CLIMATE ACTION NETWORK

PLATFORM FOR ACTION ON RENEWABLE ENERGY (PoA)

BRIEFING PAPER

GEOTHERMAL ENERGY

Introduction

Geothermal energy, which literally translates to 'earth's heat energy' is the latest entry into the basket of renewable energy sources that has an important role in the transition to a 100% renewable energy future. Geothermal energy is a renewable resource because it exploits the earth's high and low temperature heat found in deeper or volcanic hot geological rocks, and in the sub-surface with widely spread ambient heat which is abundant. The hot groundwater or steam used to transfer this subterranean heat to the point-of-use can be reused, without significant loss. Geothermal energy can be harnessed for energy applications either through the generation of electricity or through the direct-use applications such as industrial heat requirements and space heating.

As of 2021, geothermal is mostly used for electricity primarily in some South East Asian countries and the USA. Its overall share of global installed capacity has been less than 1% over the years. As indicated in Table 1, the installed capacity has been increasing in the last decade. However, due to rapid expansion of solar and wind power in the world, the total share of geothermal energy in the renewable energy basket is dropping.[1]

Table 1: Share of installed Global Geothermal energy capacity

Year	*Total RE installed around the world (MW)*	*Total global Geothermal capacity (MW)*	*% of Geothermal capacity*
2011	1,329,886	10,134	0.76%
2012	1,442,763	10,481	0.73%
2013	1,564,390	10,718	0.69%
2014	1,697,061	11,159	0.66%
2015	1,847,258	11,799	0.64%
2016	2,010,005	12,122	0.60%
2017	2,180,389	12,677	0.58%
2018	2,358,749	13,241	0.56%
2019	2,538,441	13,866	0.55%
2020	2,799,094	14,050	0.50%

Source: IRENA (2021) Pg 36

[1] IRENA (2021) "RE Capacity Statistics 2021," Pg 36, https://www.irena.org//media/Files/IRENA/Agency/Publication/2021/Apr/IRENA_RE_Capacity_Statistics_2021.pdf

Despite the share of geothermal energy being very small, low temperature heat combined with electric heat pumps in buildings will increasingly have a large role to play in countries where residential and office heat demand is high in colder seasons, like in many parts of the Northern hemisphere. In combination with high building envelope insulation and energy conservation, geothermal with heat pumps are the crucial, and the most relevant and decentralised option for providing to buildings clean low/zero carbon space heating in winter and replacing oil and gas burners. For instance, European buildings consume almost two third of their total energy use for space heating requirements.

