

Country Update of Japan

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ABSTRACT

Geothermal power production in Japan began in 1967. Its installed capacity reached 531 MW_e in 2000 with 17 units, and 540 MW_e in 2010 with 20 units. After the implementation of geothermal FiT in 2012, the number of units has rapidly increased and was doubled in 2016 and tripled in 2017 (69 units by February 2018). However, most of these new units are quite small, ranging from 10 kW_e to 5 MW_e with an average of 0.5 MW_e. Thus, the capacity increase by these new units is merely 24.4 MW_e in total. Moreover, in recent years, several old geothermal plants, which capacity factors had been less than 50%, renewed their units with smaller generators. This renewal resulted in decreasing power capacity of 68.2 MW_e. As a result, there was a 43.8 MW_e decrease from 2010 to February 2017. Nevertheless, two new large power plants began operation in early 2019, adding 53.7 MW_e. This resulted in a total power capacity of approximately 550 MW_e. Since many other fields are under exploration by private sectors, more increase by 2030 is expected.

The number of ground source heat pump (GSHP) installation is multiplicatively increasing these years. The total installation number in Japan at the end of 2015 is 2,230 with a total capacity of 134 MW_t. The annual heat use (geothermal contribution) is estimated to be 162.2 GW_t-h. The annual installation number is approximately 300 by the year 2015. Note that the cooling function of GSHP is even more important than heating in terms of energy saving, which is estimated to be 305.9 GW_t-h a year.

Conventional direct use in Japan is rather stable. Its dominant part has been bathing, but the number of visitors and total flow rate of these geothermal baths both gradually decreased with peaks in 2002 and 2007, respectively. On the other hand, the number of other direct use facilities are slightly increasing due to subsidy from the federal government to promote geothermal energy use.

1. INTRODUCTION

The Japanese Islands are located at the eastern end of the Eurasian Plate at the junction of the Pacific and the Philippine Sea Plates (see Figure 1). 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 three newly added volcanoes in 2011 and 2016, that is 7% of the volcanoes on the earth (JMA, 2017). Therefore, most of the promising geothermal resources in Japan have a volcanic origin.

Japan is blessed with geothermal energy with a theoretical potential of over 20 GWe at a depth of 3 km (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 was done for more than a decade since the year 2000, mainly because of legal, social and socio-economic barriers. The three major barriers were; 1) regulations on natural parks, 2) cost and development risk, and 3) social acceptance. However, the former two problems were largely mitigated after the nuclear accident in 2011 by the federal government. This government changed several regulations on natural parks and putting new economic incentives to promote geothermal development. The third one may not be easily mitigated. Negative campaigns for geothermal developments by hot spring owners are so influential that geothermal projects were delayed or even stopped in several cases. Nevertheless, the government began several actions to raise social acceptance for geothermal development. Given such support from the government, private sectors moved toward geothermal development drastically.

The installation of ground source heat pump (GSHP) systems increased steadily in Japan. Although the number of installation is still limited to a few thousand, the annual installation is increasing exponentially. The government gives incentives for the installation of GSHP systems mainly because of environmental aspects. On the other hand, conventional direct use has not increased significantly (Table 2). This paper provides the status of Japan in 2019 for geothermal power generation, conventional direct use, and GSHP separately.

