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Country Update of Japan

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ABSTRACT

Located along the Circum-Pacific Volcanic Belt "Ring of Fire," Japan is blessed with an abundance of geothermal energy. Japan has a national target to increase geothermal power capacity to be 1500 MW by 2030. However, the installed capacity by 2021 is merely 546MW in spite of a wide range of supporting measures by the government. The Ministry of Economy, Trade and Industry will continue its support to fulfill the target even if some delay may be admitted. Beside promotion of geothermal developments, the ministry supports geothermal R&D. A highlight of current national research project is subduction origin super critical geothermal resources development which has a target year of 2040 for pilot a plant operation. Use of ground source heat pump (GSHP) has been increasing, but its increase rate is declining recent years. For its promotion, The Ministry of Environment has been providing subsidies for its demonstration projects. The detailed trend and technology development will be presented in this paper.

1. INTRODUCTION

The Japanese Islands are located at the eastern end of the Eurasian Plate at the junction of the Pacific and Philippine Sea Plates. Its archipelago is considered to have been built by the subduction activities such as accretion, metamorphism, magmatism and volcanism. Thus, its geology is composed mainly of accretionary complex, metamorphic rocks, plutonic and volcanic rocks and surface sediments. Under such geological settings, Japan has 111 active volcanoes, including newly added three volcanoes in 2011 and 2016, that is 7% of the volcanoes on the earth (JMA, 2017). Therefore, most of promising geothermal resources in Japan has volcanic origin.

Japan is blessed with geothermal energy with theoretical potential to a depth of 3 km of over 20 GW_e (Muraoka et al., 2008). In spite of this fact, the use of geothermal energy in Japan is still limited (Table 1). No new geothermal development had been done for more than a decade since year 2000 mainly because of legal, social and socio-economic barriers. The three major barriers were; 1) regulations on natural parks, 2) development risk and cost, and 3) social acceptance. However, the former two problems have been largely mitigated after the nuclear accident in 2011 by the federal government, changing several regulations on natural parks and putting new economic incentives to promote geothermal development. The third one may not be easily mitigated in a situation that negative campaigns to geothermal developments by hot spring owners are so influential that geothermal projects have been delayed or even stopped in several cases. Nevertheless, the government has begun several actions to raise social acceptance of geothermal development. Given such support from the government, private sectors moved toward geothermal development drastically.

Installation of ground source heat pump (GSHP) systems increased steadily in Japan. Although the number of installations is still limited to few thousand yet, the annual installation is increasing exponentially. The government gives incentives in installation of GSHP system mainly from environmental aspects. On the other hand, conventional direct use has not increased significantly (Table 2). This paper provides status of Japan in 2022 for geothermal power generation, conventional direct use, and GSHP separately.

2. GEOTHERMAL POWER GENERATION

Table 2 shows the present status of geothermal power plants in Japan (as of March 2021). Because of high FiT price for small geothermal power, numerous local companies begin small geothermal businesses applying binary systems to high temperature hot spring wells. Therefore, it is quite difficult to collect data from these very small power plants and several such plants may be missing in Table 2. Many of small power plants does not provide power generation data so that the power generation is left blank for these power plants in Table 2. Therefore, the total amount of power generation must be slightly bigger than shown in Table 2.

Due to long leading time of geothermal power plants in Japan, no "full-scale" geothermal power plant had been commissioned for many years after the new economic incentives by the government has been set since 2012.Finally in 2019, two flush-type power plants started operation at Matsuo-Hachimantai (7.499 MW) in Iwate prefecture and at Wasabizawa (46.199 MW) in Akita prefecture. Several other full scale power plants are planned, such as Oyasu (to be 15 MW in 2024) in Akita prefecture.

The Ministry of Economy, Trade and Industry (METI) is providing various supports for geothermal development. Feed in Tarif (FiT) mechanism, public acceptance activities, and certain technology developments are directly supported by METI while most technology developments and subsidies are done by METI's funding agencies such as Japan Oil Gas and Metal Company (JOGMEC) and New Energy and Industrial Technology Development Organization (NEDO). Currently NEDO is conducting a long-term project "Subduction origin super critical geothermal resources" targeting power generation by super critical geothermal resources in 2050. JOGMEC develops technology for cost reduction/speed-up of geothermal development and sustainable geothermal power generation

such as exploration technology, drilling technology, EGS technology and monitoring technology. Beside technology development, JOGMEC also provides economic incentives to private developers through low-interest loan, exploration and drilling subsidies, etc.

