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Direct-Use Geothermal Development in Korea: Country Update 2000-2004

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ABSTRACT

Geothermal utilization in Korea has been of direct-use, mainly on public baths with low-temperature geothermal water from hundreds of wells down to several hundred meters or more than 1 km along fracture zones. In the beginning of the new millennium, this kind of private activity on developing hot spa is declining partly due to excessive drilling cost and partly from over-development situation

On the other hand, governmental investment is rapidly increasing after 2002. Geothermal heat pump started its business although it is still on the stage of proof-of-concept around big cities and thus detailed statistics are not available yet. Korea Institute of Geoscience and Mineral Resources (KIGAM) started research on thermal characteristics of Korean geology, and provided this result, we expect that geothermal heat pump will continuously expand its application to space heating and cooling in urban area. The most important progress is the new low-temperature geothermal development project for district heating in a city at southeastern part of Peninsula which shows high geothermal anomaly in terms of geothermal gradient, heat flow and lineament distribution. KIGAM has launched this project in the year of 2003 aiming that the practical heat supply system is designed by the end of 2005.

1. INTRODUCTION

In Korea, we can hardly expect to find geothermal energy resources for electric power generation since there cannot be seen any recent volcanic or tectonic activities. Instead, there have been many hot springs for bathing for more than a thousand years (Yum, 1999). Consequently, geothermal utilization in Korea has been of direct-use, mainly on public baths with low-temperature geothermal water from hundreds of wells down to several hundred meters or more than 1 km along fracture zones. In the beginning of the new millennium, however, this kind of private activity on developing hot spa is slightly declining partly due to excessive drilling cost and partly from over-development situation.

Governmental investment to R&D on geothermal development and utilization is rapidly increasing after 2002. KIGAM has launched a new low-temperature geothermal development for the purpose of district heating and greenhouse uses in the year of 2003. This is the first large-scale geothermal exploration and exploitation in Korea and provided successful result in this site, we will expand this work to other places of high geothermal potential. Geothermal heat pump started its business although it is still on the stage of proof-of-concept around big cities and thus detailed statistics are not so clear yet. Since little is known about thermal characteristics of subsurface materials in Korea, KIGAM started research on measuring and analyzing the thermal properties of water-saturated rocks and soils in order to promote the utilization of geothermal resources of shallow subsurface.

2. GEOLOGIC SETTING

Figure 1 shows digital geologic map of South Korea (KIGAM, 1995). The geology of Korea is composed of relatively old rocks that age from Precambrian to Quaternary. The Precambrian metamorphic rocks (PR and AR groups in Figure 1) crop out extensively in the Korean Peninsula from the north to south covering almost a half of the territory. Especially in South Korea, Archean (AR) groups mainly consist of gneiss and schist complexes and exposed in the Gyeonggi Massif, central Korea and in the mountainous area over southern part of the Peninsula. The Paleozoic sediments (PT, O, and og group) are distributed mainly in central-eastern part of South Korea forming high mountains. It is very difficult to find some hot spring or evidence of geothermal phenomena in those areas composed of Precambrian and Paleozoic (PAL group) rocks.

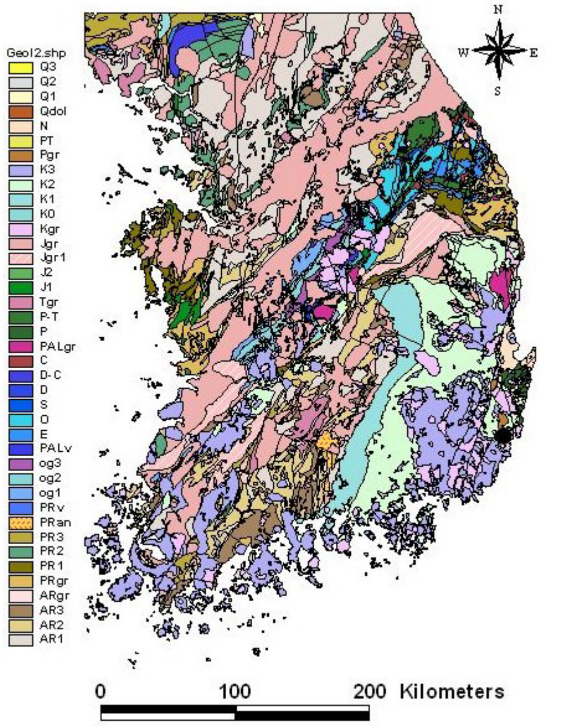

Figure 1: Digital Geology Map of South Korea (KIGAM, 1995).

