YRKESHÖGSKOLAN NOVIA

Hybrid solution
Solar Assisted Ground Source Heat Pumps (SAGSHP)

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EXAMENSARBETE

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Abstrakt

Eftersom tillgången till några av de mest populära energiresurserna idag, som t.ex. oljan och andra fossila bränslen är begränsad, så har efterfrågan och investeringen på förnybara energikällor ökat i vår tid. Två av de mest kända energiresurserna är solenergi och geotermisk energi. Dessa två metoder har varit i användning för olika ändamål under flera decennier, liksom för byggnadsuppvärmning, vattenuppvärmning för byggnader och för att alstra elektricitet. Men kombinationen av dessa två energikällor är ganska nytt eftersom teknologin för att möjliggöra kombinationen av dessa två källor har förbättrats under de senaste åren. Detta examensarbete studerar möjligheten för kombinationen av solvärmefångare tillsammans med jordvärmekällor för att förse hushållvarmvatten och fjärrvärme. Funktionerna och komponenterna för både solvärmefångare och jordvärmekällor har studerats skilt för sig för att kunna hitta olika möjliga lösningar att kombinera dessa två förnybara energikällor. I slutet av detta examensarbete finns det beskrivningar på olika möjliga kombinationer såsom parallell, serie och återgenerativa kombinationer.
Ändamålet för detta examensarbete är att studera olika kombinationer för dessa två energikällor för att kunna uppnå mer ekonomiska och energivänliga hushåll.

Språk: Engelska Nyckelord: Solvärme, Värmepump

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Abstract:

Since some of the popular energy sources such as oil and fossil are in danger of being depleted, demand and investments in renewable energy sources are increasing all the time. Two of the most common energy resources are solar energy and geothermal energy. These two alone have being utilized for decades for different purposes, such as providing space heating and water heating for buildings or providing electricity. But the combination of these two resources is a rather new subject since the technology to combine the two systems has been improved over the years. This thesis examines the possibility of the combining solar thermal collectors together with ground source heat pumps to provide domestic hot water and district heating for the building. In order to find the possible ways of combining way for the combination of these two renewable sources of energy, both solar thermal collectors and ground source heat pumps functions and components are studied separately. Towards the end, several possible combinations such as parallel, series, and regenerative combination have been described.
The purpose of the thesis is to study the possibility of different combination of these two energy resources for achieving more economical and energy efficient houses.

Language: English Key words: Heat pumps, Solar panel

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1 Introduction of Renewable Energy and Hybrid Solution

According to Max Planck, energy is the ability of a system to case external action. (Kaltschmitt, Streicher & Wiese,.2007.2)

There are three main categories of energy carriers: primary, secondary, and final energy. Primary energy is the pristine energy which can be found in crude oil, gas, hard coal, biomass, solar energy, wind energy, geothermal energy, and lignite. Secondary energy are the energies which can be extracted from primary energy sources, such as; gasoline, heating oil, rape seed oil and electrical energy. Final energy are energies which consume by final costumer. (Kaltschmitt, Streicher & Wiese.,2007.2)

2 State of the Art of SAGSHP

This thesis presents the state of art of the combined technology of solar collector (solar thermal and solar photovoltaic) with ground source heat pumps for achieving more efficient (ground source heat pumps) GSHP's performance and more energy efficient houses. Many energy resources are in danger of depletion. Electricity is more expensive than it was several years ago, and it is predicted that the price of electricity will increase even more in future. Therefore, need for renewable energy resources which can reproduce themselves in a short periods of time is increasing. Energy resources such as solar energy and geothermal energy are two considerable renewable energies which have the ability of reproducing themselves in short period of times. In human history, there has always been many innovations which attempt to find a better way of using solar and geothermal energy even more efficiently. For example, utilizing solar energy by solar thermal panel and solar water heating for providing domestic hot water, heating swimming pools and space heating. Using, so called photovoltaic solar panels, for producing electricity from sun radiations. Also utilizing geothermal energy sources such as ground hot water, heat which has been stored in underground and also heat from earth's core, for space heating and DHW, by using for example geothermal heat pumps or ground source heat pumps. This thesis mainly focuses on the possibility of integrating solar collector together with ground source heat pumps for increasing overall system performance. We also discuss practical matters of both systems.

3 What you will learn studying this?

This thesis deals with the use of renewable energy for providing domestic hot water and space heating for residential buildings, you will learn about:

- The solar thermal energy, solar collectors, photovoltaic collectors and their components.
- Geothermal heat pump system and ground source heat pumps and their components and performance.
- The combination of ground source heat pump together with solar collectors and different configurations of for it.

4 Geothermal Energy

Geothermal energy is earth's thermal energy which has been created and stored in the earth for millions of years from the creation of earth. The temperature inside the earth's core can be as high as 6650 ℃. On average, the temperature increases by 3°C for every 100^{th} meter into the crust, but in areas with volcanic or tectonic activities, this number can be 10 to 30 times higher than average. Earth's crust contains different elements, some of them radioactive, such as Uranium (U-235, U-238), Thorium(Th-232) and Potassium(K-40) which by their nuclear reactions produce heat in the crust.

In addition to nuclear energy, other energy sources such as solar radiation also heats the earth. But the variation in the heat energy of the crust be divided into three thermal regimes:

- Shallow thermal regime:
  - The earth surface in this regime is strongly influenced by the change in the ambient air. The temperature can vary with ±10℃. The temperature variation decreases approximately 5m from the surface.
- Transition zone:

- This is a zone approximately 5 to 10m below the surface. Temperature in this zone is influenced by thermal activity bellow and above the surface, but less so than the shallow thermal zone, where air temperature greatly influences it.

- Deeper earth regime:
  - This zone begins around 10m below the surface. The Temperature in this zone increase with increasing depth. For each additional 100m, the temperature rises with approximately 3°C. (Wiles & Sons.,2016)

5 Heat Pump Technology

The heat pump is a technology which extracts thermal energy from a source with lower temperature (ground, water, ambient air) and transports it through the pipes the destination place with higher temperature. Heat pumps are running on a vapor-compression cycle and they have similar basic components as a refrigeration system. The main difference between these two systems is that the refrigeration system primary product is the cold side, whilst the goal of the heat pump is to move energy from one side to the other – either to cool down or heat up a building. The basic components of a vapor cycle plant are a compressor, evaporator, expansion valve and heat exchangers (Dincer.,2003.215).

5.1 Heat Pump Components

The main heat pump components are compressor, condenser, evaporator and expansion valve, see Figure 1.

- Compressors is one of the main components in a heat pump system. It compresses the refrigerant vapor to high pressure, thereby heating the fluid. It also makes the refrigerant flow through the pipes (Dincer.,2003.113).

- The condenser cools the hot fluid, extracting energy from it (www.britannica.com).

- Evaporator task is to change form of the fluid to a vapor, by expanding the volume of the fluid, turning it into a gas. This requires heat input, which is taken from the ground in the case of a ground heat pump (www.swtc.edu).

- Expansion valve: expansion valve decreases the pressure of the high-pressure liquid. (www.swtc.edu)

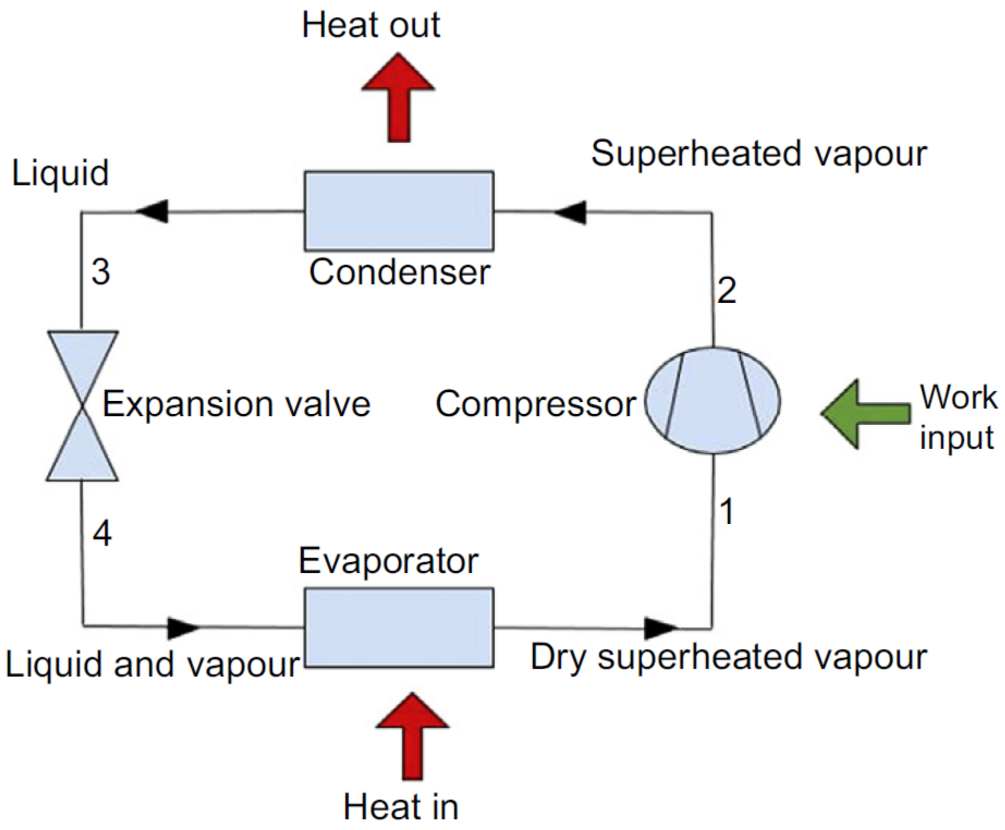

Figure 1. Heat pump components (S.J.Rees,2015,2)

5.2 Coefficient of Performance (COP)

COP is the ratio of heat output to electrical energy input of heat pump. For example, if COP of a geothermal heat pump is 4, it means that for every 1kW electricity's input it receives, it can deliver 4 kW heat output. Different heat pumps have different COP depending on which sources they use to extract the heat. For example, water and ground source heat pumps have more efficient COP. Ambient air temperature can change more often and frequency during the seasonal change. For instance, if the outside temperature drops below 4.4℃, for an Air-source heat pump, loop temperature drops below the freezing point, and it can build up ice crystals on the surface. This can at some point prevent air flow passing over the loop-which will decrease the COP of the heat pump (Dincer.,2003.218).

5.3 Energy Efficiency Ratio (EER)

The EER is the ratio of the cooling capacity to the power input (in watts). The higher the EER rating, the more efficient the air conditioner (energy.gov).

5.4 Heating Season Performance Factor (HSPF)

Heating seasonal performance factor (HSPF) determine heat pumps heating efficiency. It is the difference between the electricity consumed by heat pumps, compare to its total heating output. Higher HSPS indicate better efficiency of heat pump (energystar.zendesk.com).

6 Ground Source Heat Pump (GSHP)

Ground source heat pumps or Geothermal heat pump, is a system which extract thermal energy from the ground and uses this energy to heat the building in the cold season, see figure 2. It may also reject the heat from the building to the ground to cool down the building during the hot season. As mentioned before, ground temperature remains same at about 10m depth, independent of ambient air temperature. This makes the GSHP one of the most efficient forms of domestic heating and heating DHW (domestic hot water). (Greenmatch.co.uk).