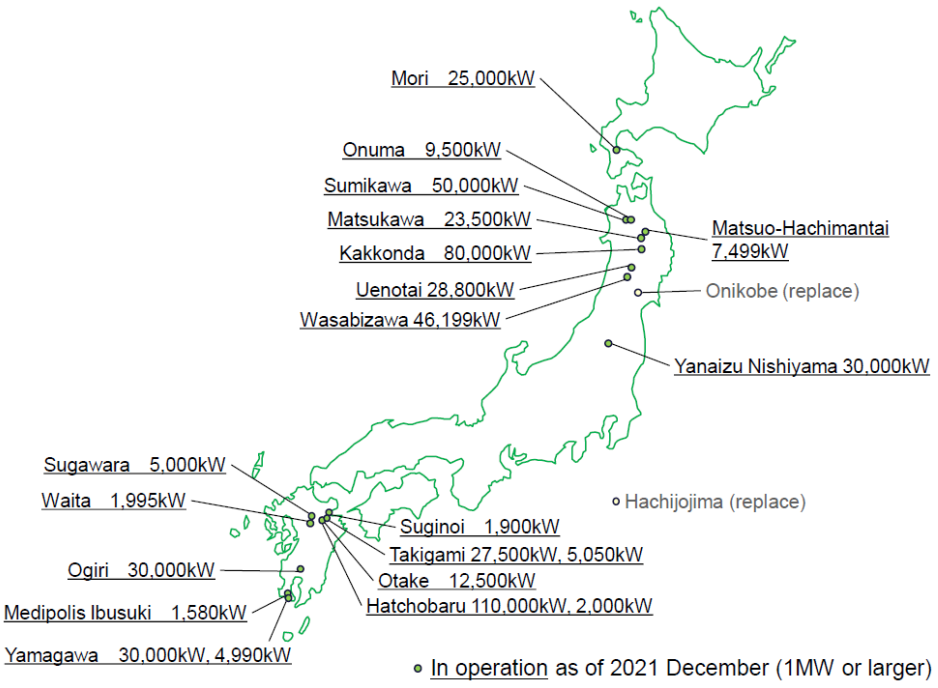

Figure 1: Major geothermal power plants in Japan as of December 2021 (TNPES, 2021)

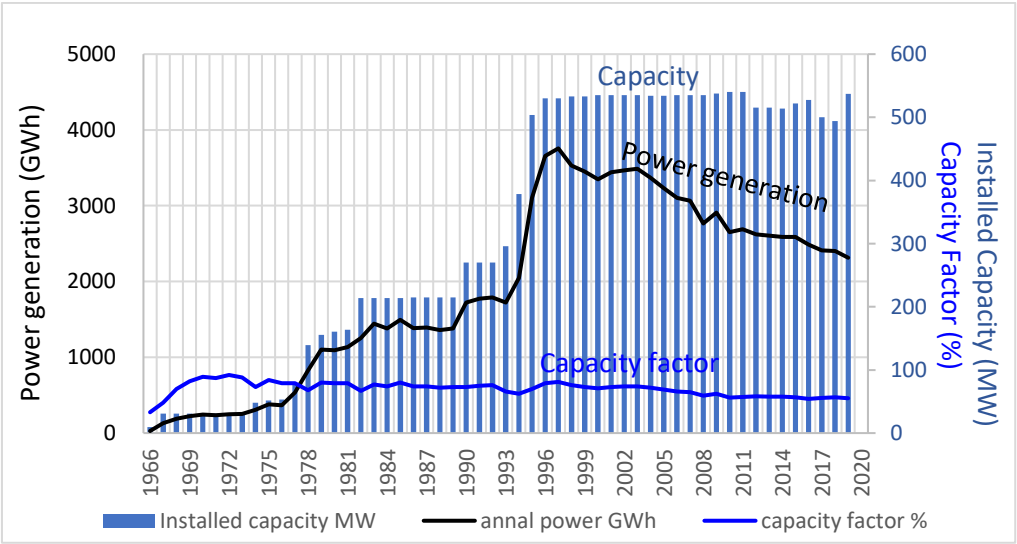

Figure 2: Geothermal power in Japan: total installed capacity, power generated, and capacity factor (TNPES, 2021)

A topical thing for 2021 is changes of legal frameworks for geothermal drilling in hot spring law as well as in natural park law.

Toward a carbon neutral society, in early 2021 a taskforce under the cabinet of Japan reviewed laws which prevent deployment of renewable energy. For geothermal power generation, the taskforce requested amendment of a guideline and a notification under hot spring law and natural park law, respectively. Therefore, MOE conducted these amendments in September 2021 as described below.

In Japan, permission of a geothermal-well-drilling is given by local government (prefecture) following “hot spring low” which guideline describes cautions on drilling of a new well to protect already existing hot spring wells. Under this low, many prefectures set regulation on spacing or density of drillings. However, such regulations are not appropriate for geothermal drillings, in which multiple well drilling from an identical drilling base is common. Also, permission for each well is not appropriate from a viewpoint of reservoir management. Therefore, amendment in 2021 was concentrated to change the guideline from “well to well control” to “reservoir control.” MOE ordered local governments to withdraw regulation that limits spacing or density of geothermal drillings. Under the new guideline, drilling permission of the second or later wells into an identical reservoir by identical geothermal developer

should be given easier than before only if a proper reservoir evaluation is done. On the other hand, drillings into an identical reservoir by another developer or drillings without reservoir evaluation may not be permitted. Thus, the new guideline must encourage larger geothermal development but discourage "overfishing."

Natural parks in Japan (national parks and prefecture parks) are divided into five zones from more protected zone to less protected zone as follows: special protection zone, special zone 1, special zone 2, Special zone 3 and normal zone. Among them, special zones 2 & 3 and normal zone are used for residence and commercial activities. Geothermal power generation in special zones 2 & 3 and normal zone, and directional drilling toward special zone 1 are allowed under some conditions as described in notification of natural park law. However, the conditions such as "not disturbing the scenery" or "with special caution on environment" are not very specific so that the judgement by the local authority have not been uniform. Furthermore, since the prescription of the notification clarifies as "geothermal power generation is basically prohibited in natural parks," most geothermal projects in natural parks have been rejected although they might have satisfied the conditions. By the regulation easing in 2021, the very sentence in the prescription is deleted and a new sentence "Geothermal power generation with special caution on environment should be encouraged" is inserted. Many good examples of geothermal projects "not disturbing the scenery" and "with special caution on environment" are added into the notification to specify the conditions.