The major outcrop of the Jurassic granite (J group) occurs as batholith stretching along NE direction in the middle part of the Peninsula across the country from the east to the west. Cretaceous granite is mainly limited in the south-eastern part. Following the granite intrusion and tectonic movement in the south-eastern part during the Cretaceous (K group) and the early Tertiary (P group), several linear structures has formed with direction of NEE, parallel to the eastern coast line (Figure 1).

Quaternary volcanic rocks (Q group) are exposed in some islands in the South and East Sea, and in some areas in the main land of Korea. There is no geothermal phenomenon such as hot springs or high subsurface temperatures in those volcanic areas.

3. GEOTHERMAL POTENTIAL

The low-temperature geothermal phenomena in Korea are closely related to granite distribution, especially of Jurassic and Cretaceous periods, and localized through deeply connected fracture system as geothermal water conduit. In the point of geothermal gradient or heat flow, however, high geothermal anomaly does not always coincide with granite region but sometimes with areas covered with sedimentary rocks. This resulted from that the thermally low conductive sedimentary formation preserves the heat contained in the granite basement and thus showing high geothermal gradient.

Figure 2 shows the distribution of heat flows in South Korea. Total 248 heat flow data has been measured although not of even distribution. Average heat flow is 64±14 mW/m^2. Southeastern part of Korea that is covered with Tertiary sediments shows the highest heat flow more than 90 mW/m^2. Geothermal gradient measured along the boreholes in this area also shows as high as 40 °C/km. Considering average geothermal gradient in Korea is 25.7 °C/km, this high anomaly along with high heat flow value indicates a high geothermal potential for low-temperature utilization.

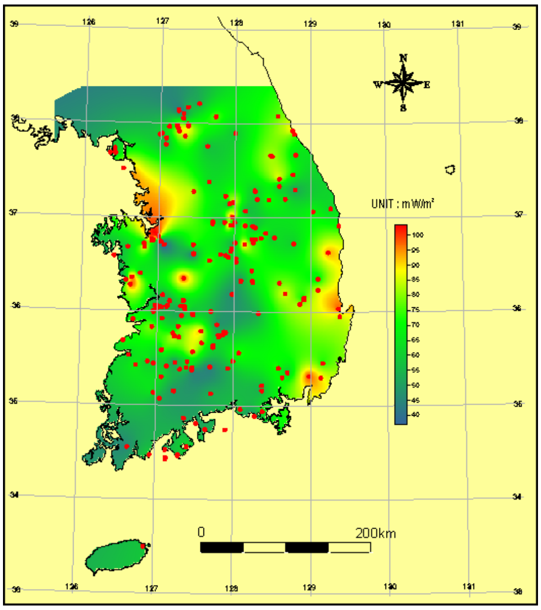

Figure 2: Heat flow distribution map of South Korea (Kim, 2004).

4. RECENT R&D ON GEOTHERMAL DEVELOP-MENT

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, for district heating and agricultural application. 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 Tertiary Pohang Basin overlying Cretaceous sedimentary rocks, biotite-granite intrusion and Eocene volcanic such as tuff. Pohang Basin is consists of Miocene marine sediments and bottommost land sediments layer. Heunghae basin, main target of the geothermal exploration, is covered with Quaternary alluvium underlain by these thick Tertiary sediments of low thermal conductivity and thus preserving high geothermal gradient, which is quite uncommon in Korea.

Numerous geophysical survey methods have been applied such as gravity and magnetic surveys for interpretation of regional geologic setting, magentotelluric (MT) and controlled-source audio-frequency MT surveys for mapping the resistivity structure and possible fracture zones, and self-potential survey to figure our 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 at August in 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 temperature gradient of 40 °C/km and existence of several permeable zones related with fracture systems. Various kinds of geophysical logging and hydrologic tests have also been applied and integrated analysis is on going. Next step will be drilling of 2 km deep production well and injection well, if necessary.

