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Geothermal Development in the Republic of Korea: Country Update 2020-2022

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ABSTRACT

Geothermal utilization in Korea is of direct use, especially with geothermal heat pump (GHP) installation, because there are no high temperature resources associated with active volcanoes or tectonic activity. Installed GHP capacity has increased rapidly since the middle of the 2000's, with more than 100 MW_{th} of new installation annually until 2018. Annual new addition shows a decreasing trend since 2019, with ~74 MW_{th} estimated new installation in 2021. The total installed capacity estimated to be ~1.6 GW_{th} at the end of 2021. Major installations are for large facilities including public and office buildings and greenhouses mainly thanks to strong government subsidy programs and the mandatory act. Other direct uses including hot springs, individual heating and space heating application remain stagnant for the last decade at ~44 MW_{th}.

There have been continuous R&D efforts for utilizing deep geothermal resources including theoretical and technical potential assessments, exploration of potential hydrothermal resources, pre-feasibility study and a pilot project of enhance geothermal system (EGS). However, all activities associated with deep geothermal development or exploration were stopped after the earthquake which occurred in the vicinity of the Pohang EGS pilot plant site in November, 2017.

1. INTRODUCTION

Direct use geothermal utilization in Korea is primarily from ground-source or geothermal heat pump (GHP) installation. Installed GHP capacity has increased rapidly since the middle of the 2000's, with more than 100 MW_{th} of new installation annually until 2018. However, annual new addition shows a decreasing trend since 2019, with ~74 MW_{th} estimated new installation in 2021. There are several areas producing hot spring water of discharge temperature higher than 60 °C, which circulates through deeply extended fractures in crystalline rocks. This hot water has been utilized for heating in a hot spring area for more than 30 years. In another place, a small-scale district heating and greenhouse heating with hot spring water started in 2008. However, utilization of these hydrothermal resources remain stagnant for the last decade at ~ 44 MW_{th}.

There are neither high temperature hydrothermal resources for power generation nor the regional anomalous zones such as deep sedimentary basin for large-scale district heating in Korea. For the limited Tertiary sediment region, Pohang in southeastern part of the Korean Peninsula, there have been extensive exploration and drilling works to find a way of exploiting low-temperature geothermal water resources since 2003. Although the expected flow rate was not achieved, we could realize high geothermal potential and the activities have led to launching of the government funded EGS pilot project at the end of 2010. The Pohang EGS pilot project targeted a MW class power generation plant through a pair of injection and production wells (Song et al., 2015). However, because of the damaging earthquake which occurred at a close vicinity of the well site two months after the stimulation tests in 2017, any further development activities have been stopped. All other activities regarding deep geothermal development or exploration were also stopped after the earthquake.

Renewable energy of the national energy policy is getting more important, but geothermal is not separately specified yet. The Third National Energy Master Plan which was fixed and declared on June 2019 by the Korean Government has a vision of 'Sustainable growth and improving the quality of people's life through energy transition'. In addition, in December 2020 the government declared 'Carbon neutrality' or 'Net zero' by 2050 with a 'Green New Deal' policy. The Fifth New and Renewable Energy Basic Plan which was declared at the end of 2020 states that the target of renewable electricity's share is 22.2% (installed capacity of 80.8 GW) by 2034, while final consumption of renewable energy is targeted at 12.4% (23.5 TOE) by 2034. There are ongoing subsidy programs and mandatory act for supporting renewable energy deployment which includes GHP installation.

We have not seen any notable progress of R&D and actual development for geothermal since our last Country Report to WGC 2020+1 (Song and Lee, 2021) due to the significant decrease of R&D funding and investment. Therefore, we do not separately describe R&D activities here, instead we repeat the same description as the former report for general geology and potential geothermal area along with geothermal potential for the sake of readers' understanding. And we discuss on the statistics of direct use in view point from the new format of WGC 2023.

2. GEOLOGIC SETTING AND GEOTHERMAL POTENTIAL

Figure 1 shows digital geologic map of South Korea (KIGAM, 1995) and its superimposed on a topographic relief map of Korean Peninsula by Korea Institute of Geoscience and Mineral Resources (KIGAM). The geology of Korea is composed of relatively old rocks and also various formations 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 hard to find hot spring or geothermal manifestation in those areas composed of Precambrian and Paleozoic (PAL group) rocks.

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 southeastern part. Following the granite intrusion and tectonic movement in the southeastern part during the Cretaceous (K group) and the early Tertiary (P group), several linear structures has formed with direction of NNE, parallel to the southeastern coast line. Major hot springs are mostly found in these granite areas. 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 surface geothermal manifestation such as hot springs in those volcanic areas.

