YR 2013 COUNTRY UPDATE ON GEOTHERMAL ENERGY IN KOREA

Tae Jong Lee[1] and Yoonho SONG[1]
[1]Geothermal Resources Team, Korea Institute of Geoscience and Mineral Resources, 124 Gwahang-no, Yuseong-gu, Daejeon 305-350, Korea
e-mail: megi@kigam.re.kr

ABSTRACT

Geothermal utilization in Korea showed remarkable increase in the recent 10 years, especially in geothermal heat pump (GHP), which is mainly due to strong governmental supports including various subsidy programs, R&D expenditures, mandatory public new and renewable energy use act, flat electricity charge rates, etc. Total installed capacity for direct use is estimated to be 551.7MWt at the end of 2012, most of which is for GHP installation followed by hot spring usage. GHP installation in Korea has increased more than 50% annually for the last five years and total installed capacity exceeded 500 MWt in 2012. This rapid increase was possible thanks to active government support programs and legislation and we expect it will continue to increase at least for the next five years. As for deep geothermal resources, although Korea does not have high-enthalpy geothermal resources from volcanic sources, it still has huge amount of geothermal resources at depth. An EGS potential assessment was made following a recently announced protocol in 2010. Theoretical potential for EGS power generation in the depth range 3-10 km was estimated 6,975 GWe which is 92 times of total power generation capacity. Technical potential considering depth limit, land accessibility, recovery factor and temperature drawdown factor reaches 19.6 GWe. Increasing interests in geothermal power generation has resulted in launching the first EGS pilot plant project at the end of 2010. Geothermal power generation is going to be realized within five years by EGS technology. National technological roadmap (TRM) aims to achieve 200 MWe install capacity by 2030. R&D programs according to the national geothermal TRM will support the technical background for nationwide deployment of GHP and EGS systems.

Keywords: geothermal heat pump (GHP), enhanced geothermal system (EGS), direct use, power generation, EGS potential, technological roadmap (TRM)

1. INTRODUCTION

Since the first installation of GHP system to US embassy building in Seoul in 2000, which was very late compared to the US and European countries, Korean experts have devoted their efforts to develop the GHP technology suitable for the geology of Korea, to figure out characteristics of rock and soil, to make people and the government know about geothermal, etc., which consequently moved the government to support geothermal. And for the deep geothermal resources, Korea Institute of Geoscience and Mineral Resources (KIGAM) have been engaged on development of deep geothermal resources since early 90s, but most of the projects had failed to get the budget for deep drilling until the Pohang project has launched (Song et al., 2006; Lee and Song, 2008). The project aimed to develop geothermal water higher than 70 °C within 2 km deep and to utilize the water to district heating, greenhouse and aquaculture. During the 6 years from 2003 until 2008, four exploration wells have been drilled to figure out the geological and geothermal structure of the target area. Well logging from the four wells commonly showed geothermal gradient higher than 30 °C/km, while national average of geothermal gradient is about 25 °C/km (Lee and Song, 2008). Assessment of geothermal resources in Korea (Lee et al., 2010) showed that the temperature at 5 km depth of Pohang area is expected to be about 180 °C. Based on the scientific results, the government and industry decided to launch a proof-of-concept project for power generation by EGS technology in Korea in December 2010.

In this article, we first summarize the geothermal resources in Korea, then discuss on current situation of GHP and EGS project in Korea and newly developed geothermal technology roadmap 2011, and finally outlook the future of geothermal in Korea.

2. GEOTHERMAL D/B IN KOREA

A geothermal database (D/B) has been made and opened in July, 2010 by KIGAM (Kim et al., 2010; http://kgris.kigam.re.kr). The D/B contains various geothermal properties of rock in Korea, including 2,163 thermal conductivity, geothermal gradient from 715 well data, 492 heat flow data, and 180 heat production data. It also contains corresponding properties of rocks such as density, specific heat, and porosity (Figure 1).