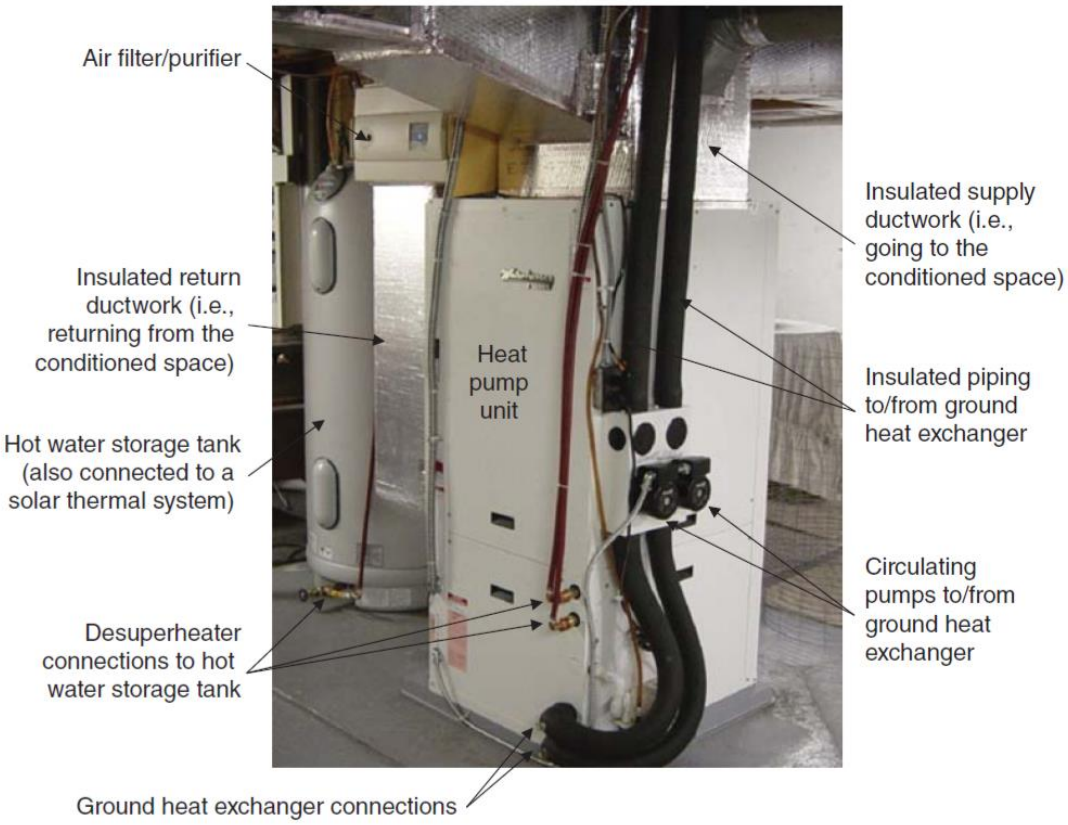

Figure 2. Photo of a geothermal heat pump in a residential building (Andrew D. Chiasson. 2016,17).

Ground source heat pumps have also other expound base on the earth coupling, such as: ground water heat pump (GWHP), ground-coupled heat pump (GCHP), surface water heat pump(SWHP) and standing column well (SCW) system (Andrew D. Chiasson. 2016, 14).

Ground heat exchanger, or ground loop, is a network of pipes installed underground, to extract energy from the heat of the crust. The pipes can be installed vertically or horizontally. The ground loops carry a mixture of water and antifreeze solution, to prevent freezing of the fluid. The underground pipes collect energy and transport it to the evaporator. This cools the fluid down, which is then pumped down into the ground loop again. Distribution system receive the produced heat from the GSHP and distribute it inside the house, see figure 3. It can be in form of underfloor heating pipes, HVAC or domestic hot water(DHW) or radiators(Greenmatch.co.uk).

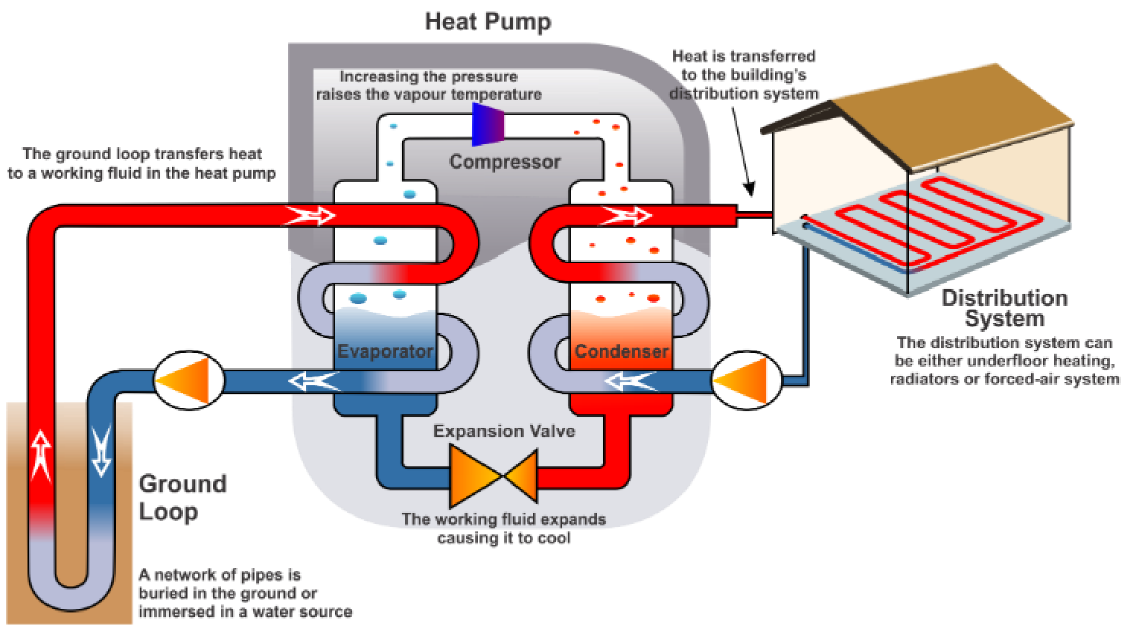

Figure 3. Distribution system receive the produced heat from the GSHP and distribute it inside the house (greenmatch.co.uk)

6.1 Open-Loop Horizontal Borehole System

One of the main differences between horizontal and vertical GHXs is their positioning. For the buildings with large land area, horizontal GHXs can be economic and simpler choose. Because they can burry in a shallow surface (normally less than 2m) so the installation cost will be relative cheap compare than vertical GHXs configuration. And they normally do not require drilling equipment. Although, it has to be considered that in the shallow surface the ground temperature changes seasonally. Therefore, in order to be able to have a sufficient GHXs, we need to do a careful mathematical calculation considering seasonal temperature changes in shallow surface (Andrew D. Chiasson. 2016 ,219).

The GHXs can be place in the excavation in several ways, such as serpentine arrangement or in the coiled arrangements on the excavation floor. When there is not so much available land for installation and the cost of digging might be limited, there are also other methods which can be used for placing the horizontal GHXs. These methods are two-, four-, or six-pipe GHXs, see figure 4. (Andrew D. Chiasson. 2016 ,220)

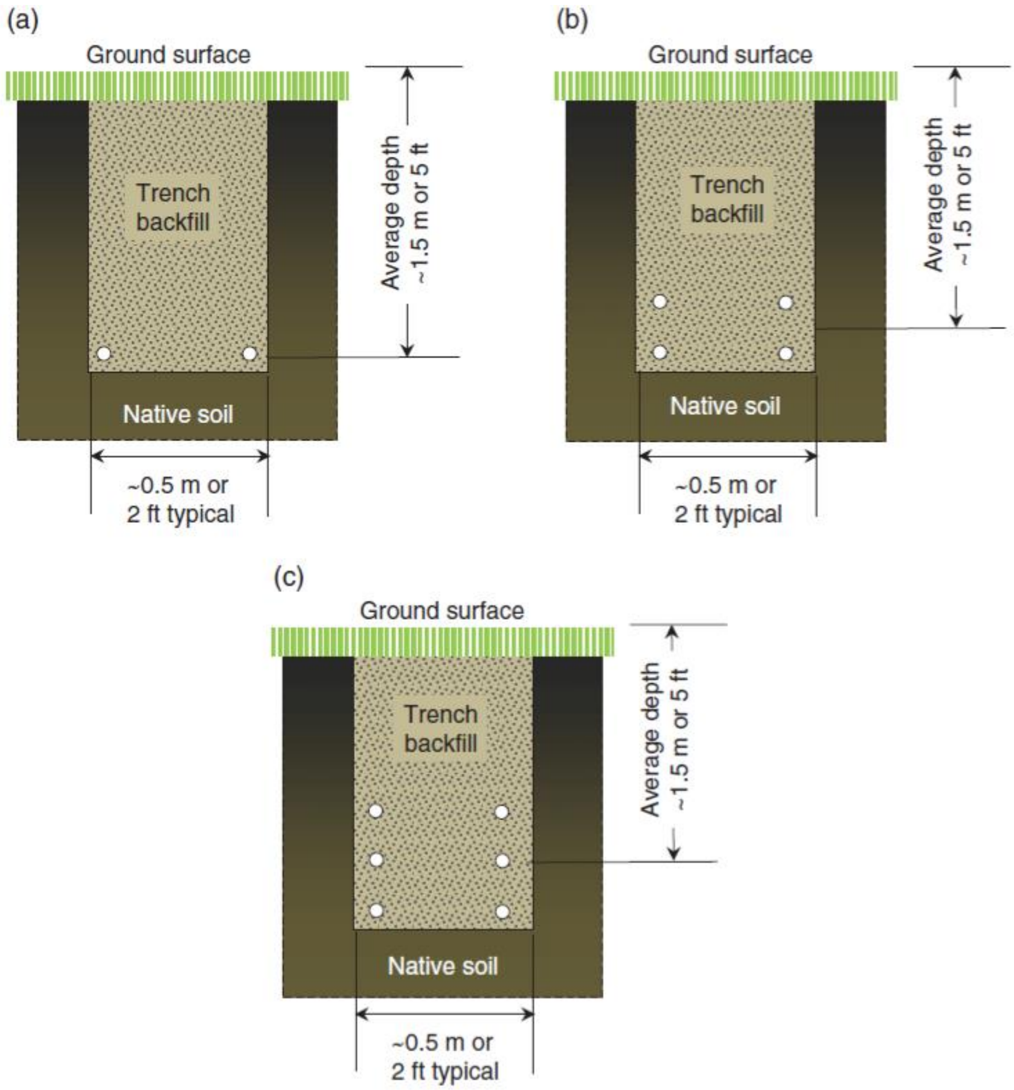

Figure 4. Two-, four-, and six-pipe horizontal GHXs in a trench(Andrew D. Chiasson. 2016 ,221).

6.2 Close-Loop Vertical Borehole System

A close-loop vertical borehole system is included a system of plastic pipes which have been buried in vertical borehole from 50 to 100 m depth, see figure 5. A heat exchange fluid (either only water or a mixture of water with an anti-freeze liquid) is circulating through the plastic piping system extracting the heat from the ground to the distribution system and rejecting the heat from distribution system back into the ground. In a close-loop vertical borehole system design, we must consider several important parameters which have an important impact on the system performance. These parameters are included: Design of borehole heat exchanger, proper subsurface characterization, and sizing and dimensioning of the ground heat exchanger (Andrew D. Chiasson. 2016 ,16).