Geothermal energy is harnessed through three different methods, viz.,

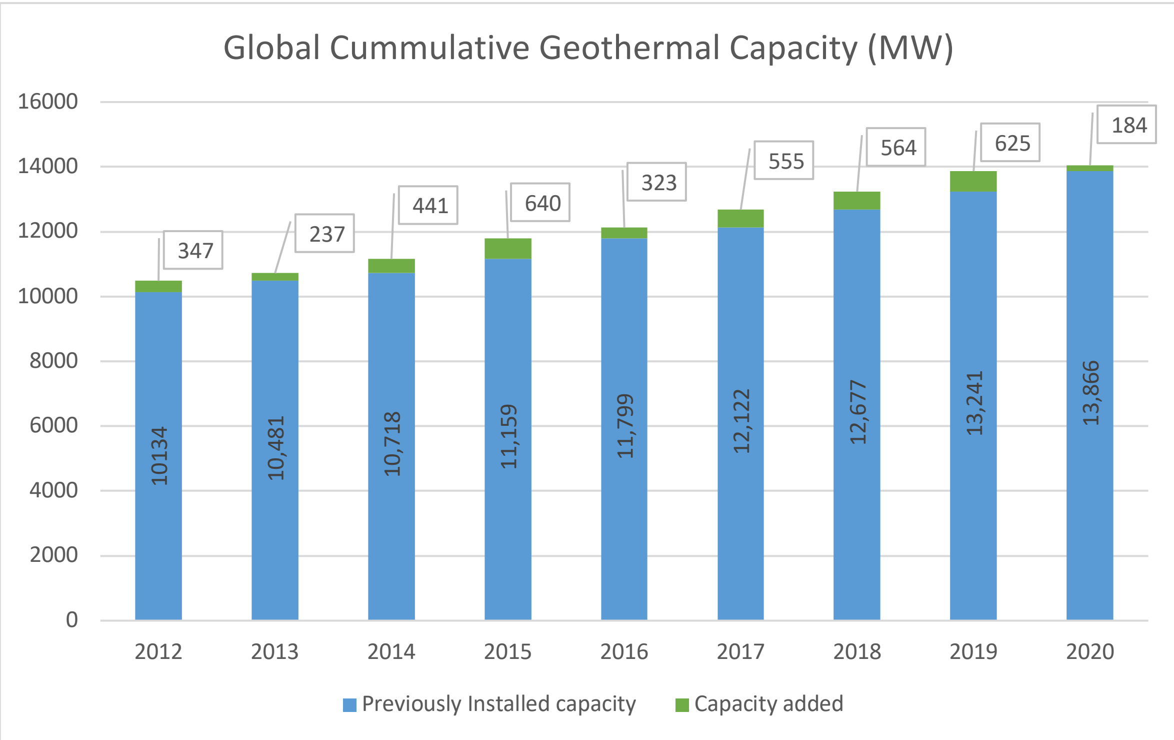
a) Hydrothermal electricity production, where wells are drilled into a geothermal reservoir of hot water or steam, and this hot water or steam is used to generate electricity at a power plant.
b) Engineered geothermal systems (EGS), where a sub-surface fracture system is created and water and other media is injected as a carrier of the heat. This heat is then used to generate electricity in a power plant or for direct-heat applications. Advanced EGS uses a closed loop system by which the geothermal energy utilisation is maximised and the carrier media is conserved to the maximum possible.
c) Direct use of the hot water from the geothermal source or use of the heat from the geothermal media for applications such as industrial processes, space heating, etc. Geothermal heat pumps that take advantage of the earth's subsoil's almost constant temperatures over the year (roughly the annual average air temperature on aboveground) as a source and sink of heat are among the most efficient cooling and heating options available.

When compared to other promising renewable energy technologies like solar and wind, geothermal energy has a distinct advantage that it can be used both for electricity generation as well as for heating purposes. Furthermore, it is not seasonal and weather-dependent, and can be made available 'on-demand' like energy generated from fossil fuels, and hence has the potential to become one of the largest sources of clean energy in the transition to a new energy paradigm, especially in geographies that have medium to high potential geothermal resources. On the other side, as hot water or steam might lose heat content comparably rapidly in piped transport processes, unlike electrons from renewable power, the endpoint of utilisation cannot be very far from the source. Another advantage is that if used for decentralised low-heat consumption in houses or commercial buildings, it does not need a large grid system or infrastructure like that for oil and gas supply. However, if electricity is produced, geothermal plants need connectivity to the grid.

Current Status

Geothermal electricity generation was around 97 Terawatt hours (TWh) in 2020.[2] This amounts to 3% of the electricity generated from global renewable electricity (3147 TWh) and 0.36% of the of total global electricity generated (26823.2 TWh) in 2020.[3] The direct useful thermal output was about 128 TWh or 0.462 Exajoule (EJ).[4] This compares to 2.1% of global renewable heat (~21.5EJ) and 0.26% of total global heat production (~176 EJ) in 2020.[5] Approximately 184 Megawatt (MW) of new geothermal power generating capacity came online in 2020, bringing the global total to around 14.1 Gigawatt (GW).[6] 2020 also saw the lowest capacity addition to geothermal generation during the last decade with just 1.2% additional growth, with Turkey alone contributing close to 60%. The United States of America, Indonesia, the Philippines, Turkey and New Zealand are the top 5 countries with geothermal power capacity.

