SCOPE OF GEOTHERMAL ENERGY USAGE FOR AIR CONDITIONING IN BUILDINGS

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ABSTRACT

In the present scenario a very large portion of energy is used for the air conditioning of the buildings. Which is the wastage of energy as it is required for cooling in summer and for heating in winters. So it is desired that we must use the renewable sources of energy for this purpose and geothermal energy may be one of the suitable energy source. Geothermal energy is the energy stored in the earth which is received by earth directly from sun and produced by the slow decay of radioactive substances present in the earth’s crust. Further the temperature of earth in depths is almost remains constant in all seasons. So this constant temperature can be utilised for air conditioning in the buildings. This paper presents the possibilities of geothermal energy uses for the air conditioning of buildings. The use of geothermal energy in air conditioning replaces the amount of energy (electricity) required to produce the heat. Use of this energy also minimises the production of greenhouse gases.

KEYWORDS: Geothermal Energy, Air Conditioning, Environment, Sustainable Energy, Power Plants, Heating

INTRODUCTION

Geothermal energy comes from the heat within the earth. The word "geothermal" comes from the Greek words geo, meaning earth," and therme, meaning "heat" [1]. This energy is clean, cheap and sustainable. Resources of this geothermal energy range from the shallow ground hot water to hot rocks which are found a few miles under the Earth's surface, having the extremely high temperatures of molten rock called magma.

The shallow ground or upper 10 feet of the Earth's surface maintains an almost constant temperature between 50° and 60°F (10° and 16°C) [2]. The temperature of earth increases with the increase in the depth i.e. moving from the surface towards the earth’s core. The earth's core lies almost 4,000 miles beneath the earth's surface. Estimates of the temperature of the core range from 5,000 to 11,000 degrees Fahrenheit (F). Heat is continuously produced within the earth by the energy received from the sun and the slow decay of radioactive particles that is natural in all rocks [1]. Surrounding the earth's core is the mantle, thought to be partly rock and partly magma. The mantle is about 1,800 miles thick. The outermost layer of the earth, the insulating crust, is not one continuous sheet of rock, but is broken into pieces called plates. The interior of earth is shown in the figure 1[3]. Geothermal energy is called a renewable energy source because the water is replenished by rainfall, and the heat is continuously produced by the earth.

![Figure 1: Internal Details of Earth](image-url)
History of Geothermal Energy

Many ancient peoples, including the Romans, Chinese, and Native Americans, used hot mineral springs for bathing, cooking, and heating. Water from hot springs is now used world-wide in spas, for heating buildings, and for agricultural and industrial uses. Many people believe hot mineral springs have natural healing powers. Using geothermal energy to produce electricity is a relatively new industry. It was initiated by a group of Italians who built an electric generator at Lardarello in 1904. Their generator was powered by the natural steam erupting from the earth [1].

The heat pump was described by Lord Kelvin in 1853 and developed by Peter Ritter von Rittinger in 1855. After experimenting with a freezer, Robert C. Webber built the first direct exchange ground-source heat pump in the late 1940s[4]. The first successful commercial project was installed in the Commonwealth Building (Portland, Oregon) in 1946, and has been designated a National Historic Mechanical Engineering Landmark by ASME[5].

The technology became popular in Sweden in the 1970s, and has been growing slowly in worldwide acceptance since then. Open loop systems dominated the market until the development of polybutylene pipe in 1979 made closed loop systems economically viable[5]. As of 2004, there are over a million units installed worldwide providing 12 GW of thermal capacity.[6] Each year, about 80,000 units are installed in the US (geothermal energy is used in all 50 US states today, with great potential for near-term market growth and savings)[7] and 27,000 in Sweden.[6]

SOURCES OF GEOTHERMAL ENERGY

Geothermal energy in the layers of earth is continuously produced by the energy received by from the sun and slow decay of radioactive substances underneath the surface especially in the rocks [1]. The energy produced underneath the surface of earth comes to the surface through various natural sources like volcanoes, hot springs, geysers and fumaroles [3]. Geothermal energy is mainly available on earth surface in the four main kinds of geothermal resources which are:-

- Hydro-thermal
- Geo-pressured
- Hot dry rock
- Magma

Energy is available from the four major sources of geothermal energy but out of which hydrothermal resources are the only kind in wide use. The other three resources are still in the infant stages of development this is due to the difficult and costly process requirements for the use of later three sources viz. Geo-pressured, Hot dry rock and Magma.

APPLICATIONS OF GEOTHERMAL ENERGY

There is more than one type of geothermal energy, but as stated above only one kind is widely used to make electricity. It is called hydro thermal energy.

