CURRENT STATUS OF GEOTHERMAL DEVELOPMENT IN KOREA

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ABSTRACT

Geothermal utilization in Korea has been of direct-use, mainly on public bath with low-temperature geothermal water from hundred wells to deeply-connected fractures. Since 2002, government R&D investments on geothermal development are increasing. There is on-going program to develop deep geothermal water in Southeastern part of Korea. The pilot drilling showed a geothermal gradient of 40 °C/km and existence of several permeable zones related with fracture systems and a production well down to 2 km deep is under development for the purpose of district heating usage. Geological and geophysical investigations for several candidate sites for geothermal developments are also ongoing. Geothermal heat pump installation is rapidly increasing and government supports researches on the thermal characteristics of subsurface materials and groundwater thermal energy utilization techniques, as well. R&D activities are expected to continue to increase thanks to high public awareness on the importance of renewable energy and recent high oil-price situation.

Keywords: geothermal, low-temperature, district heating, geothermal heat pump

1. INTRODUCTION

It is well known that the geothermal resources in Korea is characterized by absence of high-temperature resources for power generation and hot springs are associated with localized, deeply-connected fracture system mainly in the granite area. Recently we identified a geothermal anomaly in terms of high heat flow and geothermal gradient at the Tertiary sediment area in the southeastern part of Korean Peninsula, where the low-temperature geothermal development program is now being carried out.

Geothermal heat pump installation is now booming and thus government research and development (R&D) program is focused on systematic utilization of shallow geothermal resources such as studies on borehole heat exchanger and groundwater thermal energy utilization. In 2005, a systematic approach to investigating subsurface thermal and hydraulic properties to analyze the thermal behavior during geothermal heat pump operation was made in a borehole heat exchanger site and continuous monitoring of temperature profile along the heat exchange is being made.

New low-temperature geothermal potential has been identified at an island close to Seoul, the capital of Korea, and a drilling led to hot water of 70 °C overflowing the well. A magnetotelluric (MT) survey over the area and well logging indicates that there exists an electrically conductive zone which is interpreted as series of fractures for hot water conduit and we expect higher temperature resources to be exploited. Another geothermal exploration program is being performed in Jeju Island to see if there remain thermal resources after Quaternary volcanic eruption and if there exist deeply extended fractures or deep aquifer.

2. NATIONAL POLICY

The Korean Government does not have independent strategy for geothermal yet but ‘new and renewable energy policy’. In 2000, the government began to establish the foundation for certification research and performance analysis with an aim to promote the use of renewable energy. The development of Korean ‘new and renewable systems’ began by focusing investment on the technology development in the three selected areas of photo voltaic, wind power and fuel cell with big market potential. The “Second Basic Plan for the Development, Use and Supply of New and Renewable Energy Technology (2003~2012)” was established in 2003 along with detailed promotional plans for the annual development and supply of new and renewable energy sources to achieve the goal of increasing the use of new and renewable energy to 3% by 2006 and 5% by 2011.

The ‘Alternative Energy Development Promotion Act’ was enacted in 1987 and the ‘New and Renewable Energy Technology Development Project’ was launched in 1988. In addition, the ‘Alternative Energy Development Promotion Act’ was amended to the ‘Alternative Energy Development and Use Promotion Act’ in 1997 to promote the use of new and renewable energy and to launch case supply projects as well as to offer long-term low-interest loans, tax benefits and government/public funds for those using new and renewable energy. Also the “Basic Plan for New and Renewable Energy Technology Development & Supply” was established in 1997 to promote the development and supply of new and renewable energy technology.

The total use of new and renewable energy at the end of 2005 is estimated to reach 6.6 million ton of oil equivalent (TOE) accounting 2.8 % of the total energy consumption. The annual growth rate of new and renewable energy (1995~2005) is at an average of 23.0 %, which is about four times faster than the increasing rate of total energy consumption. However, it only amounted to 2.8 % of the primary energy at the end of 2005, which is still significantly lower than most of advanced countries.

Status and prospect of geothermal energy still does not seem significant because government program focuses on the three major items 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. Therefore, we expect some remarkable progress can be made in the next five years.

