IEA GEOTHERMAL

Republic of Korea Country Report 2012

IEA Geothermal Implementing Agreement

National Activities
Chapter 15 of Draft 2012 GIA Annual Report
Republic of Korea

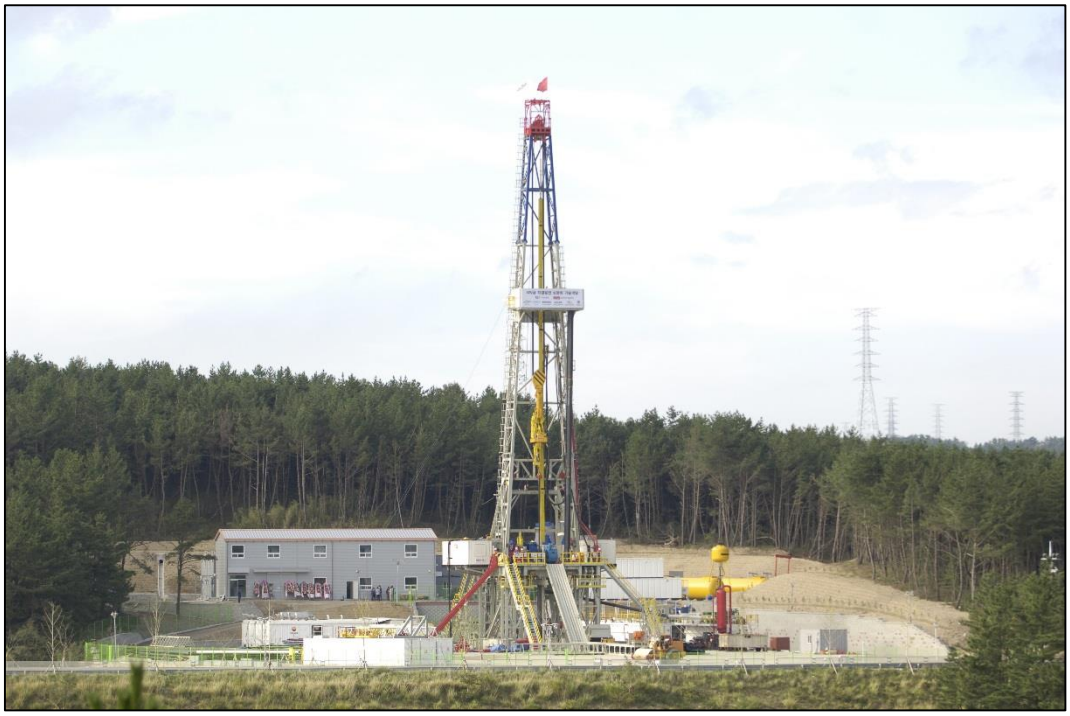

Figure 15.1 Drill rig with API static hook load of 3,150 kN at the EGS pilot plant project site in Pohang, southeastern part of Korea.
(Figure courtesy of Yoonho Song)

15.0 Introduction and Overview

Geothermal utilization in Korea has been direct use, especially with ground-source or geothermal heat pump (GHP) installation, because there is no high temperature resources associated with active volcano or tectonic activity. GHP installation in Korea has increased rapidly since middle of 2000's and total installed capacity is estimated to exceed 500 MW_{th} at the end of 2012 (see Table 15.1). This successful deployment made general public as well as people in energy sector become well aware of what the geothermal energy is, especially its nature of covering base load. Information on recent stories of low-temperature power generation including enhanced geothermal system (EGS) in Europe, Australia and US have made decision makers and industries in Korea be interested in geothermal power generation, which led to launching of the EGS pilot plant project at the end of 2010.

Table 15.1 Status of Geothermal Energy Use as of December 2012 (estimates).

Direct Use	
Total Installed Capacity (MW_{th}) excluding GHP	43.7
New Installed Capacity (MW_{th}) excluding GHP	0
Total Heat Used in GWh/yr [TJ/yr] excluding GHP	164.9 [593.6]
Total Installed Capacity GHP (MW_{th})	508.8
New Installed Capacity of GHP (MW_{th})	177.7
Total Heat generated with GHP in GWh/yr [TJ/yr]	571.0 [2,055.6]

In 2012, the first well drilling for the Korean EGS pilot plant project spudded in September in Pohang area. Target depth of drilling is between 4.5 km and 5 km at which

subsurface temperature is expected to be as high as 180 °C. The first well went down to 2.25 km in December and the well is to be re-entered in May 2013. For the EGS project, a micro-seismic monitoring system with nine (9) borehole three-component accelerometers has been completed and currently under operation. All individual observatories are connected to internet network through high speed optical LAN so that high frequency data can be handled in real time.