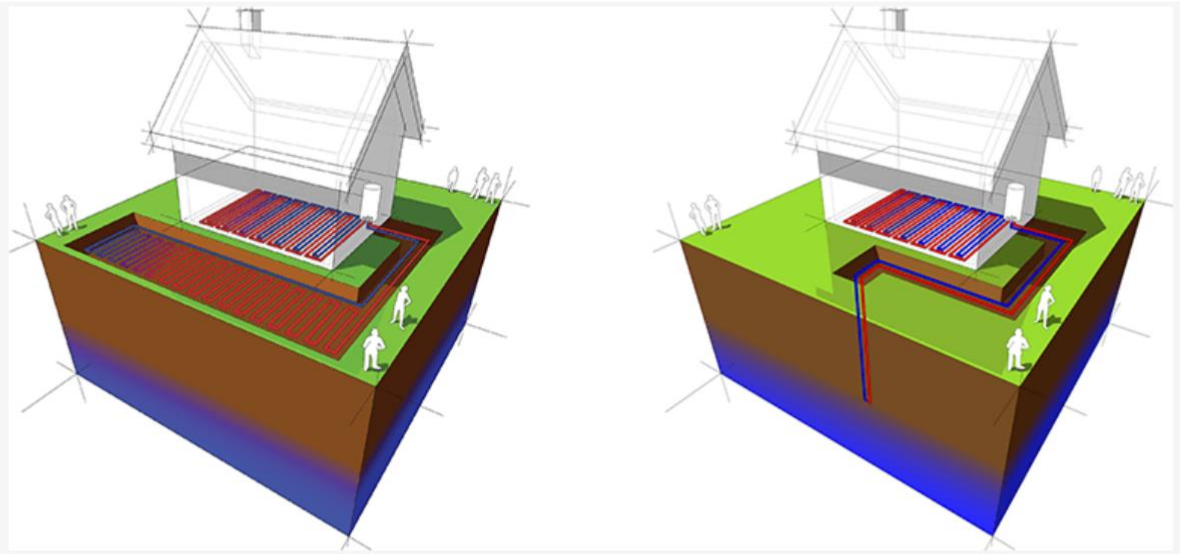

Figure 5. Horizontally (right) and vertically (left) GHX (greenmatch.co.uk)

6.3 Vertical Borehole Ground Heat Exchangers(GHXs)

GHXs consist of multiple vertical BHEs connected together. Depending on the building's area, the required amount of the BHXs can be variable. For example, residential buildings may require 3-5 vertical BHEs, while larger building such as school or hospital may require tens to hundreds of them, see figure 6. When designing GHXs, the conventional sizing of total number, depth, and spacing of the BHEx is very important so that it can function efficiently over its lifetime (Andrew D. Chiasson. 2016 ,181).

One of the most complex element in designing GHXs, unlike the single BHEs, is the thermal interaction between boreholes. When designing GHXs, the conventional sizing of total number, depth, and spacing of the BHEx is very important so that it can function efficiently over its lifetime. Inappropriate design of borehole heat exchanger can lead to oversized borehole which can cost excessively high and if the borehole is undersized, it might not be able to meet the considered heating loads (Andrew D. Chiasson. 2016 ,182).

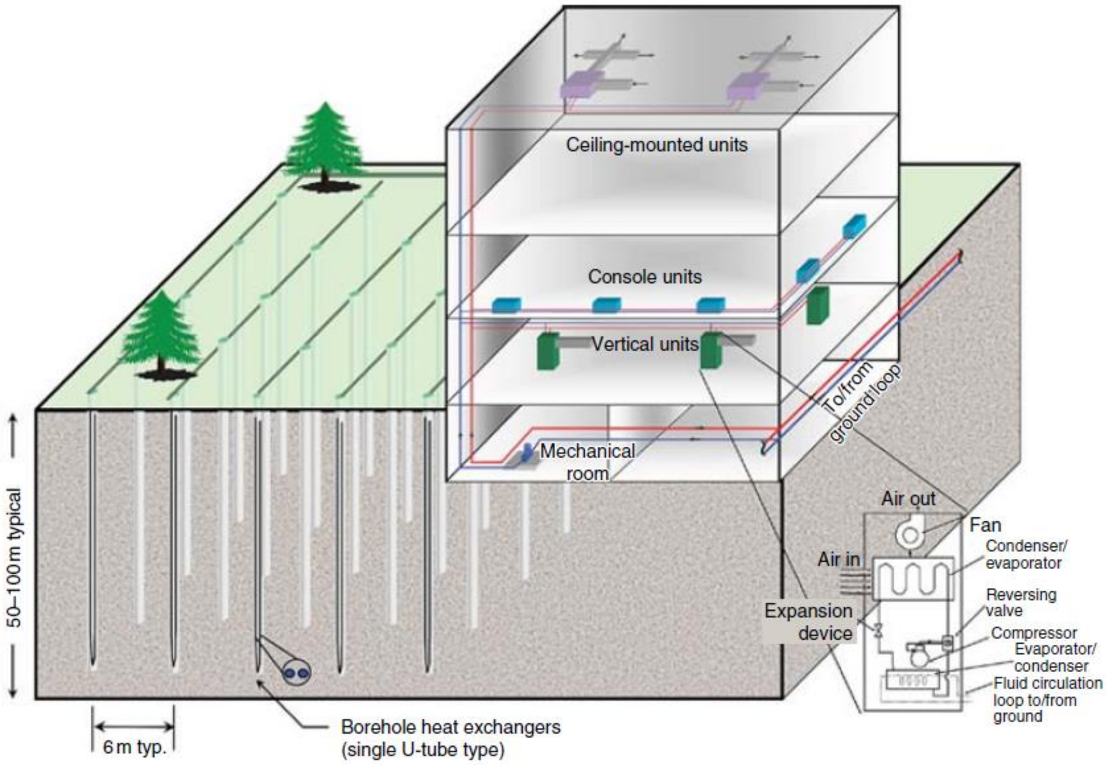

Figure 6. Configuration of a vertical GHX coupled to an office building (Andrew D. Chiasson. 2016, 183).

7 Fundamental BHE Designs

Borehole heat exchanger (BHX) is a close-loop pipe installed in a vertical borehole for intention of heat exchange with the earth (Andrew D. Chiasson. 2016 ,139). There are two common type of BHEs configuration such as U-tube (concentric tube) and coaxial tube, as shown in figure 7. Arrangement of Flow channels in borehole are determining the borehole thermal resistance (Andrew D. Chiasson. 2016 ,157).

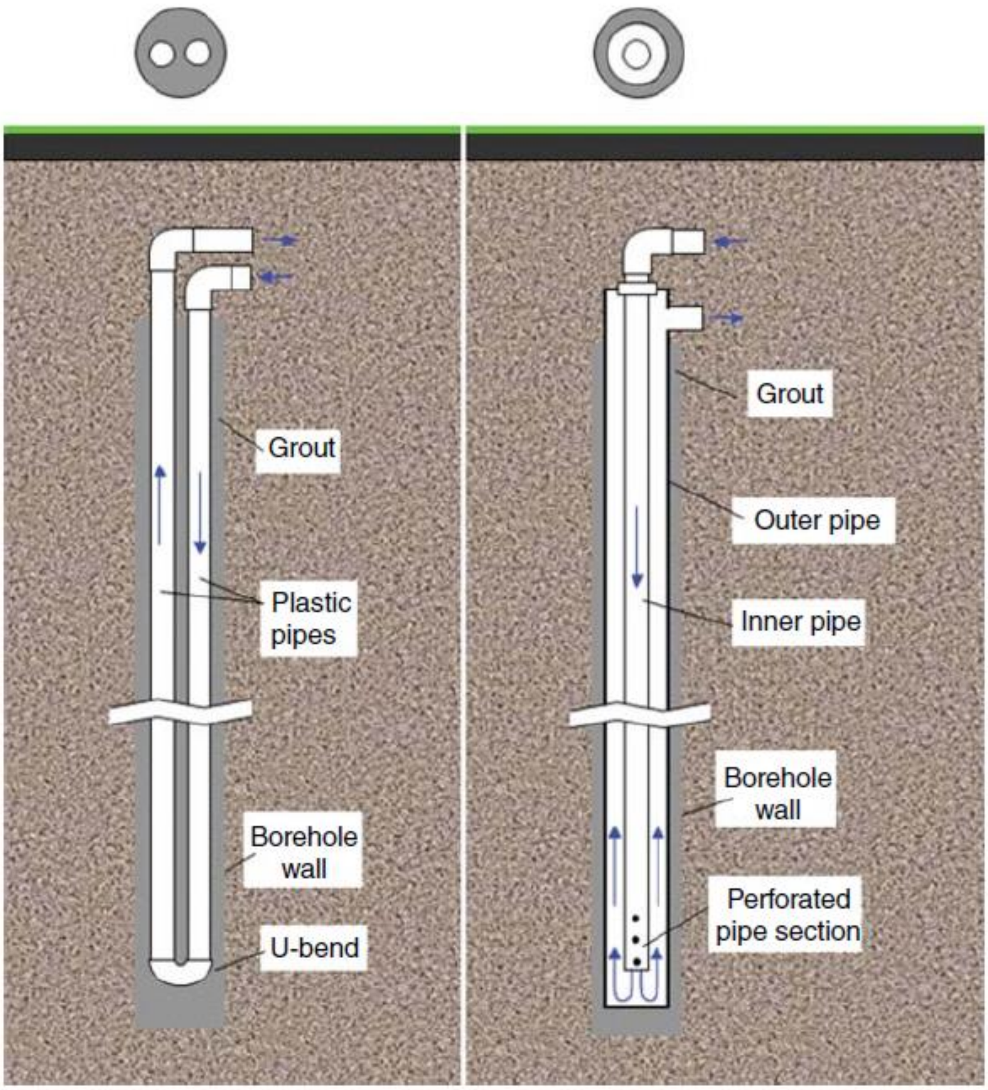

Figure 7. The two fundamental BHE designs: U-tube (left) and coaxial pipe (right)(Andrew D. Chiasson. 2016, 157)

7.1 Borehole Calculation for Ground Heat Exchanger (Efficient Borehole Size)

To set up prerequisite borehole length and to calculate the outcome fluid temperature, it is important to anticipate the thermal behavior inside and in the surrounding area of BHXs (Andrew D. Chiasson. 2016,138).

The pipe thermal resistance and the filling resistance are two important factors for calculation of the stable mode borehole thermal resistance for BHEs. (Andrew D. Chiasson. 2016,157).

As shown in figure 8, yellow box is for input date and calculations are in the right side of the picture. Dropdown boxes allow options for the U-tube spacing, the nominal pipe size, the pipe SDR (Standard dimension ratio), and the borehole heat transfer fluid. (Andrew D. Chiasson. 2016,167).

