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A Review on Analysis of Geothermal Heat Pump, Its Use and Benefits

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ABSTRACT

Geothermal system are becoming popular day by day during the surge of green building. Ground Source heat pump (GSHP) or Geothermal heat pump are arrangments of Uniting heat pumps with high enthalpy geothermal resources or by providing by ground water from well in open loop system. Since few decades of research focusing on GSHP through world resulted in a well recognised concept of sustainability for this technology. Heat pump systems offer economical alternatives of recovering heat from different sources for use in various industrial, commercial and residential applications. As the cost of energy continues to rise, it becomes imperative to save energy and improve overall energy efficiency The major benefits of this system are they do not pollute environment and reason behind this is because they are operated from earth's natural energy and do not alter the chemical compound. The large number of geothermal heat pumps are operational , but meanwhile installing and control on quality of system is major issue till today. This study deals with reviewing heat pump studies , analysis the develpoment and type in first part, benefits and usage was brifely given and paper conclude with analysied data on GSHP.

1. INTRODUCTION

Geothermal energy is pure and suistainable source of energy, which can be used to decrease individual ecological footprints and make envirnment pollutant free. Geothermal energy has been used for various purpose like aquaculture, agriculture, electricity genration, spcae heating and cooling. Etc. countries like England, Sweden and China use technology of ground source heat pump for space heating and cooling purpose. Gujarat as a state has been atforefront in renewable energy sector in India and 17.8% of its intalled capacity is from renewable energy source.

Commercial and domestic facilities are answerable for high energy consumption and greenhouse gas emission. To reduce this emission and mve towards cleanner source of energy, it is appropriate to use ground source heat pump system for exploitation of geothermal energy. This system can be used from large building or complexes to small residential houses. The commercial sectors, installation of GSHP tends to be much larger than that of residential houses. The technology to exploit geothemal energy has improved by leaps and bounds since then Vaidya et al. (2017).

Heat pump is a device used to tranfer heat from one source to another (sink) it can be either be used for heating or cooling purpose sircar et al. (2017). It can either be used for heating or cooling purpose. Before performing the simulation for the system using different temperature cases, it is important to perform pre-feasibility studies such as geochemical testing and sustainability of temperature and flow rate of producing water.

2. GROUND SOURCE HEAT PUMP (GSHP)

The demand of GSHPs has increased currently Due to increase in the capital and operational expenditure of conventional heating and cooling applications along with various environmental issues. The latest trend in residential and commercial heating and cooling is installation of ground source heat pumps. The purpose of heat pump is to transfer of heat to a high temperature medium, called heating load. When we are intrested in heat energy supplied to high-temperature space, this device is caled heat pump. In general , the term heat pump is used to described cycle as heat energy is removed from low-temperature space and rejected to high temperature space. The performance of heat pump is expressed in terms of coefficint of perfomance (COP).

A geothermal heat pump (GHP) or ground source heat pump (GSHP) is a central heating and/or cooling system that transfers heat to or from the ground, often through a vapor-compression refrigeration cycle. It uses the earth all the time, without any intermittency, as a heat source (in the winter) or a heat sink (in the summer). This design takes advantage of the moderate temperatures in the ground to boost efficiency and reduce the operational costs of heating and cooling systems, and may be combined with solar heating to form a geosolar system with even greater efficiency. They are also known by other names, including geoexchange, earth-coupled, earth energy systems. The engineering and scientific communities prefer the terms geoexchange or ground source heat pumps to avoid confusion with traditional geothermal power, which uses a high temperature heat source to generate electricity. Ground source heat pumps harvest heat absorbed at the Earth's surface from solar energy. The temperature in the ground below 6 metres (20 ft) is roughly equal to the local mean annual air temperature

The net thermal efficiency of a heat pump should take into account the efficiency of electricity generation and transmission, typically about 30%. Since a heat pump moves three to five times more heat energy than the electric energy it consumes, the total energy output is much greater than the electrical input. This results in net thermal efficiencies greater than 300% as compared to radiant electric heat being 100% efficient. Traditional combustion furnaces and electric heaters can never exceed 100% efficiency

The heat pump is the central unit that becomes the heating and cooling plant for the building. Some models may cover space heating, space cooling, (space heating via conditioned air,hydronic systems and / or radiant heating systems), domestic or pool water preheat (via the desuperheater function), demand hot water, and driveway ice melting all within one appliance with a variety of options with respect to controls, staging and zone control. The heat may be carried to its end use by circulating water or forced air. Almost all types of heat pumps are produced for commercial and residential applications.