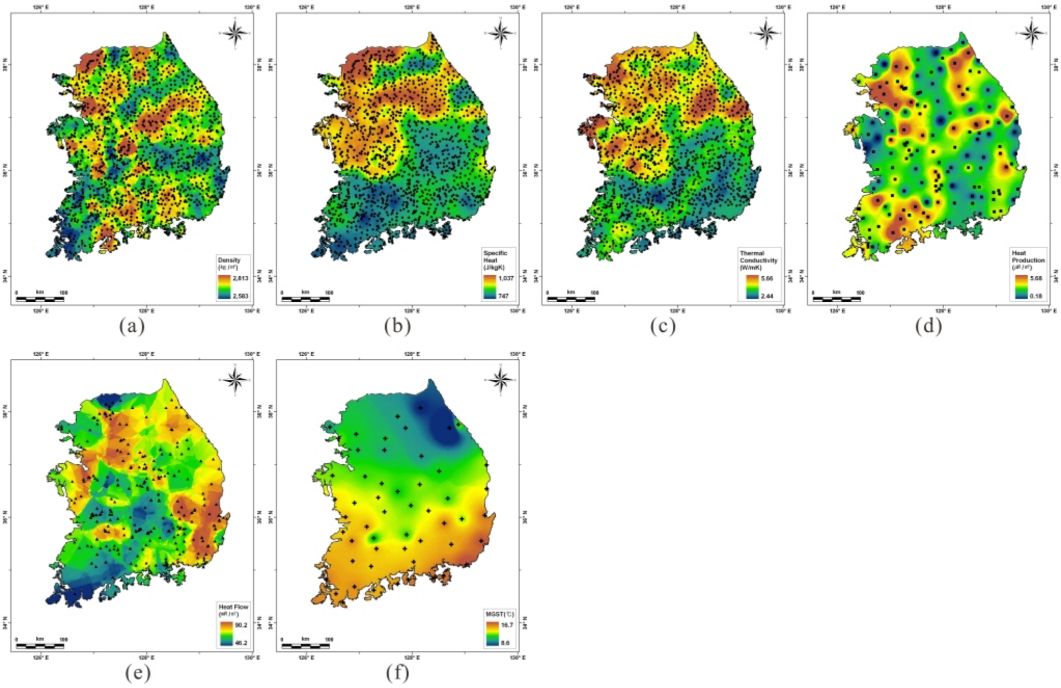

Fig. 1. Distribution of thermal and physical properties on the geothermal D/B: (a) density, (b) specific heat, (c) thermal conductivity, (d) heat production, (e) heat flow, and (f) mean surface temperature (Song et al., 2011).

Using the data from the D/B, a geothermal resource assessment has been carried out to figure out the heat contents and the temperature at depths in Korea (Lee et al., 2010; Song et al., 2011). Lee et al. (2010) estimated the temperature at depths and conducted geothermal resource assessment in Korea. They argued that total available subsurface geothermal energy down to 5 km in South Korea was 1.01×10^{23} J. Assuming only 2% of the geothermal energy to be developed, it would be about 484×10^{8} toe, which is equivalent to more than 200 times of nationwide primary energy consumption (~ 2.33×10^{8} toe) in 2006. Song et al. (2011) calculated geothermal power generation potential through EGS technology following a protocol, which is recently proposed and endorsed by international organizations. Estimated theoretical potential from 3 km to 10 km beneath the South Korea reached 6,975 GWe which is 92 times of total power generation capacity of Korea in 2010. Technical potential down to 6.5 km is 19.6 GWe, which considers the current technological limits, land accessibility, thermal recovery ratio of 0.14, and temperature drawdown factor of 10 °C.

Note from Figure 1e that high-heat flow can be expected at depth in south-eastern part of Korea, where thick Tertiary Pohang Basin covers the surface. A new project has been started in 2012 to update the D/B and to figure out the reason why the south-eastern part of Korea shows high heat flow anomaly. As a first year in 2012, a total of 3,175 thermal conductivity, 763 of geothermal gradient data, 763 heat production data, and 753 of heat flow data have been gathered.