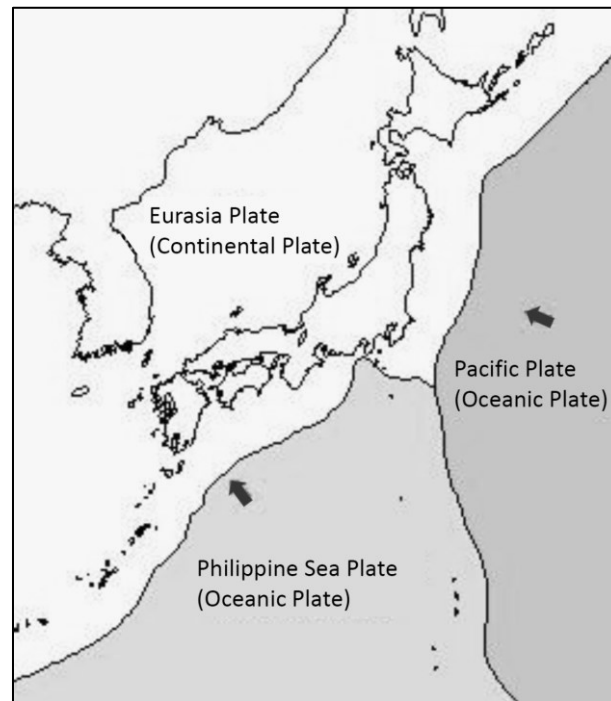


Figure 1: Plate tectonic settings of Japan (GSJ, 2017)

Table 1: Present electricity production in Japan (as of December 2018)

	Geothermal	Fossil Fuels	Hydro	Nuclear	Other Renewables	Total
Capacity in Operation [MWe]	500	188,047	50,053	38,042	12,076	300,330
Gross Prod. [GWh/y]	2,409*	708,100	85,000	62,100	34,591**	892,200
Under Construction in December 2018 [MWe]	54	-	-	-	-	-
Funds committed but not yet under construction [MWe]	0	-	-	-	-	-
Estimated total by 2020 [MWe]	554	-	-	-	-	-

Data source for geothermal; Thermal and Nuclear Power Engineering Society (2018), for the others; Energy Agency (2019).

*Data from 2017, should be revised with new data for 2018.

**[This number] = [All renewables in 2018] – [Geothermal in 2017]; should be revised with new data of geothermal in 2018.

Note: Biomass and waste power generation are double-counted in the original literature (Energy Agency, 2018) in “Fossil Fuels” and “Renewables” because they are combined units. In this table, they count as renewables only. Therefore the numbers for Fossil Fuels are smaller than in the original literature.

Table 2: Present status of geothermal use in Japan (as of 2018)

	Power Generation*	Conventional Direct Use	GSHP
Installed capacity	500.0 MWe*	2,407.4 MWt	163.4 MWt
Used (produced) Energy	2409.3 GWh/y	29,958.4 TJ/y	764.9 TJ/y

Data source of power generation; Thermal and Nuclear Power Engineering Society (2018), for Conventional Direct Use; original of this study based on NEF (2012) and Kurasaka (2018), see section 3.1, and for GSHP; MOE (2019).

*Installed capacity of the power plant means the status of 2018, which is different from Table 3. Its annual produced energy means data of FY2017, which is the same value as in Table 3.

2. GEOTHERMAL POWER GENERATION

Table 3 shows the present status of geothermal power plants in Japan (as of May 2019). Because of a 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 plants may be missing in Table 3. For power plants which installed capacities are shown, but the produced energy is not shown in the source literature, an estimation was made based on the assumption on the capacity factor (see NOTES below Table 3). Such estimated values are not included in the official total but shown in brackets as a reference.

Due to a long leading time of geothermal power plants in Japan, no “full-scale” geothermal power plant was commissioned for many years after the new economic incentives by the government were set since 2012. In such situation, the commissions of Sugawara binary power plant, 5MW in 2015 and Yamakawa binary power plant, 4.99 MW in 2017 were encouraging news. Finally, in 2019, two flush-type power plants started operation in Matsuo-Hachimantai (7.499 MW), in Iwate prefecture, and in 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. METI directly supports the Feed-in Tariff (FiT) mechanism, public acceptance activities, and certain technology developments. Meanwhile, 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). METI’s budget for geothermal technology development by NEDO and JOGMEC in FY2018 is 2.45 billion JPY in total. NEDO has developed technology for surface facilities, including scale measures, landscape measures (ecological design), and small-scale, low-cost power generators. Currently, NEDO is conducting a long-term project “Subduction origin for supercritical geothermal resources” targeting power generation by supercritical 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. Besides technology development, JOGMEC also provides economic incentives to private developers through a low-interest loan, exploration and drilling subsidies, etc., which budget in FY2018 is 9 billion JPY.