In 2005, total investments by government reached some US$ 6 million including:

- 'Development of deep-seated, low-temperature geothermal resources': $ 3 million
- 'Information system of geothermal resources distribution and utilization': $ 1 million
- Various geothermal heat pump utilization programs: $ 2.1 million

This shows about 20 % increase comparing 2004 and this is mainly due to newly launched 'Information system of geothermal resources distribution and utilization' program. Industry expenditure is still quite small and mainly a type of matching fund to government R&D funding which reaches 15 % up to 50 % of total budget depending on the size of business. In 2005, total amount is estimated to be some US$ 0.8 millions.

3. CURRENT STATUS OF GEOTHERMAL ENERGY USE

By the end of 2004, the installed thermal power is 23.2 MWt including hot spar usage and heat pump (see Table 1). Thermal energy used in 2004 is estimated to be 220 TJ and capacity factors are 0.38 and 0.18 for hot spar and heat pump, respectively.

Table 1. Geothermal direct heat uses in Korea as of December 2004.

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr=1012 J/yr)	Capacity Factor
Bathing and Swimming	13.53	163.29	0.38
Geothermal Heat Pumps	9.65	56.9	0.18
Total	23.18	220.2	

There exist some constraints for geothermal development. In the view points of technical and social barriers, a barrier to progress of geothermal heat pump may be explained by lack of information on the thermal properties of subsurface materials and lack of scientific knowledge on hydrogeological conditions influencing heat extraction/injection rate. Also general perception that geothermal heat pump system is of high initial cost while there does not exist any guaranteed example of performance since it is quite beginning stage. Therefore, people tend to consider that a natural gas or an oil boiler is cheaper in initial stage and durable.

In environmental point of view, on the other hand, the 'Groundwater law' states that all boreholes must be reported on depth and purpose prior to drilling. Also if somebody is to use groundwater, he or she must undergo environmental impact evaluation and submit its result. It is also effective for groundwater thermal utilization even though subject to re-injection. Heat pump business society claims that heat extraction from groundwater will not affect the quality of the water and thus thermal utilization should be free from such regulation. Some arguments are still going on.

4. RESEARCH ACTIVITIES

R&D activities in Korea are focused on low-temperature geothermal water development and geothermal heat pump application. Almost all of the research activities are initiated by government fund. R&D in geothermal investigation, exploration and exploitation is led by Korea Institute of Geoscience and Mineral Resources (KIGAM), the only government funded research institute on geoscience field in Korea. The Geothermal Resources Group of KIGAM is leading the two major government funded R&D program: 'Development of deep-seated, low-temperature geothermal resources' and 'Information system of geothermal resources distribution and utilization'. Some other research on geothermal heat pump installation for cooling and heating of buildings is performed by the other research institutes and private sector, which occupied 30 % of government funding in 2005.

Figure 1 shows the resultant heat flow map of Korea and sample location map with dots. A total of 359 heat flow data of in-land Korea is presently available. Among them, 35 data have been measured in the 1970's and 213 data were compiled until 1997 by KIGAM researchers. During the year of 2004 and 2005, another 111 rock samples have been collected in the area close to the deep boreholes where geothermal gradient measurements had been made. We measured the thermal conductivity of the rock samples, to compile updated heat flow map of Korea. The weighted average of heat flow values over Korea with an areal window of 500 m by 500 m is 60 ± 11 mW/m^2.

In the year of 2003, KIGAM launched a project to develop the geothermal water in the area showing high geothermal anomaly, north of Pohang city, the southeastern part of Korea, for district heating and agricultural application. The target area was selected first by the geothermal anomaly shown from heat flow and geothermal gradient maps. Next, lineament distribution analysis using Landsat image and from structural geology mapping was applied to figure out possible deep fractures that would work as geothermal water conduit. The area belongs to the Tertiary Pohang Basin overlying Cretaceous sedimentary rocks, biotite-granite intrusion and Eocene volcanic rocks such as tuff. The Pohang Basin consists of Miocene marine sediments and bottommost clastic sediments layer. The Heunghae basin, the main target of the geothermal exploration, is covered with Quaternary alluvium underlain by these thick Tertiary sediments with relatively low thermal conductivity and thus preserving high geothermal gradient, which is quite uncommon in Korea (see Figure 2).

