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The Role of Geothermal Energy Development on CO_2 Emission by 2030

Hossein Yousefi, Atefeh Abbaspour, HamidReza Seraj

Faculty of New Sciences and Technologies, Department of Renewable Energies and Environment, University of Tehran, Iran

Hosseinyousefi@ut.ac.ir, Atefeh.abbaspour@ut.ac.ir, Hr.seraj@ut.ac.ir

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ABSTRACT

In recent years, concerns about global warming and CO_2 emissions have led the policymakers to develop clean and renewable energies. In this regard, the exploitation of geothermal energy, as a major source of low-carbon energy production, can be a significant contributor to reducing CO_2 emissions. Geothermal energy unlike the other renewables, such as solar and wind, is a source of sustainable energy which is independent of time or season. Geothermal technologies can be used for electricity generation or direct use. Today, 26 countries are using geothermal resources to generate electricity and also, more than 60 countries use geothermal heat directly. This article aims to investigate the effect of development of geothermal resources on reducing CO_2 emissions. Furthermore, according to forecasts about geothermal energy deployment, it is concluded that almost 195 million tones CO_2 emission will be avoided by utilizing geothermal resources in the year 2030.

1. INTRODUCTION

Global warming which results from increasing greenhouse gasses emissions is now recognized in most societies as a fact that will affect the future of the environment. Considering this issue has led to a shift in the technological and economical development of the world; in such a way that most countries are interested in utilizing low emission energy resources. Many meetings, including Paris conference, have been held in recent years to explore options to achieve the low carbon development and the utilization of renewable resources has identified as an effective solution. The diversity of these resources makes it feasible to utilize at least one form of the renewable energy in each country; also recently with the development of their manufacturing technology and expansion of the applications, their cost-effectiveness has increased and make them competitive in terms of financial feasibility.

Geothermal energy offers a sustainable option in the pursuit of renewable energy. It refers to the heat energy generated and stored beneath the surface of the Earth. Geothermal energy can be extracted without burning fossil fuels directly for heating purposes or transformed into electricity. An advantage of the Geothermal over some other renewable energy sources (e.g. solar and wind) is that it is a stable source of energy; which means that the energy output of a geothermal plant is independent from daily and seasonal variations and it is available year-long. Geothermal energy has recently been identified as a high potential source to displace fossil fuels and help meet clean air and decarbonziation obligations. In this regard, various studies have been done about the development of geothermal resources and its role in reducing greenhouse gas emissions. Bertani (2016) analyzed the major activities carried out for geothermal electricity generation from 2010 to 2015. Also all the countries with active geothermal plants for power generation have been introduced in his paper. Finally he concluded that installed geothermal power increased about 1.8 GW (17%) in the five year term 2010-2015.

Lund and Boyd (2016) presented a review on the worldwide applications of the geothermal energy for direct utilization. By investigating data from 2010 to 2015, the concluded that direct use of geothermal sources grew by 40 percent in the five year term. Also the energy saving, amounted to 352 million barrels of oil annually, preventing 149 million tones CO_2 being released to the atmosphere. Li et al. (2015) compared the Geothermal with Solar and Wind power generation systems in terms of potential, installed capacity, cost, efficiency and environmental impacts. Rybach (2010) worked on the effect of geothermal energy development, especially heat pump, on the CO_2 emission mitigation by the year 2050. He estimated that development of geothermal resources for direct use or electricity production would lead to reduction of 300 and 100 million tones CO_2 emissions in the year 2050, respectively. Fridleifsson et al. (2008) presented the scenarios for electricity production and direct use of geothermal energy. They also assessed its current and future potential to reduce CO_2 emissions. Ogola et al. (2012) investigated about geothermal energy contribution in mitigating the impact of climate change. Also the potential of geothermal resources, its utilization and its greenhouse gas emissions is presented in their work. In this report an updated report of the geothermal energy development in the world and leading countries is presented. Also, the effect of geothermal resources utilization in reducing CO_2 emissions both in direct-use and electricity production sectors is estimated by the year 2030.