A recent research on the EGS potential in Korea following the protocol endorsed by IEA GIA shows that theoretical and technical potentials are estimated to be 6,975 GW_e and 19.6 GW_e, respectively (Song et al., 2011). A technical roadmap of greenhouse gas reduction technology in Korea states that there can be 200 MWe of installed capacity with geothermal by 2030 in Korea (KETEP, 2011), which is one percent of the technical potential. The outcome of the Korean EGS pilot plant project, if successful, will surely be a milestone initializing the roadmap and we expect this pilot plant project to be scaled up to level of 10 MWe class by 2020.

15.1 National Programme

National energy strategy has stayed at the same level since 2008 (see 2011 Annual Report) and 'The Second National Energy Master Plan' will be set up in 2013. National plan for renewable energy will also be revised according to the newly set up master plan. Therefore, there may be a notable change of renewable energy R&D and deployment plan starting from 2014.

The total primary energy consumption at the end of 2012 reached around 277.633 million ton of oil equivalent (toe) while geothermal provided 63,281 toe (= 2,649.2 TJ) 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. 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.

Table 15.2 Geothermal R&D expenditure for the period 2010-2012 (in US$ 1,000).

	2010	2011	2012
Government	8,750	8,294	12,980
Industry	2,000	4,554	4,199
Total	10,750	12,828	17,179

R&D investment by government increased in 2012 reflecting support for EGS drilling as shown in Table 15.2 while industry matching fund rather stayed the same. Figure 15.2 shows increasing trend of GHP installation for the last ten years. Note that we don't include the trend of energy uses since there have not been estimates of pure geothermal uses of GHP considering operating electricity before 2011.

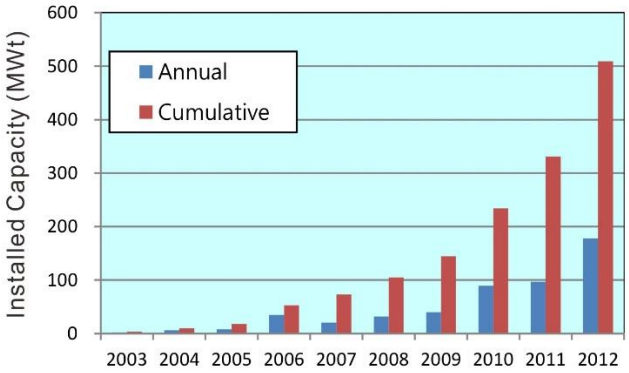

Figure 15.2 Increasing trend of GHP installation. (Data from Korea Energy Management Corporation; estimates for 2012 based on the amount of subsidy and plan reported according to the 'Mandatory Act').

15.2 Industry Status and Market Development

Geothermal industry in Korea has mainly focused on GHP design and installation. According to official report, there are more than 100 small businesses for GHP, but among them less than 20 companies are active with more than 50% of market share. There are two industry associations; Korea Geothermal Energy Association (registered to the Ministry of Knowledge Economy) and Korea Groundwater and Geothermal Energy Association (registered to the Ministry of Land, Transport and Maritime Affairs), both of them are for GHP installation.

Main drives of the rapid increase in GHP installation are active government subsidy program and a special Act for new and renewable energy ('Mandatory Act'). There are several subsidy programs; 'Deployment Subsidy Program', 'Rural Deployment Program', and '1 Million Green home by 2020 Program' through which government subsidizes 50% of total installation cost based on competition with pre-determined budget each year. Another powerful subsidy program which was enacted from 2010 is 'Greenhouse Deployment Program' for which the central government subsidizes 60% and local government covers 20%, which means rural farmers pay only 20% of GHP installation cost for greenhouses and aquacultures. Annual market from this special program amounted up to US$ 45.2 million in 2012.

In 2012, the 'Mandatory Public Renewable Energy Use Act' was amended to state that "In all public buildings bigger than 1,000 m^2 in area, more than 10% of annual energy uses should be from new and renewable energy sources". The minimum percentage is to increase annually; 11% in

2013, 12% in 2014, and so on. According to the Act, GHP installation plans amounting total of 114 MW_{th} in 2011 and 120 MW_{th} in 2012 were reported, which would become realized two or three years after planning due to construction period.

