Geothermal Energy: A Review

Rijuta S. Bapat[1]

[1]*Associate Professor, Dept. of Interior Design,*

L.A.D. & Smt. R.P. College for Women, Nagpur.

[1]*rijuta.bapat@gmail.com*

Abstract: *The objective of the paper is to introduce geothermal energy as a renewable resource of energy. It elaborates various methods of extracting energy for various purposes, throws light on the advantages and disadvantages of geothermal energy. It covers the potential of geothermal energy and advancements. It also discusses the global scenario of the use of geothermal energy for reduction of carbon footprint and conservation of fossil fuels. Future of geothermal energy is also covered.*

Keywords: **Geothermal energy, renewable resource**

1. Introduction

Geothermal energy involves trapping heat underground, then building energy that rises near the surface in the form of heat. When this heat naturally creates hot water or steam, it is harnessed and then used to turn a steam turbine to generate electricity. The Italians were the first to use geothermal energy for commercial purposes in the early 1900's. Geothermal energy is considered one of the most promising and reliable energy resources. Templeton J (2013) stated that it is barely affected by weather and available for operation 98% of the time, which provides a reliable and steady output. Future growth is expected that geothermal energy could meet more than 3%3% of global electricity demand by 2050 [1].

Geothermal energy is extremely kind to the environment. It offers a constant, efficient supply of clean energy with minimal impact on its surroundings [2]. Since the earth's core continuously produces heat with the radioactive decay of elements such as potassium and uranium, geothermal energy turns out to be a renewable, abundant, and reliable energy source. A geothermal energy plant does not make use of fuel; thus, it is both sustainable and safe for the environment. Emissions of geothermal energy operations are low. These operations neither pollute the air nor contribute to global warming [3]. As per Javid M. (2015), renewable energies meet the growing energy needs and allow the technological developments without damaging the future of our planet, the atmosphere, and the environment. Geothermal energy, which is one of these energies, has great importance for some part of world. For example, Turkey has very rich geothermal energy resources and it is ranked fifth in the world after China, Japan, USA and Iceland; and the Turkish government support and promotion of the renewable energies has also been a major boost in the geothermal power [4].

This paper is a review of geothermal energy as renewable resource, its potential uses, advantages, disadvantages, methods of extraction. The paper also updates about the global scenario in using geothermal energy for various purposes.

2. Geothermal energy potential

Geothermal energy, or energy derived from heat coming from the earth's interior, has many different uses. These uses can be grouped into three categories: for heating systems (and direct use), for generation of electricity, and for use in geothermal heat pumps. Besides these practical uses of geothermal energy, there are many other things that make geothermal energy a valuable energy resource.

Geothermal hot water can be used for many applications that require heat. Its current uses include heating buildings (either individually or whole towns), raising plants in greenhouses, drying crops, heating water at fish farms, and several industrial processes, such as pasteurizing milk. With some applications, researchers are exploring ways to effectively use the geothermal fluid for generating electricity as well [5].

Exploiting geothermal energy from abandoned wells requires that wells be retrofitted into heat exchangers. A great part of these studies is devoted to open-loop systems. The purpose of an open-loop system is to use the oil or gas reservoir as a groundwater geothermal reservoir. Open-loop systems consist of at least one injection well and one extraction well.

A fluid is pumped through an injection well into a reservoir, where it gains heat from surrounding rocks before it is circulated through an extraction well. Many researchers (Kujbus 2007; Wei et al. 2009; Reyes 2007; Kurevija and Vulin 2011; Lund et al. 2005; Kharseh et al.; Barbacki 2000) have recently carried out these studies from the economical and practically feasible perspective.

Wight and Bennet (2015) evaluated the use of abandoned petroleum wells to extract the geothermal heat using water as the working fluid. They calculated that a power of 109 KW could be generated from a 4200 m deep well located in Texas with the mass flow rate 205 Kg/s. They also showed that the power output increases with the mass flow rate; however, this requires deep wellbore depth to obtain sufficient fluid temperature [6].

A. Types of geothermal energy systems

The most applications of geothermal energy worldwide are listed in research papers by Lund and Boyd [7].

There are three main types of geothermal energy systems:

- Direct use and district heating systems

Direct use and district heating systems use hot water from springs or reservoirs located near the surface of the earth. Ancient Roman, Chinese, and Native American cultures used hot mineral springs for bathing, cooking, and heating.

Today, many hot springs are still used for bathing, and many people believe the hot, mineral-rich waters have health benefits.

Geothermal energy is also used to directly heat individual buildings and to heat multiple buildings with district heating systems. Hot water near the earth's surface is piped into buildings for heat. A district heating system provides heat for most of the buildings in Reykjavik, Iceland.

