# TODAY AND THE FUTURE OF GEOTHERMAL ENERGY IN KOREA

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## 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. 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; i.e. technical geothermal potential of 19.6 GWe within 6.5 km deep by enhanced geothermal system (EGS) technologies. The first proof of concept project for geothermal power generation by EGS in Pohang has been started in Dec. 2010. Geothermal power generation is going to be realized in 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. 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.

**Keywords**: geothermal, resources, potential, geothermal heat pump (GHP), enhanced geothermal system (EGS), technological roadmap (TRM)

## 1. INTRODUCTION

Korea does not have any active volcanic or tectonic activity for more than thousand years, thus it is hard to expect high-enthalpy geothermal resources like in Japan. It, however, still has huge amount of geothermal resources to be developed and utilized beneath the earth. The ubiquitous energy can be utilized anytime and anywhere, theoretically, from the earth by ground-source (or geothermal) heat pump (GHP) and enhanced geothermal system (EGS).

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) had been engaged on development of deep geothermal resources from 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 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 RESOURCES IN KOREA

A geothermal database 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, currently. It also contains corresponding properties of rocks such as density, specific heat, porosity and so forth (Figure 1). 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).

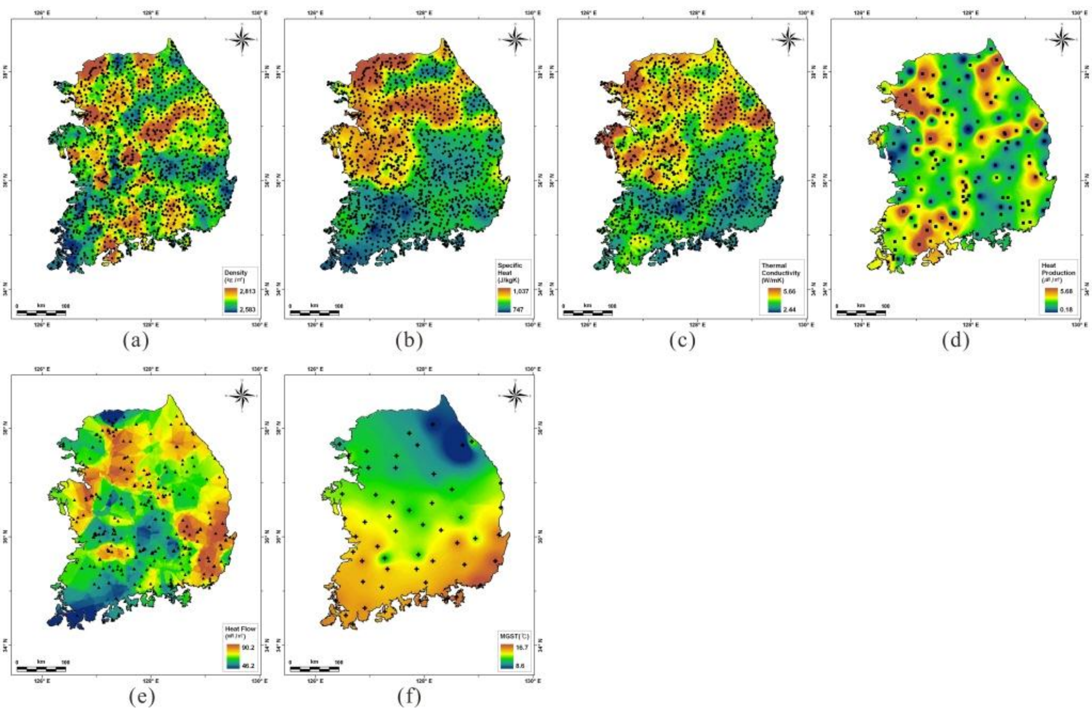

**Fig. 1**. Distribution of thermal and physical properties on the geothermal D/B: (a) density, (b) specific heat, (c) thermal conductivity, (d) heat production, (e) heat flow, and (f) mean surface temperature (Song et al., 2011).