Borehole calculation for ground heat exchange is one of the most challenging areas of GSHP installation. Besides the other elements, the efficiency of the GSHP is very much depending of the right size GHE borehole. The efficient borehole size is dependent on three factors:

1) Long-term heat rejection and extraction (drawing out, removal) to and from the ground

2) ground thermal properties

3) the thermal resistance of the borehole

(J Rees 2015, 29)

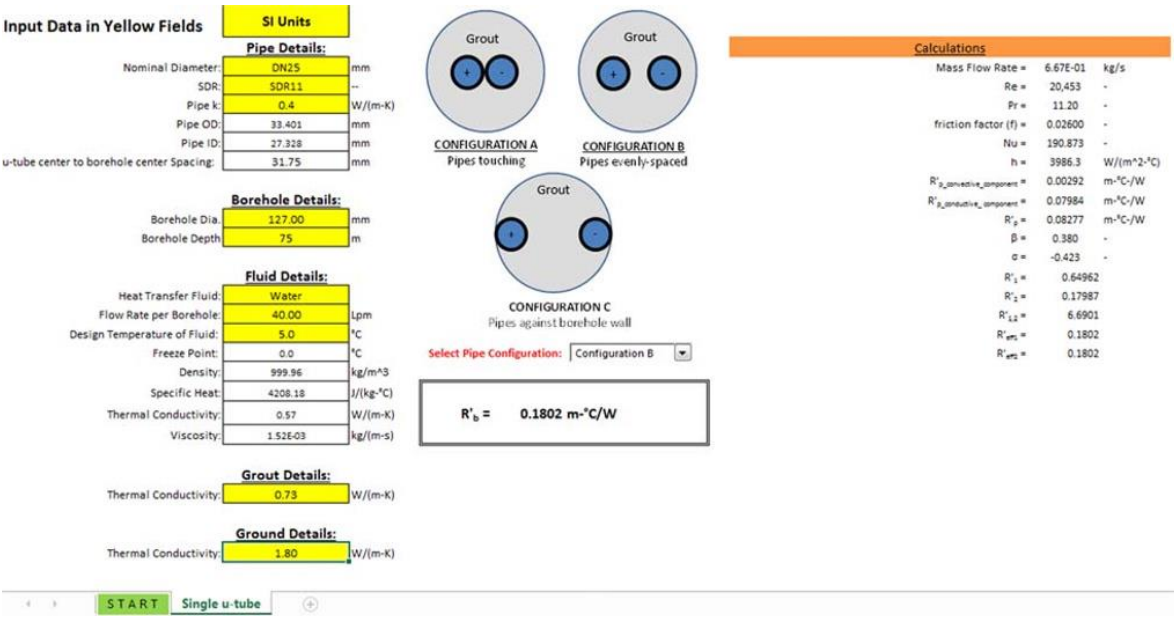

Figure 8. (Screen capture of the single U-tube borehole thermal resistance calculator tool) (Andrew D. Chiasson. 2016,166).

8 Solar Energy

Solar energy is a renewable energy source which comes from sun irradiation and it can be converted into heat and electricity by solar thermal panels and photovoltaic cells. Solar energy has become more popular since the technology for converting it into heat and electricity has been improved and it is a clean energy source which is also environmentally friendly. Unlike other energy sources such as fossil fuels, solar energy is available almost everywhere on the earth every day. Solar thermal panels can provide domestic hot water and space heating while photovoltaic cells can provide electricity for commercial and residential buildings, see figure 9. There is also some disadvantage with solar panels, for instance they are not so efficient on cloudy and rainy days, or they might not be functional in night time(Greenmatch.co.uk).

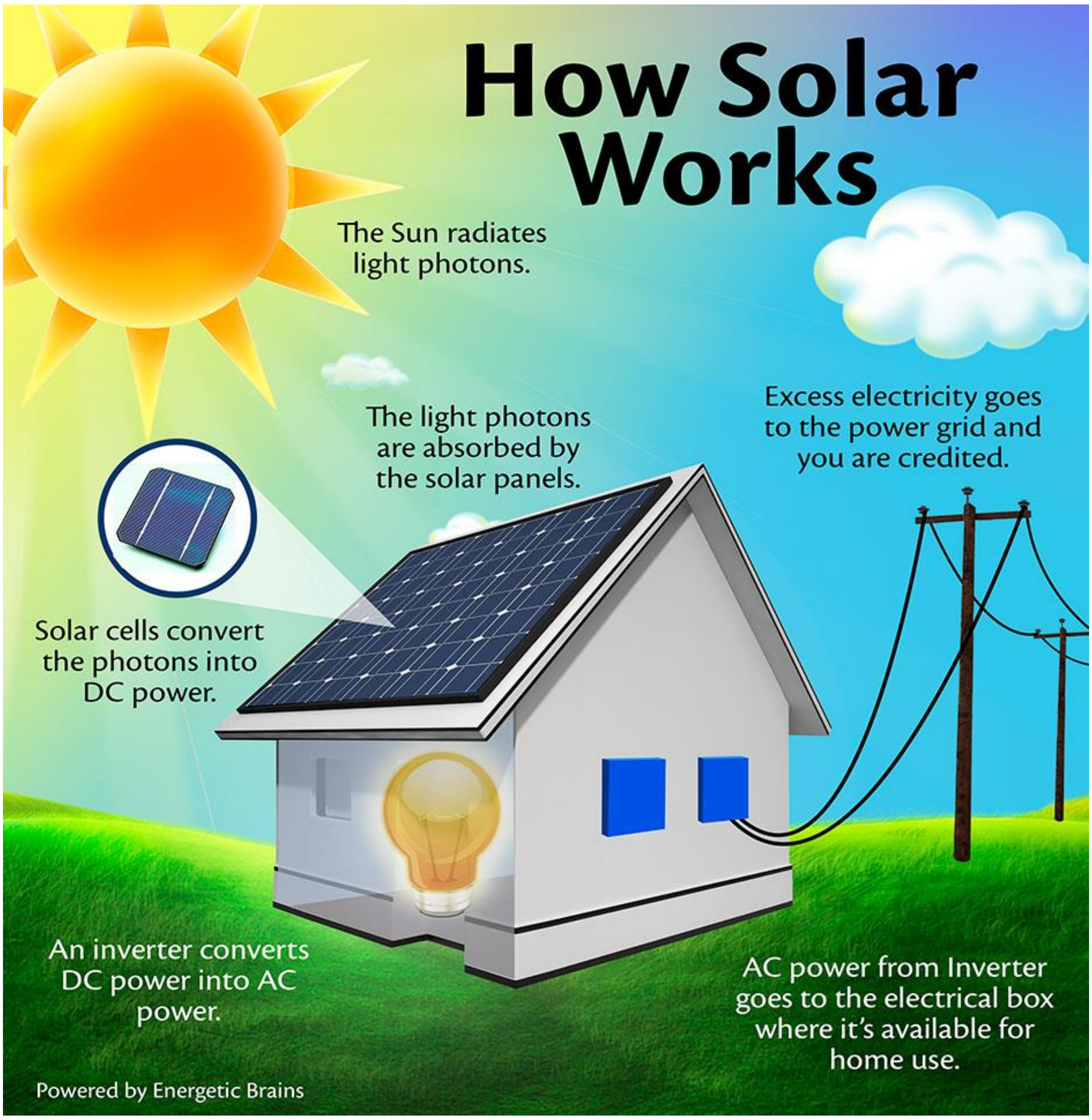

Figure 9. Solar energy (whittingtonsolar.com)

8.1 Active Solar Water Heating Systems

There are two kinds of active solar water heating system, direct circulation system and indirect circulation system. In a direct circulation system, water circulates directly by pumps through the collectors and then into the home water system. This system functions well in climate where water rarely freezes. In an indirect circulation system, an anti-freeze mixture circulates through the collectors by pumps. This anti-freeze mixture transfers the heat from the collectors to warm up the water before water circulate through the home water system, as shown in figure 10. (energy.gov)

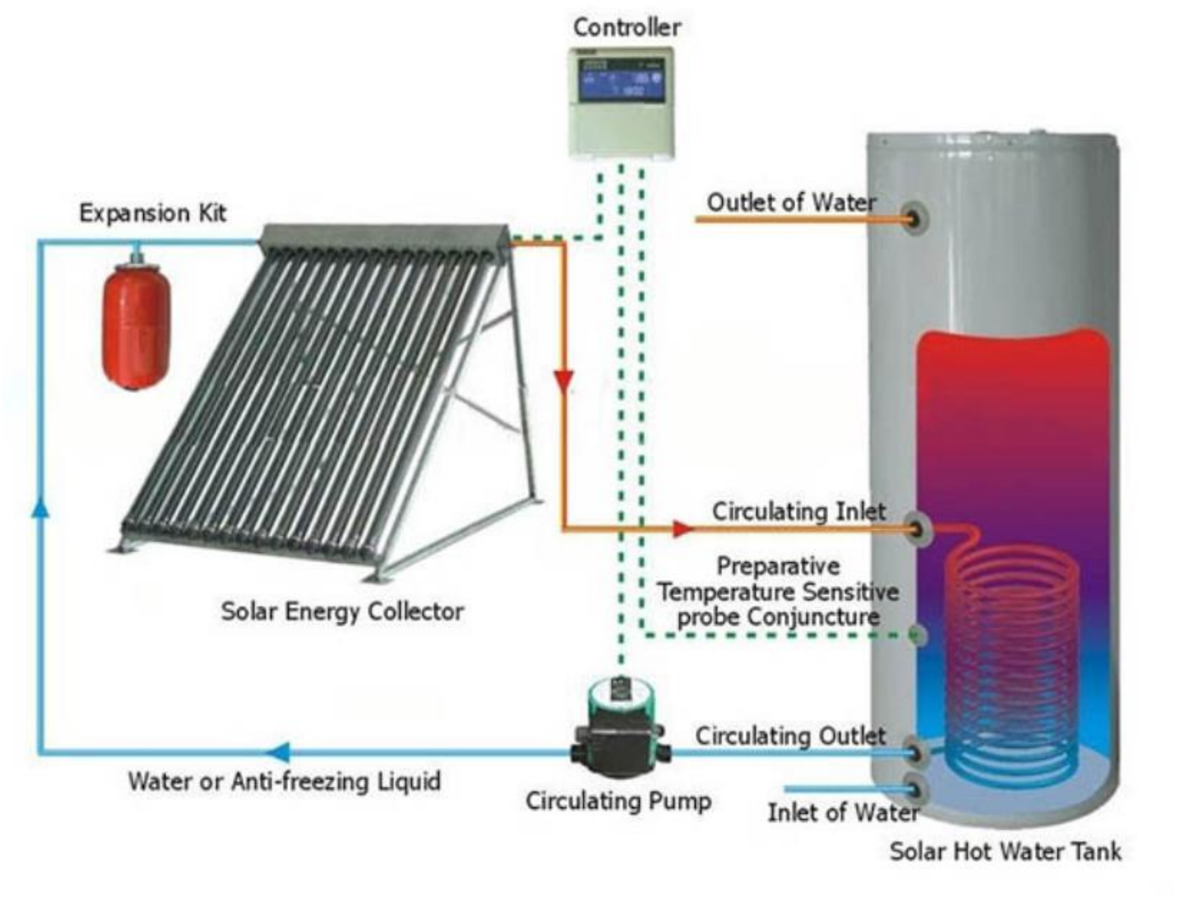

Figure 10. Active Solar heating system for heating the interior space or saving into the storage tank (kawkabuna.com)

8.2 Storage Tank

The storage tank is part of most solar water heaters. It has a supplementary outlet and inlet which are connected to the collector. There are two kind of storage tank, two tank systems and one tank system. It two-tank system, water preheated by solar water heater before it enters the regular water heater system. In one-tank system solar storage tank are included the back-up heater (Energy.gov).

9 Solar Thermal Collector Components

The main solar thermal collector components are absorbers, transparent cover, the collector box and thermal insulation.

1) Absorber: Absorber is part of the solar thermal collector which convert short wave sun radiation into heat by using semiconductor material such as copper, aluminum or polymeric material. The absorber must be able to have a good heat conductivity. They have to be temperature-resistant since temperature inside the absorber can reach up to 200°C (Kaltschmitt & streicher &wiese 2007,130).

