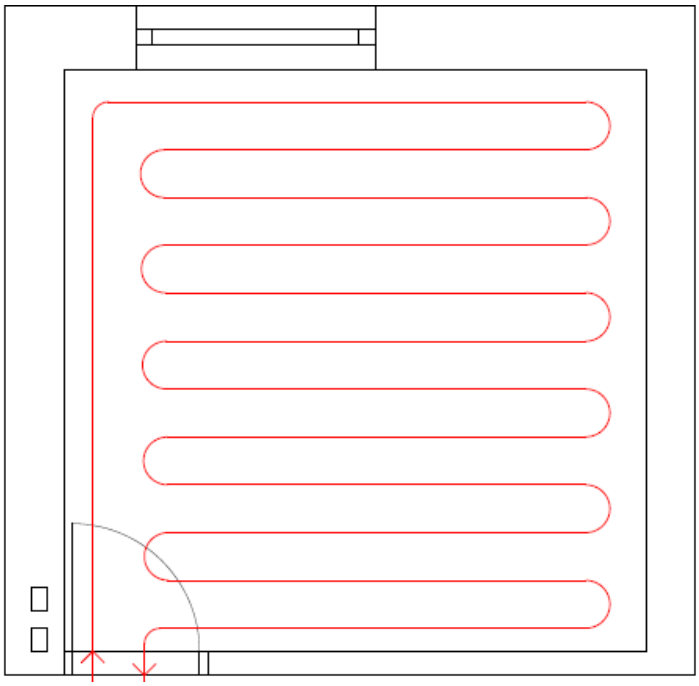

Figure 4: *The heating tubing layout - meander*

The second type of layout is in the shape of a spiral and it can be seen in Figure 5. The biggest advantage of this layout is that the warmest water in the heat pipes is heating up the edges of the room first and then it is flowing to the middle of the room and then back.

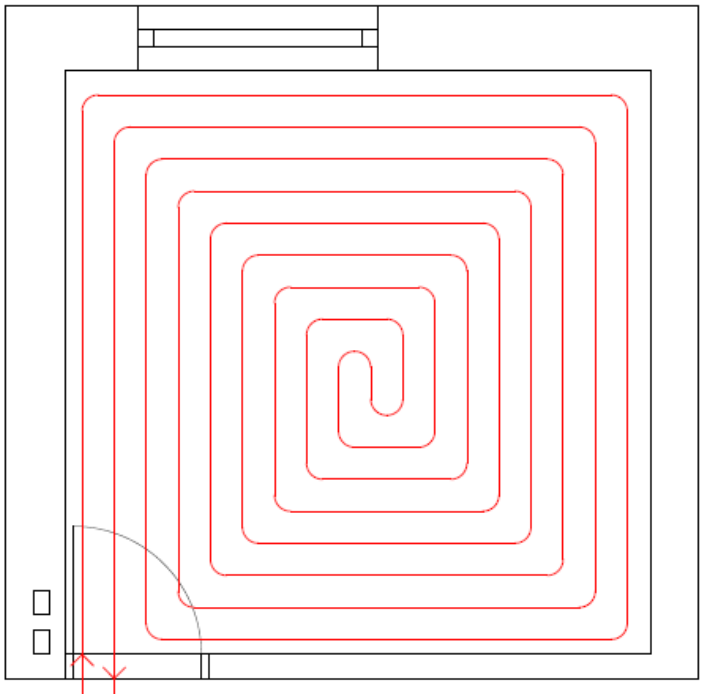

Figure 5: *The heating tubing layout - spiral*

Material of piping

The material used for piping can be metal (frequently copper), plastic or the piping can be multi-layered. Copper is an old traditional material for heating systems due to its high resilience and durability. Copper is very smooth so the friction is minimized. The piping from plastic has already become more popular, because the manipulation with them is easier and they are also very flexible. The first plastic material used for tubing was Polybutylene (PB) but it was replaced by PEX tubing. PEX is crossed-linked polyethylene and its advantage is that it can be used with a wide range of temperatures and pressures. There is also a possibility to use multi-layered piping, which means that it has metal and also plastic layers and it combines properties of both materials. [3]