Red circles on the right map of Figure 1 indicate potential geothermal areas where various exploration activities have been performed during the last twenty years. Among them, the area in the southeast is where Pohang EGS pilot project was performed, which has been stopped due to M_w 5.4 earthquake occurred on November 15th, 2017. A small, remote Ulleung Island in the East Sea is the area where recent exploration activities including drilling of the four gradient boreholes of maximum 1 km deep and 3-D magnetotelluric (MT) survey have been done to conclude potential existence of hydrothermal resources (Lee et al., 2019). However, further activities including exploration well drilling down to 2 km depth is stopped as well. For the Seokmo Island, various geophysical surveys and well loggings have been performed around existing artesian wells (Lee and Song, 2010) and heat supply to a small-scale greenhouse and 21 house-holds started operating in 2008 as can be found as Field Name of GangHwa in TABLE 4. Jeju Island is a volcanic island where intensive MT surveys were done during the years from 2004 until 2007 to locate potential geothermal area (Choi et al., 2013). But because most of the central area is designated as a national park where a deep conductive anomaly has been interpreted, no further exploration activity has been made yet.

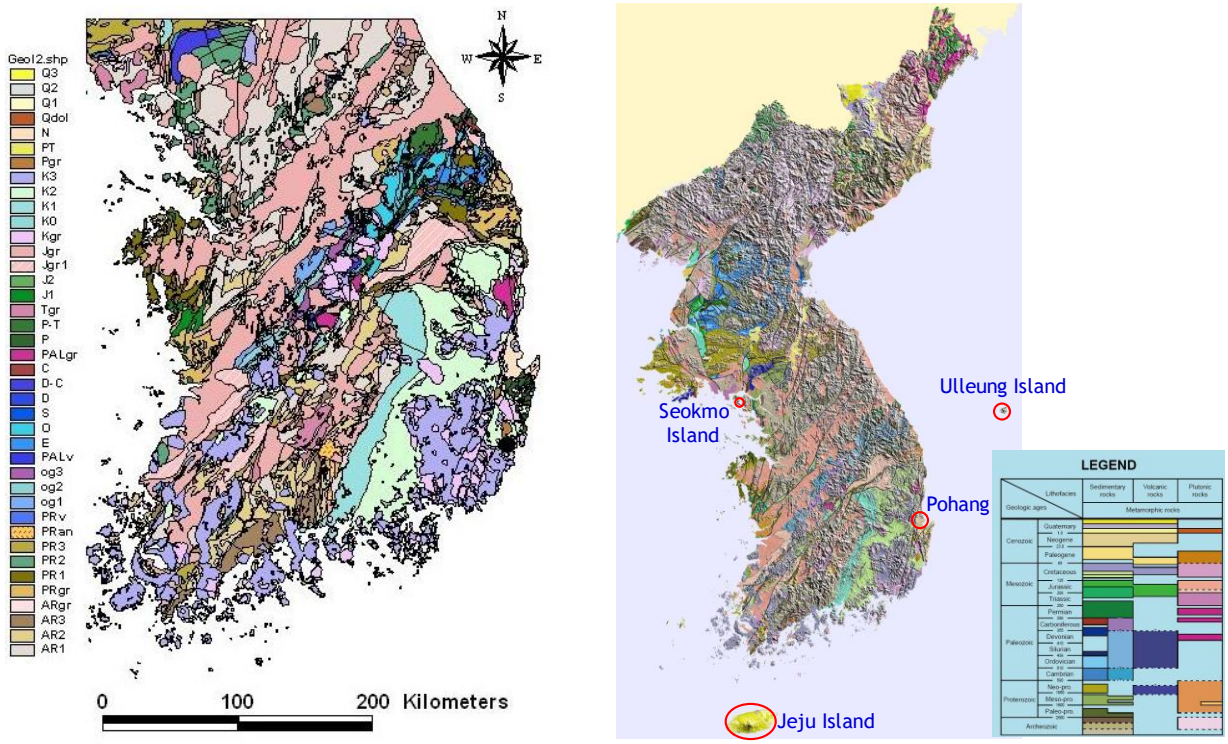

Figure 1: Digital geology map of Korea (KIGAM, 1995) and its superimposed on a topographic relief map of Korea Peninsula by KIGAM. Red circles in the right map indicate potential geothermal areas where exploration activities have been made (Song and Lee, 2021).

In 2011, Song et al. (2011) performed the estimation of geothermal power generation potential of Korea with EGS technology. The methodology and some of the resultant figures are summarized in the 2015 report (Song and Lee, 2015). Major features of the estimation were that theoretical potential down to 10 km reaches up to 6,975 GWe which amount to almost 60 times total electricity generation capacity of Korea in 2019. Technical potential down to 6.5 km appears 19.6 GWe.