2. WORLDWIDE GEOTHERMAL DEVELOPMENT

2.1 Geothermal Power Generation

Utilizing geothermal energy to generate electricity is a considerably new industry, which manifested 1904 in Italy. Nonetheless, the first successful large-scale geothermal power plant operated 1960 in the Geysers, north California. In recent years, geothermal power generation growth has lagged behind the explosive growth in wind and solar generation. This result reflect both the limited distribution of geothermal resources and the cost position relative to the solar and wind. Over the past decade, world geothermal power generation capacity grew at a rate of 3 or 4 percent per year and in 2017, has overpassed from 13.3 GW, with almost 90 TWh annual electricity generation (IRENA, 2017). Today, geothermal energy contributes a small proportion of world electricity generation with less than 0.5 percent of world's capacity; spread from 26 countries. However, subjects such as diversification of energy supply, clean air regulations and the decarbonization incentives have led the global society to turn the spotlight on the utilization of geothermal energy. Therefore based on current data and under construction projects, the global geothermal industry is expected to reach about 18 GW by 2020; and according to the Geothermal Energy Association (GEA), if all countries follow through on their geothermal power development goals and targets, the global market could reach 32 GW by the end of 2030 (GEA, 2017). Fig. 1 illustrates the global cumulative installed geothermal power capacity from 1995 to 2017 and its projection by the year 2030. From a regional point of view, Asia & Pacific is the largest geothermal power market, representing almost 38 percent of world installed capacity; followed by North America (over 32%), Europe (13%), Middle East & Africa (12%) and South America & Caribbean (4.5%) (IEA, 2018).

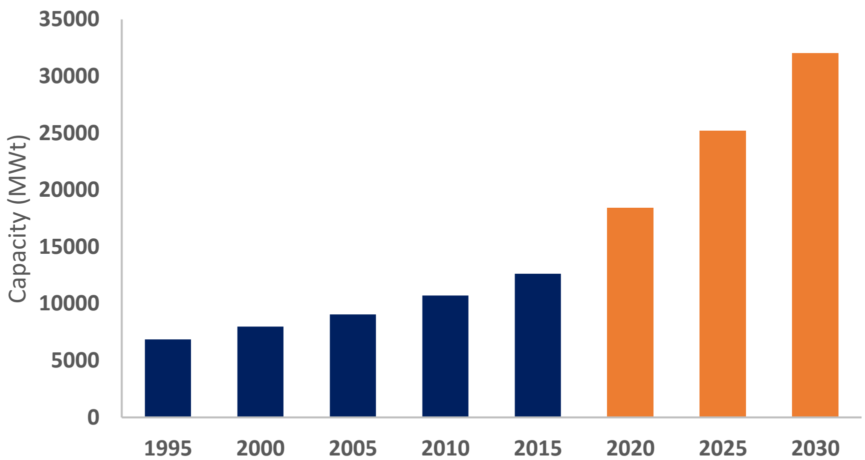

Fig. 1. The global cumulative installed geothermal power capacity (GEA, 2017)

Many countries in the world, have the capacity of geothermal power utilization and its manufacturing technology is developing in different regions; therefore geothermal power projects around the globe continue to accelerate and expand. By the end of 2017, 26 countries had seen commercial geothermal power activity and four of them, had more than 1 GW in operation. The number of countries which are constructing new geothermal power project continues to grow. Some new entrants into the geothermal market including Iran and Malaysia, have announced intensions to build project or development goal in the next two or three years. In terms of geothermal power utilization, three leading countries are United States, Philippines and Indonesia. The United States has ranked first in cumulative installed capacity with about 3.7 GW of installed nameplate capacity and 2.7 GW of net capacity by the end of 2017 (GEA, 2017). It has about 0.8 GW of ongoing projects that are likely to be operational, and another 0.9 GW of projects that are under development with the potential to come inline by 2020. Overall, although development in this sector is constrained by competition from other renewable resources and low natural gas prices, but it is expected that U.S. will maintain its leadership position in the next 2-3 years.