Hydrothermal resources have two common ingredients viz. water (hydro) and heat (thermal) [3]. Depending on the temperature of the hydrothermal resource, the applications are mainly divided in to three categories depending upon the temperature available from the source and these are:-

- Geothermal Electricity production (High Temperature)
- Direct Use or Heating (Low Temperature)
Geothermal Electricity Production

Most of the power plants need steam to generate electricity. The energy of steam is used to rotate a turbine which is coupled to a generator, which produces electricity and most of the power plants still use fossil fuels to boil water to form steam. Geothermal power plants, however, use steam produced from reservoirs of hot water found underneath the Earth's surface. There are three types of geothermal power plants: dry steam, flash steam, and binary cycle. A geothermal power plant is shown in figure 2 [8].

**Dry Steam Power Plants:** These power plants draw the steam from underground resources of steam. The steam is piped directly from underground wells to the power plant, where it is directed into a turbine/generator unit. There are only two known underground resources of steam in the United States: The Geysers in northern California and Yellowstone National Park in Wyoming, where there's a well-known geyser called Old Faithful. Since Yellowstone is protected from development, the only dry steam plants in the country are at The Geysers.

**Flash Steam Power Plants:** These power plants are the most common. They use geothermal reservoirs of water with temperatures greater than 360°F (182°C). This very hot water flows up through wells in the ground under its own pressure. As it flows upward, the pressure decreases and some of the hot water boils into steam. The steam is then separated from the water and used to power a turbine/generator. Any leftover water and condensed steam are injected back into the reservoir, making this a sustainable resource.

**Binary Cycle Power Plants:** These power plants operate on water at lower temperatures of about 225°-360°F (107°-182°C). These plants use the heat from the hot water to boil a working fluid, usually an organic compound with a low boiling point. The working fluid is vaporized in a heat exchanger and used to turn a turbine. The water is then injected back into the ground to be reheated. The water and the working fluid are kept separated during the whole process, so there are little or no air emissions. Small-scale geothermal power plants (under 5 megawatts) have the potential for widespread application in rural areas, possibly even as distributed energy resources. Distributed energy resources refer to a variety of small, modular power-generating technologies that can be combined to improve the operation of the electricity delivery system [8].

**Direct Use or Heating**

Direct use as the name suggests uses the heat energy of earth to condition the air used in the buildings for comfort conditions. This can be achieved by the use of heat exchangers and heat pumps which works with the almost constant temperature of earth at depths and hence controls the temperature of the buildings for which they are used.
GEOTHERMAL AIR CONDITIONING OF BUILDINGS

Geothermal systems use a renewable resource, the Earth, which is efficient and non-polluting. It works because it costs less to move heat than to create it. The Earth is like a solar battery absorbing nearly half of the sun's energy, resulting in a relatively constant ground temperature throughout the year.

An appropriately designed loop field of HDPE (high density polyethylene) pipe is buried within the ground. A suitable medium like water is circulated through the loop, picking up the temperature of the earth, approximately 41° F (5°C) and delivers this to the system fixed in the building, thus heating the building space in winter when air temperature is less. Also it takes the heat from the building during summer and delivers it to the underground loop hence cooling the building space.

By the use of geothermal energy only a single geothermal heat pump will provide heating, air conditioning and hot water for a home. Standard geothermal equipment applications are forced air, attached directly into the building’s ventilation system, and/or a water to water (boiler type unit), which connects to a fan coil, radiant floor system or hot water tank.

Types of Geothermal Heating Systems

Systems are uniquely engineered to the current or future building specifications. The loop field itself can come in various configurations [9]:

- Pond/Lake Loop
- Horizontal Loop
- Vertical Loop
- Drain Water Heat Recovery
- Radiant Floor Heating

Pond/Lake Loop

This is a most effective set up for a geothermal system heating system. Coiled pipe is placed at the bottom of the lake or pond instead of into the ground. It costs less because there is no digging or major excavating. The high conductivity of water results in even more savings because of the shorter loop fields.
Horizontal Loop

A horizontal application requires considerable space, and is therefore ideal for acreages or farms. Trenches are dug 8 feet deep and pipe is laid in loop circuits.

Vertical Loop

Vertical loops are used in residential areas or smaller lots, where you simply don't have the option to lay out 300 feet of pipe horizontally. A series of boreholes are drilled in the ground and loops are placed vertically at an average depth of 250 feet (depending on soil conditions).

Drain Water Heat Recovery

This device effectively triples the capacity of hot water system. The heat from waste water leaving the building is transferred back into hot water tank, with no chance of contaminating the fresh water. Hot water tank no longer needs to do all the work. The preheated water cuts down on energy requirement, saving about 35-40% of total hot water costs. The
Drain Water Heat Recovery unit becomes a part of drainage stack and is the same diameter as stack to avoid any chance of leakage or clogging.

![Figure 7: Drain Water Heating System](image1)

**Radiant Floor Heating**

A special kind of pipe can also be placed in the house beneath the floors to provide radiant floor heating. This system requires a water to water geothermal heat pump and would do the work of a conventional boiler in a non-geothermal home.