3. DIRECT HEAT USE

Table 3 shows the summary of direct use geothermal heat in Japan. There is no new census for conventional direct heat use. Therefore, the same value as the paper in WGC2020 is used to compile data for Table 3.

The census on GSHP in Japan is conducted every other year by MOE and the latest data "census 2020" was released in 2021 (MOE, 2021). The installation of GSHP in Japan has been increasing in recent years, although the total number is still rather small (Figure 3). The total number of facilities using GSHPs is 2,994 (2,662 in "census 2018") including 2,511 (2,314) closed-loop, 460 (327) open-loop, and 22 (21) using both[4,6]. No data is shown for capacity and energy use in the census 2020. According to a report based on the census 2018, installed capacity of all the GSHPs is 163 MW_t, and annual energy use is 765 TJ/yr (Yasukawa et al., 2021).

Many systems have been installed in the northern regions including Hokkaido where heating needs are intensive, indicating the economic predominance of GSHPs when they replace an old oil boiler with a GSHP. GSHPs are also widely used in other parts of Japan; cooling needs are quite high in the middle to south-western Japan and GSHP with high performance COPs for cooling are contributing to electricity savings.

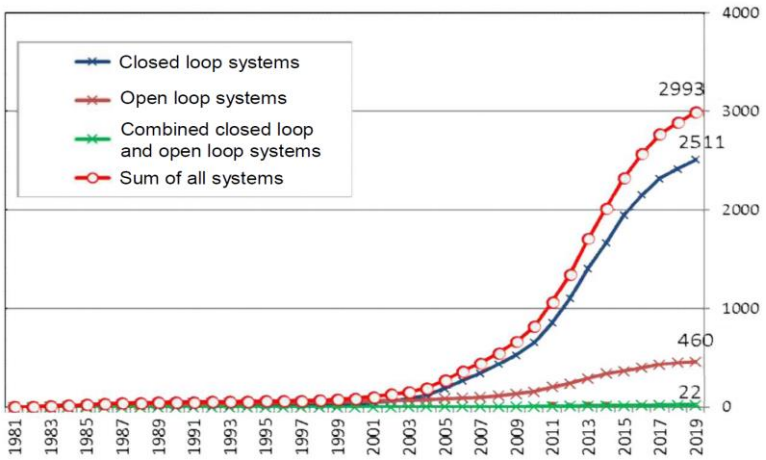

Figure 3 Cumulative installations of GSHP systems in Japan (MOE, 2021)

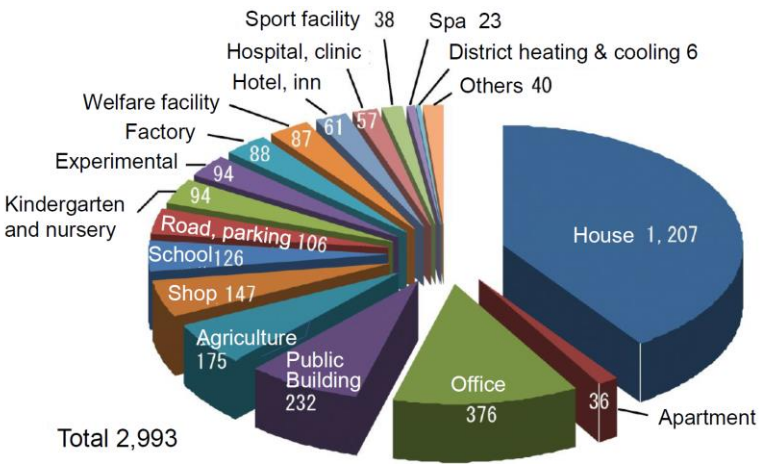

Figure 4 The number of facilities using GSHP system (MOE, 2021)

Figure 4 shows the cumulative number of GSHP systems by different facilities category (MOE, 2020). The largest share is individual houses, followed by offices and public buildings. There are 36 installations for apartments which was zero in the former census in 2018.

4. RESEARCH HIGHLIGHT

4.1 Geothermal Power

Two METI funded agencies; JOGMEC and NEDO (New Energy and industrial technology Development Organization), started projects in 2013 developing geothermal technology. NEDO began research on subduction-origin supercritical geothermal resources with a target year of 2040 for a pilot plant to be operational. This is one of the NESTI2050 projects, which is looking to contribute to the 2050 CO_2 reduction targets set by the Cabinet of Japan in 2017. The NEDO work is focusing on geothermal technologies that are to be realised in the longer term whilst JOGMEC is focusing on surveys, technologies and support that are effective in the short term.

In order to promote geothermal development, JOGMEC has undertaken a survey program to acquire basic data for the evaluation of some geothermal prospects since 2013. The program currently consists of airborne helicopter geophysical survey, land-based geological and geophysical surveys, and slim-hole drillings for subsurface temperature survey. The acquired data is published and used by private companies to develop their new exploration projects. By the end of 2021, airborne surveying had been conducted in 19 regions, land-based survey in 18 regions, and slim-hole drilling in 17 regions.

