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A Review on Robustness of Geothermal Energy in Japan

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ABSTRACT

Energy has a strategic role in social and economic development of all the countries around the world and it's consumption due to increasing standards of living and fast Industrial development is rising considerably. However limited sources of fossil fuels and their rather rapid depletion as well as the increasing CO_2 emissions in the atmosphere and its dangerous consequences in terms of climate change, has lead that their replacement with new sources seems to be inevitable. As a renewable source of energy, geothermal energy because of being economically viable, locally available and also competitiveness with other forms of energies, has found a great attention among many countries around the world. Japan by having several volcanoes and approximately 28,000 hot springs in the country has a significant geothermal resources and currently has the third ranking geothermal energy potential, and eighth ranking geothermal electricity production in the world. Geothermal energy with the share of 0.5% or 2.4 Mtoe in 5.7% or 24.9 Mtoe of Total Primary Energy Supply (TPES) and also by producing 2.6 TWh or 0.3% of renewable electricity generation and 7.8% of total domestic energy production in 2015, has a substantial potential of supplying heat and electricity in Japan. Moreover the Japanese government with several strategies like Feed-in-Tariff (FIT) scheme and subsidies has been encouraging investors to facilitate geothermal power development.

1. INTRODUCTION

All human societies around the world are highly dependent on various type of energies. Every human activities and all economical sectors require constant supply of energy. Different energy sources guarantees the possibility of existence for creatures and civilizations. The rapid population growth and improvements in the quality of life have expanded the consumption of energy in a way that life without decent access to various energy sources is completely unbearable for human beings (Hoppe et al., 2016). The global consumption of energy during 1950 to 2010 under the same growth rate for Growth Domestic Product (GDP) has increased from 86 Exajoule (EJ) or 85×10^{18}J to 503 EJ and, the global energy consumption in 2050 would extend roughly to 1000 EJ. In addition, CO_2 emission has increased from 310 ppm during 1950 to 390 ppm in 2010 (Moriarty and Honnery, 2012). Intensive dependence of developed countries on conventional sources like fossil fuels not only reduces fossil fuel reserves but also causes unfavorable effects on human health and environmental impacts such as pollutions and climate changes (Hoppe et al., 2016; Sovacool, 2012).

Although burning fossil fuels has caused a serious climatic changes, the world unfortunately requires more fossil energy. However the intense use of energy to fulfill vital services like heating and lightening, brings about some energy security risks which might affect human life unfavorably in case of unexpected energy cuts and some environmental hazards caused by overconsumption of fossil fuels, which may jeopardize the future of next generations (ERDAL, 2015). Similar to the oil crisis which happened in the 1970's, these days the security of energy supply has attracted worldwide attention depending on the oil prices which affect the urgency level of the situation (Frondel and Schmidt, 2008). Energy security is commonly defined as the accessibility of energy at all times in various forms, in adequate amounts and reliable supply at rational prices, without unsatisfactory or irreversible impact on the economy and the environment (Knox-Hayes et al., 2013). The availability of energy is defined as a physical existence of energy sources in a sustainable manner. However the reliability and sufficient energy supply simply means that energy supply can fully meet all the needs of the global economy without any disruption. The meaning of affordable and rational energy prices is somehow less clear because it changes over time and is discerned differently by energy producers and consumers. Energy security definition also includes acceptability of different energy sources in terms of environmental concerns supply (Erdal et al., 2015; Von Hippel et al., 2011; Wonglimpiyarat, 2009).

Promoting the security of energy, requires countries to invest in advanced technologies in order to reduce energy intensity, increase energy efficiency and decrease the dependency in energy import. Reducing the intensity of energy and using the energy in a more efficient way would reduce the energy consumption and production costs (ERDAL, 2015; Felgenhauer and Bruin, 2009). In addition, increasing the energy efficiency, diversifying the energy mix and also increasing domestic energy supply potentials as well as boosting renewables as an alternative sources of energy are the factors that reduce menacing security of energy supply (Balat, 2010; Uchiyama, 2002). Diversification of energy resources by reducing the risks of energy market disruptions is an essential consideration for energy security that can enhance the security of energy (Lesbirel, 2004). Therefore countries that are mostly dependent on foreign energy sources should pursue a diversification of energy supply policy both in energy supplier countries and regions via alternative suppliers and alternative routes. In these countries, the risk of energy diversification is really essential. However the energy policy methods include diversifying the supply and importing fuels from various countries and not just relying on a small number of suppliers, diversifying fuel types and using new types of energies like renewable and sustainable energies, and industrial globalization (Neff, 1997). Moreover reducing the energy imports and increasing the energy self-sufficiency is very important for energy importing countries (Chen et al., 2014). In addition, diversification of energy sources can also help to reduce the greenhouse gas emissions by reducing the share of fossil fuel generation and also increasing the affordable use of renewable energy (Awerbuch et al., 2006). Sufficient energy is the main key for any developing and industrialized nations in order to achieve to their development goals and support their expanding economy. However, the sustainable development provides highly reliable and affordable energy which is also vulnerable by industries causing all types of environmental issues (Lu et al., 2016).