Industrial applications of geothermal energy include food dehydration (drying), gold mining, and milk pasteurizing.

- Geothermal power plants

  Geothermal electricity generation requires water or steam at high temperatures (300° to 700°F). Geothermal power plants are generally built where geothermal reservoirs are located, within a mile or two of the earth's surface.

  The United States leads the world in the amount of geothermal electricity generation. In 2019, there were geothermal power plants in seven states, which produced about 16 billion kilowatt-hours (kWh), equal to 0.4% of total U.S. utility-scale electricity generation.

- Geothermal heat pumps

  Geothermal heat pumps use the constant temperatures near the surface of the earth to heat and cool buildings. Geothermal heat pumps transfer heat from the ground (or water) into buildings during the winter and reverse the process in the summer [8].

However, Enhanced Geothermal Systems (EGS) and Ground Source Heat Pump (GSHPs). EGS and GSHP systems are important because of their potential for widespread use, as opposed to traditional geothermal energy systems which are generally limited to tectonically active regions [9].

John W. Lund et al., (2015) explained the main types of direct use of geothermal energy which are bathing/swimming/balneology (42%), space heating (35%, thereof 12% with geothermal heat pumps), greenhouses (9%), fish farming (6%), and industry (6%).Direct application can use both high- and low-temperature geothermal resources and is therefore much more widespread in the world than electricity production. Direct application is, however, more site specific for the market, as steam and hot water is rarely transported long distances from the geothermal site.

The use of geothermal energy enables to cool down the temperature in the house during hot periods. The technology takes the hot air from the house and transfers it down to the ground, where the air naturally cools down. After that, the chilled air will be sent back to your house through the pipes. The reverse geothermal heating process will take place

during the cold winter months when warmer temperatures are generated in the house by tapping into an underground heat exchange.

Geothermal energy is widely used among farmers to heat their greenhouses. It is even possible to grow tropical plants such as citrus trees in the middle of the winter. Countries such as Hungary and Italy have been using geothermal energy for many decades to grow vegetables regardless of the weather conditions. It is used for drying kinds of foods, mostly fruits and vegetables. It can also be in the process of extracting precious metals from ore. Geothermal energy is a great source for preventing sidewalks and roads from freezing in winter [10].

Mahyar G. (2019) stated that geothermal-assisted hydrogen production cost based on electrolysis is competitively lower than other sources like wind, solar thermal coupled with natural gas, solar PV, and grid [11].

Stefanie H. (2013) concluded that to guarantee a sustainable use of geothermal energy, it is necessary to consider environmental and technical criteria, such as changes in groundwater quality and temperature [12].

B. Advantages and disadvantages

National Renewable Energy Laboratory (2000) explained advantages and disadvantages of geothermal energy use. While geothermal energy is exceptionally clean, it is not as renewable as solar and wind energy. Like the energy of the sun, the energy within the earth is immense and has a lifetime measured in billions of years. However, unlike the use of sunlight, tapping into local sources of the earth's heat 3 can result in a temporary decrease in the local amount of energy available. Reinjecting geothermal fluid that remains after steam is extracted helps preserve the fluid volume of the reservoir. However, even with reinjection, the heat content of the reservoir gradually declines. The recovery period for a geothermal resource depends on how it is used. A recent study indicates that the recovery period is approximately 30 years for heat pumps, about 100-200 years for district heating, and several hundred years for electricity generation. Resources tapped for electricity generation could provide energy for 50 years or more, if effectively managed, but plant equipment typically reaches the end of its useful life before the resource is depleted. Continuous long-term use of geothermal energy for electricity generation would require the periodic construction of new plants at new sites, while previously used reservoirs recover. While geothermal is not immediately renewable like technologies such as solar and wind, it has many important advantages. Geothermal electric plants operate 24 hours per day and thus produce base-load electricity. There is no need for storage, and dispatchability is not an issue. Geothermal plants are not vulnerable to weather effects, except that cycle efficiencies (and hence plant output) tend to be higher in the winter (when heat is rejected to a lower sink temperature) than in the summer. (This is especially true for binary plants that are air-cooled.) Geothermal plants are also extremely reliable and typically operate more than 95% of the time, with some plants at over 99%. This compares to availabilities of 60% & 70% for coal and nuclear plants respectively. Geothermal plants are often located in areas of high scenic value, where the appearance of the plant is important [13].

Geothermal is an environmentally friendly technology because it produces little to no greenhouse gas emissions. Finally, the cost of geothermal energy is largely incurred up-front. One concern with geothermal power is its use of groundwater.