JOGMEC has four technology development R&D project themes with the specific projects under these themes: (A) Technology for Exploration of Geothermal Reservoirs, (B) Drilling Technology, (C) Drilling Technology, and (D) Innovative Geothermal Technology. Currently innovative technology includes (i) EGS technology development using supercritical Carbon Dioxide and (ii) Closed circuit heat exchange technology.

Since 2017, NEDO has been conducting an R&D project "Development of subduction-origin supercritical geothermal resources" to utilize 400 to 500ºC supercritical fluid at a depth shallower than 5km. Earlier surveys suggested supercritical geothermal resources may exist in/around many of the volcanic zones in Japan with total potential possibly of several tens of giga-watts. 2040 is targeted for the operation of a pilot plant (Asanuma et al., 2021).

To overcome problems with acid fluid in supercritical conditions, the project covers various fundamental scientific studies in; rock mechanics, material science, geo-science, as well as technology development, numerical simulation and drilling. The basic studies are being led and conducted by the National Institute of Advanced Industrial Science and Technology (AIST) and Kyoto University. The first phase of the project was completed in 2020 and the second phase began in 2021 to select a region for deep drilling in the 3rd phase.

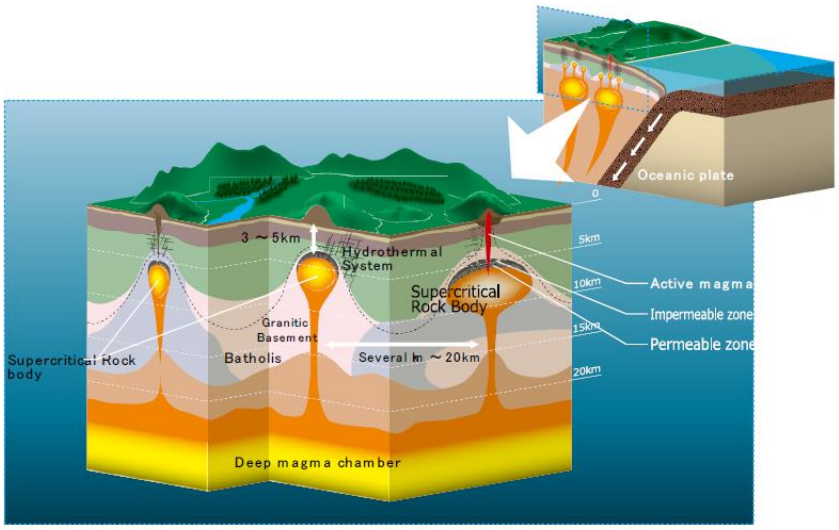

Figure 5 Conceptual Model of Supercritical Geothermal Resources in Northeast Japan (Asanuma et al., 2021)

4.2 GSHP

Japan has been developing GSHP system suitability mapping based on groundwater flow modelling in basins and plains. The study funded by NEDO, was initiated by AIST and several universities and companies have subsequently become involved.

In Quaternary basins and plains consisting of unconsolidated sediments in monsoon Asia, effective thermal conductivity of shallow underground rocks largely differs from one place to another due to both the existence of aquifers and the advection effect of groundwater flow. Since saturated rock has a higher thermal conductivity, existence of a shallow aquifer raises the heat exchange rate so that information on the water table becomes important. Also, since higher water velocity gives higher heat exchange rates, information on 3D groundwater flow is useful for designing subsurface heat exchangers.

Water table and flow velocity information is indispensable for open loop system design.

Groundwater studies based on field surveying and numerical simulation have been used to prepare separate suitability maps for open and closed loop systems. Separate maps for only heating demand, and heating and cooling demand, have been prepared based on subsurface temperature data. Shrestha et al. (2018) shows good example of separate suitability maps for closed loop and open loop systems in the Aizu Basin. This identifies suitability for open or closed loop systems according to the site location.

Based on the study results, eleven municipals in Japan have compiled GSHP suitability maps from their own budget resources and opened the information up to their citizens seeking to increase the use of GSHP in their municipalities; with benefits from energy saving and environmentally friendly technology.

5. OTHER NATIONAL ACTIVITIES

5.1 Promotion of Geothermal Development

METI began a program in 2013 to raise social acceptance of geothermal power generation amongst local residents. It is a subsidy scheme for general public educational activities undertaken by local governments and/or private sector organization. Seven projects were adopted in 2021 (8 in 2020).

Every year since 2013, JOGMEC has held a Geothermal Symposium promoting geothermal power generation amongst the general public, seeking to increase the knowledge and the understanding of geothermal energy use. In 2021, the symposium was held in Aizuwakamatsu city, Fukushima as a hybrid event (in person meeting and live stream). More than 1600 people accessed the symposium from all over Japan and 64 people, including local citizens and members of the Diet, local parliament and local government, attended at the venue.

A wide technical knowledge gap exists between geothermal business people and local government officials, making it difficult for the officials to moderate local opinions with local social acceptance being quite important for geothermal projects. Aiming at bridging this gap, JOGMEC established in June 2016 a third-party expert organization, the "Advisory Committee for Geothermal Resources Development". Matters of consultation from eight municipals were discussed in FY2021.