The green energy resources can have an important role to address the environmental issues coming in the path of sustainable development. Therefore, for developing countries to prosper more on the path of development without impeding the environment, the sustainable and renewable energy sources can be really beneficial (Kumar et al., 2017). In order to supply the rapidly rising global energy demand, which is expected to increase about 60% in the next 20 years, it is widely acceptable to use renewable energies which are clean and domestic energy sources and are appropriate alternatives for fossil fuels as oil, natural gas, and coal that have natural origin. In addition renewable energy systems have slight environmental impact and also are greener alternatives to such non-renewable energy systems as hydrocarbon combustion engines and coal powered power plants that produce greenhouse gases which cause in global temperature rise (El-Farra and Christofides, 2017).

Higher demand for energy consumption and importance of environmental issues has encouraged researchers and policy makers to consider renewable energies more seriously. Geothermal resources are a green energy sources that can make a considerable contribution in some countries. Japan by having several volcanoes and approximately 28,000 hot springs in the country has a significant geothermal resources and currently has the third ranking geothermal energy potential, and eighth ranking geothermal electricity production in the world (Yousefi et al., 2017).

2. OVERVIEW TO GEOTHERMAL ENERGY SOURCES IN JAPAN

After the Second World War, geothermal energy because of being economically viable and competitiveness with other forms of energies, found a great attention among many countries around the world. It is totally a domestic source of energy and does not need to be imported, and, in some cases, it is the only energy source available locally (Antics and Sanner, 2007). Japan is famous for its volcanoes and there are approximately 28,000 hot springs in the country. Japan has the third ranking geothermal energy potential, and its geothermal electricity production is currently eighth in the world (Sarkar and Bhattacharyya, 2012; Sugino and Akeno, 2010). The first experimental geothermal power station was built in 1925 at Beppu, Kyushu, and the first commercial power station began in 1966 at Matsukawa. Most of the world's geothermal power plants were built in the 1970s and 1980s, following the 1973 oil crisis. The urgent growing demand for electricity generation from alternative energy sources, and the fact that geothermal energy was basically free, led to non-optimal plant designs for geothermal resources (Kanoglu, 2002; Sarmiento and Steingrimsson, 2007).

In 2009, 20 geothermal power plants were in operation at 17 locations nationwide. Most are in the Tohoku and Kyushu districts. Total net power output from all geothermal power plants reached 535.26 MWe in 2006. Fig. 9, shows locations and details of geothermal power stations in Japan. Total installed geothermal power capacity was 0.2% of all power generation facilities in Japan in March 2009 (Sugino and Akeno, 2010).