The process of extracting this water may unintentionally release carbon dioxide and hydrogen sulphide to the atmosphere. Mitigating the release of these emissions is a key challenge with developing this technology.

Geothermal technology can only be used in locations with specific geologic conditions. For this reason, the major regions of geothermal development are in the most volcanically and tectonically active regions of the world [14].

3. Global scenario

John W. Lund and Tonya L. Boyd (2015) mentioned that in 1995, 2000, 2005 and 2010 several countries stood out as major consumers of geothermal fluids for direct uses (China, USA, Japan, Iceland and Germany); however, in most countries' development has been slow. This is not surprising as fossil fuels are a major competitor as well as the initial high investment costs of geothermal projects. Many countries have; however, been doing the necessary groundwork, conducting inventories, and quantifying their resources in preparation for development when the economic situation is better and governments and private investors see the benefits of developing a domestic renewal energy source. This is true for many of the east African countries such as: Djibouti, Eritrea, Malawi, Mozambique, Rwanda, Tanzania, Uganda, Zambia, and Zimbabwe that have potential geothermal resources associated with the African Rift Valley.

Geothermal (ground-source) heat pumps have the largest energy use and installed capacity worldwide, accounting for 70.95% of the installed capacity and 55.30% of the annual energy use. The leaders in installed units are: United States, China, Sweden, Germany and France.

The leaders in district heating in terms of annual energy use are: China, Iceland, Turkey, France, and Germany, whereas Turkey, USA, Italy, Slovakia and Russia are the major users in the individual space heating sector (a total of 28 countries).

A total of 31 countries report geothermal greenhouse heating (compared to 34 from WGC2010), the leading countries in annual energy use being: Turkey, Russia, Hungary, China and Netherlands. Most countries do not distinguish between covered greenhouses versus uncovered ground heating, and only a few reported the actual area heated. The main crops grown in greenhouses are vegetables and flowers; however, tree seedlings (USA) and fruit such as bananas (Iceland) are also grown. Developed countries are experiencing competition from developing countries due to labor cost being lower – one of the main costs of operating these facilities.

Aquaculture use of geothermal energy has increased over WGC2010, amounting to a 6.7% increase in installed capacity and a 2.7% increase in annual energy use. The installed capacity is 695 MWt and the annual energy use is 11,958 TJ/yr. Twenty-one countries report this type of use, the main ones in terms of annual energy use being USA, China, Iceland, Italy and Israel – the same as in 2010. These facilities are labor intensive and require well-trained personnel, which are often hard to justify economically, thus, the reason why the growth is slow.

Fifteen countries report the use of geothermal energy for drying various grains, vegetables and fruit crops compared to 13 in 2010 and 15 in 2005. Examples include seaweed (Iceland), onions (USA), wheat and other cereals (Serbia), fruit (El Salvador, Guatemala and Mexico), Lucerne or alfalfa (New Zealand), coconut meat (Philippines), and timber (Mexico, New Zealand and Romania). The largest uses are in China, USA and Hungary.

A total of 161 MWt and 2,030 TJ/yr are being utilized, an increase of 28.8 % and 24.2% respectively compared to WGC2010.

Industrial Process Heat has applications in 15 countries, the same as in 2010. These operations tend to be large and have high energy consumption, often operating year-around. Examples include: concrete during (Guatemala and Slovenia), bottling of water and carbonated drinks (Bulgaria, Serbia and the United States), milk pasteurization (Romania and New Zealand), leather industry (Serbia and Slovenia), chemical extraction (Bulgaria, Poland and Russia), CO2 extraction (Iceland and Turkey), pulp and paper processing (New Zealand), iodine and salt extraction (Vietnam), and borate and boric acid production (Italy). The installed capacity is 610 MWt and the annual energy use is 10,453 TJ/yr, an 18% increase and a 12% decrease compared to WGC2010.

Snow Melting and Space Cooling have very limited applications; the majority are pavement snow melting projects. Snow melting applications for streets and sidewalks operate in Iceland, Argentina, Japan, and the United States, and to a limited extent in Poland and Slovenia. An estimated 2.5 million square meters of pavement are heated worldwide, the majority of which is in Iceland (74%).

Use of bathing and swimming is done by almost every country for spas and resorts with geothermal water including balneology for the treatment of diseases with water [15].

Nasruddin et al., (2016) stated about Indonesia's geothermal energy potential which is estimated about 40% of the world's geothermal energy potential or about 28,617 MW. However, only about 4.5% is being utilized as electrical energy in the country [16]. Table 1 shows world´s top countries using geothermal in direct uses Installed.