2) Transparent cover**:** The transparent cover must be transparent enough for the solar radiation and for the long-wave thermal reflection of the absorber. It also has to be able to reduce the thermal losses of the panel into ambit air. Transparent cover is usually made of glass sheets, synthetic plates or synthetic foils (such as polyethylene or Teflon). (Kaltschmitt & streicher &wiese 2007,131)

3) The frame (collector box): All the components of the solar collector such as essential components for radiation, transmission, absorption, heat conversion and insulation are inside the collector box. The collector box is usually made of aluminum, galvanized steel plate, synthetic material or wood (Kaltschmitt & streicher &wiese 2007,131)

4) Thermal insulation: Thermal insulation is made of material such as polyurethane, glass fiber wool or mineral wool (Kaltschmitt & streicher &wiese 2007,132)

9.1 Flat Plate Collector

A flat plate collector is normally a large heat absorbing sheet which converts the sun irradiation into the heat by using semiconductor materials such as aluminum or copper which are good heat conductors, see figure 11. The surface material of the semiconductor is usually painted black for absorbing most of the sun irradiation for maximum efficiency. On the surface of the black absorber sheet, there are several parallel copper pipes which are called Risers. They are containing heat transfer fluid, usually water, which transfers the absorbed heat from the absorber for heating domestic hot water or even heating outdoor swimming pool. Because they mainly absorb the heat and not the sunlight, they can also be functional on the cloudy days by absorbing surrounding heat (alternative-energy-tutorials.com)

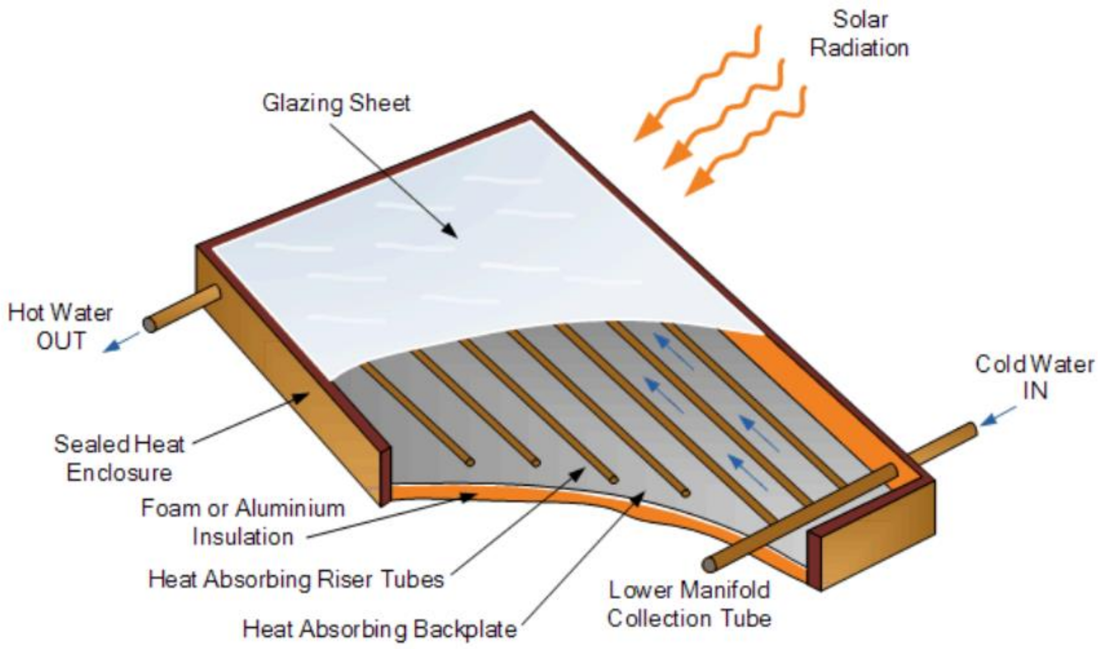

Figure 11. Flat plat collector (alternative-energy-tutorials.com)

9.2 Evacuated Tube Collector

The evacuated tube collector consists of several parallel transparent glass tubes which are placed on heat an absorbing plate, see figure 12. The glasses have a cylindrical shape which makes them efficient even when the sun goes down, since the sun irradiation is always in 90-degree angle to the heat absorbing tube. Because of their specific shape, they are practical options for the area with cold, cloudy and wintry weathers. The parallel transparent glass tube is placed inside the frame. Each single tube can vary in diameter between 25mm to 75mm and 1500 to 2400mm in length. The variation between diameter is depending on the manufacturer. Each tube made of two layers, one outer thick glass and one inner thin glass, which is called “twin-glass tube” or a “thermos-flask tube”. The glasses are covered with a special layer which absorb the sun irradiation while preventing the glasses from the heat losses. The tubes are made of borosilicate or soda lime glass, which is strong and possesses a high thermal resistance. The tubes are called Evacuated tubes since the air has been removed from the space between the two tubes, forming a vacuum. The vacuum functions as a heat isolation and makes the evacuated tubes even more efficient by preventing heat losses. They can produce high fluid temperature because of the vacuum effects and become very hot in summer (alternative-energy-tutorials.com)

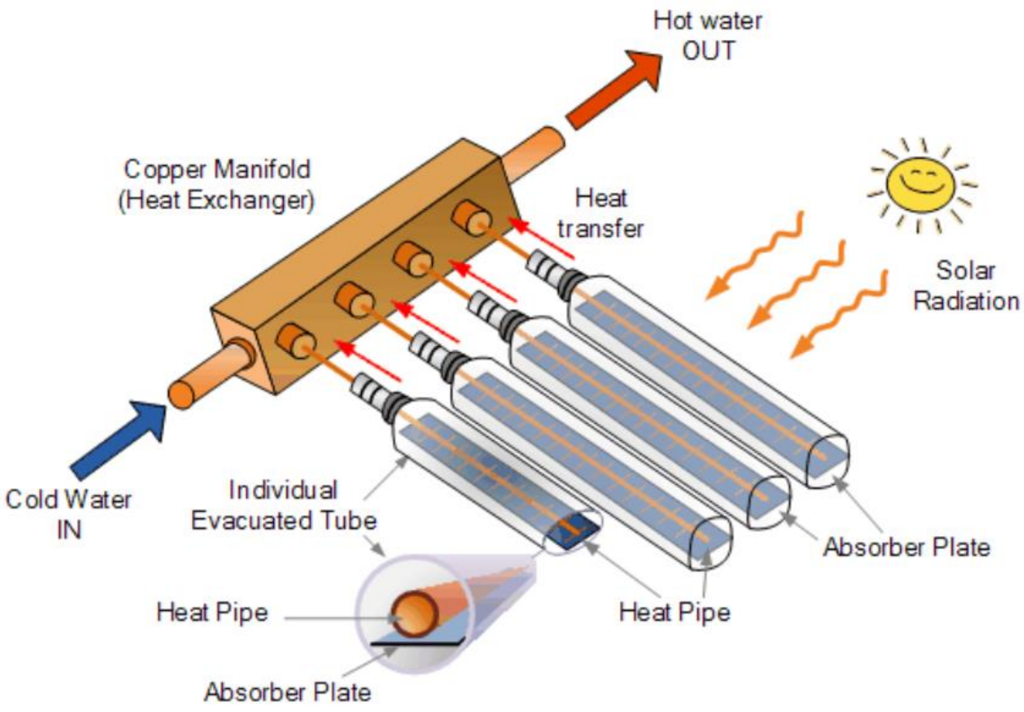

Figure 12. Evacuated tube collector (alternative-energy-tutorials.com)

9.3 Parabolic Concentrating Collectors

The parabolic concentrating collectors is a solar thermal collector usually in form of a U-shaped parabolic. It is included in an absorber heat tube called receiver that is located across the focal point axis of the reflective trough, see figure 13. (alternative-energy-tutorials.com).

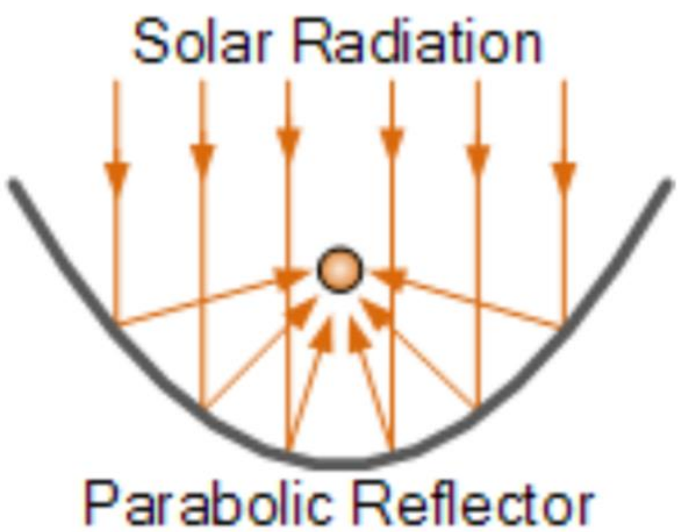

Figure 13. U-shaped parabolic (alternative-energy-tutorials.com)

Parabolic reflectors or PTR, are usually made of a simply bent sheet of highly polished material which have a parabolic shape called parabola. The parabolic reflector as solar thermal energy is a long parabolic reflecting mirror which is normally painted a reflective silver or use polished aluminium, or mirror which extends linearly into the trough shape. Compared to the flat plate collectors, the parabolic collectors can produce higher temperature more effectively because of their smaller absorber surface area, see figure 14. Temperature inside this collector can reach to more than 200°C (alternative-energy-tutorials.com).

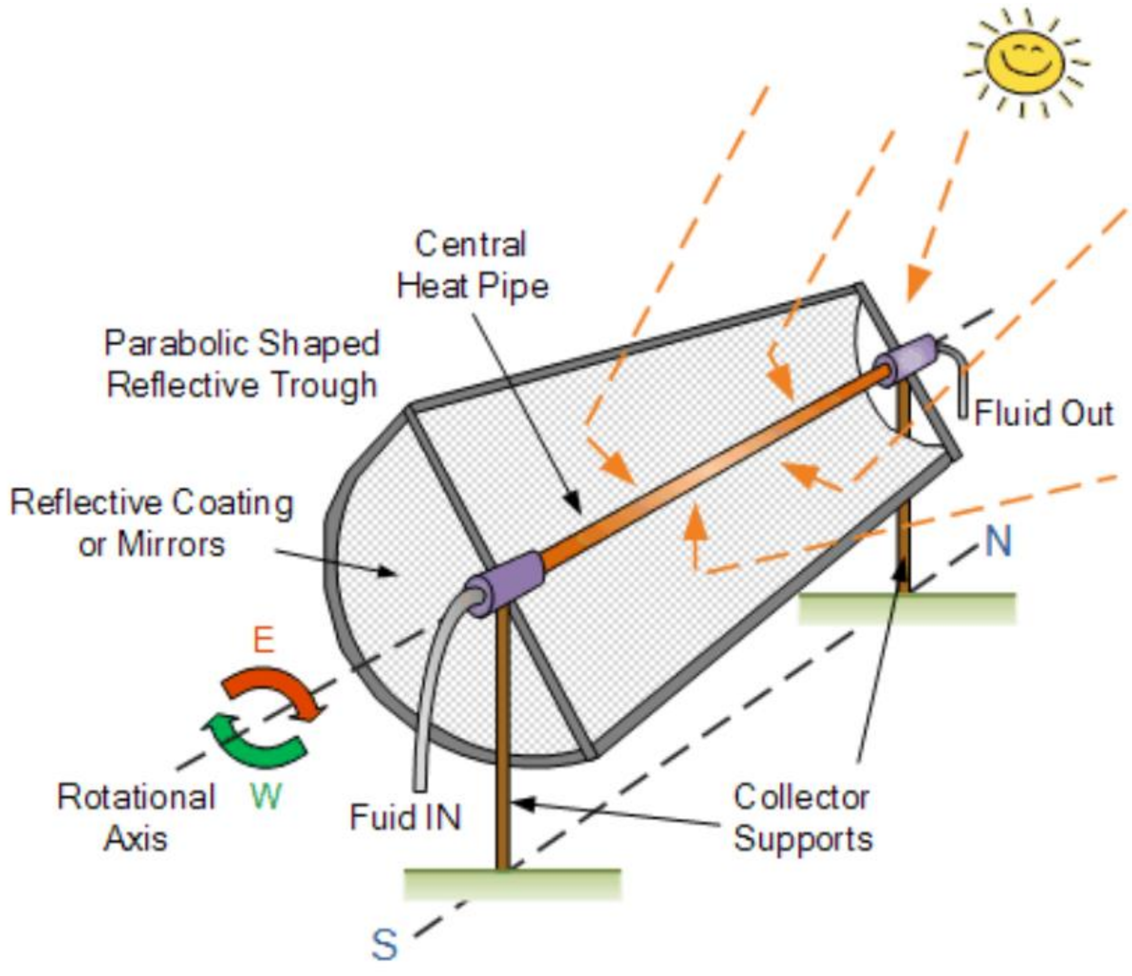

Figure14. Parabolic reflector (alternative-energy-tutorials.com)

10 Solar Photovoltaic(PV) Systems

Photovoltaic system converts sun light directly into electricity, without any moving parts. The conversion occurs inside the PV cells. A group of PV cells is called a module (or a PV panel) a group of modules creates a PV array, see figure 15 (Roberts & Guariento,2015.15). PV cells are made of semiconductor materials such as silicon, germanium, gallium arsenide, but modern cells almost universally use silicon due to cost, availability and efficiency (Roberts & Guariento,2015.15).