The Philippines is second for total geothermal power capacity with 1870 MWe in operation and its eight geothermal field now supply about 5 percent of the nation's electricity (REN21, 2017). The success of the Philippines in exploiting geothermal energy may be attributed on good governance and commendable government-industry collaboration. There was a strong pressure to reduce dependency on foreign oil and gas supply which led to consistent national effort to explore and exploit geothermal energy resources. Resulting from these attractive Philippines government incentive, the number of geothermal companies increased from 2 to 11 and geothermal projects rose from 10 to 33. Nevertheless, the evidence show that, with regard to issues including high cost of its low temperature resources development, Philippines will lose its position in a short-term. Another leading country in terms of geothermal power utilization in Indonesia. The country added more than 300 MW of new capacity in the last 2 years, reaching the cumulative capacity to more than 1.8 GW by the end of 2017 (REN21, 2017). Indonesia is estimated to contain the world's largest energy reserves. According to the statistics, existing capacity in Indonesia is less than 6 percent of the country's total geothermal power potential, therefore Indonesia aims for continued rapid development of these resources. It is an ambitious target, but by 2023, the Indonesian government targets to overtake the U.S. position as a leadership of geothermal power market.

2.2 Direct Use of Geothermal Energy

The direct use of geothermal energy is the use of heat or fluid from geothermal resources without intervening medium as opposed to its conversion to other form of energy such as electricity. Direct use of geothermal energy, is one of the oldest methods to exploit energy from the nature. People have been using geothermal springs for heating and bathing for hundreds of years; but recently application of the source has also expanded to geothermal heat pumps, agriculture, aquaculture and industrial process. Fig. 2 illustrates the amount of direct use of geothermal energy for various applications in the years 1995 and 2015. As shown in Fig. 2, lately the geothermal heat pumps has the greatest share in direct utilization of geothermal resources, while in 1995, the majority of primary energy exploited from geothermal sources was consumed for space heating and bathing purposes.

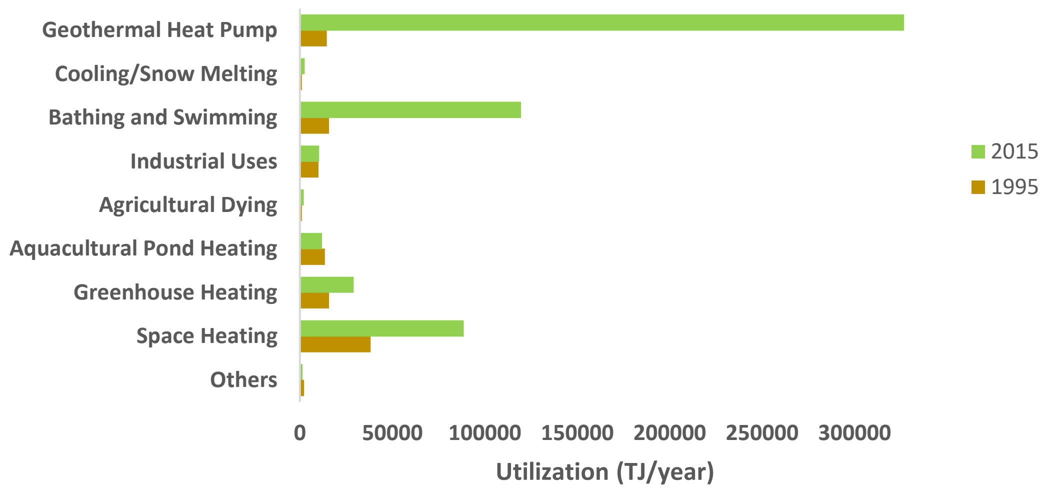

Fig. 2. Different applications of geothermal energy in direct use (1995-2015) (Lund and Boyd, 2016)