Embedding of pipes

There are many different ways to embed the pipes in the system. The basic division is to those that are built-in and those that are freely lied down. The embedding of pipes is above a hydro insulating layer from PVC or PE, which is on an insulation board. In the case of usage of the modular board, there is no need to use a dedicated hydro insulation layer, because these systems already have a specially prepared the surface working as hydro insulation. The piping can be embedded by tying to a net, by plastic clamps to a net, by cladding them to a special plastic lath, by clamps to insulation boards, by pushing them into the system boards etc. [1]

Floor construction

The construction of the floor has a big influence on the radiant floor heating system efficiency. Therefore it has to be decided at the design stage about the heating setup so the floor construction can be arranged in a way that it would suit best the chosen solution.

Different sources of energy used with the radiant floor heating system

The radiant floor heating system is the low-temperature system. It works with a big variety of heat sources. Gas- and oil-fired boilers are the most common type of heat source, but nowadays it is starting to be more and more popular to use a combination of the radiant floor heating system with some renewable source of energy. [3]

Solar energy

The solar energy in the form of solar radiation is used to heat the building by using solar collectors. They can be divided to two types of solar collectors: covered solar collectors (glazed) and unglazed solar collectors. There are different parts to the total heat gains of solar panels. It consists of the long wave and short wave solar radiation exchange, energy gains from rain, convective heat exchange with air and the heat conduction at the bottom side of the solar panel. The heat gains can be seen in Figure 6. [4]

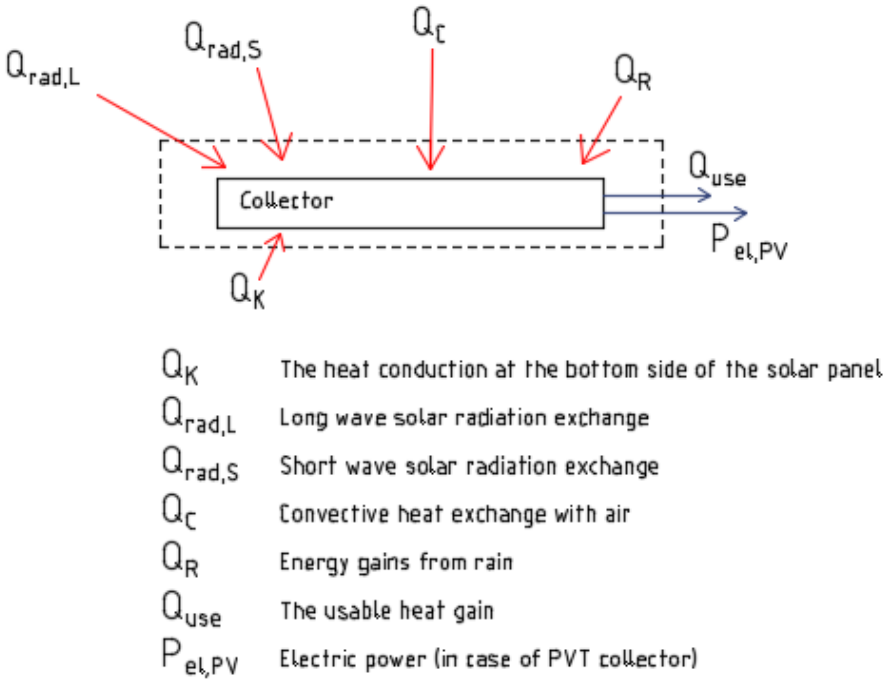

Figure 6: *The heat gains of a solar collector*

For the purpose of radiant floor heating system a flat plate collector (FPC) or a compound parabolic concentrating (CPC) solar collector can be used. [5]

Flat plate collectors

A flat plate collector belongs to the group of covered collectors. It consists of flat glazing and a flat sheet of absorbing material, which can be made from copper, stainless steel or aluminium. It usually works at a temperature range from 40 to 80°C. There are different variations of this type of collector. For example, there can be different layout of pipe inside of collector, it may contain ventilation hole or it can be already designed with integral storage tank for hot water. [6]