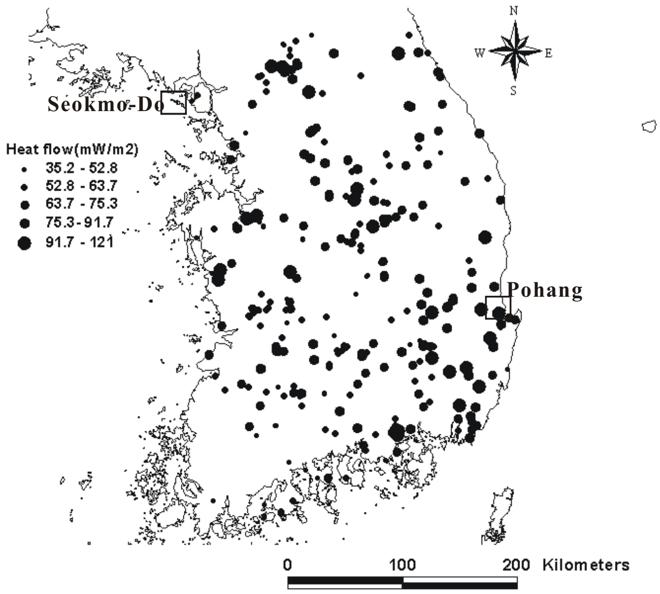

Figure 1. Heat flow map of Korea using 359 data. Two low-temperature geothermal development sites, Pohang and Seokmo-Do are shown.

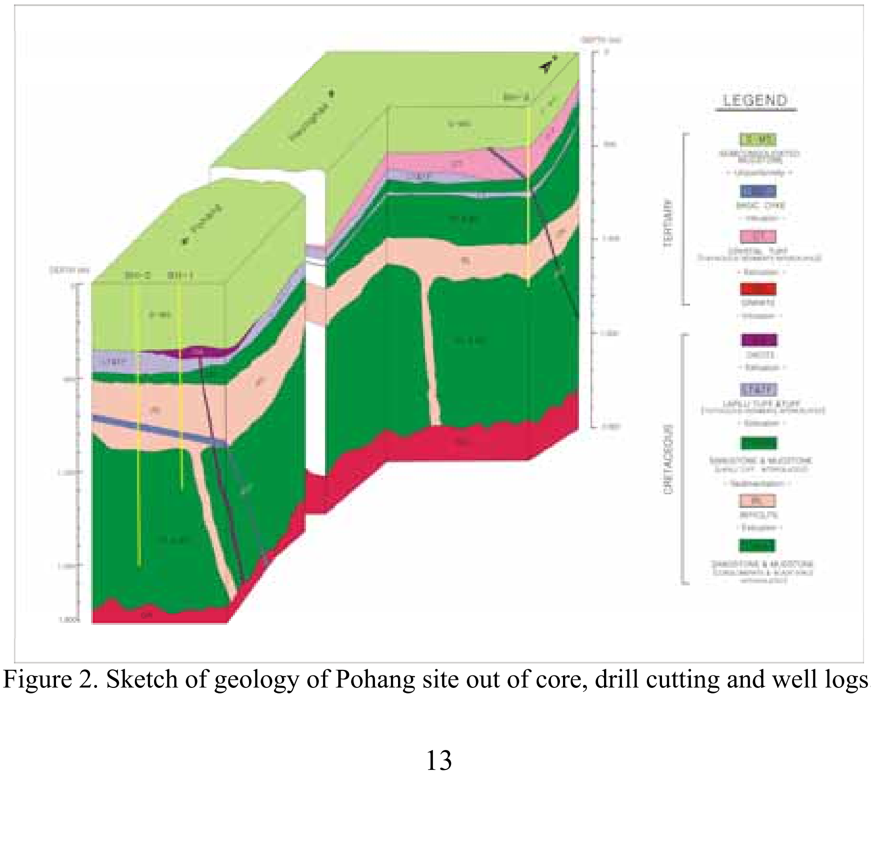

Figure 2. Sketch of geology of Pohang site out of core, drill cutting and well logs.