The working of geothermal heat pump, heat pump, and air conditioner is based on a vapor compression cycle. The basic components of a vapor-compression cycle are evaporator, condenser, compressor and expansion valve.

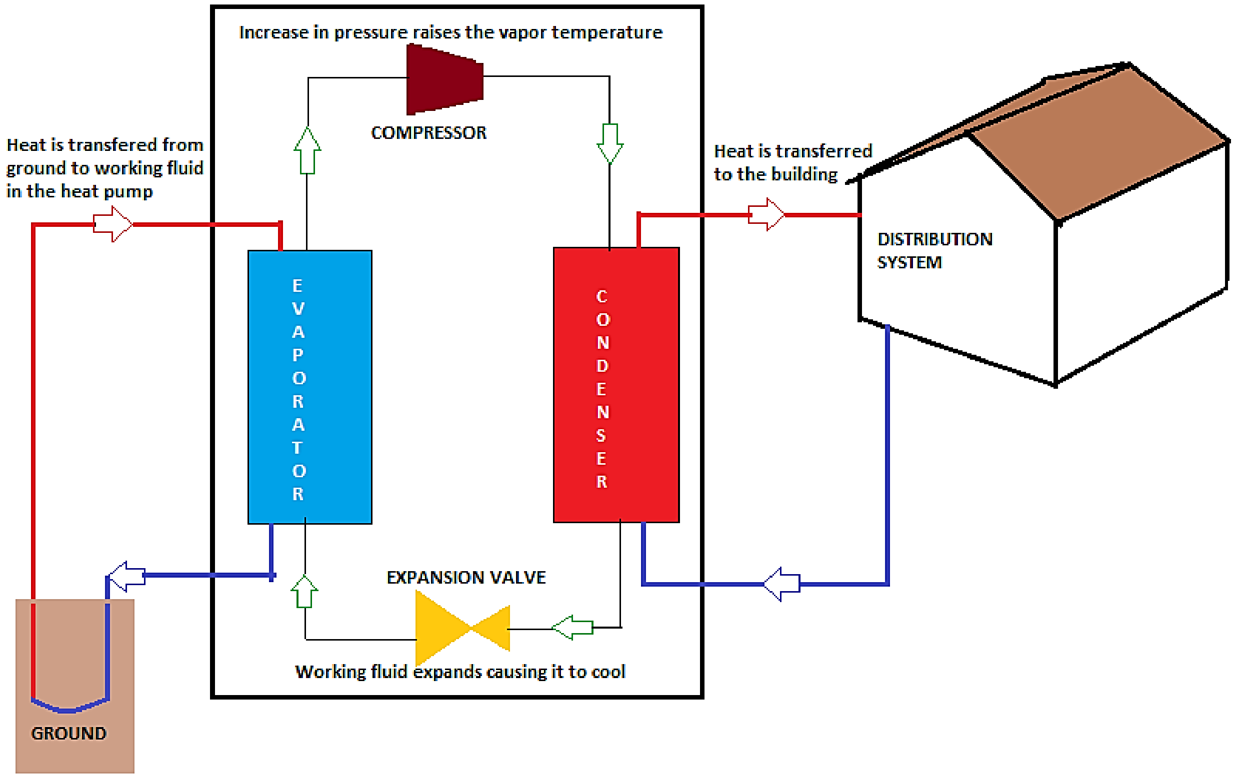

Figure 1: The Ground Source Heat Pump (GSHP).

Heat transfer in ground source heat pump generally drives using working fluid, also known as refrigerant which is shown in Figure 1. In the evaporator section, the heat transfer takes Place between the hot fluid (source) and the circulating refrigerant. Refrigerant is selected in such a way that, it has the boiling point lower than that of water. The hot refrigerant is then fed into a compressor section where gas compression helps increase the pressure and temperature. This section is powered by an external source. The compressed refrigerant passes in to the condenser section where heat from the refrigerant is rejected (sink). The refrigerant then enters an expansion chamber where temperature and pressure drop significantly Pertzborn et al.(2010) sircar et al.(2017). The same cycle is repeated in the heat pump. Depending upon the temperature difference and surrounding conditions, the amount of work required varies

Ground source heat pump (GSHP) systems use the ground as a heat source/sink to provide space heating and cooling as well as domestic hot–water. The GSHP technology can offer higher energy efficiency for air-conditioning compared to conventional air-conditioning (A/C) systems because the underground environment provides higher temperature for heating and lower temperature for cooling and experiences less temperature fluctuation than ambient air temperature change Ioan and calin, (2015). To date, the GSHP systems have been widely used in both residential and commercial buildings. It is estimated that the GSHP system installations have grown continuously on a global basis with the range from 10% to 30% annually in recent years.