5.2 International collaboration and human capability development

Human resource development is an important issue in the international geothermal community. The Japan International Cooperation Agency (JICA) is organizing training courses for geothermal specialists from developing countries. The program is basically provided by Kyushu University and supported by lecturers from other universities, institutes and private companies in order to cover all aspects of a geothermal energy development. JICA has also been active in conducting Official Development Assistance (ODA) projects in geothermal development in Asian, African and Latin American continents for many decades.

JOGMEC and GNS Science (New Zealand), have a memorandum of understanding for collaboration in geothermal technology. A joint online seminar "Carbon neutral geothermal" was held on 10 December 2021, in addition to four past workshops held in Japan and in New Zealand on scaling, community acceptance, reservoir engineering and geothermal geology.

For domestic capability development, JOGMEC has been providing a three-week-long geothermal training course every year. In 2021, it was held from late November to mid-December in Kosaka city, Akita and in Tokyo. It covers the basics of geothermal energy including technical, economic and social aspects of geothermal energy projects. This course is valuable for private developers, many of whom have little experience in geothermal business.

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Table 1. PRESENT PRODUCTION OF ELECTRICITY (METI, 2022 for Gross Electrical generation, METI, 2021 for Installed Capacity and TNPES, 2021 for geothermal)

Energy source	Geothermal		Other Renewables (specify)		Nuclear		Fossil Fuels		Other sources		Total	
	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 March 2021	546	2,661	16,630	117,239	33,080	38,800	170,260	763,700	49,680	78,400	**270,196**	**1,000,800**

Table 2. GEOTHERMAL POWER FIELDS, PLANTS AND UNITS IN THE COUNTRY (TNPES, 2021)

Geothermal Field						**Power Plant**		**Power Unit**						
(1) Name	**(2) Field operator**	**(3) Wells in operation**	**(4) Depth of deepest production well (m)**	**(5) Reservoir type**	**(6) System type**	**(7) Name or number**	**(8) Plant operator**	**# of units**	**(14) Type of unit**	**(15) Year of commission**	**(16) Status**	**(17) Turbine manufacturer**	**(18) Installed Capacity (MW)**	**(20) NEP (GWh/year)**
Mori, Hokkaido	Hokkaido Electric Power Co., Inc	16	3250	Hydrothermal	Two-phase, liquid-dominated: Medium enthalpy	Mori	Hokkaido Electric Power Co., Inc	1	2F	1982	Operating	Toshiba	25.000	127.541
Onuma, Akita	Mitsubishi Materials Co,	8	2030	Hydrothermal	Two-phase, liquid-dominated: Low enthalpy	Onuma	Mitsubishi Materials Co,	1	1F	1974	Operating	Mitsubishi	9.500	39.914
Sumikawa, Akita	Mitsubishi Materials Co,	25	2634	Hydrothermal	Two-phase, liquid-dominated: High enthalpy	Sumikawa	Tohoku Electric Power Co., Inc.	1	1F	1995	Operating	Mitsubishi	50.000	281.115
Matsuo-Hachimantai, Iwate	Iwate Geothermal Co., Ltd.	5	2050	Hydrothermal	Two-phase, liquid-dominated: High enthalpy	Matsuo-Hachimantai	Iwate Geothermal Co., Ltd.	1	1F	2019	Operating	MHPS	7.499	data not open
Matsukawa, Iwate	Tohoku Sustainable & Renewable Energy Co.Inc	9	1600	Hydrothermal	Two-phase, vapour-dominated	Matsukawa	Tohoku Sustainable & Renewable Energy Co.Inc	1	Dry Steam	1966	Operating	Toshiba	23.500	79.377

Kakkonda, Iwate	Tohoku Sustainable & Renewable Energy Co.Inc	46	2818	Hydrothermal	Two-phase, liquid-dominated: High enthalpy	Kakkonda	Tohoku Electric Power Co., Inc.	1	1F	1978	Operating	Toshiba	50.000	125.274
Kakkonda, Akita	Tohoku Sustainable & Renewable Energy Co.Inc	28	3000	Hydrothermal	Two-phase, liquid-dominated: High enthalpy	Kakkonda II	Tohoku Electric Power Co., Inc.	1	1F	1996	Operating	Toshiba	30.000	81.766
Uenotai, Akita	Tohoku Sustainable & Renewable Energy Co.Inc	16	2228	Hydrothermal	Two-phase, liquid-dominated: High enthalpy	Uenotai	Tohoku Electric Power Co., Inc.	1	1F	1994	Operating	Toshiba	28.800	173.051
Wasabizawa, Akita	Yuzawa Geothermal Co., Ltd.	11	1800	Hydrothermal	Two-phase, liquid-dominated: High enthalpy	Wasabizawa	Yuzawa Geothermal Co., Ltd.	1	2F	2019	Operating	Toshiba	46.199	341.092
Onikobe, Miyagi	J-POWER	0	-	Hydrothermal	Two-phase, liquid-dominated: Medium enthalpy	Onikobe	J-POWER	1	1F	1975	Not operating temporarily	Kawasaki	14.9 MW to be replaced	
Yanaizu-Nishiyama, Fukushima	Okuaizu Geothermal Co., Ltd.	18	2300	Hydrothermal	Two-phase, liquid-dominated: High enthalpy	Yanaizu-Nishiyama	Tohoku Electric Power Co., Inc.	1	1F	1995	Operating	Toshiba	30.000	132.177
Hachijojima, Tokyo		0	3031	Hydrothermal	Two-phase, liquid-dominated: Low enthalpy	Hachijojima			1F	1999	Not operating temporarily	Fuji	3.3 MW replaced to 4.4MW	
Beppu, Oita	Suginoi Hotel	5	300	Hydrothermal	Hot water	Suginoi	Suginoi Hotel	1	1F	1981	Operating	Fuji	1.900	-
Kuju, Oita	Makinoto Co.	1	-	Hydrothermal	Hot water	Kuju	Makinoto Co.	1	1F	2000	Operating	Mitsubishi	1.995	0
Otake, Oita	Kyushu Electric Power Co., Inc.	9	2084	Hydrothermal	Two-phase, liquid-dominated: Medium enthalpy	Otake	Kyushu Electric Power Co., Inc.	1	2F	1967	Operating	MHPS	14.500	67.431
Hatchobaru, Oita	Kyushu Electric Power Co., Inc.	23	3031	Hydrothermal	Two-phase, liquid-dominated: High enthalpy	Hatchobaru	Kyushu Electric Power Co., Inc.	1	2F	1977	Operating	Mitsubishi	55.000	251.79