Compound parabolic concentrating solar collectors

The idea of compound parabolic concentrating solar collectors was firstly proposed in 1975. The CPC can reflect and absorb big amounts of solar energy because it works as a system of surfaces that allows energy to be absorbed by several internal reflections. The outlet fluid's temperature can achieve maximally 95 °C. Currently there are studies into the optimization of the design of these collectors so it would reduce the price and increase their efficiency. [7]

Solar energy and radiant floor heating system

When solar energy is a source of energy, it is suitable to be used for the radiant floor heating system and also for a domestic water heating system, because it can be designed in a way that the heated water is accumulated in a storage tank. The water for radiant floor heating system is extracted from the lower part of the tank because the coolest water has the highest density so it is accumulated at the bottom part of the storage tank. The water used as a domestic hot water is extracted from the upper part of the tank because it has a higher temperature there. [8]

The Easter Mediterranean University in North Cyprus held a research comparing the efficiency of Flat plate collectors and Compound parabolic concentrating solar panels used for radiant floor heating. The biggest difference between these two types of collectors is the maximum temperature of outlet fluid. The research was held on the 13th of January, which is the coldest day of the year at Cyprus, and it showed that the 2 m^2 of compound parabolic concentrating solar panels perform the same as 8 m^2 of flat plat collectors. [5]

The usage of solar collectors for the radiant floor heating system is the most efficient in the warmer areas with the high number of hours of the sun per year. There are a number of

studies focused on the use of solar energy for radiant floor heating systems. They are held for example in Turkey, Beirut or South Korea.

Heat pumps

Heat pumps belong to renewable sources of energy. They work on the principle, that it basically pumps the energy from the surrounding area. The most common medium to transfer the energy from the surrounding area is some form of liquid, for example denatured alcohol. This medium is heated in the collectors dug in the soil and afterward, it heats the refrigerant in the evaporator. The refrigerant in the evaporator evaporates and the gas that has arisen goes to the compressor where it is compressed and due to the increased pressure, it is heated up. This heated up refrigerant goes to the condenser where it heats up the heat transfer medium in the heating system or it can heat up the domestic hot water. The refrigerant condensates in the condenser and in the form of a liquid continue to the expansion valve where it is cooled down back to its initial temperature. From the expansion valve, it goes to the evaporator and the whole cycle starts again. The principle as described above can be seen in Figure 7. [9]