Table 1: World´s top countries using geothermal in direct uses Installed

Country	Installed MWt	Production (GWh/a)
China	2282	10,531
Japan	1167	7482
USA	3766	5640
Iceland	1469	5603
Turkey	820	4377
New Zealand	308	1967
Georgia	250	1752
Russia	308	1707
Sweden	377	1147
Hungary	473	1135

In Europe, 30% of energy use is for space and water heating alone, representing 75% of total building energy use.This energy is stored in rock and is trapped in vapor/liquids, for example, water or brines that can be used to generate electricity and for providing heating. Electricity generation usually requires geothermal resource's temperature of over 100°C. According to the roadmap by International Energy Agency, geothermal electricity generation has the potential to reach 1400 TWh/year, which is around 3.5% of global electricity production by 2050, reducing almost 800 megatonnes (Mt) of CO_2 emissions per year . The quantity of gases and metals contained within the geothermal fluids depends on the depth and location of the geothermal reservoir, characteristics of the electricity generation systems and the abatement systems [17].

Chandrashekharan D. (2016) mentioned that Saudi Arebia has the potential of generating 200×10^6 kWh from hydrothermal sources and 120×10^6 Terawatt-hour from Enhanced Geothermal System (EGS) sources [18].

Mehmet Melikoglu (2019) elaborated about geothermal energy installed capacity of Turkey reached to 623.9 MW at the end of 2015[19]. Rudiger Schellschmidt concluded (2010) concluded that due to the moderate temperature gradients persisting in most parts of Germany geothermal energy use is still on a comparatively low level. The installed capacity for geothermal heat is about 2500 MWt. 90% of which is attributed to about 178,000 decentralized units using heat from shallow depth [20].

Ladislaus Rybach and Walter J.Eugster (2010) concluded that Geothermal heat pumps are the key to the utilization of the ubiquitous shallow geothermal resources. Theoretical and experimental studies, performed in Switzerland over several years, have established a solid scientific base of reliable long-term operation of borehole heat exchanger-coupled heat pump systems [21].

Hemant K. Singh putforth (2016) putforth about several potential geothermal fields predominantly controlled by the high heat-producing granites which are available in different parts of India. Planned production of electricity from these fields is 850 GWh/year by the year 2020. A wet geothermal system, as well as enhanced geothermal system, can be utilized to generate electricity at low production cost. Moreover, some to be utilized for domestic purposes [22]. R. R. Shahet et al., (2014) explained that India is yet to produce the electric power from geothermal energy except for nominal 5KW binary power plant set at Manikaran that was operational for very short time. India has high scope in utilizing its geothermal resources [23].

Mirjana Golusin analysed that 160 long holes are being exploited whose water temperature is around 60 °C (140 °F) and their heat power reach 160 MJ/s. It was stated that adequate exploitation of existing and new geothermal sources a yearly would save about 500,000 tons of fossil fuels what is proportional to the 10% of the today's heating system. The total amount of heat accumulated at geothermal deposit sites in Serbia, up to 3 km of depth, is two times greater than the total amount of heat that may be generated by burring all available coal reserves in Serbia [24].

Gholamhassan Najafi (2011) elaborated about how Iran is developing a geothermal plant for power production. Iran government plans to build 2000 MW of renewable energy capacity over the next five years. Total projected use (geothermal capacity) has been estimated 100 MW at the end of 2010. Exploration drilling is currently in-progress for Meshkinshahr project in North-Western Iran. The Sabalan geothermal power plant is expected to produce 50 MW electric powers in 2011 [25].

4. Conclusion

Geothermal energy is extremely kind to the environment. It is becoming increasingly more competitive with fossil fuels. The energy within the earth is immense and has a lifetime measured in billions of years. It offers a constant, efficient supply of clean energy with minimal impact on its surroundings. Emissions of geothermal energy operations are low. The cost of geothermal energy is largely incurred up-front.

Direct use and district heating systems use hot water from springs or reservoirs located near the surface of the earth. Geothermal heat pumps use the constant temperatures near the surface of the earth to heat and cool buildings.

Use of bathing and swimming is done by almost every country for spas and resorts with geothermal water including balneology for the treatment of diseases with water. The United States leads the world in the amount of geothermal electricity generation. Indonesia's geothermal energy potential is estimated about 40% of the world's geothermal energy potential about 28,617 MW. Adequate exploitation of existing and new geothermal sources a yearly would save about 500,000 tons of fossil fuels which is proportional to the 10% of the today's heating system.