The dependence of net thermal efficiency on the electricity infrastructure tends to be an unnecessary complication for consumers and is not applicable to hydroelectric power, so performance of heat pumps is usually expressed as the ratio of heating output or heat removal to electricity input. Cooling performance is typically expressed in units of BTU/hr/watt as the energy efficiency ratio(EER), while heating performance is typically reduced to dimensionless units as then coefficient of performance(COP). The conversion factor is 3.41 BTU/hr/watt. Performance is influenced by all components of the installed system, including the soil conditions, the ground-coupled heat exchanger, the heat pump appliance, and the building distribution, but is largely determined by the "lift" between the input temperature and the output temperature

3. OPERATING PRINCIPLE OF HEAT PUMP

Heat pump is a thermal installation which is based on a reverse thermodynamic cycle (consumes action energy and produces a thermal effect). Any heat pump takes heat from a low potential thermal source, at temperature source ts and with an energy action EA it raises the thermal potential and yeild this heat for a consumer at uniform temperature.

• Heat source can be: − a gas or air (oudoor air, warm air from processes of cooling or ventilation, hot gases from industrial.

− a liquid called generic water: surface water (river, lake, sea), ground water (underground water,geothermal water), discharged hot water (domestic,recirculated in cooling towers, technological);

− soil (with the advantage of accessibility and the temperature constance at a depth of over 4 m, but with the disadvantage of low heat transfer).

• Heat Consumer.

The heat pump yields thermal energy at a higher temperature is depending on the application of heat consumer. This energy can be used to:

− spaces heating; heating with heat pump who will be related to heating systems that require low temperature: radiant systems (radiant panels, heating from floor), warm air or convective systems (ventiloconvectors);

− water heating (pools, domestic and technologic hot water);

− achivement of technological processes (drying, distillation of solutions, salt concentration).

It is recommended that whenever possible, the heat consumer to be associated with a cold consumer, in which case, the same installation will achieve both effects: the heat production and cold production. This can be performed with either a reversible (heating-cooling) or a double effect (it produces simultaneously heat and cold) installation.

• Action Energy.

Heat pumps can use to engage different forms of energy:

− electrical energy (electrocompressor installation);

− mechanical energy (mechanical compression installation, with the action energy produced with expansion turbines);

− thermal energy (installation with mechanical compression, absorption or ejection). In this case is required either a fuel feeding the thermal motor of compression installation with an internal combustion motor, or thermochemical compressor digester of absorption installation with direct combustion or a hot fluid (steam, condensate, hot water, warm gases) which supplies the digester of absorption installation or the ejector of ejection installation

4. TYPES OF HEAT PUMPS

Heat pumps basified by (1) heat source and sink, (2) heating and cooling distribution fluid, (3) thermo-dynamic cycle.

- **Air-to-air heat pumps**: This type of heat pump is the most common and is particularly suitable for factory-built unitary heat pumps.
- **Water-to-air heat pumps**: These heat pumps rely on water as the heat source and sink, and use air to transmit heat to or from the conditioned space. They include the following: 1)ground-water heat pumps, which use ground-water from wells as a heat source and/or sink; 2)surface water heat pumps, which use surface water from a lake, pond, or stream as a heat source or sink; 3) solar-assisted heat pumps, which rely on low-temperature solar energy as the heat source.
- **Ground-couplet heat pumps**: These use the ground as a heat source and sink. A heat pump may have a refrigerant-to-water heat exchanger or may be direct-expansion (DX). In systems with refrigerant-to-water heat exchangers, a water or antifreeze solution is pumped through horizontal, vertical, or coiled pipes embedded in the ground. Direct-expansion ground-coupled heat pumps use refrigerant in direct-expansion, flooded, or recirculation evaporator circuits for the ground pipe coils.
- **Water-to-water heat pumps**: These heat pumps use water as the heat source and sink for heating and cooling. Heating/cooling changeover can be done in the refrigerant circuit, but it is often more convenient to perform the switching in the water circuits. Several water-to-water heat pumps can be grouped together to create a central cooling and heating plant to serve several air-handling units. This application has advantages for better control, centralized maintenance, redundancy, and flexibility.
- **Hybrid heat pumps**: A hybrid ground-coupled heat pump is a variation that uses a cooling tower or air-cooled condenser to reduce the total annual heat rejection to the ground coupling. A hybrid air-to-water heat pump system integrates an air-to-water heat pump with another non-renewable heat source.
- Recently, the ground-source heat pump (GSHP) system has attracted more and more attention due to its superiority of high energy-efficiency and environmental friendliness Bose et al. (2002) Sarbu et al.(2010) Ioan and calin (2015). Renewable forms of energy such as solar, wind, biomass, hydro, and earth energy produce low or no GHG emissions. The temperature of the ground is fairly constant below the frost line. The ground is warmer in the middle of winter and cooler in the middle of summer than the outdoor air. Thus, the ground is an efficient heat source. A GSHP system includes three principle components: (1) a ground connection subsystem, (2) heat pump subsystem, and (3) heat distribution subsystem.