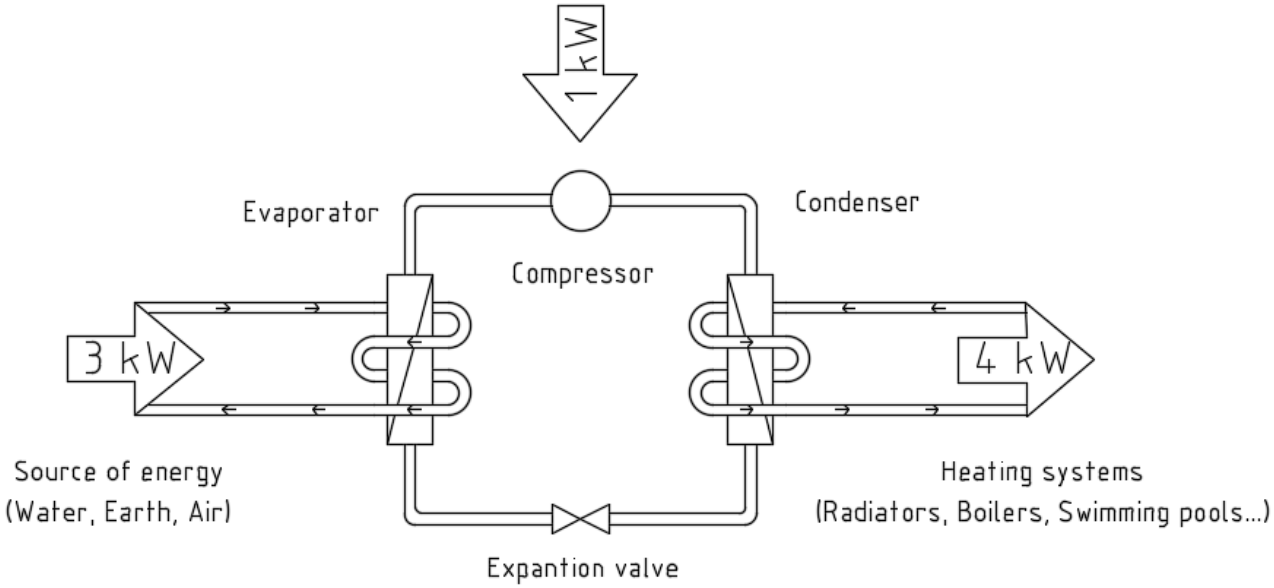

Figure 7: *The principle of heat pump*

The main parameter of heat pumps is COP – Coefficient of Performance. This parameter describes the efficiency of the heat pump.

The cost of the system with heat pumps is higher than the cost of ordinary systems depending on the type of heat pumps (the most expensive solution is the geothermal heat pump). But the return of the investment is typically in 3 - 10 years. [10]

The usage of heat pumps drastically reduces greenhouse gases leakage to the atmosphere, especially production of CO_2. [11]

Heat pump: Earth/Water

Geothermal heat pumps use a source of energy earth ground. They are extracting energy from the earth and transfer it to the building heating system. One of the advantages of this system is that in the summer heat pump is able to work reversibly. That means it can extract energy from the building and transfer it to the ground so it cools down the building. There are two basic types of geothermal heat pumps. One of them is the vertical type and the second one is the horizontal. The horizontal type is the system when the pipes run horizontally below the ground and this system is very shallow so it is subjected to the seasonal variation of temperatures. The pipes of this system have to be situated below the ground under the frost line (typical depth is 1 to 2m). The horizontal type is more common than the vertical type because the cost is cheaper. The vertical type consists of vertical pipes in the hole ranging from 22m to up to 150m in depth (and it can be even more). In order to maximize the heat transfer, there can be used bentonite to fill the hole with the pipes. The advantage of this system is that is reliable and does not vary within the year because the pipes are in such a depth that the seasonal change does not affect them. According to The U.S Environmental Protection Agency (EPA), geothermal heat pumps are the most energy-efficient, environmentally clean, and cost-effective space conditioning system that is possible to use nowadays. [10]

Horizontally collector works on the principle that the soil accumulates the direct or non-direct energy from the sun (radiation, rain...) from this reason it is crucial that the ground with the horizontal collector is not covered. It is quite a simple solution regarding the cost and permits. The only aspect that is a disadvantage is the size of the land required for horizontal collectors. This part of the plot cannot be used in the future for other construction. [9]

The types of layout of horizontal collector:

1. Common layout that can equally pump energy from the soil as it can be seen in Figure 8

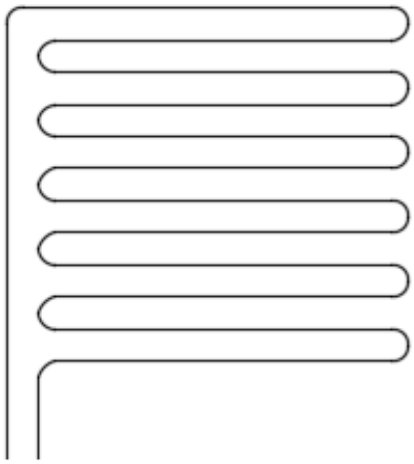

Figure 8: *Common layout of horizontal collector*

2. Spiral layout as it can be seen in Figure 9

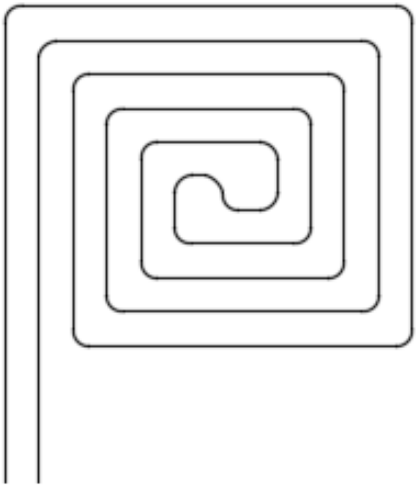

Figure 9: *Spiral layout of horizontal collector*

3. Special layout (slinky) which is good for the places with limited area as it can be seen in Figure 10

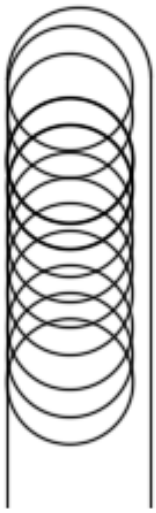

Figure 10: *Special layout (slinky) of horizontal collector*

Heat pump: Air/Water

The heat pumps with the source from air always need to be designed in the bivalent way, which means that there are two sources (heat pump and for example gas boiler). These sources cooperate and according to the external condition and amount of energy that can be taken from the air the second source starts to work to even up the internal temperature. The reason is that the external air as a source of energy is not stable and it varies according to seasonal changes. This solution is definitely not recommended for mountain locations where the outside temperature is very low most of the time. [9]

Heat pump: Water/Water

The water being used is groundwater because it is stable and it has a temperature of 10°C, which is quite a low compared to other sources of energy. It requires digging out two wells. The minimal distance between these two wells 15 m and the spring of the water that fills the first well should have the minimal intensity 0,5 l/s so the capacity is sufficient. [9] The first well is the source of the heated ground water and the second well is the place where the water goes from the heat pump. The water in the well has to be under observation for a long time to prove that it has sufficient qualities to be used as a source of energy for a heat pump. The problem might occur because the water in the well is not controlled so its chemistry and

composition are unknown. In order to prevent corrosion, it is recommended to use different metals in the system. [10]

Generally, it is possible to use a pond or river as a source of water also, but it is not recommended for a couple of reasons. Firstly, the water at the bottom of the pond or river does not have a stable temperature throughout the year especially flowing water in the river has a very unstable temperature. Secondly, problems associated with the ownership of a suitable pond or river and all the legislative complexities connected with the usage of others property. Although this solution provides the highest heating factor, it is a very rare solution because its execution is hard and it requires many special conditions. [9]

Heat pump: Air/Air

The principle of this heat pump is quite similar to the system air/water one, because the source of the energy is the same. The difference is that these types of heat pumps are usually just small heat pumps used either in the small flat or it is quite a convenient source of energy for holiday cottages. It has to be taken into consideration while designing this source of energy that it will exhale heated air only to the room where it is placed and it is hard to provide the same thermal comfort to the rooms that are separated from the source by doors. [9] The advantage of this system is that it can easily switch to cooling instead of the heating. [11]

Heat pumps and radiant floor heating

The great advantage of combining the radiant floor heating system with the heat pump is the fact that the radiant floor heating system operates at low temperatures. The lower the output temperature from the heat pump is the more effective it works. The studies at The WPZ Test Institute shows that the change of flow temperature from 35°C to 40°C means the drop of the COP and efficiency around 14%. This would result in not only higher energy costs but also higher CO_2 emissions. It is important to mention that over the past decade the heat pumps are still improving to increase COP and to optimise their operation, especially in a case of geothermal heat pumps. For example, in case of air/water system there have not been considerable improvements. [11]

The other advantage of the using radiant floor heating system with a geothermal heat pump is that it can also operate reversibly. When the water is cooled down in the geothermal heat pump in a way that was already presented above it circulates in the pipes under the floor and cools down the room. The only problem is that it is very important to be sure that the surface temperature of the floor is not lower than dew point's temperature of ambient air because it

can cause condensation that may cause mould growth or that the floor will be slippery and someone injures. [10]

Wood pellet heating system

The wood pellet heating system started evolving since the early 1980s. It was firstly developed in Sweden and now this solution is used the most in Sweden, Austria, Canada and the USA. The wood pellets are produced from the wood waste from the wood industry and also from the wood from the local forests. The wood pellets have a cylindrical shape with approximately 10 to 30 mm in length and 6 to 12 mm in diameter. They are compact so the transport is easier and cheap. They have denser structure than wood chips and during their combustion, they produce less ash and low CO_2 emissions. The ash produced during the combustion can be used for example as a soil fertilizer.