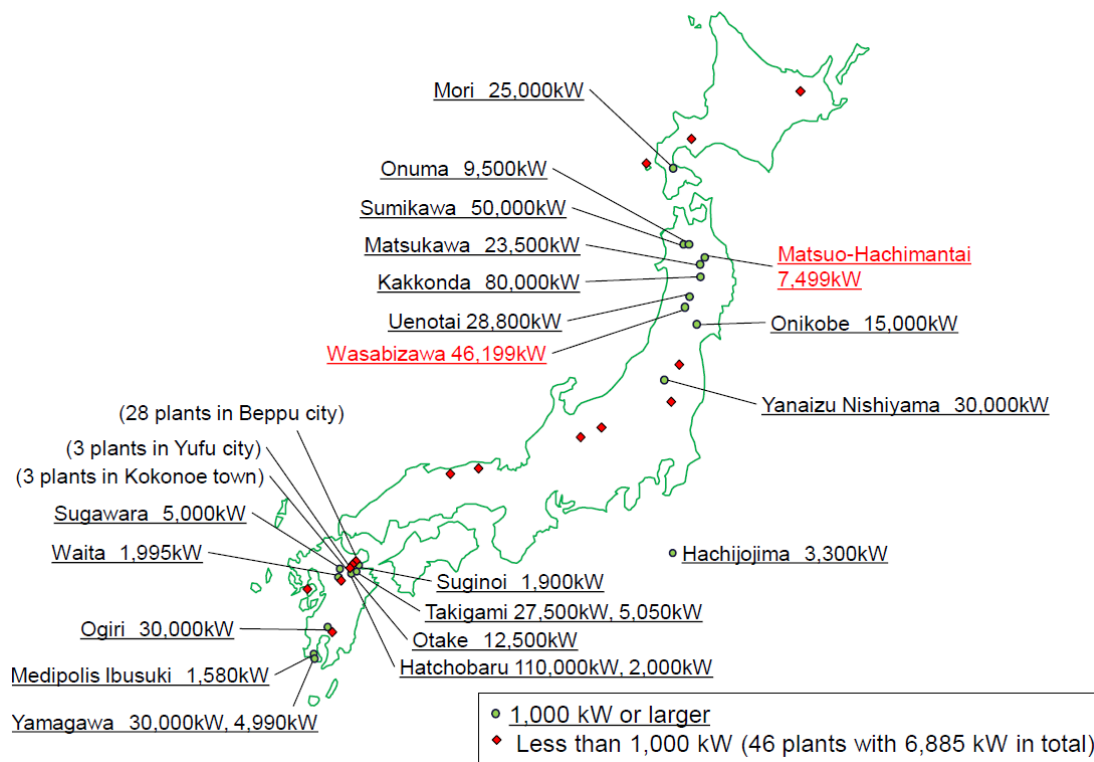


Figure 2: Geothermal power plants in Japan (as of June 2019).

Table 3: List of geothermal power plants in Japan by June 2019. The annual energy produced is the value of FY2017 (TNPES, 2018).