3. GEOTHERMAL UTILIZATION - STATISTICS AND DISCUSSION

There is no geothermal power generation in Korea yet as can be found in TABLE 1, data from KEPCO (2022). Electricity generation by other renewables is ~7.3% of gross national power generation as of December 31, 2021, most of which are from photovoltaic and wind.

TABLE 3 shows summary of direct uses which is categorized into Geothermal Heating and Cooling Installations in WGC 2023 report format. Total installed capacity is estimated to 1,622.6 MW_{th}. Heating and cooling for buildings and Agriculture fields are almost from GHP installations which reaches up to 1,579 MW_{th} at the end of 2021.

Figure 2 shows increasing trend of GHP installation in Korea since 2006. We can see more than average 50% of annual increase until 2011 and more than100 MW_{th} installations per year from 2012 until 2018. Main drivers of the rapid increase in GHP installation are active government subsidy programs and a special Act for new and renewable energy (‘Mandatory Act’). There are several subsidy programs; ‘Building’, ‘Local’, ‘Residential’, and ‘Hybrid’ programs through which government used to subsidize up to 50% of total installation cost based on competition with pre-determined budget each year. Another powerful subsidy program which was enacted from 2010 is ‘Agricultural Energy Efficiency Program. This program drove more than 20 MW_{th} installations per year until 2013 and

around 10 MW_{th} new installations per year since 2014. However, annual new installations show a decreasing trend since 2019, with ~74 MW_{th} estimated installed in 2021, partly reflecting decrease of construction activities.

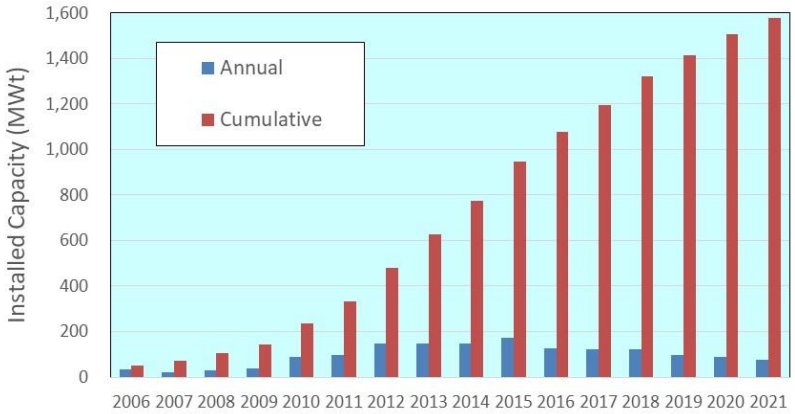

Figure 2. Increasing trend of GHP installations in Korea. Data are based on 'New and Renewable Energy Deployment Statistics' by KEA (2021). Data for 2021 are estimated accounting for plans according to 'Mandatory Act' and subsidizing programs.

TABLE 4 describes direct uses of hot spring water resources at 13 locations with discharge temperatures higher than 42 °C, which has remained stagnant since 2008 and no further survey was made.

4. SUMMARY AND FUTURE OUTLOOK

Geothermal utilization in terms of GHP installation will continue to steadily increase but at a lower rate: less than 100 MW_{th} expected annually. The rapid increase was due to the active subsidy programs and the special 'Mandatory Act'. However, the installation plan of GHP according to the 'Mandatory Act' shows a decreasing trend since 2017, while the total subsidy stayed more or less at the same level, between 20 and 30 million USD annually.

Geothermal utilization statistics are an on-going issue. In Korea, official geothermal energy statistics deal only with GHP and thus other direct uses including space heating, spas, and greenhouse heating are not included in the national statistics. Korea has been reporting other direct use statistics to IEA Geothermal Technology Collaboration Programme (TCP) with the help of hot spring survey data. For GHP statistics, there is no official distinction between heating and cooling, but just a lump sum of all energy production throughout a year, which does not consider the 'pure geothermal contribution' as yet. Effort is needed to establish a revised method of collecting official statistics on geothermal uses that is compatible with international standards such as the IEA statistics. Since 2018, IEA Geothermal TCP has collected GHP statistics with the new scheme proposed as a result of Working Group activities (Song et al., 2021) and this scheme could guide the updating of Korean GHP statistics once it is accepted by the international community.