Lee et al. (2010) estimated the temperature at depths (Figure 2) and conducted geothermal resource assessment in Korea. They argued that total available subsurface geothermal energy down to 5 km in South Korea was $1.01 \times 10^{23}$ J. Assuming only 2% of the geothermal energy to be developed, it would be about $484 \times 10^{8}$ TOE, which is equivalent to more than 200 times of nationwide primary energy consumption (~ $2.33 \times 10^{8}$ TOE) in 2006. Note from Figure 2 that high-temperature can be expected at depth in south-eastern part of Korea, where thick Tertiary Pohang Basin covers the surface.

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.

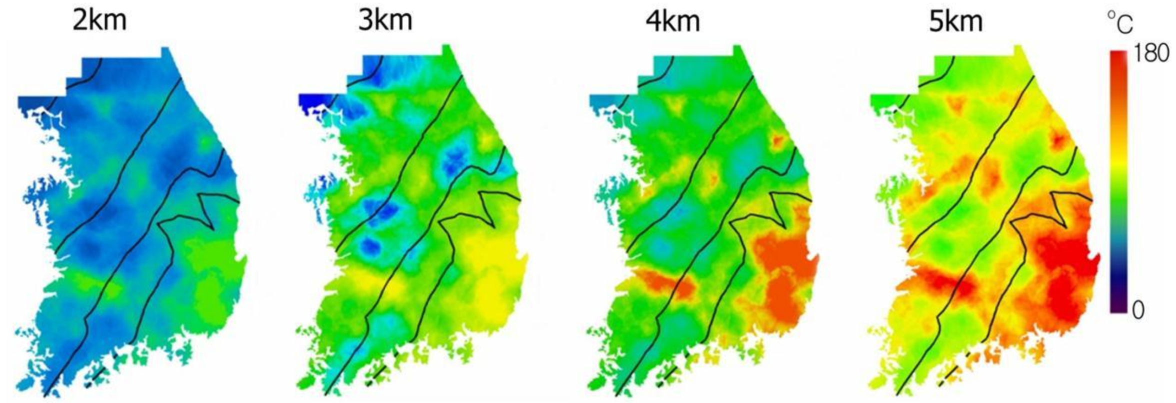


**Fig. 2**. Estimated temperature distribution in South Korea at various depths (Lee et al., 2010). Note high temperature estimated on the south-eastern part of Korean Peninsula, where Pohang locates.

## 3. GEOTHERMAL DIRECT USE IN KOREA

Geothermal energy use in Korea has been mostly for bathing and swimming from 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 exceeded 43.6 MWt in 2010, and 593.7 TJ/yr of annual use which is surely very small amount in comparison of geothermal potential of $1.01 \times 10^{23}$ 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 2010.

Apart from direct use of deep geothermal energy, GHP shows pretty rapid increase in both the install capacity and annual energy use as shown in Figure 3. Total installed capacity of GHP

system in Korea reached about 229.8 MWt, and corresponding energy use exceeded 900 TJ/yr in 2010 (Table 1), which shows 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 (17 million US$ in 2010)
   - Low-interest long term load programs
   - R&D expenditure (10.75 million US$ in 2010)
2) Greenhouse subsidy program for 5 years from 2010 (48 million US$ in 2010): subsidizing 80% of total installation cost
3) Mandatory public new and renewable energy use act: minimum 5% of total budget must be used to install renewable energy in constructing public building bigger than 3,000 $m^2$
4) Flat electricity charge rates for GHP system, otherwise progressive stage system

Thus obviously, the rapid increase is going to continue at least next five years as long as the governmental subsidy programs go on.