Today the installed thermal capacity for direct utilization of geothermal energy has reached over 70 GW and the generated thermal energy amounted to nearly 175 TWh per annum (WER,2016). Geothermal heat pumps play an important part in the development of geothermal energy direct utilization; in this regard, the statistics recorded a 22-fold growth in the utilization of geothermal heat pumps in the las 20 years. Fig. 3 illustrates the trend of installed thermal capacity for direct use between 1995 and 2017 and its projection to 2030. According to the estimations, the installed capacity in this sector will reach to 120 GW with over 300 TWh energy production. Also, as shown in Fig. 3, lately about 60 percent of the energy exploited from geothermal resources for direct use, supply from the geothermal heat pumps; and it will reach to nearly 75 percent by the end of 2030 (Lund and Boyd, 2016).

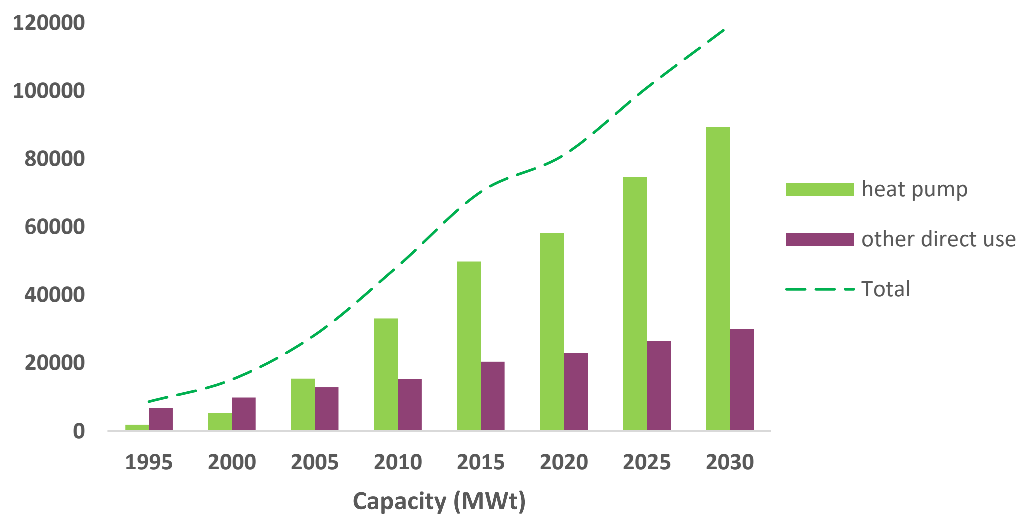

Fig. 3. Installed capacity of direct utilization of geothermal energy

From a regional point of view, Asia has the greatest share in direct utilization of geothermal resources, representing 44 percent of world energy production; followed by Europe (36%) and North America (15%). Fig. 4 shows share of different regions in direct use of geothermal energy in the year 2017 (IEA,2018).

Over the past decade, world geothermal direct energy utilization grew at a rate of 9-10 percent per year. Most of this growth took place China and United States. These countries now accounted for approximately 45 percent of installed thermal capacity (WER,2016). China as the leadership of direct geothermal utilization envisions a significant increase, in pursuit of the sustainable use of geothermal resources to reduce air pollution while also protecting water resources. Under its 15th five-year plan, China aims to increase direct use of geothermal heat to 500 million square meters of heated space by 2020 (REN21, 2017). In the United Stated, the growth of direct use over the past decade is all due to the increased use of geothermal heat pumps. Geothermal heat pumps in the U.S. are being installed at an 8 percent growth rate per year. However, as long as most direct-use projects are small scale, there are few developers or investors who are interested in supporting these installations; therefore no significant development can be expected in this sector in U.S (Boyd et al.,2015).