The wood pellets are burned in special boilers designed for wood pellet burning. One type of this boiler can be seen in the scheme in Figure 11.

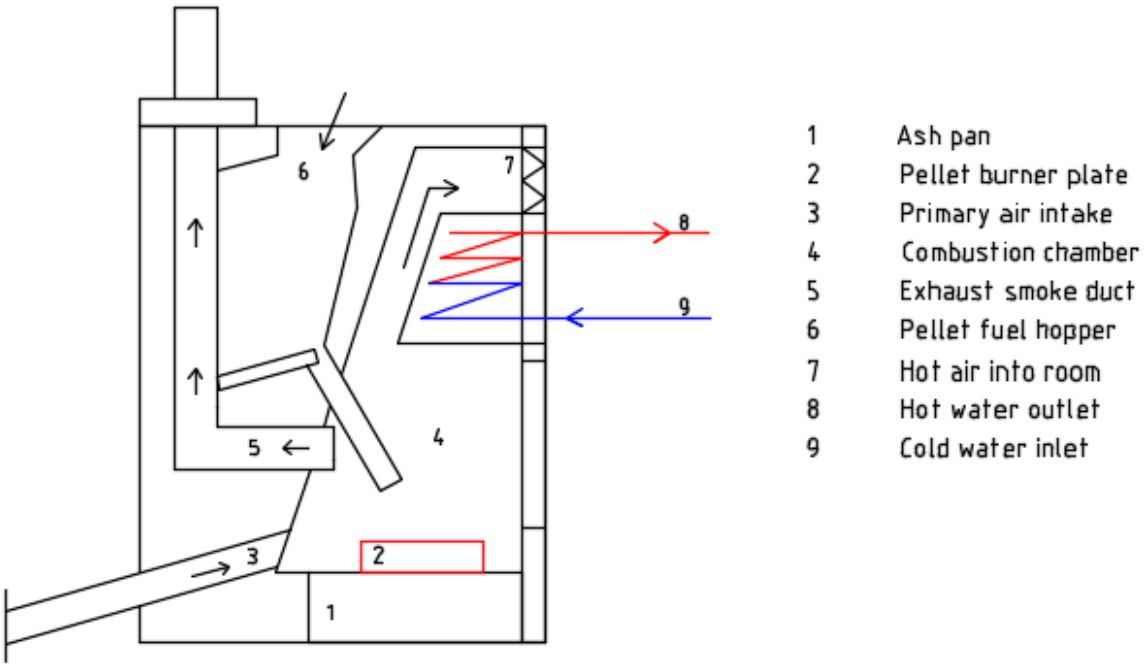

Figure 11: Diagram of wood pellet stove

The wood pellets that are produced with the high-quality control can be considered carbon-neutral by European Union countries. This means that the wood produces the same amount of carbon while burning as is absorbed by the trees which the wood is made from. Basically, any type of wood can be used to produce wood pellets nevertheless the most common is the

spruce. The deciduous wood is often mixed with the other types of wood in order to optimize the consistency of the final pellets. There is also the possibility to use recycled wood but it has to be cleaned properly so there is no paint or heavy metals.

An interesting aspect of the production of the wood pellets is that it helps to create jobs in forestry, transport and wood management so it supports the local economy.

The first information needed while designing the heating system with the use of wood pellets combustion is the predicted amount of wood pellets needed to heat up the building per year. The calculation of this number depends on the size of the area for heating and the heat losses. It is very important to design the proper size of the system because in case it is oversize the combustion will be ineffective and it will increase the amount of waste and emissions. On the other hand, in the case of the undersized system, it will never heat up the space entirely. For example, the typical house in the UK with the area of 200 m^2 and the average system output of 12 to 20 kW needs 3 to 5 tons of wood pellets per year.