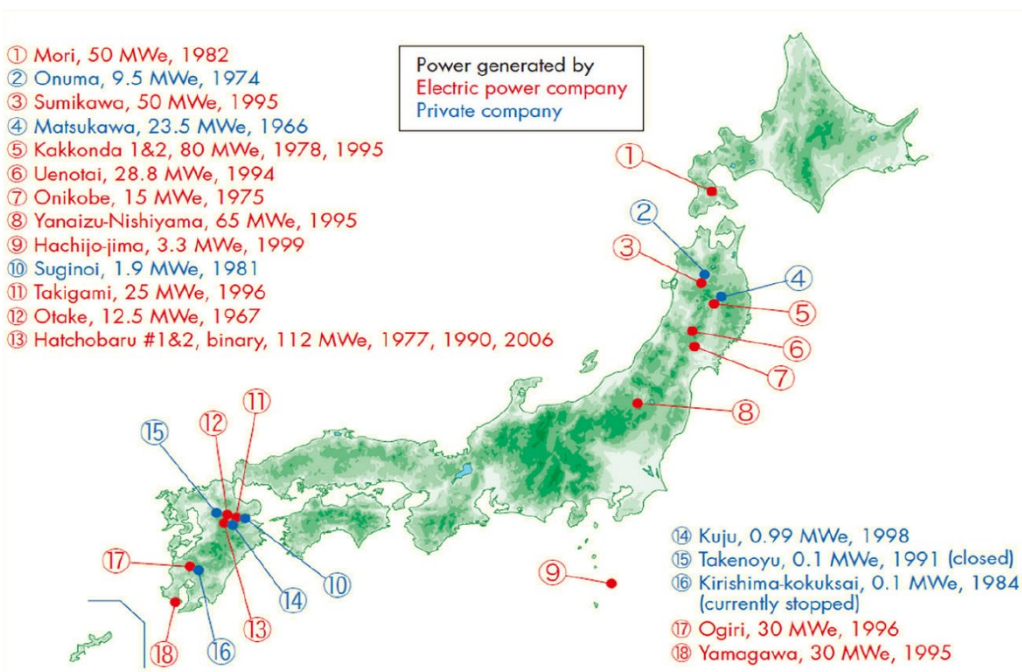


Figure. 1. Geothermal power stations in Japan (Sarkar and Bhattacharyya, 2012)**.**

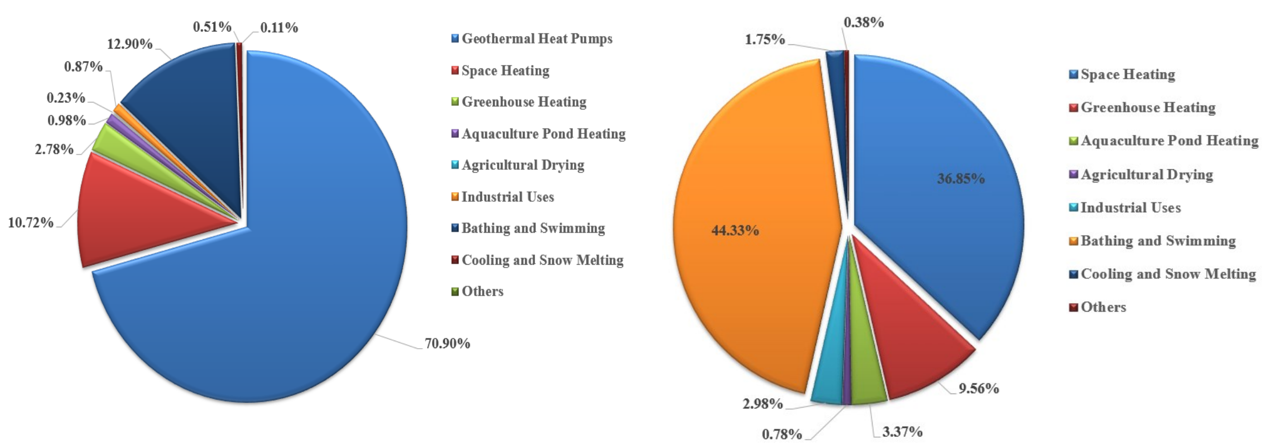
Japan has significant geothermal resources that most of them are situated in natural protection areas. Geothermal energy with the share of (0.5% or 2.4 Mtoe) in (5.7% or 24.9 Mtoe) of TPES, 2.6 TWh (0.3% of renewable electricity generation) and 7.8% of total domestic energy production in 2015, has a substantial potential of supplying heat and electricity in Japan (IEA, 2016). Geothermal power development and production in Japan like other renewable energies are demanding tasks, and they need strong support from governmental sectors to be able to compete as a strong technology with other energy sectors. the Japanese government has been encouraging investors with FIT scheme and subsidies to facilitate geothermal power development in its 2014 Strategic Energy Plan (IEA, 2016).

Details of Japanese geothermal power plants as well as their capacities are shown in Table 1. It should be considered that geothermal resources can be classified in different ways. Some authors use temperature for a controlling factor which in most classification methods is a main parameter, whereas others use enthalpy like low, medium and high enthalpy resources (Saeid Jalilinasrabady, 2013). Moreover geothermal systems and reservoirs can also be classified on the basis of various aspects, such as reservoir temperature, exergy, entropy, physical state, or their nature and geological setting (Yousefi et al., 2017).