Although pilot plant project of geothermal power generation has started at the end of 2010 and targets 1 MWe plant by the end of 2015, there is no legal frame or supportive measures for geothermal power generation, yet. Korean government has initiated Renewable Portfolio Standards (RPS) system from 2012, but geothermal power generation is not included yet because there is no reference data for costs. This lack of legal frame is major barrier to active industry participation in geothermal business. Geothermal community in Korea expects that geothermal power generation will be included in RPS in 2013 but how high Renewable Energy Certificate (REC) is to be allocated for geothermal still remains as main issue. Geothermal law is expected to set up as a part of Mining law by 2014.

15.3 Research, Development and Demonstration/Deployment

Almost all of the research activities in Korea are initiated by government fund. R&D activities can be categorized into two main fields: 1) shallow geothermal utilization using various GHP types, and 2) geothermal power generation. For shallow geothermal utilization, there were several successful R&D works such as sampling & measurement of subsurface thermal properties for borehole heat exchangers resulting in big database, and simulation of T-H-C coupled behavior with borehole heat exchanger under groundwater flow. There are also researches on efficiency of borehole heat exchanger types and on utilizing groundwater thermal energy along with aquifer thermal energy storage (ATES).

The EGS pilot plant project launched at the end of 2010 is the first attempt to realize geothermal power generation in Korea. It is a five-year term, government funded and industry matching project. Target area is Pohang field of higher heat flow in southeastern part of Korean Peninsula (see 2006 Annual Report). The project consists of two phases: I) site preparation, drilling down to a 3 km deep well and to confirm the temperature anomaly in two years, and II) extending the 3 km deep well down to 4.5 - 5 km, hydraulic stimulation and reservoir creation, drilling another well and completing doublet system, and finally installing a MWe class binary power plant in another three years (See Figure 15.3).

For monitoring reservoir creation and growth, a micro-seismic (MS) monitoring system with nine (9) borehole three-component accelerometers was completed in 2012 and currently under operation. Eight observatories are located on two circles with radius of 3 and 5 km, respectively, centered on EGS site (see 2011 Annual Report for location map). Depths of accelerometers are 120-130 m except the one at the site which was installed at 180 m depth. All nine observatories are connected to high speed internet network so that we can process the data with sampling frequency of as high as 1,000 Hz in real time.

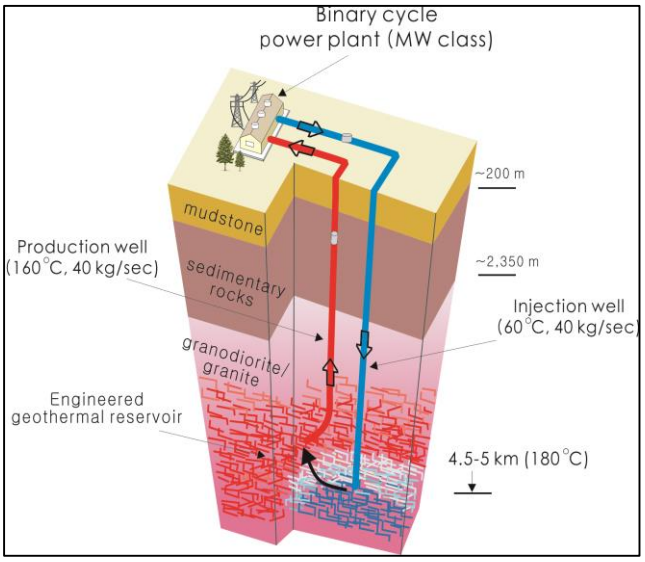

Figure 15.3 Conceptual model of Korean EGS pilot plant project.

Drilling of the first well PX-1 was spudded on 19th of September 2012 with 17.5 inch bit through pre-installed surface conductor of 20 inches in diameter. Progress of drilling was slower than plan mainly due to lack of experience including procurement problem of spare parts, necessary items and services. The well reached 2,250 m (2,241 m GL) on 14th of December. While drilling PX-1, a seismic-while-drilling (SWD) survey has been conducted using drill bit vibration as seismic source, in order to get information on seismic velocity distribution in deeper region. For SWD, four radial surface geophone arrays were deployed to 500 m length each and geophones were at every 10 m in array. Covered bit depth ranges were from 330 m to 1,700 m in 2012.