REFERENCES

[1] *J. Templeton, "Abandoned petroleum wells as sustainable/renewable sources of geothermal energy", Master thesis in Department of Mining and Materials Engineering. McGill University, Canada,* ***(2013)****.*

[2] *URL http://www.geothermalengineering.co.uk/ accessed on 29/5/2020.*

[3] *URL http://www.albertageothermal.ca/ accessed on 29/5/2020.*

[4] *M. Javid et al., "Review Article-Renewable Energies", Energy Procedia. vol. 74,* ***(2015)****, pp. 1289 – 1297.*

[5] *URL https://www.renewableenergyworld.com/types-of-renewable-energy/tech-*

[6] *D. Sui , E. Wiktorski, M. Røksland & T. Basmoen, "Review and investigations on geothermal energy extraction from abandoned petroleum wells", Journal of Petroleum Exploration and Production Technology, vol. 9,* ***(2019)****, pp.1135–1147.*

[7] *J. Lund and T. Boyd, "Direct utilization of geothermal energy worldwide review, Proceedings world geothermal congress,* ***(2015)****, pp.1-31.*

[8] *https://www.eia.gov/energyexplained/geothermal/use-of-geothermal-energy.php*

[9] *I. Johnston, G. Narsilio & S. Colls, "Emerging Geothermal Energy Technologies, KSCE", Journal of Civil Engineering., vol. 15,(2015), pp. 643–653.*

[10] *W. John, Lund & L. Tonya, "Direct Utilization of Geothermal Energy 2015 Worldwide Review", Proceedings World Geothermal Congress,* ***(2015)****.*

[11] *M. Ghazvini, M. Sadeghzadeh, M. Ahmadi, S. Moosavi, F. Pourfayaz,* ***"****Geothermal energy use in hydrogen production: A review", International Journal of Energy Research.,* ***(2019)****. URL:https://doi.org/10.1002/er.4778, accessed on 29/5/2020.*

[12] *S. Hahnlein, P. Bayer, G. Ferguson, P. Blu, "Sustainability and policy for the thermal use of shallow geothermal energy", Energy Policy., vol. 59,* ***(2013),*** *pp. 914-925.*

[13] *NREL, 2000, The Status and Future of Geothermal Electric Power.*

[14] *URL: https://w(2015), ww.studentenergy.org/topics/geothermal accessed on 29/5/2020.*

[15] *W. John and L. Tonya, Proceedings World Geothermal Congress, Direct Utilization of Geothermal Energy 2015 Worldwide Review,* ***(2015)****,19-25 April.*

[16] *Nasruddin et al., "Potential of geothermal energy for electricity generation in Indonesia: A review", Renewable and Sustainable Energy Reviews.,vol.53,****(2016)*** *Pages 733-740.*

[17] *A. Kohl & R. Nielsen, "Gas Purification (Fifth Edition)", Gulf Professional Publishing****,(1997)****, pp. 731-865.*

[18] *D. Chandrashekharan, "The potential contribution of geothermal energy to electricity supply in Saudi Arabia", International Journal of Sustainable Energy., vol. 35(9),* ***(2016)****, pp.1-4.*

[19] *M. Melikoglu, "Geothermal energy in Turkey and around the World: A review of the literature and an analysis based on Turkey's Vision 2023 energy targets", Renewable and Sustainable Energy Reviews.,vol 76,* ***(2017)****, pp****.*** *485-492.*

[20] *R. Schellschmid, "Geothermal Energy Use in Germany", Proceedings World Geothermal Congress 2010 Bali, Indonesia,* ***(2010),*** *25-29 April.*

[21] *L. Rybach and W. Eugster, "Sustainability aspects of geothermal heat pump operation, with experience from Switzerland", Geothermics., vol. 39, Issue 4****,(2010),*** *pp. 365-369.*

[22] *Hemant K. Singh, "Potential Geothermal Energy Resources of India: A Review", Regional Renewable Energy.,* ***(2016),*** *vol.3, pp. 80-91.*

[23] *R. Shahet et al., "Geothermal Energy: An Alternative Source of Energ", Int. Journal of Engineering Research and Applications., vol. 4, Issue 4****, (2014)****, pp. 63-68.*

[24] *M. Golusin, "Exploitation of geothermal energy as a priority of sustainable energetic development in Serbia", Renewable and Sustainable Energy Reviews., February 2010, vol. 14, Issue 2,* ***(2010)****, pp. 868-871.*

[25] *G. Najafi, B. Ghobadian, "Geothermal resources in Iran: The sustainable future", Renewable and Sustainable Energy Reviews., vol. 15, Issue 8,* ***(2011)****, pp. 3946-3950.*