Table 1. Geothermal power plants in Japan and their calculated (Jalilinasrabady and Itoi, 2015)

Number	Power Plant	Capacity (kW)
1	Mori	50,000
2	Onuma	9,500
3	Sumikawa	50,000
4	Matsukawa	23,500
5	Kakkonda 2	30,000
6	Uenotai	28,800
7	Onikobe	12,500
8	Yanaizu- Nishi yama	65,000
9	Hachijojima	3,300
10	Suginoi Hotel	1,900
11	Takigami	25,000
12	Otake	12,500
13	Hatchobaru	2,000
14	Hatchobaru 1	55,000
15	Hatchobaru 2	55,000
16	Kujukanko Hotel	990
17	Ogiri	30,000
18	Yamagawa	30,000

Geothermal energy can be used in wide variety of applications in direct and indirect ways. Fig 2, shows the direct applications of geothermal in the world in 2015 with and without geothermal heat pumps, distributed by percentage of total installed capacity (MWt).



(a) **(b)**

Fig. 3. Geothermal direct applications worldwide in 2015, distributed by percentage of total installed capacity (MWt) (a) With heat pumps, (b) Without heat pumps (Lund and Boyd, 2016)

In addition in Japan the direct use of medium and low enthalpy geothermal water is mainly located in the areas around the high enthalpy geothermal areas where hot spring resources are abundant. Otherwise, the use of shallow geothermal heat pump systems is available nationwide. Geothermal heat pumps are used for space heating and cooling, domestic hot water and snow melting. Many new systems have been installed in Hokkaido replacing old oil boilers. Approximately 84% of geothermal heat pumps are closed loop, 15% open loop, and 1% using both systems. Bathing, mainly at Japanese-style inns (onsens) is very popular with the Japanese people and accounts for about 90%of the direct-use applications. However based on the data from recent investigations it has been reported that about 77.37 MWt and 969.49 TJ/year geothermal energy in Japan is used for space heating, 36.92 MWt and 451.73 TJ/year for greenhouse heating; 7.91 MWt and 141.86 TJ/year for fish farming; 1.24 MWt and 30.92 TJ/year for industrial applications; 1810.19 MWt and 23,519.81 TJ/year for bathing and swimming; and 45.76 MWt and 154.88 TJ/year for air conditioning and 106.78 MWt and 361.39 TJ/year for snow melting. The estimated installed capacity for heat pumps is 100 MWt and annual energy use of 500 TJ/year, based on extrapolations from 2012 data (62 MWt at that time). This gives a total for the country of about 2186.17 MWt and 26,130.08 TJ/year (Yasukawa and Sasada, 2015) (Lund and Boyd, 2016).

The first experimental geothermal power station was built in 1925 at Beppu, Kyushu, and the first commercial power station began in 1966 at Matsukawa. With the 1973 oil crisis, development of new geothermal fields accelerated, reaching 215MW during 1974–1978 (Bertani, 2015). In 2009, 20 geothermal power plants were in operation at 17 locations nationwide. Most are in the Tohoku and Kyushu districts. Total net power output from all geothermal power plants reached 535.26 MWe in 2006.Total installed geothermal power capacity was 0.2% of all power generation facilities in Japan in March 2009 (Sugino and Akeno, 2010).In addition geothermal energy with the share of 0.5% or 2.4 Mtoe in 5.7% or 24.9 Mtoe of Total Primary Energy Supply (TPES) and also by producing 2.6 TWh or 0.3% of renewable electricity generation and 7.8% of total domestic energy production in 2015, has a substantial potential of supplying heat and electricity in Japan (Yousefi et al., 2017).

3. CONCLUSION

Limited sources of fossil fuels and their rather rapid depletion as well as the increasing CO_2 emissions in the atmosphere and its dangerous consequences in terms of climate change, has led scientists and researchers to find an ecofriendly, abundant and affordable sources of energies and the replacement of fossil fuel resources with new sources seems to be inevitable. As a renewable source of energy, geothermal energy because of being economically viable, locally available and also competitiveness with other forms of energies, has found a great attention among many countries around the world. Japan by having several volcanoes and approximately 28,000 hot springs in the country has a significant geothermal resources and currently has the third ranking geothermal energy potential, and eighth ranking geothermal electricity production in the world. Geothermal energy with the share of 0.5% or 2.4 Mtoe in 5.7% or 24.9 Mtoe of Total Primary Energy Supply (TPES) and also by producing 2.6 TWh or 0.3% of renewable electricity generation and 7.8% of total domestic energy production in 2015, has a substantial potential of supplying heat and electricity in Japan. Moreover the Japanese government with several strategies like Feed-in-Tariff (FIT) scheme and subsidies has been encouraging investors to facilitate geothermal power development.

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