Hatchobaru, Oita	Kyushu Electric Power Co., Inc.			Hydrothermal	Two-phase, liquid-dominated: High enthalpy	Hatchobaru II	Kyushu Electric Power Co., Inc.	1	2F	1990	Operating	Mitsubishi	55.000	304.829
Hatchobaru, Oita	Kyushu Electric Power Co., Inc.	0	-	Hydrothermal	Two-phase, liquid-dominated: High enthalpy	Hatchobaru Binary	Kyushu Electric Power Co., Inc.	1	B-ORC	2006	Operating	Ormat	2.000	0
Takigami, Oita	Idemitsu Oita Geothermal Co., Ltd.	11	2707	Hydrothermal	Two-phase, liquid-dominated: Low enthalpy	Takigami	Kyushu Electric Power Co., Inc.	1	1F	1996	Operating	Mitsubishi	27.500	187.512
Takigami, Oita	Idemitsu Oita Geothermal Co., Ltd.	0	-	Hydrothermal	Two-phase, liquid-dominated: Low enthalpy	Takigami Binary	Idemitsu Oita Geothermal Co., Ltd.	1	B-ORC	2016	Operating	Fuji	5.050	31.174
Sugawara, Oita	Kuju Town	3	870	Hydrothermal	Hot water	Sugawara Binary	Kyuden Mirai Energy Co., Ltd.	1	B-ORC	2015	Operating	MHPS-Turboden	5.000	42.53
Waita, Kumamoto	Waita-kai Co., Ltd.	5	619	Hydrothermal	Hot water	Waita	Waita-kai Co., Ltd.	1	1F	2015	Operating	Toshiba	2.145	15.393
Ogiri, Kagoshima	Nittetsu Mining Co., Ltd.	17	2695	Hydrothermal	Two-phase, liquid-dominated: Medium enthalpy	Ogiri	Kyushu Electric Power Co., Inc.	1	1F	1996	Operating	Mitsubishi	30.000	178.653
Yamagawa, Kagoshima	Kyushu Electric Power Co., Inc.	16	2105	Hydrothermal	Two-phase, liquid-dominated: High enthalpy	Yamagawa	Kyushu Electric Power Co., Inc.	1	1F	1995	Operating	Mitsubishi	30.000	153.39
Yamagawa, Kagoshima	Kyushu Electric Power Co., Inc.	0	-	Hydrothermal	Two-phase, liquid-dominated: High enthalpy	Yamagawa Binary	Kyuden Mirai Energy Co., Ltd.	1	B-ORC	2017	Operating	Fuji	4.990	39.275
Ibusuki, Kagoshima	Medipolis Energy Co., Ltd.	2	1500	Hydrothermal	Two-phase, liquid-dominated: Low enthalpy	Medipolis Ibusuki	Medipolis Energy Co., Ltd.	1	B-ORC	2015	Operating	JFE-Ormat	1.580	data not open
Teshikaga, Hokkaido	KOKUSHO KANKOKAI INC.	1		Hydrothermal	Hot water	Mashuko onsen-netsu	KOKUSHO KANKOKAI INC.	1	B-ORC	2016	Operating	Access Energy	0.125	-
Toyako, Hokkaido	Toyako Onsen Community	1		Hydrothermal	Hot water	Toyako onsen KH-1	Toyako Onsen Community	1	B-ORC	2017	Operating	KOBELCO	0.072	0
Okushiri, Hokkaido	Koshimori Oil Electric Business	1		Hydrothermal	Hot water	Okushiri GPP	Koshimori Oil Electric Business	2	B-ORC	2017	Operating	Daiichi Jitsugyo	0.250	1.331