3. GEOTHERMAL DIRECT USE IN KOREA

Geothermal energy use in Korea has been mostly for bathing and swimming since the ancient era. Hot springs are mainly associated with deeply connected fracture system in granite area. Highest temperature developed so far is 76 °C at Bugok hot springs near Busan, where some of hot water is utilized for space heating. As summarized in Table 1, total installed capacity using the hot spring water is estimated to be 43.6 MWt since 2008, and 593.7 TJ/yr of annual use which is surely very small amount in comparison of geothermal potential of 1.01×10^{23} J in Korea. Excluding bathing and swimming of the hot spring water, only about 11 MWt of heating facility are installed, 86 TJ/yr of energy is used in 2012.

Apart from direct use of deep geothermal energy, GHP shows pretty rapid increase in install capacity as shown in Figure 2. Total installed capacity of GHP system in Korea exceeded 500 MWt at the end of 2012, and corresponding heating energy use exceeded 2,000 TJ/yr in 2012 (Table 1), which continues the highest expansion in the world (Lund et al., 2010).

Several reasons can be raised for the rapid increase in GHP system in Korea. Most important one is strong governmental supports, which includes;

1) New and Renewable energy development and use act:
   - Government supports max. 50% of installation cost of GHP by deployment subsidy program, rural deployment program, 1 million green home program (25.7 million US$ in 2012)
   - Low-interest long term load programs
   - R&D expenditure (11 million US$ in 2012)
2) Greenhouse subsidy program for 5 years from 2010 (36 million US$ in 2012): subsidizing 80% of total installation cost
3) Mandatory public new and renewable energy use act: minimum 10% of total energy use in public buildings with area bigger than 1,000 m^2 must be from renewable energy sources, which has been effective from 2012 and the minimum percentage is to increase 1 %/year.
4) Flat electricity charge rates for GHP system, otherwise progressive stage system
5) long-term low-interest loans and tax benefits for those using renewable energy

Table 1. Geothermal direct heat uses, fossil fuel saving and avoided CO_2 emission in Korea as of December 2012.

Use	Installed Capacity (MWt)	Annual Energy Use		Capacity Factor	Fossil fuel saving** (toe/yr)	Avoided CO_2 emission** (ton)
		TJ/yr	GWh/yr			
Individual Space Heating	8.66	53.43	14.84	0.20	1,881	6,070
District Heating	2.21	31.28	8.69	0.45	1,101	3,554
Greenhouse Heating	0.17	1.33	0.37	0.25	47	151
Bathing and Swimming	32.56	507.61*	141.0*	0.49	17,864	57,669
Geothermal Heat Pumps***	508.2	2,055.6[4)]	571.0[4)]	0.23	72,340	233,523
Total	551.68	2,649.2	735.9		93,233	300,967

* ∑ [(supplying water temp.: 42 – leaving water temp.: 27) × (flow rate) × (operating time)]
** uses 35.2 toe/TJ (126.7 toe/GWh) and 113,611 CO_2 kg/TJ (409 kg/MWh) assuming 70% of oil boiler (following IEA-GIA conversion rate; Mongillo, 2005)
*** estimates for 2012 based on the amount of subsidy and plans reported according to the 'Mandatory Act'.
4) uses 'Pure Geothermal Contribution of heating only' according to E = Q*(1-1/COP); COP: Coefficient of Performance.

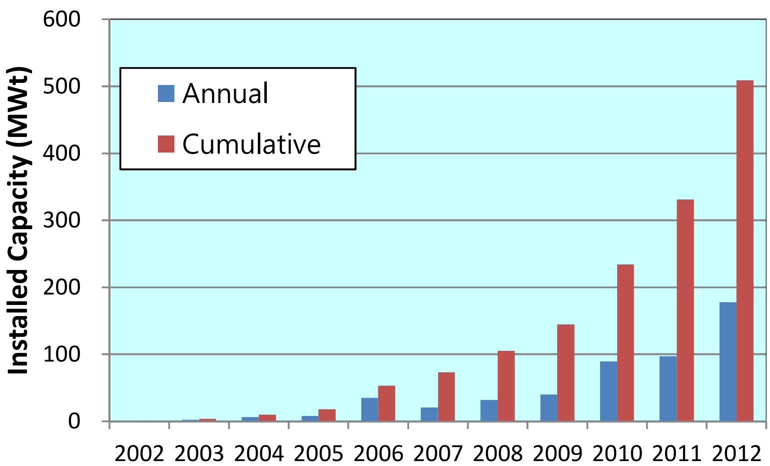

Fig. 2. Increase of installation of GHP in South Korea.