PV installations can be done in several ways such as: Ground-mounted, roof-mounted and integrated into the building (Roberts & Guariento,2015.10).

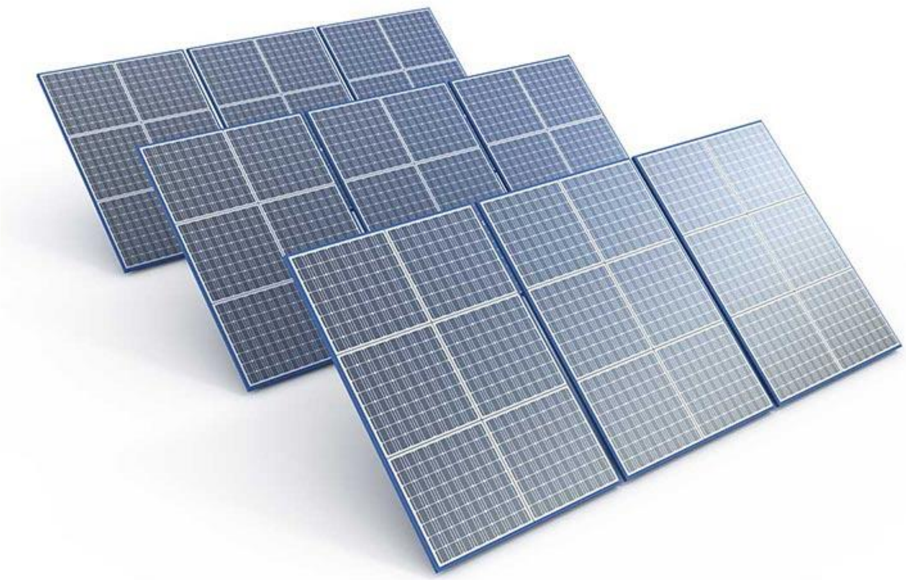

Figure 15. PV array (etap.com)

10.1 Stand-Alone PV System

A standalone PV system as shown in figure 16, is a system which is consisted of several individual photovoltaic modules, usually of 12 volts with power outputs of between 50 and 100 watts each. For isolated or country side area which are not able to have access to the grid, a stand-alone PV panel can be practical option. The stand-alone PV system produce electricity to charge banks or batteries during day time, so they can use this stored electricity power at night when the sun is not available (alternative-energy-tutorials.com).

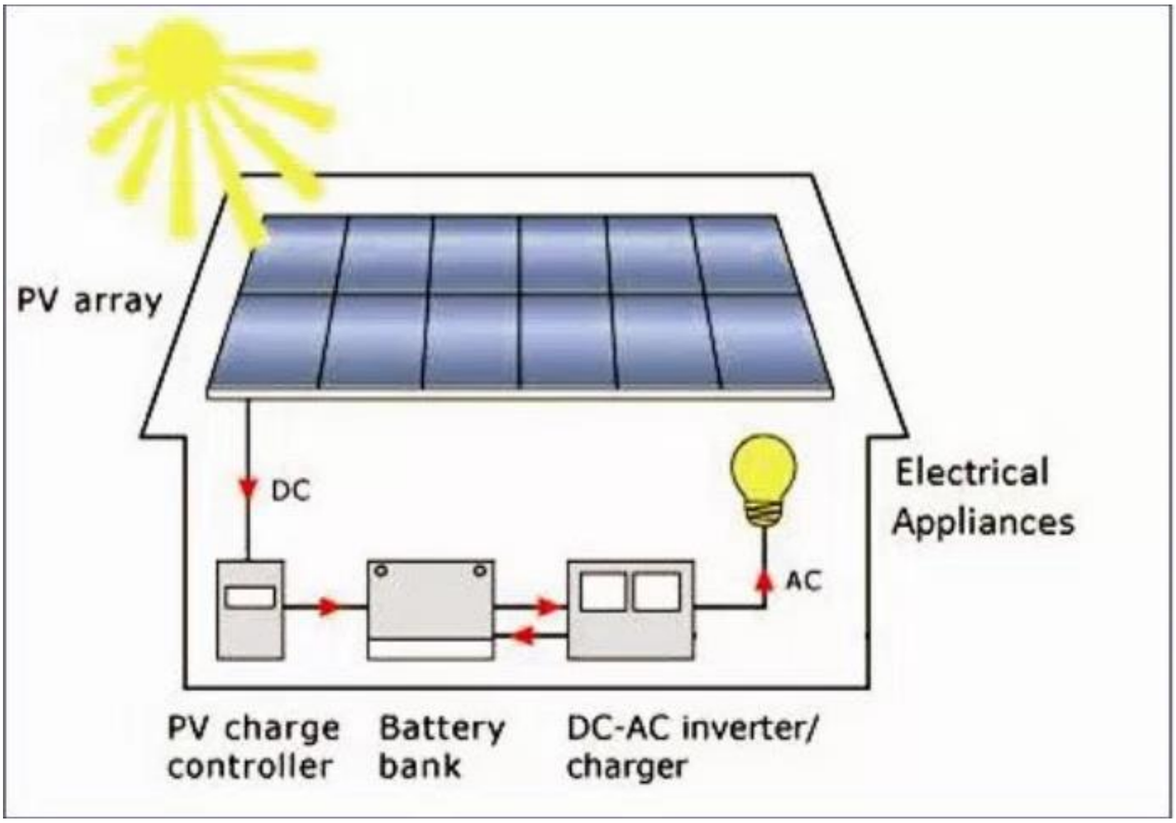

Figure 16. Stand-alone PV system (www.myace.in)

10.2 Grid Connected PV System

In the Grid connected PV system, part or most of the building electricity needs can be provided by solar panels during the day time, mostly in sunny days. During the night time or cloudy and rainy days, the local electrical grid can provide the building's electricity needs. Since the electricity cost is increasing, it can be an economic solution for the electricity consumer to supply some portion of their electricity needs from the solar panels, special during the sunny summer days when solar panels are most productive (alternative-energy-tutorials.com).

10.3 Photovoltaic-Thermal Collectors

PVT collectors as shown in figure 17, can provide both heat and electricity in one piece. It can produce a sufficient amount of energy without needing a large installation area for the collectors. The combination of PVT collectors in series or dual-source systems are beneficial combination. The efficiency of the photovoltaic collectors can decrease by increasing their temperature. Heat pumps evaporator can cool down the PV collectors and thereby improve their sufficiently (Ernst & Sohn, 2015,184)

Figure 17. Photovoltaic-thermal collector (cityu.edu.hk)

10.4 Direct Expansion Collectors

Direct expansion solar-assisted heat pump water heaters is a series of systems in which the solar collector is not filled with antifreeze, but with the refrigerant of the heat pump cycle. This system is more use for DHW in warm climate (Ernst & Sohn, 2015,184)

11 Several Configurations of SAGSHP (Hybrid)

The main question here is why do we even need a combination of an extra source with GSHP?

As previously discussed, a GSHP works by extracting and rejecting heat from the ground as a thermal source or sink. In a warm climate, where the cooling mood of the GSHP is more important, a combination of GSHP with an evaporative cooling tower, can help the GSHP to work more efficiently. Cooling towers help by carrying away the extra heat which has been rejected by GHX, so borehole temperature does not increase (Man et al.,2008,2010). Cooling towers can also prevent unacceptable change in ground temperature caused by rejecting extra heat from GHX. In a cold climate, were GSHP utilizing more for its warming propose, ground temperature decrease can be a problem, because energy is extracted from the ground continually for long periods of time. In this case, an added heat source for the GSHP can decrease ground heat loses (Dai et al,2015) As shown in figure 18, there are several configurations of combining solar panels and ground source heat pump.

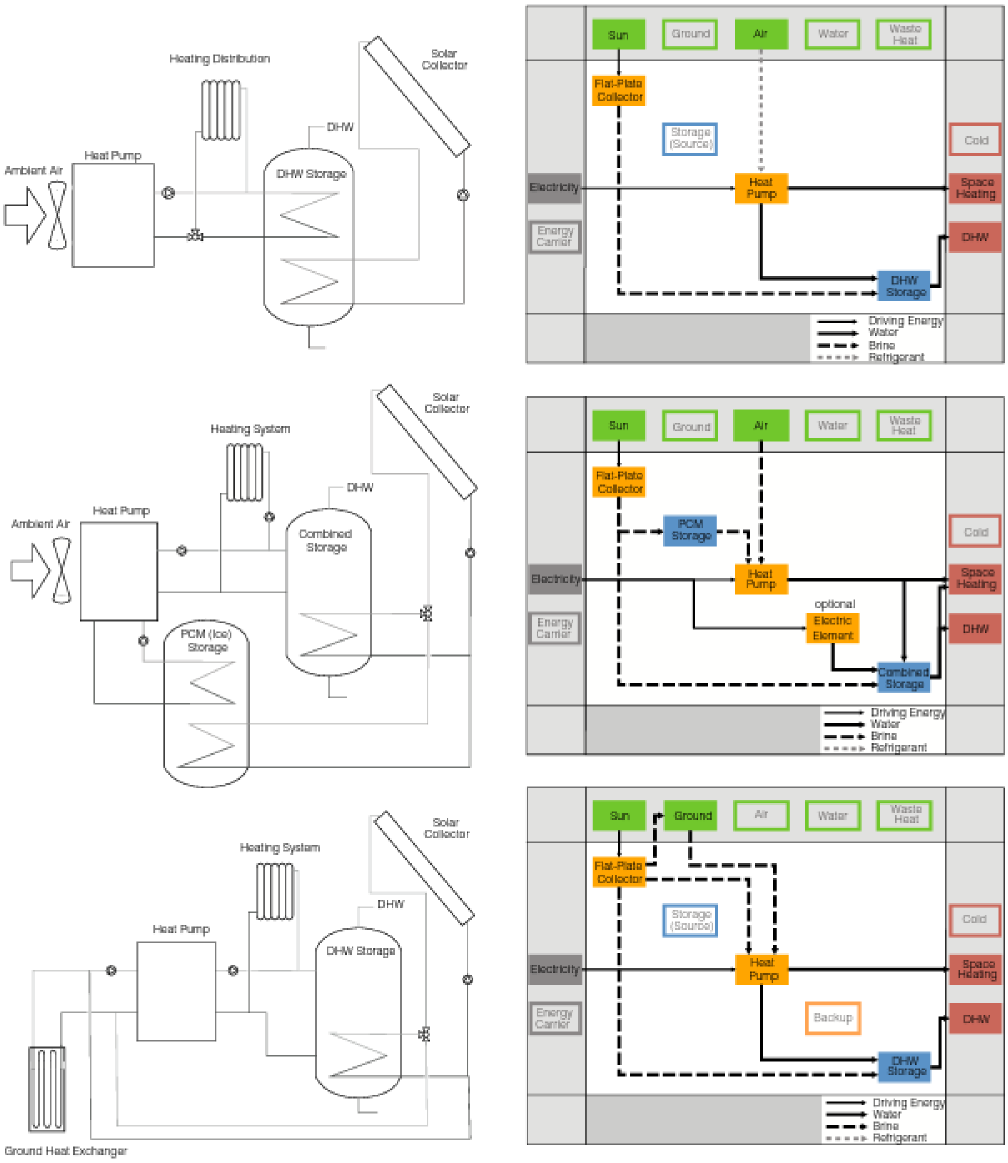

Figure 18. Several configurations of SAGSHP. Simplified hydraulic schemes (left) and corresponding visualizations (right) of different solar and heat pump systems. From top to bottom, a parallel, a parallel– series, and a parallel series– regenerative system is shown. (Ernst & Sohn, 2015)