The other requirement during the design of this system is also a special requirement. While designing a house with the wood pellets as a source of energy it is important to think about the storage of the wood pellets. It has to be some place which is accessible to the delivery and at the same time, it should be connected with the boiler room. [12]

Wood pellet and radiant floor heating

The system to use wood pellet and radiant floor heating system is a bit more complicated than other renewable sources of energy. The reason is that the heat obtained by combustion is high and so the water is heated to 60°C. The water heated is accumulated in special water storage tanks and the water from these tanks goes to the heating system. One part of the heating system should be mixing valve that enables water to be mixed directly in the pipes. The incoming water is mixed with the water returning from the system and this creates the optimal temperature for radiant floor heating. There are new boilers developed specially for wood pellet combustion and radiant floor heating system mainly in Austria. These boilers require the highest possible quality of wood pellets (known as white pellets) which is not that affordable compared to other types of wood pellets.

Gas condensation boiler

The condensation gas boiler is a type of gas boiler with the highest efficiency. The gases used are natural gas, propane-butane and propane itself and butane itself. Sometimes producers

claim what kind of gas should be their product used with. These gases have some dangerous properties. They are explosive under a certain ratio of the mixture of gas and air and they are poisonous, because when the combustion is not complete CO is produced. [13]

When the gas is burning it produces water vapour. In the other appliances that burn gas, this water vapour is exhaust with the rest of the waste. The condensation gas boiler is designed in the way that there is a tight network of pipes and buffers and there might be also two heat exchangers. The water vapours are cooled down and condense. The process of condensation produces latent heat which increases the efficiency of the boiler. The condensate water is collected in the condensate trap. The condensate is slightly acidic so the parts of the boiler in the contact with the condensate have to be made from special anticorrosive material. The example of principle of condensation gas boiler is in Figure 12. [14]

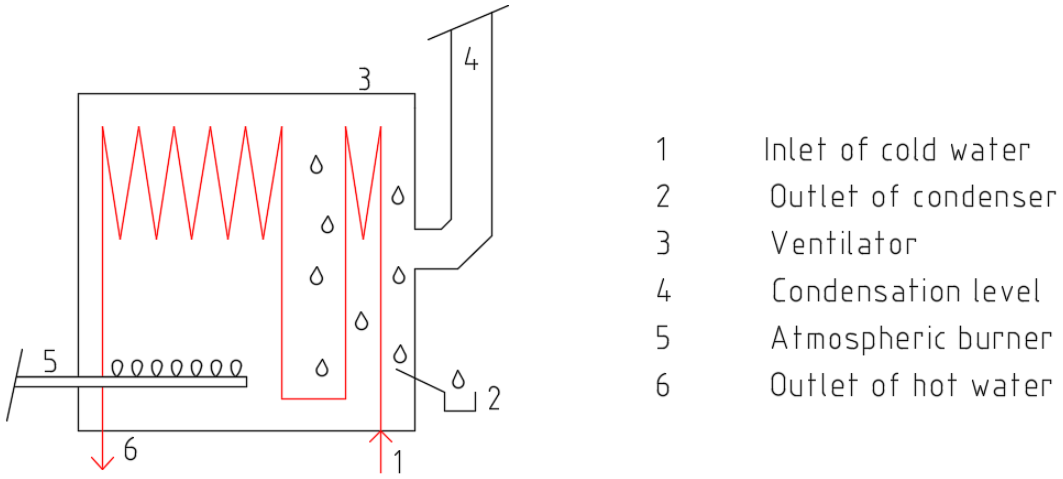

Figure 12: *The principle of condensation gas boiler*

The gas boiler should not be situated in the same room where the gas meter and the main shutoff valve for gas are. There is also restriction that for each 1kW of output you have to add 0,8 m^3. The minimal distance of boiler from the combustible items is 20 cm. The boiler room should be also properly ventilated (a chimney with sufficient draught) and it should be situated in the house so the main gas pipe can be easily connected. It is also helpful if the internal temperature of the boiler room is regulated to obtain efficiency of the operation. [13]