In 2008, Korean government proclaimed 'The First National Energy Master Plan (2008-2030)' according to 'The Energy Law' passed in 2006 and amended in 2008 under the slogan of "*low-carbon, green-growth*". There are four basic strategies: a low-carbon and energy-conscious society, increased clean energy supply, green-driven growth, and affordable energy for all. This plan also emphasizes balancing of the 3-E's; energy security, energy efficiency, and environmental protection. According to the master plan, 'The Third Basic Plan on New & Renewable Energy Technology Development, Utilization and Diffusion (2009-2030)' has been set up aiming new & renewable energy's share of 11% of total primary energy supply and of 7.7% of electricity generation by 2030. Target of geothermal energy is 3.8% of total new & renewable energy contribution by 2030 which means only 0.42% of the total primary energy. However, geothermal community expects that much more portion can be covered by geothermal; more than 1 % of total considering the rapid increase of GHP installation in these days. For renewable energy deployment, an ambitious deployment project named 'One Million Green Home by 2020' has also been launched. This is to be fulfilled by developing the 'Smart Energy System' that combines various renewable sources such as PV, solar, geothermal, wind and fuel cell. This project will help GHP installation continue to increase in the future.

The total primary energy consumption at the end of 2012 reached around 277.633 million ton of oil equivalent (toe) while geothermal heat provided 63,218 toe which covered only 0.023% of the total primary energy consumption. Status and prospect of geothermal energy in national target still does not seem significant because government program mainly focuses on the three major items for electricity generation such as photo voltaic, wind power and fuel cell. Fortunately, however, importance of geothermal utilization is being acknowledged by the government and the public side and the geothermal's share of market stimulating incentive came to be significant. Therefore, we could see some remarkable progress of GHP installation in recent years.

4. GEOTHERMAL POWER GENERATION

In contrast to the direct use of geothermal energy, Korea does not have a geothermal power plant (GPP) so far. But, as already mentioned in section 2, high temperature can be expected at depth in south-eastern part of Korea, where Pohang locates. The area is covered by thick Tertiary sediments which act as a cap rock, quite uncommon in Korea. Geothermal exploration in Pohang area has been carried out for more than 6 years by KIGAM and four deep boreholes have been drilled. The deepest well (BH-4) has started to be drilled on September 2005 and reached down to 2.385 km depth on November, 2006. The well is vertical starting with 16 inch diameter and ending with 6 and half inches. Drilling logs and well logging results show that there are lots of fractured zones at various depths. From the temperature log that was obtained in 2006, right after the drilling, geothermal gradient for BH-4 is about 38 ^{o}C/km, so that temperature at 2 km depth was estimated over 91 ^{o}C. In this background, the first proof of concept project for GPP by EGS in Pohang has been started in Dec. 2010. The project aims to construct a MW scale GPP in 5 years within 5 km depth of the site. Nexgeo Inc. as principal contractor leads the project with institute (KIGAM and Korea Institute of Construction Technology (KICT)), university (Seoul National University (SNU)), and industry (POSCO and Innogeo Tech. Inc.) participations. A total budget for the project is assumed to 43.8 Million US dollar, 18.5 million from the government and 25.3 million from the industry. Details about this project can be found from Song et al. (2013) of this symposium.

5. GEOTHERMAL TECHNOLOGICAL ROADMAP FOR 2030

A geothermal technological roadmap (TRM) of Korea has been released at the end of the year 2011. The roadmap highlights 4 specific items to be developed by 2020; two items for GHP, one for direct use of deep geothermal water, and the other one for GPP (KETEP, 2011);

1) Large scale, high performance GHP system (5 > MWt with APF > 4.0)
2) Hybrid geothermal system with other new and renewable energy sources
3) 50 MWt geothermal system for district heating
4) 20 MWe EGS geothermal power plant

Research and development (R&D) for GHP system in the world commonly aims to higher system performance, larger system, diverse of energy sources, sustainable use, and with environmental friendly manner. The first two items will follow the general trend and cover all of necessary R&D for GHP. Besides the R&D programs, strong governmental support including subsidy programs and mandatory act will be continued, it can be expected 50 ~ 100 MWt new GHP installation per year at least for the next five years.