The GSHPs comprise a wide variety of systems that may use ground−water, ground, or surface water as heat sources or sinks. These systems have been basically grouped into three categories by ASHRAE et al. (2011) Ioan and calin, (2015): (1) ground-water heat pump (GWHP) systems, (2) surface water heat pump (SWHP) systems, and (3) ground-coupled heat pump (GCHP) systems

5. ECONOMIC ANALYSIS OF HEATING SOLUTIONS FOR A BUILDING

Ground source heat pumps are characterized by high capital costs and low operational costs compared to other HVAC systems. Their overall economic benefit depends primarily on the relative costs of electricity and fuels, which are highly variable over time and across the world. Based on recent prices, ground-source heat pumps currently have lower operational costs than any other conventional heating source almost everywhere in the world. Natural gas is the only fuel with competitive operational costs, and only in a handful of countries where it is exceptionally cheap, or where electricity is exceptionally expensive.In general, a homeowner may save anywhere from 20% to 60% of money annually on utilities by switching from an ordinary system to a ground-source system.

Ground source heat pumps are recognized as one of the most efficient heating and cooling systems on the market. They are often the second-most cost effective solution in extreme climates after co-generation, despite reductions in thermal efficiency due to ground temperature. (The ground source is warmer in climates that need strong air conditioning, and cooler in climates that need strong heating.) The financial viability of these systems depends on the adequate sizing of ground heat exchangers (GHEs), which generally contribute the most to the overall capital costs of GSHP systems.

5.1. Assumptions for Calculation

A study is performed for the heating of a living building in rural areas with a water-water heat pump, using as heat source the underground water comparative to other sources of primary energy. The building with useful surface of 240 m2 (basement-floor, ground-floor, floor, and bridge) is heated from 1993 with radiators from thermal station with gas-oil. Indoor air temperatures were considered in accordance with the wishes of the client: +20 °C for the stairway and annex spaces; +22 °C for day rooms and bedrooms; 24 °C for baths. Construction materials which distinguish heated spaces are: 50 cm brick for exterior walls, concrete 10 cm and 15 cm layer of expanded polystyrene insulation for the bridging, double glazing in oak. Exterior walls will be isolated from the outside with expanded polystyrene (10 cm).

Calculation of heat demand Qnec was performed for the existing building envelope (exterior walls without insulation) and after thermal rehabilitation of it (exterior walls insulated with 10 cm expanded polystyrene), for more outdoor air temperatures (table 1) in order to choose efficient heat source. For the preparation of domestic hot water is necessary to consider a heat Qdhw = 3 kW (3 persons,3 bathrooms and a kitchen).

Table 1: Heat demand for heating

T_c [ºc]	Q_{nec} [kW]	Q_{nec} [kW]
	Existent envelope	**Rehabilitated envelope**
+5	18.9	13.6
0	20.2	15.5
-5	21.6	17.4
-10	23.0	18.3
-15	24.3	19.1
-20	25.6	21.1

5.2. Solution Proposed

Building heating is realised as follows:

− heating of living spaces (living rooms, bedrooms, stairway) with the floor convector-radiator;

− bathroom heating with radiators (towel− port);

− hot water temperature to radiators and convector− radiator: 50/40 °C;

− for supply of radiators and convector-radiators are used distributor/collector systems;

− distribution network for radiators and convector− radiators, pexal made, is placed at ceiling, basement-floor, ground-floor and floor.

The heat demand of building will be provided by a heat pump type Thermia Eko 180 and a boiler with the capacity of 300 liters. Mechanical compression heat pump (scroll compressor) operates with ecological refrigerant R404A. The heat source is the groundwater aquifers with minimum temperature of 10 °C.

In the operating conditions with t_o = 8 °C and t_c = 50°C the thermal power of heat pump is QPC = 21 kW. It finds that this thermal power assure part of the building heat demand, only for outdoor temperatures higher than −5 °C, in the actual situation, and almost entirely (even for the outdoor temperature of −20 °C), in conditions of thermal rehabilitated envelope (exterior walls isolated additional). To assure the rest of heat demand (heating and preparation of domestic hot water) heat pump is equipped with 3 electrical resistance by 3 kW, which operate automatically.