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status	Type of Unit	Total Installed Capacity MW _e	Total Running Capacity MW _e	Annual Energy Produced GWh/yr	Under Constr. or Planned MW _e
Iwate	Matsukawa	1966	1		D	23.5	8.34	73.047	
Oita	Otake	1967	1		1F	12.5	10.02	87.782	
Akita	Onuma	1974	1		1F	9.5	5.01	43.862	
Miyagi	Onikobe	1975	1		1F	15	-	N	
Oita	Hatchobaru	1977	3		2F	55	28.69	251.31	
Iwate	Kakkonda	1978	3		1F	50	14.91	130.586	
Oita	Suginoi	1981	1		1F	1.9	1.04	9.099	
Hokkaido	Mori	1982	1		2F	25	16.77	146.913	
Kagoshima	Kirishima Kokusai Hotel	1983	1		1F	0.1	-	N	
Oita	Hatchobaru II	1990			2F	55	41.16	360.556	
Akita	Uenotai	1994	1		1F	28.8	20.06	175.705	
Kagoshima	Yamakawa	1995	1		1F	30	13.23	115.927	
Akita	Sumikawa	1995	1		1F	50	32.09	281.085	
Fukushima	Yanaizu-Nishiyama	1995	1		1F	30	15.22	133.338	
Kagoshima	Ogiri	1996	1		1F	25.8	16.86	147.715	
Oita	Takigami	1996	1		1F	27.5	25.38	222.352	
Iwate	Kakkonda II	1996			1F	30	13.11	114.84	
Tokyo	Hachijojima	1999	1		1F	3.3	1.19	10.46	
Oita	Kuju	2000	1		1F	0.99	0.676	5.918	
Oita	Hatchobaru Binary	2006			B	2	0.203	1.782	
Oita	Goto-en	2014	2		B	0.144	0.049	0.426	
Nagano	Shichimi Onsen Hotel binary	2014	1		B	0.02	0.003	0.024	
Hyogo	Yakushi Onsen binary	2014	2		B	0.04	0.018	0.156	
Oita	Tatara Daiichi	2014	1		B	0.072	0.036	0.317	
Kumamoto	Oguni Matsuya	2014	3		B	0.06	0.041	0.359	
Oita	Yuyama	2014	2		B	0.144	0.080	0.703	
Oita	Cosmotech Beppu binary	2014	4		B	0.5	0.024	0.206	
Kagoshima	Medipolis Ibusuki	2015	1		B	1.58	[1.106]*	[9.695]*	
Oita	Kamenoi	2015	1		O (Total Flow)	0.011	0.004	0.036	
Kumamoto	Waita	2015	1		1F	1.995	1.575	13.797	
Oita	Sugawara Binary	2015			B	5	4.43	38.847	
Oita	Yufuin Forest Energy binary	2015	1		B	0.105	0.040	0.353	
Nagasaki	Obama Onsen binary	2015	1		B	0.125	0.083	0.723	
Tottori	Kyowachiken Consultant Yurihama	2015	1		B	0.02	0.010	0.084	
Oita	Fino binary	2015	2		B	0.25	0.076	0.663	
Fukushima	Tuchiyu onsen No.16 binary	2015	1		B	0.4	0.309	2.709	

Tochigi	Hotel Sun Vallery binary	2015	1	B	0.02	0.006	0.054	
Oita	Takigami Binary	2016		B	5.05	3.581	31.367	
Hokkaido	Mashuko onsen-netsu	2016	1	B	0.125	0.014	0.123	
Hokkaido	Toyako onsen binary	2016	1	B	0.05	0.033	0.289	
Oita	PPSN binary	2016	1	B	0.125	0.073	0.638	
Oita	Sumo Power	2016	1	B	0.125	0.081	0.713	
Oita	SNS Power	2016	1	B	0.125	0.071	0.621	
Oita	Sanko Chinetsu Kaihatsu binary	2016	1	B	0.053	0.042	0.366	
Oita	Makino PP	2017	1	B	0.125	0.045	0.397	
Oita	BLD Binary PP	2017	1	B	0.25	0.071	0.62	
Oita	RE-Energy GPP	2017	1	B	0.125	0.037	0.323	
Oita	Rena PP No.1	2017	1	B	0.25	0.057	0.5	
Oita	P-Power PP	2017	1	B	0.25	0.023	0.199	
Oita	Yufuin Forest Energy binary 2	2017	1	B	0.072	0.031	0.272	
Gifu	Ichiegane No.2 Binary	2017	1	B	0.072	0.006	0.05	
Hokkaido	Okushiri GPP	2017	1	B	0.25	0.018	0.162	
Shizuoka	Shimoda onsen binary	2017	1	B	0.11	0.052	0.453	
Oita	Kuju Noya-chiku binary	2017	1	B	0.0495	0.039	0.339	
Oita	Hot Lagoon Oita GPP	2017	1	B	0.072	0.011	0.096	
Oita	OTE Oita Okue onsen binary	2017	1	B	0.072	0.026	0.226	
Kagoshima	Yamakawa Binary	2017	1	B	4.99	[3.493]*	[30.620]*	
Oita	others	2015-2017	10	B	1.467	[0.525]**	[4.602]**	
Miyagi	Naruko onsen binary	2018	1	B	0.065			
Oita	Dual energy, Beppu Tsurumi, Sanko Chinetsu	2018	3	B	Planned to start operation in 2018, but operation not confirmed as of June 2019.			0.572
Kagoshima	Iwatech No.1 Onsen PP	2018	1	B	0.0125			
Akita	Wasabizawa	2019	1	2F	46.199			
Iwate	Matsuo-Hachimantai	2019	1	1F	7.499			
Hokkaido	Minami-Kayabe	2022	1	B				6.5
Iwate	Appi	2024	1					15
Akita	Katatsumuri-yama	2024	1					15
Akita	Shitanotai-Kijiyama	?						[15]
Official Total [Estimated]			82		553.959	275.06 [280.18]	2409.5 [2454.4]	37.072 [52.072]