<**Table 1**> Geothermal direct use in South Korea as of Dec. 31, 2010 (Song and Lee, 2011)

| Use | Capacity (MWt) | Annual Energy Use (TJ/yr = $10^{12}$ J/yr) | Capacity Factor |
|---|---|---|---|
| Individual Space Heating | 8.66 | 53.43 | 0.20 |
| District Heating | 2.21 | 31.28 | 0.45 |
| Greenhouse heating | 0.17 | 1.33 | 0.25 |
| Bathing and Swimming | 32.56 | 507.61 | 0.49 |
| Geothermal Heat Pumps | 229.8 | 903.24 | 0.23 |
| Total | 262.36 | 1,496.9 | |

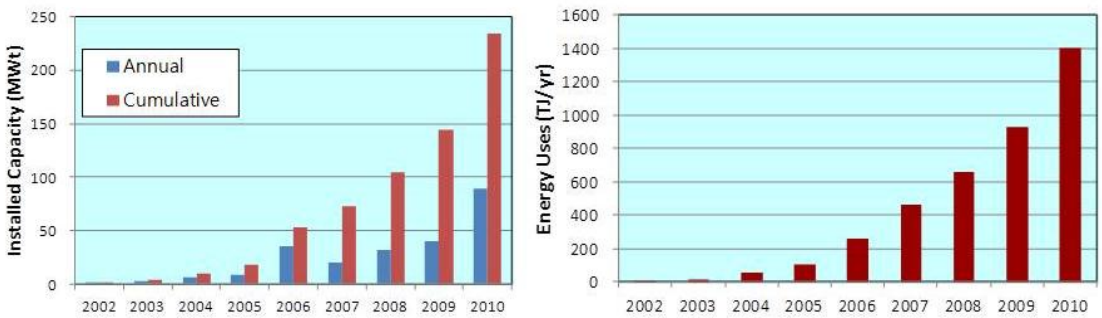


**Fig. 3.** Increase of installation and annual energy uses by GHP in South Korea (Song and Lee, 2011).

## 4. GEOTHERMAL POWER GENERATION - The Korean EGS project

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) is 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 31 $^{o}$C/km and thus bottom temperature was estimated over 90 $^{o}$C (left of Figure 4). The temperature profile is surely disturbed by the drilling. Temperature profile measured in 2010 showed 91 $^{o}$C in 2 km depth, and even higher temperature can be expected at the bottom.

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, 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.

The 5-year project is divided into two phases (Figure 5). At the first phase (2010-2012), various geothermal explorations will be conducted including geological/geophysical investigation of the target area, two exploration wells of 1 km and 3 km depths, thermal property measurements of the rock and core samples, well logging and stress field measurements, monitoring of micro-seismicity during drilling, and finally geothermal resource assessment of the site. The goal of the first phase is to confirm the temperature higher than 100 $^{o}$C at the depth of 3 km, and to estimate the amount of energy that can be extracted by EGS from 5 km depth of the site. Reaching the first goal is not necessarily very difficult because we have already observed temperature higher than 90 $^{o}$C at the site. But care must be taken for 3 km drilling, because BH-4 (2.383 km) is the deepest well that has ever drilled by drilling technology in Korea. The second phase (2012-2015), will be devoted to complete a doublet system of 5 km depth including deep drilling, hydraulic stimulation, circulation test and eventually to construct a binary GPP of MW scale.

In the first year of the project, most of time has been devoted to select the appropriate site for EGS within the area. Site selection is not an easy work because of various regulations and restrictions related to the agriculture, protection of green area, residential area and so forth. Despite the difficulty, thanks to the support from the local government, a pilot site is readily fixed.