Figure 1: Global Cumulative Geothermal Capacity



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[2] REN21 (2021), p. 100, Renewables 2021 - Global Status Report

[3] BP(2021) "BP Statistical Review of World Energy 2021", https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

[4] REN21 (2021), p. 100, Renewables 2021 - Global Status Report

[5] IEA (2020) "Renewables 2020: Renewables Heat", https://www.iea.org/reports/renewables-2020/renewable-heat

[6] IRENA (2021) "Renewable Capacity Statisitcs 2021" https://www.irena.org/publications/2021/March/RenewableCapacity-Statistics-2021

Worldwide, the capacity for geothermal direct use i.e., direct extraction of geothermal energy for thermal applications increased by an estimated 2.4 gigawatts-thermal (GWth) (around 8%) in 2020, to an estimated 32 GWth. The top countries for geothermal direct use (in descending order) in 2020 were China, Turkey, Iceland and Japan, which together represented roughly 75% of the global total Geothermal energy use. Thermal applications grew an estimated 11.3 TWh during the year to an estimated 128 TWh (462 PJ).

Geothermal heat has varied direct applications. Bathing and swimming are the largest applications and comprises of around 44% of total use in 2019. This application is growing at an annual average of around 9%. Second, but with the fastest growth, is space heating, which is around 39% of direct use and expanding around 13% annually. The remaining 17% of direct use is for greenhouse heating (8.5%), industrial applications (3.9%), aquaculture (3.2%), agricultural drying (0.8%), snow melting (0.6%) and other uses (0.5%).[7]

Opportunities

Geothermal power has considerable potential for growth. For instance, heat stored under the United States of America alone is estimated to be 2.5x 10^7 calories. To put this in perspective, this energy is equivalent to the solar radiation received by the United States for nearly 200 years, or equivalent to the heat content of 8.1 x 10^{14} tons of coal[8]. Another research by the Magma Energy Program at USA estimates that energy contained at the depth of 10km is between 5275.2 EJ to 5.275 x 10^5 EJ.[9] Present global energy production is less than 650 EJ in 2020. The global technical potential for electricity generation from hydrothermal resources is estimated to be 240 GW, with a lower limit of 50 GW and an upper limit between 1,000 GW and 2,000 GW, under the assumption that unidentified resources are likely five to ten times larger than currently identified resources.[10] There is a strong economic case for the deployment of geothermal energy. The costs for electricity generation from geothermal technologies are becoming increasingly competitive, and they are expected to continue to drop through 2050.[11] Moreover, geothermal energy is not seasonal and weather-dependent, and can be made available 'on-demand' like energy generated from fossil fuels. In addition to this, geothermal power is highly stable and plants have a high-capacity factor, thus making geothermal power plants an excellent option for meeting baseload energy demand.

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[7] REN21 (2021), p. 102-103, Renewables 2021 - Global Status Report

[8] White, Donald E (1965), "Geothermal energy: Geological Circular 519", Washington, Page 6, https://www.osti.gov/servlets/purl/7306829

[9] US Department of Energy (2006), "A history of geothermal research and development in the United States", Geothermal Technologies Program, https://www.energy.gov/sites/prod/files/2014/02/f7/geothermal_history_1_exploration.pdf

[10] IRENA (2017), Geothermal Power: Technology Brief, International Renewable Energy Agency, Abu Dhabi

[11] Sigfusson, Bergur & Uihlein, Andreas. (2015). 2015 JRC Geothermal Energy Status Report. 10.2790/959587.

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Bottlenecks

However, despite the massive potential, deployment of geothermal power faces several bottlenecks. The challenges faced by this sector can be classified into technical, financial, environmental and political, as summarized in Table 2.