The outlook for geothermal power generation in Korea is not positive due to concerns of possibly damaging earthquakes. After the damaging earthquake occurred close to the Pohang EGS site, all deep geothermal exploration activity was stopped and all projects are currently in hiatus. The government is very keen to foster renewable energy deployment, but even so the outlook for geothermal investment is not promising at least for the time being.

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Table 1. PRESENT PRODUCTION OF ELECTRICITY

Energy source	Geothermal *(2)*		New and Renewables		Nuclear		Fossil Fuels		Other sources		Total *(3)*	
	Installed Capacity (MWe)	Gross Electrical generation GWh/yr	Installed Capacity (MWe)	Gross Electrical generation GWh/yr	Installed Capacity (MWe)	Gross Electrical generation GWh/yr	Installed Capacity (MWe)	Gross Electrical generation GWh/yr	Installed Capacity (MWe)	Gross Electrical generation GWh/yr	Installed Capacity (MWe)	Gross Electrical generation GWh/yr
In operation in December 2021 *(1)*	-	-	24,855	42,156	23,250	158,015.23	80,847	370,916	5,067	5,723	**134,019**	**576,809**

TABLE 3. SUMMARY OF GEOTHERMAL HEATING AND COOLING INSTALLATIONS IN THE COUNTRY

2021

(1) Geothermal Application	(2) Total Installed Capacity (MWt)	(3) Total Energy produced (TJ/year)	(4) Total Energy used (TJ/year)	(5) Number of Installations	Notes
Agriculture and food processing	187.1		888.1	300	Most of installations are using GHP
Industrial process heat	0		0	0	
Health, recreation and tourism	32.6		507.6	13	Hot spring usage
Heating and cooling for buildings	1402.9		5317.6	>18,000	Most of installations are using GHP
Other uses	0		0	0	
Total values	**1622.6**	**0**	**6713.3**		

TABLE 4. HEATING AND COOLING PROJECTS IN THE COUNTRY AND RELATED GEOTHERMAL FIELDS

Geothermal Field				Geothermal project (facility)					
(1) Location	(2) Name	(3) Type of geothermal system	(7) Max. temperature of the fluid (°C)	(10) Geothermal application	(11) Geothermal production technology	(12) Nominal Capacity (MWt)	(14) Energy produced (gross) (TJ/year)	(17) Inlet temperature (°C)	(18) Outlet temperature (°C)
Busan	DongRae	Hot water system	69.9	Health, recreation and tourism	Direct use of the fluid	2.94	43.41	42.00	27.00
	DongRae	Hot water system	69.9	Heating and cooling for buildings	Heat Exchanger	3.92	28.02	64.00	44.00
	HaeWunDae	Hot water system	57.8	Health, recreation and tourism	Direct use of the fluid	2.27	35.32	42.00	27.00
Incheon	GangHwa	Hot water system	69.4	Health, recreation and tourism	Direct use of the fluid	2.76	30.47	42.00	27.00
	GangHwa	Hot water system	69.4	Heating and cooling for buildings	Heat Exchanger	2.21	31.28	68.00	56.00
	GangHwa	Hot water system	69.4	Agriculture and food processing	Heat Exchanger	0.17	1.33	68.00	56.00
Daejeon	YuSeong	Hot water system	58	Health, recreation and tourism	Direct use of the fluid	5.13	65.03	42.00	27.00
Gangwon	SokCho	Hot water system	49	Health, recreation and tourism	Direct use of the fluid	3.71	64.82	42.00	27.00
Chungbuk	SuAhnBo	Hot water system	53.9	Health, recreation and tourism	Direct use of the fluid	2.82	28.53	42.00	27.00
Chungnam	OnYang	Hot water system	57.4	Health, recreation and tourism	Direct use of the fluid	2.76	48.06	42.00	27.00
	Deoksan	Hot water system	49.1	Health, recreation and tourism	Direct use of the fluid	0.81	17.03	42.00	27.00
Gyeongbuk	BaekAm	Hot water system	53	Health, recreation and tourism	Direct use of the fluid	4.66	79.99	42.00	27.00
	PoHang	Hot water system	50.9	Health, recreation and tourism	Direct use of the fluid	0.92	16.8	42.00	27.00
	CheongDo	Hot water system	43.2	Health, recreation and tourism	Direct use of the fluid	0.51	4.29	42.00	27.00
Gyeongnam	MaGeumSan	Hot water system	57.1	Health, recreation and tourism	Direct use of the fluid	1.05	25.31	42.00	27.00
	BuGok	Hot water system	76	Health, recreation and tourism	Direct use of the fluid	2.22	48.67	42.00	27.00
	BuGok	Hot water system	76	Heating and cooling for buildings	Heat Exchanger	4.74	25.41	76.00	44.00
Total values							**593.77**		