5. GEOTHEMAL UTILIZATION – STATISTICS AND DISCUSSION

As mentioned earlier, there do not exist any geothermal resources for power generation in Korea. Furthermore, since R&D on geothermal development for district heating has just been started almost all statistics are related to the utilization to public bath.

5.1 Table 1. Present and Planned Production of Electricity

In Korea, production of electricity is mainly from fossil fuel and nuclear energy. Other renewables are small hydro, biomass, wind, and solar (photovoltaic), listed from the largest production. Due to recent high oil price, total projected use by 2010 may be updated to higher percentage of renewables.

5.2 Table 3. Utilization of Geothermal Energy for Direct Heat

Being different from earlier report (Yum, 2000), we list 10 localities showing the outlet temperature higher than average (values in brackets) of 40 °C and present total sum for other 264 localities. The 264 localities distributed all over the country show temperature range of 25 – 40 °C and should be heated prior to supply to public bath so estimation of the energy value seems meaningless.

5.3 Table 4. Geothermal Heat Pumps

Geothermal heat pump in Korea has just started its business and detailed statistics on performance is not available yet. We report only the total summary of 30 localities from private business sector. However, government investment to R&D and pilot plant setup is increasing so we expect that detailed technical data as well as statistics will be available in near future.

5.4 Table 5. Summary table of Geothermal Direct Heat Uses

This table summarizes the information listed in Tables 3 and 4. Although there may be individual space heating around hot spa localities using geothermal water, it is negligible amount and no statistics are available.

5.5 Table 6. Wells Drilled for Electrical, Direct and Combined Used of Geothermal Resources

Total 176 wells have been drilled for the purpose of public bath by private sector and cumulative depths are 97.59 km. The number of drill wells is slightly decreasing after 2002 partly due to excessive drilling cost and partly from over-development situation. Note that there are two exploration wells for low-temperature geothermal development by KIGAM as explained in the previous chapter.

5.6 Table 7. Allocation of Professional Personnel to Geothermal Activities

This table shows increasing personnel regarding geothermal activities in the new millennium. Especially personnel in private industry are mainly engaged in geothermal heat pump business. There are also professional drilling engineers for deep geothermal drilling. Government personnel are scientists mainly in KIGAM who work for low-temperature geothermal development and R&D on shallow geothermal utilization such as heat pump.

5.7 Table 8. Total Investments in Geothermal

Since geothermal investment had been mainly made by private sector, its statistics were quite ambiguous. In this report, therefore, we restrict the data that is verifiable though any kind of report or estimates. Consequently, there can be seen serious decrease in field development although this is not true in reality. Another remarkable change is obvious in R&D part, since more than 4 million US dollars has been given to KIGAM's low-temperature geothermal development project through the latest two years. There is also significant contribution for R&D on fundamental and field-scale study on shallow geothermal utilization using heat pump.

6. CONCLUSION AND FUTURE WORKS

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. Since fundamental study on the thermal characteristics of Korean geology has not made so far, KIGAM has also started the R&D on the subject, which would help promoting the utilization of geothermal heat pump. The newly started low-temperature geothermal development project led by KIGAM aims to design practical layout for the purpose of cascade use for district heating, greenhouse and aquaculture by the end of 2005. If this would be successful, we expect ten sites over the country to be explored through the long-term geothermal development project. Therefore, geothermal utilization in Korea is likely to continue to increase for the next five years, too.

REFERENCES

Kim, H.C.: Interpretation of Geothermal Anomaly Using Heat Flow and Geologic Data in South Korea, Ph.D. Thesis, Chungnam National University, Korea (2004).

Korea Institute of Geoscience and Mineral Resources: Geology Map of Korea (1:1,000,000) (1995).

Yum, B.W.: Historical review of hot spring waters in the Republic of Korea. In: *Stories from a heated Earth, Our geothermal heritage*, Geothermal Resources Council, International Geothermal Association (1999), 379-392

Yum, B.W.: The Present Status of Korean Geothermal Research and Investigations, Proceedings, World Geothermal Congress 2000 (2000), 499-504.