Naruko, Miyagi	Naruko Onsen Community	1		Hydrothermal	Hot water	Naruko onsen binary	Naruko Onsen Community	1	B-ORC	2018	Operating	Anest-Iwata	0.065	-
Tuchiyu, Fukushima	Tsuchiyu Onsen Community	1		Hydrothermal	Hot water	Tuchiyu onsen No.16 binary	Genki-up Tsuchiyu Co. Ltd.	1	B-ORC	2015	Operating	JFE-Ormat	0.440	2.835
Nasu, Tochigi	Hotel Sun Vallery	2		Hydrothermal	Hot water	Hotel Sun Vallery binary	Hotel Sun Vallery	1	B-ORC	2015	Operating	IHI	0.020	0.01
Takayama, Nagano	Yamagoya Solar Llc.	1		Hydrothermal	Hot water	Shichimi Onsen Hotel binary	Yamagoya Solar Llc.	1	B-ORC	2014	Operating	IHI	0.020	-
Tokamachi, Niigata	The Earth Llc.	1		Hydrothermal	Hot water	Community Power: the Matsunoyama onsen	Matsunoyama Onsen Llc.	1	B-Kalina	2021	Operating		0.210	-
Okuhida, Gifu	Okuhida Natural Eneregy Llc.	1		Hydrothermal	Hot water	Ichiegane No. 2 Binary (Okuhida 1st Binary)	Okuhida Natural Eneregy Llc.	1	B-ORC	2017	Operating		0.079	-
Okuhida, Gifu	Okuhida Natural Eneregy Llc.	1		Hydrothermal	Hot water	Okuhida 2nd Binary	Okuhida Natural Eneregy Llc.	2	B-ORC	2021	Operating		0.250	-
Okuhida, Gifu	Kitsune Power Llc.	1		Hydrothermal	Hot water	Kitsune (Fox) Power	Kitsune Power Llc.	1	B-ORC	2020	Operating		0.045	-
Okuhida, Gifu	Okuhida Onsen community	1		Hydrothermal	Hot water	Takenaka Okuhida	Takenaka Co.	1	B-ORC	2021	Operating		0.045	-
Shimoda, Shizuoka	JX Nippon Mining & Metals Co.	no data		Hydrothermal	Hot water	Shimoda onsen binary	JX Nippon Mining & Metals Co.	1	B-ORC	2017	Operating		0.110	0.583
Shin-onsencho, Hyogo	Shin-onsencho town	2		Hydrothermal	Hot water	Yakushiyu Onsen binary	Shin-onsencho town	2	B-ORC	2014	Operating	IHI	0.040	0
Yurihama, Tottori	Togo Onsen Co., Ltd.	2		Hydrothermal	Hot water	Kyowachiken Consultant Yurihama	Kyowachiken Consultant Co., Ltd.	1	B-ORC	2015	Operating	IHI	0.020	-
Obama, Nagasaki	First Obama Binary PP Llc.	1		Hydrothermal	Hot water	Obama Onsen binary	First Obama Binary PP Llc.	1	B-ORC	2015	Operating	Access Energy	0.135	-

Beppu, Oita	West Japan Geothermal Power Co., Ltd.	1		Hydrothermal	Hot water	Goto-en	West Japan Geothermal Power Co., Ltd.	2	B-ORC	2014	Operating	KOBELCO	0.144	-
Beppu, Oita	West Japan Geothermal Power Co., Ltd.	1		Hydrothermal	Hot water	Yuyama	West Japan Geothermal Power Co., Ltd.	2	B-ORC	2014	Operating	KOBELCO	0.144	-
Beppu, Oita	Nippon Chinetsu Kogyo Co., Ltd.	1		Hydrothermal	Hot water	Tatara Daiichi	Japan Geothermal Kogyo Co., Ltd.	1	B-ORC	2014	Operating	KOBELCO	0.072	-
Beppu, Oita	Chinetsu World Koryo. Co., Ltd.	1		Hydrothermal	Hot water	Kamenoi	Chinetsu World Koryo. Co., Ltd.	1	Other	2015	Operating	Turboblade	0.011	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	Cosmotech Beppu binary	Cosmotech Co., Ltd.	4	B-ORC	2014	Operating	Access Energy	0.500	2.251
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	Fino binary	Fino Binary PP Llc.	2	B-ORC	2015	Operating	Access Energy	0.250	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	PPSN binary	PPSN Co., Ltd	1	B-ORC	2016	Operating	Access Energy	0.125	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	SUMO Power	Sumo Power Co., Ltd.	1	B-ORC	2016	Operating	Access Energy	0.125	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	SNS Power	Sns Power Co., Ltd.	1	B-ORC	2016	Operating	Access Energy	0.125	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	Makino	Makino-kaiun Co., Ltd	1	B-ORC	2017	Operating	Access Energy	0.125	-
Beppu, Oita	Jet System Co., Ltd.	1		Hydrothermal	Hot water	BLD (Beppu Tsurumi Power Station)	BLD Power Stations co., Ltd.	2	B-ORC	2017	Operating		0.250	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	Chiba	Chiba Co., Ltd	2	B-ORC	2017	Operating	Access Energy	0.250	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	Chiba HD	Chiba Holdings Co., Ltd.	2	B-ORC	2017	Operating	Access Energy	0.250	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	GRACE	GRACE Co., Ltd	1	B-ORC	2017	Operating	Access Energy	0.125	-

Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	Kijyu	Kijyu Co., Ltd	1	B-ORC	2017	Operating	Access Energy	0.125	-
Beppu, Oita	Beppu Spa Service Co., Ltd	no data		Hydrothermal	Hot water	Jetsystem No.1	Jetsystem Co., Ltd.	1	B-ORC	2017	Operating	Access Energy	0.220	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	Jetsystem No.2	Jetsystem Co., Ltd.	1	B-ORC	2017	Operating	Access Energy	0.125	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	VEP Energy PP	VEP Energy Co., Ltd.	1	B-ORC	2017	Operating	Access Energy	0.125	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	RE-Energy GPP	RE Energy Community	1	B-ORC	2017	Operating	Access Energy	0.125	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	Renavis PP	Renavis Co., Ltd.	1	B-ORC	2017	Operating	Access Energy	0.125	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	Rena PP No.1	Rena Co., Ltd.	1	B-ORC	2017	Operating	Access Energy	0.250	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	P-Power PP	PPSN Co., Ltd	1	B-ORC	2017	Operating	Access Energy	0.250	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	NIS binary PP	Nis Binary PP Llc.	1	B-ORC	2017	Operating	Access Energy	0.250	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	i-BIO	i-BIO Co., Ltd.	1	B-ORC	2018	Operating	Access Energy	0.125	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	Dual energy binary	Dual Energy Binary PP No.1 Llc.	1	B-ORC	2018	Operating	Access Energy	0.250	-
Beppu, Oita	Beppu Spa Service Co., Ltd	1		Hydrothermal	Hot water	Beppu Tsurumi onsen GPP Unit 1	Beppu Tsurumi onsen GPP Unit 1 Llc.	1	B-ORC	2018	Operating	Access Energy	0.250	-
Beppu, Oita	Abe Naika Clinic	no data		Hydrothermal	Hot water	Abe Naika Clinic	Abe Naika Clinic	1	B-ORC	2015	Operating	IHI	0.020	-
Beppu, Oita	Sanko Denki Ltd.	1		Hydrothermal	Hot water	Sanko Chinetsu Kaihatsu binary	Sanko Denki Ltd.	1	B-ORC	2016	Operating	ELECTRATHERM	0.065	-
Beppu, Oita	Tsujita Kenki Ltd.	1		Hydrothermal	Hot water	Enma	Tsujita Kenki Ltd.	1	B-ORC	2017	Operating		0.070	0
Beppu, Oita	Geothermal Development Co., Ltd	no data		Hydrothermal	Hot water	Beppu Lifetech onsen	Geothermal Development Co., Ltd	1	B-ORC	2019	Operating		0.840	-

Beppu, Oita	I-bec Co., Ltd.	no data		Hydrothermal	Hot water	i-bec Beppu	I-bec Co., Ltd.	2	B-ORC	2019	Operating		0.560	-
Kuju, Oita	Takafuji Co. Ltd.	1		Hydrothermal	Hot water	Kuju Noya-chiku binary	Takafuji Co. Ltd.	1	B-ORC	2017	Operating		0.050	-
Kuju, Oita	Ote Oita Co., Ltd.	no data		Hydrothermal	Hot water	OTE Oita Okue onsen binary	Ote Oita Co., Ltd.	1	B-ORC	2017	Operating	KOBELCO	0.072	data not open
Yufuin, Oita	Yufuin Forest Energy co., Ltd.	1		Hydrothermal	Hot water	Yufuin Forest Energy binary	Yufuin Forest Energy co., Ltd.	1	B-ORC	2015	Operating	KOBELCO	0.125	-
Yufuin, Oita	Yufuin Forest Energy co., Ltd.	1		Hydrothermal	Hot water	Yufuin Forest Energy binary No.2	Yufuin Forest Energy co., Ltd.	1	B-ORC	2017	Operating		0.070	-
Oguni, Kumamoto	Oguni Matsuya PP Llc.	1		Hydrothermal	Hot water	Oguni Matsuya	Oguni Matsuya PP Llc.	3	B-ORC	2014	Operating	IHI	0.060	-
Hishikari, Kagoshima	Sumitomo Metal Mining Co., Ltd.	0		Hydrothermal	Hot water	(Hishikari mine)	Sumitomo Metal Mining Co., Ltd.	-	B-ORC	2021	-		-	-
Kirishima, Kagoshima	Iwatech Co., Ltd.	1		Hydrothermal	Hot water	Iwatech No.1 Onsen PP	Iwatech Co., Ltd.	1	B-ORC	2018	Operating		0.013	0.538
Kirishima, Kagoshima	Kirishima Kokusai Hotel	0		Hydrothermal	Two-phase, liquid-dominated: Low enthalpy	Kirishima Kokusai Hotel	Kirishima Kokusai Hotel		1F	1983	Decommissioned	Fuji	0.1MW retired	
Total values		**324**						**93**					**545.744**	**2660.83**

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

(1) Geothermal Application	(2) Total Installed Capacity (MWt)	(3) Total Energy produced (TJ/year)	(4) Total Energy used (TJ/year)	(5) Number of Installations
Agriculture and food processing	38.7	470.43	470.43	-
Industrial process heat	1.06	27.02	27.02	-
Health, recreation and tourism*	1999.42	24590	24590	-
Heating and cooling for buildings	203.34	4136.83	4136.83	-
Heating and cooling by GSHP	163	765	765	2994
Other uses	164.86	733.09	733.09	-
Total values	**2570.38**	**30722.37**	**30722.37**	-