![Figure 8: Radiant Floor Heating System](image2)

**Benefits of Geothermal Heating in Buildings**

As in case of using geothermal heating system the heat of earth is only transferred from one place to another instead of creating it hence it saves a huge amount of energy which is needed to produce the heat like in electrical heaters electricity is required [9]. Hence the use of these systems results in saving of energy and following advantages:

- Much less electricity is used in the generation of hot or cold air with geothermal systems. Because electricity requires fossil fuels to be produced, this helps reduce the use of such fuels. It also lowers your electric bill.
• Geothermal systems can save energy and water, too, as the hot water produced in an open loop system can be used in various other household applications.

• Geothermal systems are said to be much more comfortable. There is much less fluctuation in indoor temperature.

• There are no visible, above-ground components that make noise and can be unsightly. The geothermal system is underground and in the building's basement.

• No emissions are produced by geothermal systems.

• There is a great deal of versatility with these systems. They can be customized for just about any dwelling, even going underground vertically in the absence of horizontal property.

ENVIRONMENTAL IMPACTS

The US Environmental Protection Agency (EPA) has called ground source heat pumps the most energy-efficient, environmentally clean and cost-effective space conditioning systems available [10]. Heat pumps offer significant emission reductions potential, particularly where they are used for both heating and cooling and where the electricity is produced from renewable resources.

Ground-source heat pumps have unsurpassed thermal efficiencies and produce zero emissions locally, but their electricity supply includes components with high greenhouse gas emissions, unless the owner has opted for a 100% renewable energy supply. Their environmental impact therefore depends on the characteristics of the electricity supply and the available alternatives.

Annual greenhouse gas savings from using a ground source heat pump instead of a high-efficiency furnace in a detached residence (assuming no specific supply of renewable energy)

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The GHG emissions savings from a heat pump over a conventional furnace can be calculated based on the following formula[14]:

\[
GHG\ Savings = HL \left( \frac{FI}{AFUE \times 1000 \frac{kg}{ton}} - \frac{EI}{COP \times 3600 \frac{sec}{yr}} \right)
\]

Where

\( HL = \) seasonal heat load \( = 80 \) GJ/yr for a modern detached house in the northern US

\( FI = \) emissions intensity of fuel \( = 50 \) kg(CO2)/GJ for natural gas, 73 for heating oil, 0 for 100% renewable energy such as wind, hydro, photovoltaic or solar thermal

\( AFUE = \) furnace efficiency \( \approx 95\% \) for a modern condensing furnace

\( COP = \) heat pump coefficient of performance \( \approx 3.2 \) seasonally adjusted for northern US heat pump
Emissions intensity of electricity ≈ 200-800 ton(CO2)/GWh, depending on region

Ground-source heat pumps always produce less greenhouse gases than air conditioners, oil furnaces, and electric heating, but natural gas furnaces may be competitive depending on the greenhouse gas intensity of the local electricity supply. In countries like Canada and Russia with low emitting electricity infrastructure, a residential heat pump may save 5 tons of carbon dioxide per year relative to an oil furnace, or about as much as taking an average passenger car off the road. But in cities like Beijing or Pittsburgh that are highly reliant on coal for electricity production, a heat pump may result in 1 or 2 tons more carbon dioxide emissions than a natural gas furnace. For areas not served by utility natural gas infrastructure, however, no better alternative exists.

The fluids used in closed loops may be designed to be biodegradable and non-toxic, but the refrigerant used in the heat pump cabinet and in direct exchange loops was, until recently, chloro-difluoro-methane, which is an ozone depleting substance.[15] Although harmless while contained, leaks and improper end-of-life disposal contribute to enlarging the ozone hole. For new construction, this refrigerant is being phased out in favor of the ozone-friendly but potent greenhouse gas R410A.

Open loop systems (i.e. those that draw ground water as opposed to closed loop systems using a borehole heat exchanger) need to be balanced by reinjecting the spent water. This prevents aquifer depletion and the contamination of soil or surface water with brine or other compounds from underground. Before drilling the underground geology needs to be understood, and drillers need to be prepared to seal the borehole, including preventing penetration of water between strata. The unfortunate example is a geothermal heating project in Staufenim Breisgau, Germany which seems the cause of considerable damage to historical buildings there. In 2008, the city centre was reported to have risen 12 cm, after initially sinking a few millimeters. The boring tapped a naturally pressurized aquifer, and via the borehole this water entered a layer of anhydrite, which expands when wet as it forms gypsum. The swelling will stop when the anhydrite is fully reacted, and reconstruction of the city center "is not expedient until the uplift ceases." By 2010 sealing of the borehole had not been accomplished. By 2010, some sections of town had risen by 30 cm.[16]

CONCLUSIONS

In this paper a deep study of geothermal energy and its use for air conditioning of buildings has been carried out and it is concluded that geothermal energy is available in large quantity in the earth. This energy can fulfill the future requirements of the energy for the planet. It is also concluded that environmental hazards and pollution associated with this energy is very less as compared to conventional energy sources when it is used with the detailed study of the geography of the area from where is used.

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