For flow rate control in the hot water distribution network from the heating cicuit, there are provided the following measures:

− a first adjustment of the flows rate that are supplied the terminal units (radiators or convectorradiators), achieved by progressive reduction of the pipe diameters;

− base adjustment, achieved through the regulating valves of flow for each column;

− final adjustment at the terminal units, developed by the thermostat valves set at the comfort temperature in each room.

5.3. Economical Analysis

: Comparing the solution described for building heating with other possible variants of primary energy sources (LPG, gas-oil and natural gas) results a superior investment for heat pump, but also an economy in operating costs, which enable the recovery of additional investment. In tables 2 and 3 are presented the necessary investments and operating costs over a period of 10 years for the considered variants

Table 2: Investment Costs I, For Heat Pumps (HP) and Different Boilers

Solution components	HP	Thermal boiler with fuel :		
		LPG	Gas-oil	Natural gas
0	1	2	3	4
Heat pump/boiler	7700	3000	3000	3000
Underground water captation	4900	-	-	-
Hear exchanger	1300	-	-	-
Circulation pumps	1200	-	-	-
Fuel tank	-	3500	3500	-
Gas connection	-	-	-	4000
Total	15100	6500	6500	7000

Table 3. Operating Expenses for heat pump (HP) and different thermal boilers

Solution characteristics	HP	Thermal boiler with fuel :		
		LPG	Gas-oil	Natural gas
0	1	2	3	4
Thermal power,[kW]	21+9	24	24	24
Fuel calorific power ,[kW/1]	-	6.30	10.0	9.44
TS efficiency/HP-COP	2.33	0.90	0.85	0.90
Hour consumption(fuel, [l/h] / electric energy [kW]	9.00	4.23	3.02	2.84
Annual operating [h/year]	18708*	1700	1700	1700
Fuel price,[€/1] / electricity price, [€/kWh]	0.087	0.500	0.900	0.300
Annual consumption, [l/an:kWh/an]	16830	7191	5134	4828
Annual energy cost, [€/an]	1464	3595.5	4620.5	1448.5
Estimated energy price increase in 10 years	1.30	1.40	1.40	2.00
Operating expense (10 years). C[€]	1903.2	5033.7	6468.7	2897.0
Annual operation of electrical is considerd 10% of the normal operation period, so at the 1700 hours/year is adding 170 hours/year.				

Results the recovery time of additional investment for heat pump, compared with thermal boilers:

− toward boiler to LPG

$$TR = \frac{I_{HP} - I_{TS,\text{LPG}}}{C_{TS,\text{LPG}} - C_{HP}} = \frac{15100 - 6500}{5033.7 - 1903.2} = 2.74 \text{ years}$$

– toward gas-oil boiler:

$$TR = \frac{I_{HP} - I_{TS,\text{gas-oil}}}{C_{TS,\text{gas-oil}} - C_{HP}} = \frac{15100 - 6500}{6468.7 - 1903.2} = 1.88 \text{ years}$$

– toward natural gas boiler:

$$TR = \frac{I_{HP} - I_{TS,\text{natural gas}}}{C_{TS,\text{natural gas}} - C_{HP}} = \frac{15100 - 7000}{2897.0 - 1903.2} = 8.15 \text{ years}$$

It is noted that compared to any of the heating solutions to boilers, heating with water-water heat pump has a recovery period of investment TR smaller than normal recovery period TRn, of 8 to 10years.

6. CONCLUSION

Accurate conversion of the heat source and the heating system for operating regime of heat pumps, leads to safe and economic operation of the heating system using heat pumps. Heat pump provides the necessary technical conditions for efficient use of solar heat for heating and production of domestic hot water. Heating installations with heat pumps produces minimum energy consumption in operation and are certainly a solution for energy optimization of buildings.

The paper gives breif information operating principle of heat pump and also explains different types of heat pumps. The perfunctory economic analysis is performed for heating of living building in rural area with water – water heat pump , a study performed with few comparision between heating boliers, LPG, Gas-oil and Heat pump as a result it is distinguished that compared to any of the heating solutions to boilers, heating with water-water heat pump has a recovery period of investment TR smaller than normal recovery period TRn, of 8 to 10years.

ABBREVIATIONS.

TC - Condensation Absoulte temperature of Refrigerants

TO – Vaporization absoulate Temperature

TS – Thermal Station

TR – Recovery Time

Q_{pc} – Heat pump Capacity

I – Investment Cost

HP – Heat pump

C – Operating Expense

Gasoil – Distillation of petroleum

LPG – Liquefied petroluem gas

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