Numerous geophysical survey methods have been applied such as gravity and magnetic surveys for interpretation of regional geologic setting, MT and controlled-source audio-frequency MT surveys for mapping the resistivity structure and possible fracture zones, and self-potential survey to figure out hydrologic condition associated with geothermal flow. Drilling of two test wells 165 m apart each other, one is rotary well and the other is coring borehole, started in August 2003 to confirm the existence of geothermal reservoir. The rotary well went down to 1.3 km and coring borehole to 1.1 km. The drilling results showed a geothermal gradient of 40 °C/km and existence of several permeable zones related with fracture systems. Presently, drilling of 2 km deep production well is under development. Figure 3 shows the three-dimensional (3-D) images of subsurface as the result of 3-D inversion of MT data over the area.

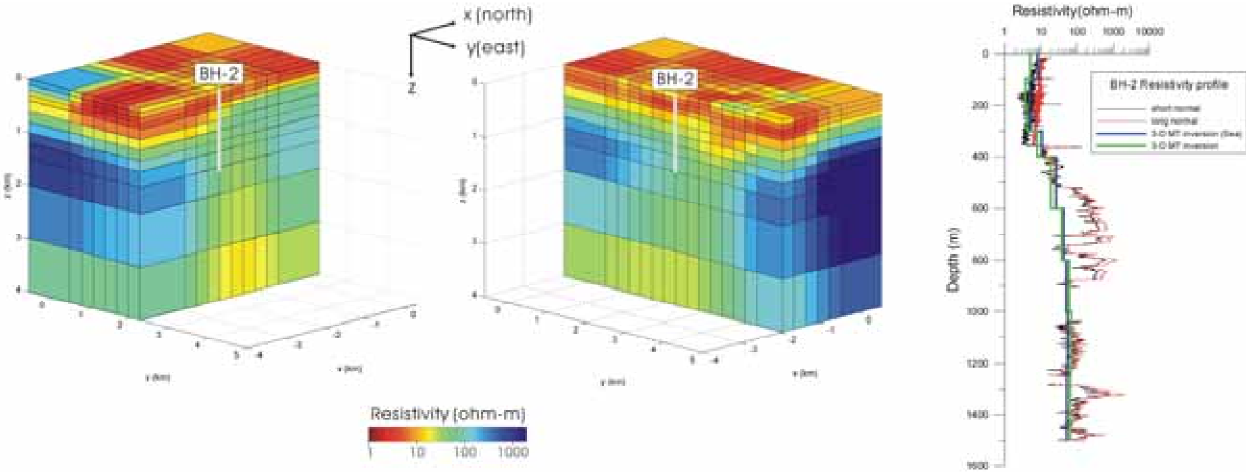

Figure 3. Image of resistivity structure of Pohang site as a result of three-dimensional inversion of MT data incorporating adjacent sea effect.

In 2005, KIGAM started investigating some artesian wells at a small island, Seokmo-Do close to Incheon (the 3rd largest city in Korea) near Seoul, the capital of Korea. Some drill wells of several hundred meters deep met deeply-connected fractures in Jurassic granite and a large amount of brine water overflowing the wells. Measured temperature of the overflowing brine water is as high as 70 °C. The results of MT survey and well logging performed in 2005 show that there exists a set of fractures, which means high potential of artesian flow with higher temperature such as 80 °C or more. Subsequent drillings will be made soon to confirm the existence of higher temperature brines and to see if it is possible to apply the first binary power plant in Korea to the area.

Figure 4. Drill rig and overflowing waters from 1,280 deep well at Seokmo-Do.

Jeju Island locating at South Sea of Korea is a volcanic island of Quaternary eruption. In 2004, KIGAM started heat flow measurement and MT survey in Jeju Island to see if there still remain thermal resources and to see if there exist deeply extended fractures or aquifer system beneath mid-mountain region. Measured heat flow is not promising: the surface is covered with highly porous basalt and there is no deep borehole in the mid-mountain area. However, 2-D MT survey results along four profiles show there exists a deeply extended conductive structure under the central region and

some other conductive anomalies, which indicates the existence of deep anomalous structures. A 3-D imaging using MT data and geologic interpretation will be made in 2006 to provide information to locating an exploration borehole, if any.
Installation of geothermal heat pump for newly constructed office buildings is rapidly increasing in Korea and KIGAM has just installed a geothermal heat pump system for its Earthquake Research Center building. The area of the building is some 3,000 m^2 and the capacity of the heat pump system reaches 400 kWt. KIGAM had made an observation borehole down to 300 m depth and measured thermal conductivities of drill cores to get the average value of 2.98 W/m-K. Temperatures in the borehole had also been monitored; various tests such as acoustic televiewer logging and pressure test had been made to see temperature changes due to groundwater flow before actual installation of borehole heat exchangers. Finally, thermal response test (TRT) has been performed to find the effective in-situ thermal conductivity of 3.28 W/m-K. This apparent increase of thermal conductivity is believed to be due to groundwater flow across the region when considering that there exist several highly permeable zones from the well logging and pressure test results.