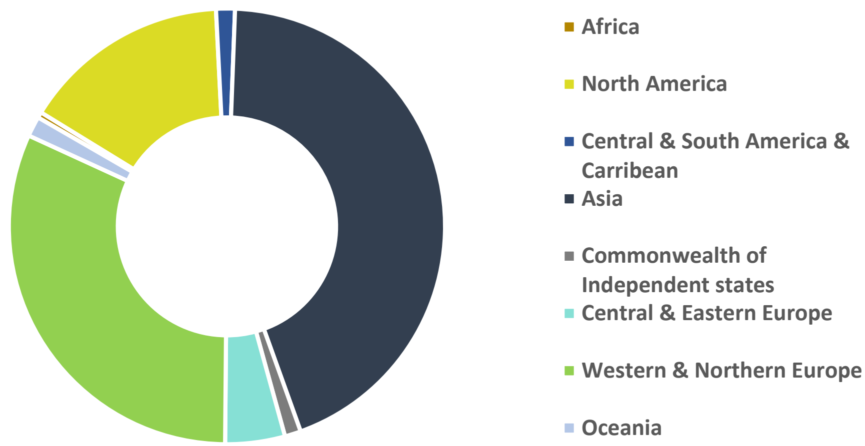

Fig. 4. Worldwide direct use of geothermal energy in the year 2015 (IEA,2018)

Overall, the geothermal energy sector is at a critical point in its evolution. For the last two decades, development has slowed down around the world; but the global community's attention to issues such as energy security, energy equity and environmental sustainability, has changed the situation and the industry in bracing itself for a new growth period.

3. IMPACT OF GEOTHERMAL ENERGY ON CO_2 EMISSIONS REDUCTION

Energy production from geothermal resources, result in the emission of some greenhouse gasses. Geothermal fluids contain dissolved gasses, mainly carbon dioxide; when two-phase geothermal fluid is separated into steam and water, these gasses emerge from the solution and are commonly vented to the atmosphere. Nevertheless, the quantity emitted is much lower in comparison with traditional fossil fueled energy generation units. Fig. 5 compares the carbon emissions from geothermal resources with fossil fuels.

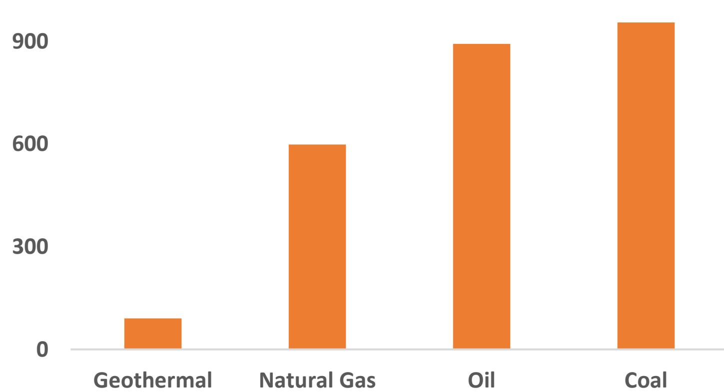

Fig. 5. Comparison of CO_2 emissions from selected energy resources in g/KWh (WER, 2016)

CO_2 emission reduction potential of geothermal energy depends on the energy diversification of each region. In fact, where fossil fuels have greater share in the energy system, there is more potential to reduce CO_2 emissions by utilization of geothermal resources; therefore carbon emission factor would be higher. Totally, according to the energy mix of the world, and CO_2 emission from geothermal power plants, it is estimated that every GWh of energy produced from geothermal resources, will avoid 380 tones CO_2 emission in the world (WER, 2016; Brander et al.). So, emission reduction can be calculated using carbon emission factor 380 tones CO_2/GWh and forecasted energy generation in 2030 which is shown in Table 1.