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (Solar, Wind, Biomass, Small Hydro)		Total	
	Capac-ity Mwe	Gross Prod. GWh/yr	Capac-ity Mwe	Gross Prod. GWh/yr	Capac-ity Mwe	Gross Prod. GWh/yr	Capac-ity Mwe	Gross Prod. GWh/yr	Capac-ity Mwe	Gross Prod. GWh/yr	Capac-ity Mwe	Gross Prod. GWh/yr
In operation In December 2004			36460	185893	3831	6716	15716	129672	133	415	56140	322696
Under construction In December 2004			8509		1600		4000				14109	
Funds committed, but not yet under construction in December 200												
Total projected use by 2010			45003	219554	6286	8542	23116	166720	266	996	74671	395812

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2004 (other than heat pumps)

I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish farming
K = Animal farming
S = Snow melting
H = Individual space heating (other than heat pumps)
D = District heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

Enthalpy information is given only if there is steam or two-phase flow

Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization: Flow Rate (kg/s)	Temperature (^{o}C) Inlet	Temperature (^{o}C) Outlet	Enthalpy[2)] (kJ/kg) Inlet	Enthalpy[2)] (kJ/kg) Outlet	Capacity[3)] (MWt)	Annual Utilization: Ave. Flow (kg/s)	Energy[4)] (TJ/yr)	Capacity Factor[5)]
Yusong	B	123.7	27-56(41.5)	40			0.78	36.02	7.13	0.29
Deoksan	B	169.8	27-49(38.0)	40			0.00	12.53	0.00	0.00
Onyang	B	46.3	42-59(50.5)	40			2.03	13.58	18.81	0.29
Donglae	B	40.5	28-61(44.5)	40			0.76	6.02	3.57	0.15
Haeundae	B	24.3	27-56(41.5)	40			0.15	7.61	1.51	0.31
Sokcho	B	59.2	40-53(46.5)	40			1.61	7.74	6.64	0.13
Suanbo	B	28.9	43-53(48.0)	40			0.97	19.48	20.56	0.67
Baekam	B	86.8	42-52(47.0)	40			2.54	5.19	4.79	0.06
Bukok	B	37	54-78(66.0)	40			4.03	27.94	97.66	0.77
Mageumsa	B	35.1	32-57(44.5)	40			0.66	4.44	2.64	0.13
Other 264	B	3,726.9	25-40					194.83		
TOTAL		4,378.5					13.53	335.38	163.29	0.38

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS
AS OF 31 DECEMBER 2004

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or water temp. (□) 1)	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type 2)	COP 3)	Heating Equivalent Full Load Hr/Year 4)	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
30 localities	16	3429.075	30	V	No data	1,470	11.93	4.52
TOTAL		3429.075	30			1,470	11.93	4.52

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2004

[1)]Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[2)]Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

[3)]Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity [1)] (MWt)	Annual Energy Use [2)] (TJ/yr = 1012 J/yr)	Capacity Factor [3)]
Individual Space Heating [4)]			
District Heating [4)]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying [5)]			
Industrial Process Heat [6)]			
Snow Melting			
Bathing and Swimming [7)]	13.53	163.29	0.38
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps	3.43	16.45	0.15
TOTAL			

[4)] Other than heat pumps
[5)] Includes drying or dehydration of grains, fruits and vegetables
[6)] Excludes agricultural drying and dehydration
[7)] Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2000 TO DECEMBER 31, 2004 (excluding heat pump wells)

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)		2			2.6
Production	>150° C					
	150-100° C					
	<100° C		176			97.59
Injection	(all)					
Total			178			100.19

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Progran
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	12		3			
2001	12		4			5
2002	15		4			8
2003	28	3	4			12
2004	30	4	4			30
Total	97	7	19			55

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US£ ¤	Million US£ ¤	Million US£	Million US£	£ ¥	£ ¥
1990-1994	0.27	139	278		99.9	0.1
1995-1999	0.15	92	184		99.9	0.1
2000-2004	6.3	14.53	No data		69.8	30.2