NOTES:

Installed capacity is the maximum gross output of the plant; running capacity is the actual gross being produced.

N: temporally non-operation

For a power plant for which the only installed capacity is shown in TNPEs (2018), the estimated values are shown in [bracket]. Such estimated values are not included in the Official Total. Estimations were done as follows:

* no data in TNPEs (2018); estimated with a capacity factor of 70%, which is the actual value of Takigami BP opened at a similar time and scale.

**no data in TNPEs (2018); estimated from an average capacity factor of 36% of the other small binary GPP less than 1MW.

3. DIRECT USE

3.1 Conventional Direct Use

No reliable data on conventional direct use exist because no census has been done since 2012. Almost all projects of hot spring water usage are managed by private enterprises in various areas in Japan. It is difficult to get statistical data regarding water temperature, discharge rate, the annual number of products, etc. Several new facilities have been installed supported by the government's subsidies for promoting geothermal energy use in these years, but none of them has a dominant capacity. At the meantime, several old facilities must have been closed but not reported. On the other hand, still, the majority of the direct use in Japan is bathing, for which some sort of data exists. Therefore, combining the recent data for bathing and old data for other direct use facilities obtained in 2012, the number of direct use is calculated, as shown in Table 4. Note that it is impossible to make a table showing locality, facility type, flow rate, and temperature of individual systems. Table 4 is the best effort with the available data.

The three major usage of hot spring water are, "Greenhouse farming" (to cultivate vegetables, mushrooms, fruits, and flowers), "Onshore fish farming" (to breed fish), and "Other usage" (heating of hotels, office buildings, and roads; cooking vegetables, eggs, and meats; and food drying). A typical example of Greenhouse farming is to cultivate the tropical fruit mango in a very cold area in east Hokkaido (The brand name is "Sunset of Lake Mashu"). The cultivation of tomato and Cucumber in the cold area of Mori town in southern Hokkaido is another common example. Other typical examples of onshore farming are to breed tilapia in the cold area in east Hokkaido, shrimp in Fukushima Prefecture, and tiger puffer in Tochigi prefecture. Typical examples of "Other usage" are hotel building heating in Beppu in Oita prefecture, road heating in front of hot spring hotels in Niigata prefecture, cooking vegetables, eggs, and others in a steam box in the Kagoshima prefecture, and in the drying facility of vegetables in the Akita prefecture.