The combustion of gas produces heat by the change of the fuel into the new compounds. It can be divided into complete combustion and incomplete combustion. The complete combustion needs the presence of oxygen, the product of such combustion is water vapour and CO_2. The incomplete combustion is caused by the lack of oxygen. In that case the

products of such combustion are various and one of them is CO which is poisonous for the humans. [14]

The advantages of the gas condensation boiler are its high efficiency (up to 95%), the smaller consumption of fuel compared to other types of boilers (10-15% smaller) and it is the lowest producer of emissions compared to other boilers. The disadvantages are the high price (it can be twice as much as the price of other boilers), the necessity of a specially modified chimney, because of acid waste and the requirements for anticorrosive parts of the system. [13]

There are strict limits regarding the operation of the gas condensation boiler. The owner is obligated to control at least once a year all parts of the system (burners, circulation pump, safety valve, et cetera). The boiler can be operated by a person who is more than 18 years old. There should be special control every three days during the heating season to control the air inlet, exhaust of combustion products and complete combustion. [13]

Gas condensation boiler and radiant floor heating

To gain the maximum efficiency from the condensation boiler it is important to design the heating system to operate at the low temperatures. This is the reason why it is recommended to be used with the radiant heating system in the floor or on the wall. [14]

The radiant floor heating system is a cost saving choice and together with condensation boiler, it can save up to 40% of energy compared to the usual heating system. [10]

Comparison of sources

Each renewable source of energy has its advantages and disadvantages. There is no way to say in general which source of energy is the best solution. It always depends on the location, geological conditions, the size of the building and the size of the plot, distribution of the engineering network and the climatic conditions.

The solar panels are a good source of energy for the areas with a high number of days of the sun per year. The development of solar panels is still in progress especially in the countries that are exposed the Sun the most (for example Cyprus or Turkey). We can expect solar panels with high efficiency that will be cheaper than nowadays. This solution can be easily implemented to the heating system with the radiant floor heating system as heat emitters.

The heat pumps are divided into many types according to the source of energy. These types offer a huge variety of solutions so they can be designed in different conditions. It is important to consider all the aspects of design to provide the solution which is the most fitting. The heat pump has the highest efficiency while working with low temperatures which make radiant floor heating system one of the most suitable solutions for them.

Wooden pellet burning boilers are quite new and not that frequent solution as a heat source for heating systems. The wooden pellets itself are a good way of utilization of waste from wood industry. The out coming hot water from wooden pellet boilers is quite high so the system that works with the radiant floor heating has to be specially designed to mix the water in the system in order to obtain optimal water temperature for this type of heat emitter.

Condensation gas boilers can be designed in the place with the gas distribution. The usage of gas boiler brings some risks so there are some restrictions and rules connected with the designed and operation of such appliances. The condensation boiler has the highest efficiency compared to other types of gas boilers and when it is designed together with radiant floor heating system it can effectively save energy.

All of these four types of heat sources reduce emissions and help to mitigate the impact on climate change. They can be all used together with the radiant floor heating system without any bigger difficulties.

Conclusion

The heat source that I chose for my bachelor project regarding the fact that most of the rooms are heated by radiant floor heating system is a geothermal heat pump with horizontal collectors. It is important to mention that the area where the building is located has no gas supply and the electricity in Slovakia is expensive compared to Czech Republic. One of the reasons is the perfect geological conditions for the geothermal heat pumps. The soil has a good composition (sand and gravel) and it is wet because the ground water level is relatively close to the surface. The other reason to choose this type of heat source is the fact that the building is situated on a large plot of land, which is also in the ownership of the owner of the building. The horizontal collectors which were chosen for the project are a cheaper solution than the vertical collectors and regarding the size of the land, it is the most suitable. This system should provide not only thermal comfort to the living spaces in the building but it will also be a cost effective solution concerning the operation cost of the heating system. The expected return of the investment regarding the size of the building and its heat losses is around 6 to 10 years but it depends on the changing price of energies and also the price of the service of the machine should be taken into consideration. The biggest advantages of the heat pump are that it is environmental friendly, its operation is easy and it has small requirements regarding the special needs for installation of the unit inside the house.

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