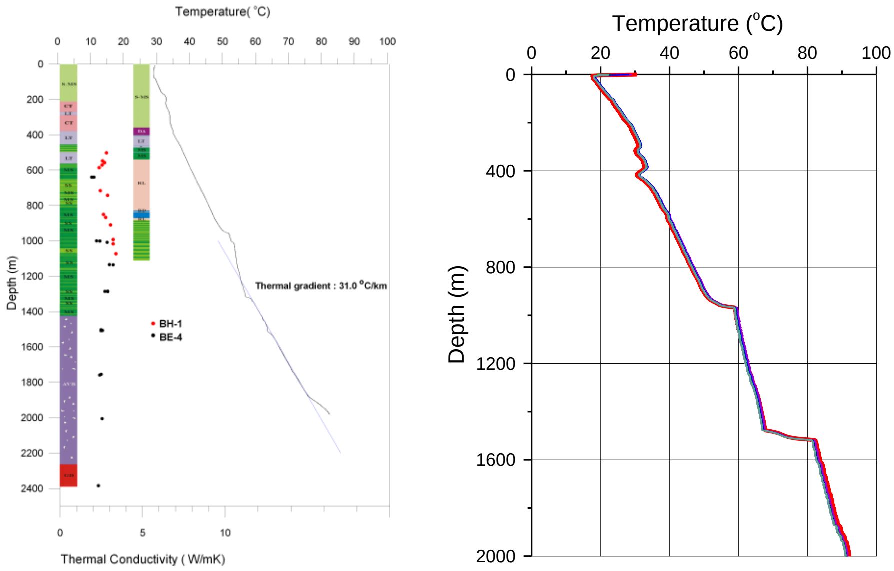


**Fig. 4**. Geological column, thermal conductivity, and temperature logs for two wells (YR 2006) and temperature monitoring for BH-4(YR 2010). Note the temperature at 2 km depth of BH-4 of about 91 °C in 2010.

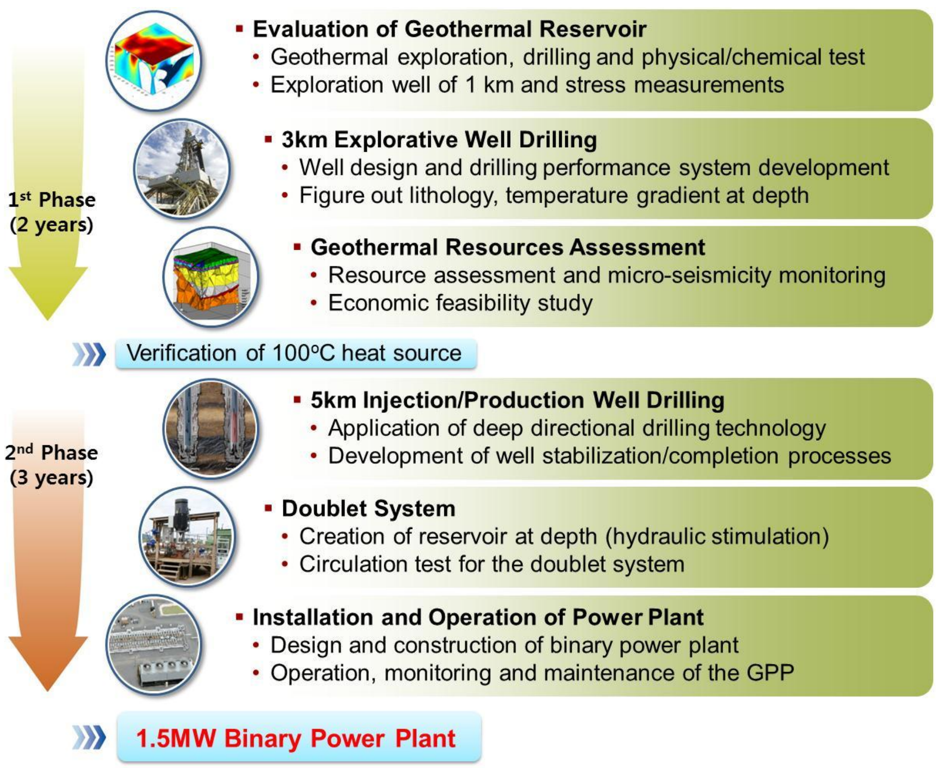


**Fig. 5**. Mater plan of the Korean EGS project.

An exploration well has been drilled for coring and stress measurement of the site, and it will be used as a monitoring well for micro-seismicity. Instruments for micro-seismic monitoring will be installed by this May within about 5 km radius from the site. Drilling for 3 km well will start in this summer. All the necessary information will be opened to the experts worldwide via the web http://www.kegs.kr. Because Korea does not have enough experience in either deep drilling and stimulation of 5 km depth or binary power generation, comments and participations of international experts will be appreciated and mostly welcome.

## 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. SUMMARY

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 invest 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 |

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