Table 4: Direct use in Japan

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr = 10^{12} J/yr)	Capacity Factor
Individual Space Heating	91.97	2,467.32	85.0 %
District Heating ¹⁾	111.37	1,669.51	47.5 %
Air Conditioning (Cooling)	-	-	-
Greenhouse Heating	24.71	267.19	34.3 %
Fish Farming	7.61	123.10	51.3 %
Animal Farming	0.36	3.41	30.0 %
Agricultural Drying	6.02	76.73	40.4 %
Industrial Process Heat ²⁾	1.06	27.02	80.8 %
Snow Melting	150.17	431.98	9.1 %
Bathing and Swimming ³⁾	1,999.42*	24,591.00*	39.0 %*
Other Uses (cooking, etc.) ⁴⁾	14.69	301.11	65.0 %
Subtotal	2,407.38	29,958.37	39.4 %
Geothermal Heat Pumps	163.44**	764.90**	14.8 %
TOTAL	2,570.82	30,723.27	37.9 %

Data source: [no mark] NEF (2012), [*] Kurasaka (2018), [**] MOE (2019)

- 1) Sum of the buildings for tourism, hospitals, welfare, and government. It may partially include a hot water supply for swimming pools.
- 2) Sum of industrial processes and food processes.
- 3) Data for bathing (swimming is partially included in District Heating). Installed Capacity is calculated from "Energy used" and "Capacity factor (no data for Installed Capacity).
- 4) Not specified in the original data. It may include Air Conditioning (Cooling) which is not categorized in the data source.

3.2 Ground Source Heat Pump (GSHP)

The installation of GSHP in Japan has been exponentially increasing, although the total number is still rather small. MOE published the statistics of GSHP systems in 2019 (MOE, 2019). It contains the statistical data of closed and open-loop systems from 1981 to 2017, but no information about individual systems. Therefore, it is not possible to make a table showing locality, groundwater, and temperature of the systems. Figure 3 is the best effort with the available data.

The total number of facilities using GSHPs is 2,662, including 2,314 closed-loop, 327 open-loop, and 21 using both. The installed capacity of all the GSHPs is 163 MWt, and the annual energy use of 765 TJ/yr. It is a large increase from the last report in WGC2015, which was 990 in the total number of installed capacity of 62 MWt (Yasukawa and Sasada, 2015), showing a double or triple increase in 5 years. Many systems have been installed in the northern districts, including Hokkaido. This indicates the economic predominance of GSHPs when they replace an old oil boiler by a new GSHP. Figure 3 shows the cumulative number of GSHP systems in different categories of facilities (MOE, 2019). The largest share is individual houses (44%), followed by offices (12%), and public buildings (7.5%).

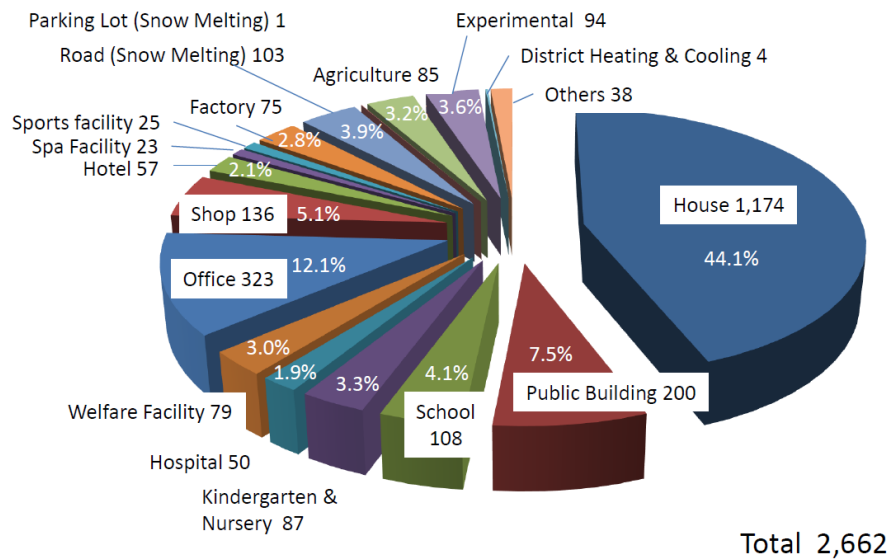


Figure 3: The cumulative number of facilities using GSHP system (MOE, 2019).

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