11.1 Parallel Configuration

Parallel configuration of Solar thermal and heat pump systems, as shown in figure 19, are one of the most commen and less complicated combination of these two systems. In this configuration both system can provide sufficent heat for direct use or heat that can be stored in the storage tank for later use. There are two different Parallel configuration systems. In one of them, solar heat can be only used for DHW. In the other one solar heat can be used for both DHW and space heating (Ernst & Sohn, 2015,159).

11.2 System using Solar Heat only for DHW

In this method heat can be stored in a water storage, see figure 19(b). Temperature in water storage is higer than temperature in solar collectors or in the heat pumps. Increasing temperature in heat storages can have several reasons:

- Heat exchanger
- It increases temperature when it stores the heat
- Storage heat waste
- Combine outcome in the storage

It is recommended that heat be stored in the heat storage only if it is necessery, otherwise direct use of heat pump for the space heating is recomended. Heat storage can be obligatory for increasing the heat pump’s lifetime by decreasing the compressor on/off cycle. For this porpuse, heat storage can be used in space heating loops. Heat storage can alo be useful to provide heat in the time that there is no electricity power to drive heat pumps compressor (Ernst & Sohn, 2015,162).

There are two models for Parallel configuration of Heat pumps and Solar panels, which use solar heat for DHW and heat pump for DHW back up. These two are:

- A DHW with two heat exchangers, one in the top which charge by heat pumps and one in down for charging by solar heat input. We must take it into consideration that heat transfer capacity in upper heat exchanger be equal to the heating power of heat pump.

- A buffer storage and an external module. Heat pump charge the buffer tank directly (Ernst & Sohn, 2015,162).

in both models, solar heat can be charged with an internal heat exchanger, mantle tank design, or an external heat exchanger (Ernst & Sohn, 2015,162).

11.3 System which use Solar Heat for both DHW and Space Heating

For the system which uses solar heat for both DHW and space heating as, shown in figure 19(a), there are two different methods such as using two separate storage tanks, one for the DHW and one for the space heating or using a combi-storage. Temperature needed for DHW and space heating are in two different levels, using two separate storage tanks helps to keep the two different temperature levels of DHW and space heating separate. In other words, using combi-storage making the heat transportation form the solar loop simpler when it is only one storage which that heat need to be transported to. It also will reduce heat loss and number of the components and installations (Ernst & Sohn, 2015,163).

11.4 Performance of the Parallel Solar and Heat Pump System

The Seasonal performance factor (SPF) of SHP system increase in a Parallel integration. It is because that solar thermal collectors can provide significant amount of heat for DHW or space heating, especially during summer times, with much higher COP than the heat pumps COP (Ernst & Sohn, 2015,164).

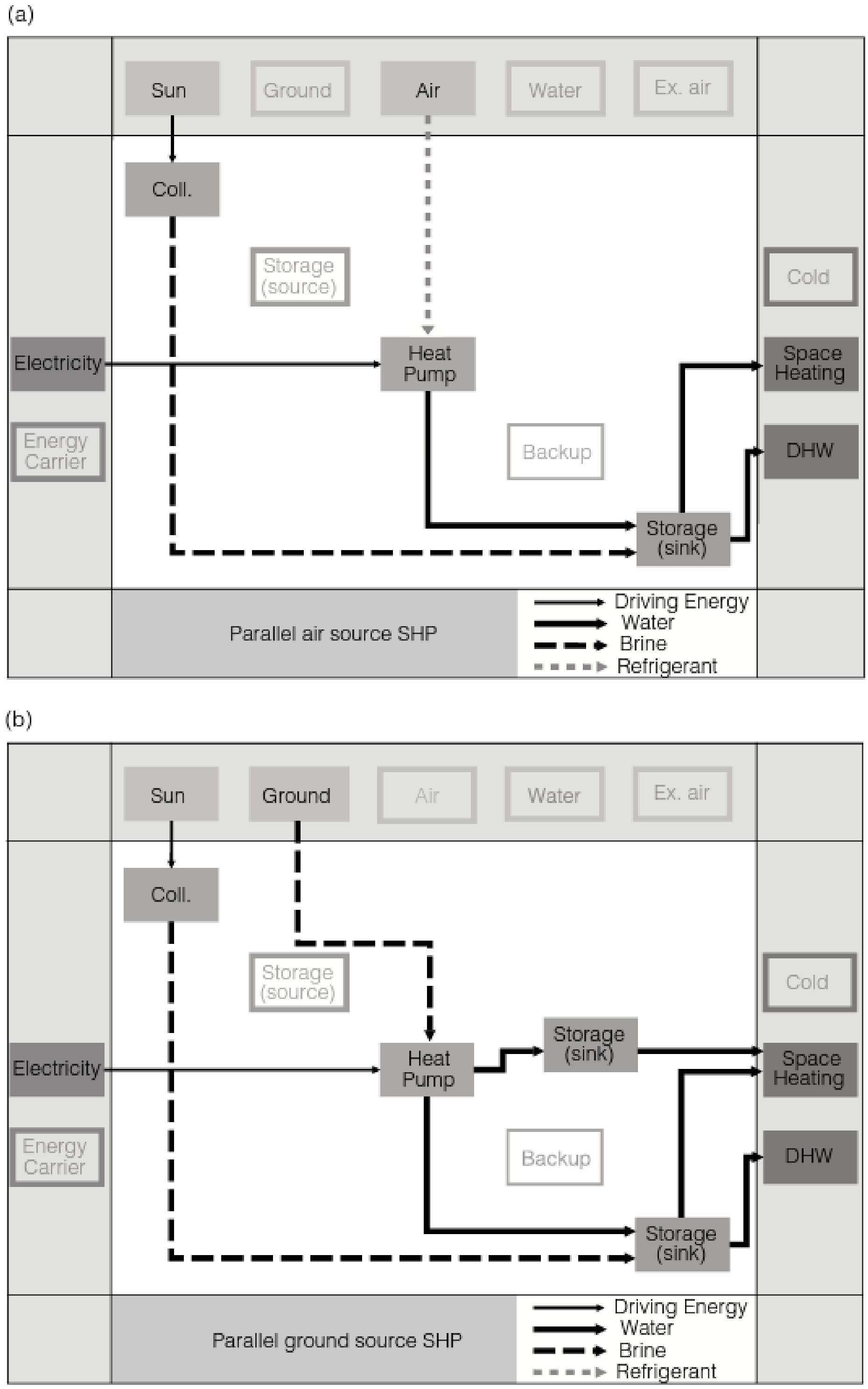

Figure 19. Use for DHW and space heating(a) solar heat is used only for DHW (b)

(Ernst & Sohn, 2015,160)

11.5 Series Configuration

In a series configuration method as shown in figure 20 (b), solar collector supply heat for the heat pumps evaporator. In a dual series configuration, heat pumps may also use other sources for heat such as air or ground heat. In a single-source series, heat pumps particularly use heat collected by solar collector or absorber. The “Single source” is a system which only use solar absorber or collector as a heat source. Aim of Single-source is to increase temperature level of the heat source or to be a replacement heat source (Ernst & Sohn, 2015,171).

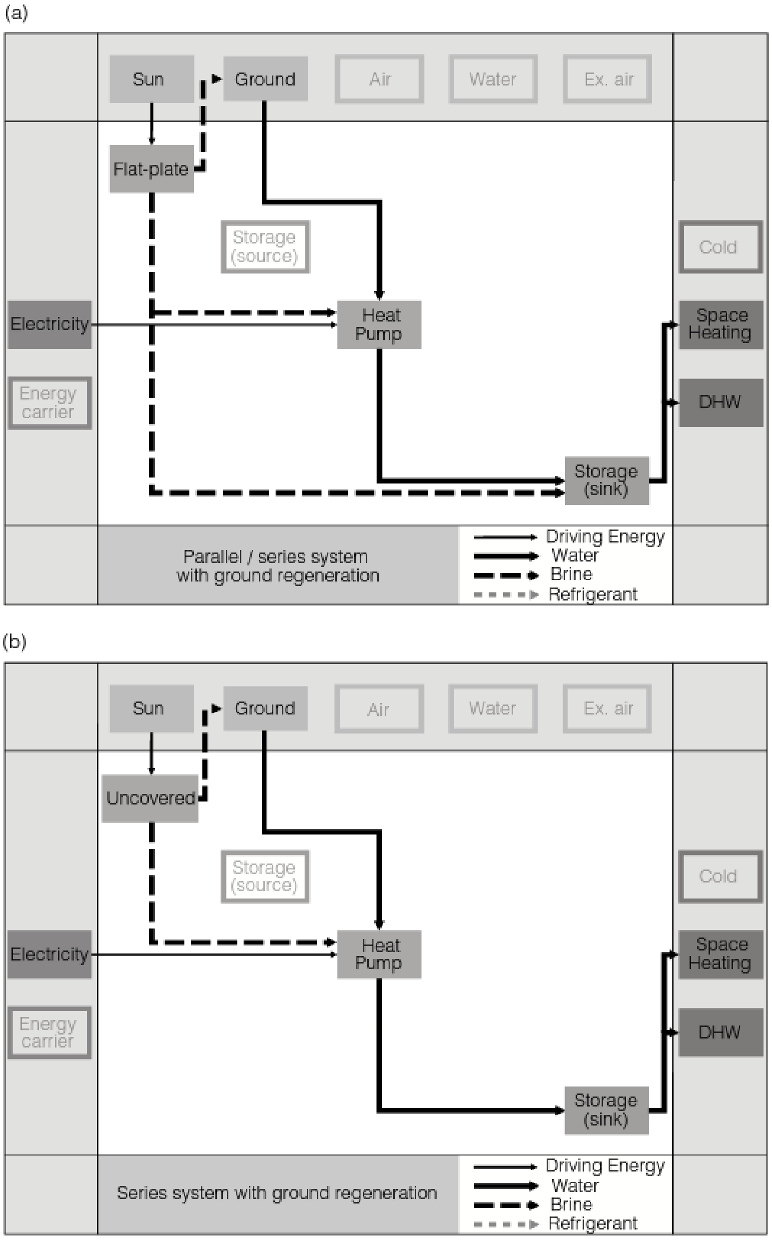

Figure 20. Energy flow chart for a Parallel/Series/Regenerative dual-source system(a) and for Series/Regenerative dual-source system(b) (Ernst & Sohn, 2015,161)

11.6 Regenerative Configuration (Ground Regeneration)

Earth thermal energy regenerate by solar irradiation in the surface and by thermal energy from the inner earth in depth 80 to 300m in a vertical borehole. If extracting heat from the vertical borehole continue, it will decrease heat output in that area over time. It will not have big effect for the single borehole (around 1K) but decreasing in temperature for the multiple boreholes with larger size, special if they have not been sized sufficiently, might have a significant impact. In the area where heat pumps constantly extract heat form the ground, the regeneration of the earth, especially from the surface and by sun irradiation, become more important. Thus, by using solar heat collector in parallel with heat pumps can provide part of the heat pump's heat, and so it can decrease the heat extraction form the ground by heat pump and help with a better heat regeneration over time, see figure 20. (Ernst & Sohn, 2015,173).