Table 1. Projected geothermal energy deployment in 2030

application	Forecasted capacity (GW)	Forecasted energy production (TWH)
Direct use	120	304
electricity	32	207
totall	152	511

Also Fig. 6 illustrates CO_2 emission mitigation which is caused by utilization of geothermal resource from 1995 to 2017 and its projection to 2030. The results show that in 2017, exploitation energy from geothermal resources, avoided almost 102 million tones CO_2 emissions. It can be expected that, if all countries follow through on their geothermal energy development goals and targets, geothermal energy will reduce more than 190 million tones CO_2 emission in the year 2030.

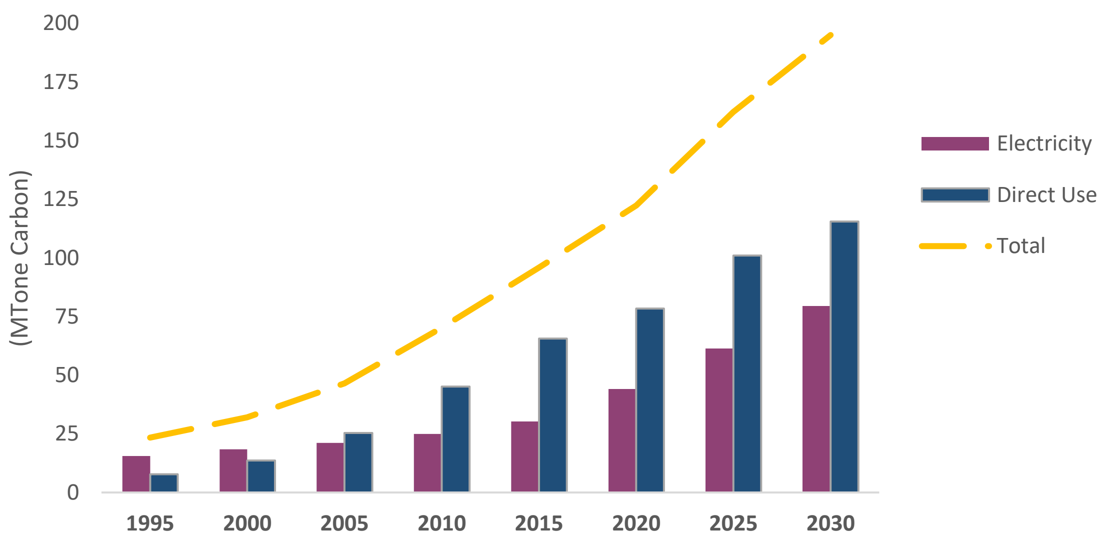

Fig. 6. CO2 emissions mitigation of geothermal energy resources in the world

4. CONCLUSION

Exhaustibility of fossil fuels, greenhouse gas emissions and the global warming issues have led to an increase in the share of renewables in the energy supply. Geothermal energy offers a sustainable option in the pursuit of renewable energies. Geothermal is a sort of renewable energy which is generated and stored beneath the surface of the Earth and can be used directly for heating purposes or transformed into electricity. Geothermal energy has recently been identified as a high potential source to displace fossil fuels and help meet clean air and decarbonziation obligations. The main objective of this study was to investigate the effect of development of geothermal resources on reducing CO_2 emissions. The overall results of this study is discussed here:

- According to the latest statistics, in 2017 geothermal power installed capacity has overpassed from 13.3 GW and it is expected to reach 32 GW by the year 2030.
- Direct use of geothermal in 2017 has reached to 300 TWh annual energy production and it is expected to raise over 500 TWh by the year. Most of the development in this sector has been due to the heat pumps utilization.
- Considering energy mix of the world, every GWh of energy produced from geothermal resources, will avoid 380 tones CO_2 emissions in the world. Therefore according to forecasts about geothermal energy deployment, it is concluded that almost 195 million tones CO_2 emission will be avoided by utilizing geothermal resources in the year 2030.

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