Figure 5. Trenches and double U-tubes for borehole heat exchanger for Earthquake Research Center building at KIGAM.

Total of 28 boreholes were drilled for heat exchangers and another two monitoring wells were made to monitor subsurface temperature variation caused by heat pump operation. Building construction has just been finished and actual heat pump operation started from January, 2006. Detailed information such as electric power consumption and down-hole temperature profile changes will be monitored and reported as operation times go by.

5. DISCUSSION AND CONCLUSIONS
Pohang low-temperature geothermal development program is the first, large-scale deep geothermal water exploitation work in Korea aiming to realization of district heating. Although its progress is now behind original schedule, we expect that rough evaluation of its productivity will be made by the end of 2006. If the result is promising, government will support to expand the deep geothermal development works to other potential areas such as Seokmo-Do and Jeju Island.
Geothermal heat pump installation in Korea is exploding since 2000 but there is no quantitative information on the thermal properties of subsurface materials made yet. There is on going government funded research program to compile underground thermal properties map and also ground surface temperature distribution map aiming to fostering geothermal heat pump installation. Another good source of thermal energy existing at most of alluvial area is groundwater. In the year of 2002, amount of groundwater use for residence and industry reaches up to 5 million tones per day that will possibly produce a huge amount of thermal energy for heating and cooling the buildings nearby. Government research institutes including KIGAM have started research program in collaboration with universities to support all the technical basis and feasibility for the shallow geothermal utilization including groundwater as well.

Activities on geothermal in Korea, especially government investment to R&D on deep-seated low-temperature geothermal development and on shallow geothermal utilization using geothermal heat pump, is rapidly increasing after 2002. We expect this trend will continue at least for a while due to recent situation of high oil-price. Furthermore, increasing interests on geothermal heat pump from government and public sectors will continue to lead steady investment. Private business of installing and consulting the geothermal heat pump is also rapidly increasing although it is not comparable to other renewables such as biomass, small hydro, solar and wind yet. Recent R&D funding trend indicates that the geothermal research in Korea will continue to be active at least for the next five years and we expect the geothermal utilization in Korea contribute to world-wide statistics to some extend by the 2010.

The total available subsurface geothermal energy in Korea is 4.25 A— 1021 J from surface to a depth of 1 km, 1.67 A— 1022 J to 2 km, 3.72 Ã— 1022 J to 3 km, 6.52 Ã— 1022 J to 4 km, and 1.01 Ã— 1023 J to 5 km. In particular, the southeastern part of Korea shows high temperatures at depths and so does high geothermal energy.Â The study has outlined that the primary motivational factor for achieving the current improved energy status of the ROK was to support the rapid industrial growth and socio-economic development of the country. The major steps taken were to manage the country's escalating energy demand and to minimize the greenhouse emissions in energy sector along its progressive economic development. 4.2 Current status of geothermal development. Currently, utilization of geothermal energy is only in the Olkaria field. Three of the seven fields namely, Olkaria East field, Olkaria west field and Olkaria Northeast field are generating a total of 127 MWe. In Kenya geothermal is mainly used for power generation from which currently the total output is 130 MW. A very small proportion of geothermal goes into direct use in drying of flowers, greenhouses and balneology. Due to rapid economic growth, the demand for electricity in the country has increased steadily and in order to meet this demand th... development and production of geothermal energy. A.3 geothermal energy licensing system.Â A.6.3. Current statistics on the heating sector and inventories of geothermal resources in Europe are incomplete. More comprehensive compilation of geothermal, heating and cooling market data and reliable statistics are required to profile baseline market data and as well as forecasting future sector growth.Â Geothermal energy deployment has the potential to significantly contribute to the current status of the European Heat Market. In order for this to be achieved, coherent European and national strategies for heat markets are required.