Recommendation for the ground regeneration configuration:

- Regeneration for the well dimensioned single borehole are not recommended since it has small effect on the long-term temperature level of the heat source. In this case it is not very economical to use thermal collectors or absorber only for the heat regeneration purpose.

- Regeneration is necessary for the large borehole which heat has been extracted from it over a longer period of time.

- Only excess heat or low exergy heat (when the collectors cannot produce enough heat to be used directly) should be used for heat regeneration purpose. Heat which has been produced by covered and unglazed collectors must be used directly.

- It must be taken into account when using regeneration mode, that it does not decrease the direct collector heat use. Having the device in the regeneration mode will decrease the collector heat temperature by cooling it down with ground heat sink, and the temperature will stay low even though it could have increased and being used as direct use. (Ernst & Sohn, 2015,174).

12 Summary

In the first section, geothermal energy, heat pump technology and different types of heat pumps are presented. There is a discussion and analysis of heat pump components and their performance as well as discussions about solar energy and different solar collectors and their components. The use of solar collectors and ground source heat pumps for domestic hot water and space heating have been considered as well. Towards the end, several configurations of ground source heat pumps with solar collectors such as Parallel, Series and regenerative have been presented and been analyzed. Seasonal performance factor (SPF) increase in a Parallel integration where solar collectors use for providing DHW and space heating, especially in summer time. Ground regeneration configuration is not recommended for single borehole, because it has only a small effect and it is not economically advantageous.

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Sammanfattning på svenska av examensarbetet

Allmän beskrivning av SAGSHP

Detta examensarbete presenterar tekniska aspekter kring att kombinera solkollektorteknik (solvärme och solceller) med jordvärmepumpar för att uppnå effektivare GSHP-prestanda och mer energieffektiva hus. Många energikällor riskerar att sina. El är dyrare än tidigare, och det förutses att priset på el kommer att stiga ännu mer i framtiden. Därför ökar behovet av förnybara energiresurser som kan reproducera sig på kort tid. Energiresurser som solenergi och geotermisk energi är två betydande förnybara energikällor som har möjlighet att reproducera sig på kort tid. I mänsklighetens historia har det alltid varit många innovationer som försöker hitta ett bättre sätt att använda solenergi och geotermisk energi ännu mer effektivt. Till exempel används solenergi genom solvärmepaneler och solvattenuppvärmning för att ge varmt vatten, uppvärmning av pool och utrymmen. Man kan också använda, så kallade solceller, för att producera el från solstrålningar. Det används också geotermiska energikällor som varmvatten, värme som har lagrats i bergsunderlaget och även värme från jordskorpen, för uppvärmning av utrymmen och varmvatten, genom att exempelvis använda värmepumpar eller jordvärmepumpar. I detta examensarbete fokuserar vi främst på möjligheten att integrera solfångare tillsammans med värmepumpar med jordkälla för att höja övergripande systemprestanda. Vi diskuterar också praktiska frågor i båda systemen.

Värmepumpteknologi

Värmepump är en teknik som extraherar termisk energi från en källa med lägre temperatur (mark, vatten, omgivande luft) och transporterar den genom rören till destinationsplatsen med högre temperatur. Värmepumparna körs på ångkompressionscykel och de har liknande baskomponenter som ett kylsystem. Huvudskillnaden mellan dessa två system är att kylsystemets primära produkt är den kalla sidan, medan värmepumpens mål är att flytta energi från en sida till den andra, antingen för att kyla ner eller värma upp en byggnad. Grundkomponenterna i en ångcykelanläggning är en kompressor, förångare, expansionsventil och värmeväxlare (Dincer., 2003. 215).

Jordvärmepump

Jordvärmepump är ett system som extraherar termisk energi från marken och använder denna energi för att värma upp byggnaden under den kalla årstiden. Det kan också avvisa värmen från byggnaden till marken för att kyla ner byggnaden under den heta säsongen. Som tidigare nämnts är marktemperaturen den samma året om vid ca 10 m djup, oberoende av omgivande lufttemperatur. Detta gör GSHP till en av de mest effektiva formerna för uppvärmning av hus och varmvatten (Greenmatch.co.uk).

Jordvärmepumpar har också annan förklarning baserat på jordkopplingen, såsom: grundvattenvärmepump (GWHP), jordkopplad värmepump (GCHP), ytvattenvärmepump (SWHP) och stående kolonnbrunn (SCW). (Andrew D. Chiasson. 2016, 14)

Jordvärmeväxlare, eller jordslinga, är ett nätverk av rör installerade under jord, för att extrahera energi från jordskorpans värme. Rören kan installeras vertikalt eller horisontellt. Jordslingorna bär en blandning av vatten och frostskyddslösning för att förhindra att vätskan fryser. De underjordiska rören samlar energi och transporterar den till förångaren. Detta kyler ner vätskan, som sedan pumpas ner i jordslingan igen. Distributionssystemet mottar den producerade värmen från GSHP och distribuerar den inuti huset. Det kan vara i form av golvvärmerör, VVS eller varmvatten (VVS) eller radiatorer (Greenmatch.co.uk).

Solenergi

Solenergi är förnybar energikälla som kommer från solbestrålning och det kan omvandlas till värme och elektricitet genom solvärmepanel och solceller. Solenergi har blivit mer populär, eftersom tekniken för att omvandla den till värme och el har förbättrats och det är en ren energikälla som också är miljövänlig. Till skillnad från andra energikällor som fossil och olja är solenergi nästan tillgänglig överallt i jorden varje dag. Solterminal kan ge hushållsvatten och värme för uppvärmning, medan fotovoltaiska celler kan ge el till kommersiella byggnader och bostadshus. Det finns också en del nackdelar med solpaneler. De är inte så effektiva under molniga och regniga dagar, eller de kanske inte är funktionella på natten (Greenmatch.co.uk).

Aktiva solvärmesystem

Det finns två slags aktiva solvärmesystem, direkta och indirekt cirkulationssystem. I ett direkt cirkulationssystem cirkulerar vattnet direkt genom pumpar genom kollektorerna och sedan in i hemvattensystemet. Detta system fungerar bra i klimat där vatten sällan fryser.

Solar Photovoltaic(PV)

Solceller systemet omvandlar solljus direkt till el, utan rörliga delar. Omvandlingen sker inuti PV-cellerna. En grupp av PV-celler kallas en modul (eller en PV-panel) en grupp moduler skapar en PV-Array (Roberts & Guariento, 2015.15). PV-celler är gjorda av halvledarmaterial som kisel, germanium, galliumarsenid, men moderna celler använder nästan endast kisel på grund av kostnad, tillgänglighet och effektivitet (Roberts & Guariento, 2015.15).

Flera konfigurationer av SAGSHP (hybrid)

Huvudfrågan här är varför behöver vi en kombination av en extra källa med GSHP?

Som det har diskuterats tidigare arbetar en GSHP genom att extrahera och avvisa värme från marken som en termisk källa / diskbänk. I ett varmt klimat, där kylningstemperaturen hos GSHP är viktigare, kan en kombination av GSHP med ett förångande kyltorn hjälpa GSHP att arbeta mer effektivt. Kyltorn hjälper till med att transportera bort den extra värme som har avvisats av GHX, så att temperaturen för borrhål inte ökar (Man et al., 2008, 2010). Kyltorn kan också förhindra oacceptabel förändring i marktemperaturen som orsakas av att avvisa extra värme från GHX. I ett kallt klimat, var GSHP utnyttjas mera för sin uppvärmning, kan nedgången i marktemperaturen vara ett problem, för energi extraheras kontinuerligt från marken under långa perioder. I detta fall kan en tillförd värmekälla för GSHP minska mängden värmeförlust (Dai et al, 2015

Parallell konfiguration

Parallell konfiguration av solvärme och värmepumpsystem är den vanligaste och mindre komplicerade kombinationer av dessa två system. I denna konfiguration kan båda systemen tillhandahålla tillräcklig värme för direkt användning eller värme som kan lagras i lagertanken för senare användning. Det finns två olika parallella konfigurationssystem. I det ena kan solvärme endast användas för varmvatten. I det andra kan solvärme användas för både varmvattenberedning och uppvärmning av hus (Ernst & Sohn, 2015,159).

Seriekonfiguration

I en seriekonfigurationsmetod matar solfångaren värme till värmepumpens förångare. I en serie med dubbla serier kan stället för värmepumpar också användas andra värmekällor, såsom luft eller markvärme. I en enskild serie använder värmepumpar i synnerhet värme som uppsamlas av solfångare eller absorberar. "Enkelkälla" är ett system som bara använder solabsorbent eller kollektor som värmekälla. Syftet med en enda källa är att öka värmekällans temperaturnivå eller att vara en ersättningsvärmekälla (Ernst & Sohn, 2015,171).

Regenerativ konfiguration (markregenerering)

Jordens termiska energi regenereras genom solstrålning i ytan och genom värmeenergi från inre jorden på djupet 80 till 300 m i ett vertikalt borrhål. Om extrahering av värme från det vertikala borrhålet fortsätter, minskar värmeutbytet i det området över tiden. Det kommer inte att ha stor effekt för det enskilda borrhålet (ca 1 K). Men minskar temperaturen för fler borrhål med större storlek, speciellt om de inte har dimensionerats tillräckligt, vilket kan ha en betydande inverkan. I områden där värme ständigt extraheras från jorden genom värmepumpar blir regenerering av värme från jorden, speciellt från ytan och genom solbestrålning, allt viktigare. Genom att använda solvärmeuppsamlare parallellt med värmepumpar kan det alstra en del av värmepumpens värme. Det kan minska värmextraktionsformen från marken med värmepump och med tiden hjälpa till med bättre värmegenerering. (Ernst & Sohn, 2015, 173).

Sammanfattning

I det första steget presenteras geotermisk energi, värmepumpsteknik och olika typer av värmepumpar. Det diskuteras och analyseras om komponenter i värmepumpar och dess prestanda samt diskussioner om solenergi och olika solfångare och deras komponenter. Användningen av solfångare och jordvärmepumpar för varmvatten och uppvärmning har också beaktats. I slutet har flera konfigurationer av jordvärmepumpar med solfångare som parallell, serie och regenerativ presenterats och analyserats. Seasonal Performance Factor (SPF) ökar i en parallell integration där solfångare används för att tillhandahålla varmvatten och uppvärmning, särskilt på sommartid. Jordförnyelsekonfiguration rekommenderas inte för singelhål, eftersom det bara har en liten effekt och det är inte ekonomiskt fördelaktigt.