Korea Institute of Geoscience and Mineral Resources (KIGAM) estimated geothermal power generation potential through EGS following the protocol endorsed by IEA GIA. Thus estimated theoretical potential reaches 6,975 GWe which is 92 times of the total power generation capacity in 2011. Technical potential limited to depth of 6.5 km and considering recovery factor of 0.14, temperature drawdown factor of 10 °C and accessible in-land area, reaches 19.6 GWe (Song et al., 2011). Figure 15.5 shows an example of procedure for potential assessment.

Figure 15.4 Steam over mud tank as mud was heated by deep circulation during drilling of PX-1.

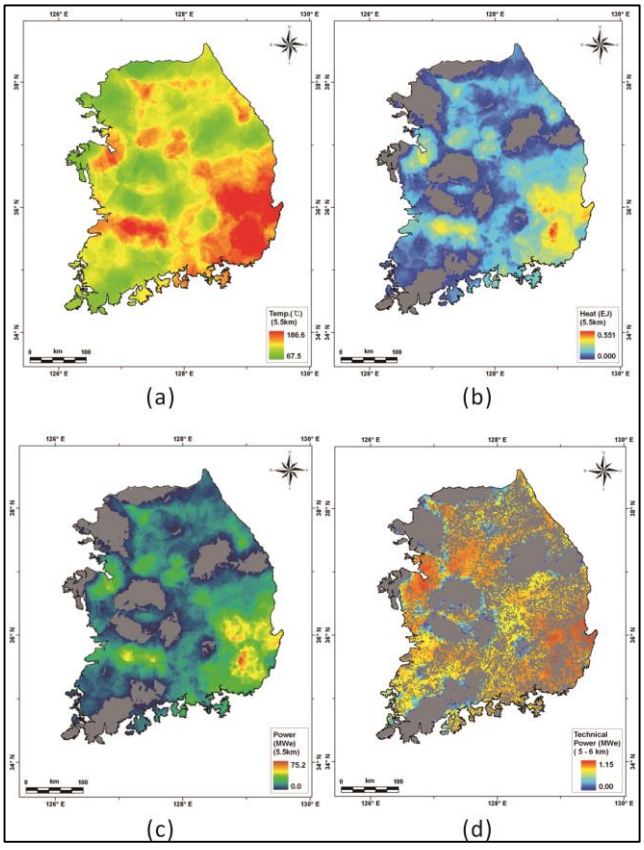

Figure 15.5 Example of EGS potential assessment procedure: (a) temperature distribution at 5.5 km depth; (b) heat contents in depth range 5-6 km; (c) theoretical potential in depth range 5-6 km; (d) technical potential in depth range 5-6 km. Note that grey regions in (c) and (d) represent area of temperature lower than surface temperature+80 °C, while in (d) include in-accessible area as well.

15.4 Geothermal Education

There are regular geothermal courses in Seoul National University both for undergraduate and graduate levels from 2009. There are many small seminars about general geothermal topics and geothermal power generation. Reflecting the progress of the EGS pilot plant project, special sessions at the domestic conferences are organized with focus on drilling, stimulation and economic aspects.

15.5 Future Outlook

Geothermal utilization in terms of GHP installation will continue to rapidly increase for the next few years: more than 100 MW_{th} annually. This is due to active subsidy programs and the special 'Mandatory Act'. There are concerns for low performance or malfunctioning of GHP system because rapid increase of market may accompany bad installations without proper design and performance validation. Long-term performance modeling and validation are another important task to keep GHP installations growing especially for large systems (bigger than 1 MW_{th} capacity).

Geothermal power generation is expected to be realized within the next five years through the success of the EGS pilot project. Active participation from industries is critical in scaling up and further commercialization, which is currently affected by lack of legal frame for supporting geothermal power generation. There are on-going activities for including geothermal in Renewable Portfolio Standard (RPS) system with higher Renewable Energy Certificates (REC) and also for implementing legal frame for geothermal. A technical roadmap of greenhouse gas reduction technology in Korea states that there can be 200 MWe of installed capacity with geothermal by 2030 in Korea (KETEP, 2011), which is one percent of the technical potential. The outcome of the EGS pilot plant project, if successful, will surely be a milestone initializing the roadmap and we expect this pilot plant project to be scaled up to level of 10 MWe class by 2020.

15.6 References and Websites

Korea Institute of Energy Technology Evaluation and Planning (KETEP) (2011) *Strategic roadmap for greenhouse gas reduction technology – Geothermal*. Ministry of Knowledge Economy, 86p. (in Korean)

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 illustrations and abstract in English)

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