Table 2: Major challenges for deployment of Geothermal Energy

Technical	Financial	Environmental	Political
• Scarcity of viable location • Long-term sustainability	• High investment costs • Perception of being a risky investment • Availability of cheaper options deter investments	• Emission of CO_2 and H_2S. • Induced seismic activity	• Government policies • Tariff rates

Technical Challenges

Geothermal energy is highly location specific. Harnessing of geothermal energy is viable only in locations with medium to high enthalpy. A geothermal power plant project generally goes through several stages involving exploration, drilling, development of production wells, reinjection wells, steam gathering system, and power plant construction and commissioning. These phases of the cycle before generation all combined take relatively long compared to solar or wind. Long-term sustainability of geothermal energy production could be a problem in some locations, which have experienced pressure and production declines. In cities like Santa Rosa, California, treated wastewater are being reinjected up to The Geysers to maintain fluid pressure, thereby prolonging the life of the reservoir while recycling the treated wastewater.[12]

Financial Challenges

Geothermal projects are capital intensive with significant up-front costs. Geothermal power projects costs are influenced by the reservoir quality, type of power plant and the number of wells required. In 2020, the global weighted-average total installed cost of Geothermal plants was USD 4.5/MW capacity, up from the USD 4/MW recorded in 2019 and from the USD 2.6/MW reported in 2010. This is very high compared to the global weighted-average total installed cost of solar (0.9 USD/MW capacity), onshore wind (1.4USD/MW) and hydro power (1.9USD/MW)[13]. Further, costs are highly site sensitive and depend on many variable factors making project financing needs unpredictable and hence projects may be considered risky, thereby attracting lesser investments. To illustrate, in the year 2020, global investment into Solar PV was 148.6 billion USD, wind energy attracted an investment of 142.7billion

[12] US Department of Energy (2006), ibid

[13] IRENA (2020) “Power Generation Costs 2020”, Page 136

USD, while investment into Geothermal energy was just 0.7 billion USD[14]. However, the flipside is that the operation and maintenance costs are low and predictable.

Environmental Challenges

Geothermal development worldwide has been plagued with a real or perceived risk of induced seismic activity related to geothermal development. This presents a social barrier to the promotion of geothermal energy. Another concern with geothermal development is the emissions of CO_2 and H_2S from open-loop geothermal facilities. Though the emissions are far below those from fossil fuel facilities, they are not negligible, and cannot be ignored. Significant progress has been made in recent years to advance the process of sequestering CO_2 from geothermal facilities to mitigate this concern.

Though there are cases where the drilling for hot water and steam have released site-specific CO2 and aggressive H2S, geothermal energy is generally not releasing any greenhouse gases or other air pollutants, it does not generate any fluid or solid waste. If the pipes are designed properly and maintained in a closed circuit, then there will be close to zero groundwater losses. However, in some exceptional cases, geological drilling for geothermal hot rocks has created some small local but generally harmless earthquakes that undermined the reputation of a very clean technology. Hence, geological underground mapping is necessary prior to any drilling.

Political challenges

Any renewable energy requires a stable government which could provide a good governance structure to the sector. Further, with the presence of cheaper options like solar and wind energy, it is difficult to convince governments to invest in geothermal energy. Unfavourable policies and power purchase agreements with low tariff rates affect the cost recovery of the market players, thereby deterring investment into the sector.

Conclusion

Geothermal energy is a renewable source of energy that has the potential to complement the efforts to replace fossil fuels and nuclear power in global energy systems, while still satisfying the increasing demand for energy services. While the technology is yet to reach commercial maturity in a number of places and regions, the benefits that geothermal energy offers far outweigh the uncertainties and risks, and with the right policy support can become an important portion of the energy baskets of almost all regions in the world for either electricity and/or low and high temperature heat supply for various purposes. The main focus on the development of the energy source as a robust and reliable alternate continues to be on technological innovation, such as new resource recovery techniques and seismic risk mitigation, with the aim of improving the economics, lowering the development risk and strengthening prospects for expanded geothermal resource development.

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[14] REN21 (2021), p. 186-187, Renewables 2021 - Global Status Report