Items 3 and 4 will cover the R&D for deep geothermal systems. Especially in the EGS GPP, the ongoing project will built 1.5 MWe GPP by 2015 and then well network technology will be developed to expand the install capacity up to 20 MWe at the same area by 2020. And by 2030, the 20 MWe system will be applied to 8 to 10 sites according to the geothermal potential described in section 2, so that a total of 200 MWe GPP installation is to be achieved.

6. DISCUSSION AND FUTURE OUTLOOK

Though Korea does not have high-enthalpy geothermal resources from volcanic sources, it still has huge amount of geothermal resources by GHP and EGS technologies. Technical geothermal potential of 19.6 GWe within 6.5 km deep is waiting to be developed and utilized underneath our feet. And surely, the higher the technology is developed, the more the resources are reserved.

In GHP systems, GHP installation and deployment increased very rapidly for the last 10 years, which is manly thanks to the strong governmental supports including various subsidy programs, R&D funds, mandatory public new and renewable energy use act, flat electricity charge rates, and so forth. It is expected that the rapid increase in GHP installation will go on at least next five years as long as the governmental subsidy programs continue. R&D programs according to the national geothermal TRM will support the technological background for nationwide deployment of GHP systems.

For the deep geothermal resources, geothermal power generation is going to be realized in five years by EGS technology. Then, the industry will recognize that geothermal power generation is not only a dream even in Korea. They will come to invest to geothermal development in domestic and even in overseas, who are very eager to find an appropriate renewable energy sources to invest by the Renewable Portfolio Standard (RPS) system activated from this year. RPS pushes 13 electricity companies of installation capacity larger than 500 MW to generate a certain ratio of electricity that should be generated by renewables as shown in Table 2. Considering the R&D expenditure by the TRM and expected investment from private sector by RPS system, GPP of 200 MW in 2030 is not very unrealizable.

<Table 2> Mandatory renewable ratio of electricity for the electricity companies larger than 500 MW.

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Renewable ratio (%)	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	10.0

REFERENCES

KETEP (2011) *Technological roadmap for mitigation of carbon dioxide – Geothermal*. Ministry of Knowledge Economy, 86p (in Korean), http://www.ketep.re.kr.

Kim, H. C., Baek, S. K. and Park, J. M. (2010) Construction of geothermal information database for Korea based on Web GIS. *World Geothermal Congress 2010, Bali, Indonesia.*

Lee, T. J. and Song, Y. (2008) Lesson learned from low-temperature geothermal development in Pohang, Korea. *The 8th Asian Geothermal Symposium, Hanoi, Vietnam.*

Lee, Y., Park, S., Kim, J., Kim, H.C. and Koo, M.-H. (2010) Geothermal resource assessment in Korea. *Renewable and Sustainable Energy Reviews,* **14**, 2392-2400.

Lund, J. W., Freeston, D. H. and Boyd, T. L. (2010) Direct utilization of geothermal energy 2010 worldwide review. *Proceedings World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010.*

Song, Y., Lee, T. J., Kim, H.C. and Park, D.-W. (2006) Recent progress of low-temperature geothermal development in Korea. *GRC Transactions*, **30**, 689-691.

Song, Y., Baek, S.-G., Kim, H. C. and Lee, T. J. (2011) Estimation of theoretical and technical potentials of geothermal power generation using enhanced geothermal system. *Econ. Environ. Geol.*, **44**, 513-523 (in Korean with English abstract).

Song, Y., Lee, T. J. and Yoon, W. S. (2013) Current Status of the Korean EGS pilot plant project. *the 10th Asian Geothermal Symposium, September 22-24, Tagaytay, Philippines.*