A review of small-scale geothermal power plants in Japan and its opportunities for New Zealand's geothermal business

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Keywords: *Japan, Onsen, small-scale geothermal power plant, direct use*

ABSTRACT

The word 'Onsen' can be found in the oldest Japanese historical documents called 'Kojiki' written in the early 700s. As of the end of March 2019, there are 27,421 Onsen hot spring wells all over Japan. Historically, Japanese people have used these hot springs for bathing, and this is associated with tourism and in many cases, they are used for medical purposes. These historical Onsen are specifically defined by Japanese law in the Hot Spring Act 1948 and these hot springs are subject to protection. Today, 87% of direct use cases of geothermal energy are for those Onsen while its use has also diversified to a variety of purposes such as greenhouses for horticulture, aquaculture to grow not only prawns but also eels, tilapia, softshell turtles, tiger puffer and sturgeon at different locations. In recent years, hot spring water has also been used to generate electricity and there are 60 such power plants in Japan. All of them are less than 2 MW installed capacity and most of them were built after 2011 when the Japanese government introduced the Feed-In Tariff system.

What does this mean for New Zealand's geothermal businesses? There may be hints for the direct use of geothermal energy in New Zealand since in the Japanese case use is unique, very diversified and the number of those direct uses is greater. The author is very confident that Japan and New Zealand can fruitfully collaborate in this area in terms of direct investment. Indeed, The author is very positive for this and it is a chance for New Zealand business to expect some return and trade benefits. We can also sell our advanced New Zealand technologies and services in Japan such as subsurface analysis and any other hot-spring-related services.

In this paper, we want to share some hints for New Zealand businesses wishing to work in Japan and identify any possible opportunities for New Zealand businesses to work in Japan.

1. INTRODUCTION

Twenty years ago, the World Geothermal Congress Kyushu-Tohoku was held in Japan. In Kyushu, which is located in the southwestern part of Japan, it was held in Beppu City, Oita Prefecture and I have heard that many New Zealand scientists participated. Beppu City is located in a position where the Beppu Shimabara Rift Valley is wide open, facing the sea that continues from the Pacific Ocean. In New Zealand, it is similar to a city like Tauranga facing the Pacific Ocean at the opening of the Taupo Volcanic Zone. Beppu's famous tourist attraction, which is one of the most famous tourist spots in the world, is, of course, the hot springs, which have 282 lodging facilities as of March 2018. Also, there are 2,291 hot springs in the city and the number of households in Beppu City is 61,931, which means that one out of every 27 households has a hot spring.

New Zealand Trade & Enterprise (NZTE hereinafter) held an event entitled Powering Up Geothermal for business persons in Beppu City, Oita Prefecture. The event was held at the Suginoi Hotel, which has a 1.9 MW flash capacity geothermal power generation facility and it is thought that about half of the electricity in the facility is provided by geothermal power generation. There are many such relatively small-scale geothermal power plants, with various operational formats, such as the Flash method and the Binary method. In this paper, I would like to clarify the trends of small-scale geothermal power plants in Japan and consider their potential impact on business in New Zealand.

1.1 Powering up: Renewable energy networking reception

NZTE offers New Zealand companies the opportunity to promote their businesses in Japan. Every year in February, a seminar called the New Zealand Geothermal Symposium is held. These seminars attract many business persons from among the members of the Geothermal Power Generation & Direct Heat Use study group, Geospace Engineering Center, ENAA Engineering Advancement Association and the Japan Geothermal Association. We offer networking opportunities for participants from both Japan and New Zealand.

In 2019, the Rugby World Cup was held in Japan and one of the matches was played at a stadium in Oita Prefecture, while a similar event was held in Beppu City because it is nearby and also a sister city to New Zealand's Rotorua. Four companies from New Zealand participated in the event and 50 people from Japan as attended the seminar. At lunchtime, about 150 participants took part in networking as this event was held in partnership with the Ministry of Foreign Affairs and Trade.

2. GEOTHERMAL POWER GENERATION AS ONE OF THE RENEWABLE ENERGY SOURCES IN JAPAN

In Japan, renewable energy is defined as energy that uses permanently available energy sources other than fossil fuels. Typical renewable energy sources include solar power, wind power, hydropower, geothermal power and biomass. Table 1 shows the trends in the proportion of renewable energy in Japan's total power generation and notes that the proportion of photovoltaic power generation has been increasing in recent years. Among these sources, geothermal power generation accounts for only 0.2% of the total power generation (see Table 1), but expectations are growing as an energy source that takes advantage of Japan's natural conditions of being home to many volcanoes.

ISSN 2703-4275

Geothermal power generation has a significantly lower CO_2 emission rate than fossil fuel power generation (see Fig. 1) and is a clean energy that is also effective as a measure to reduce global warming. Furthermore, compared to other renewable energy sources (solar, wind power, etc.), it is characterised by high stability of availability and low power generation costs (see Table 2), so it can be expected to be used as a baseload power supply. In Japan, geothermal power generation methods are roughly categorised into two definitions: the 'flash method' and the 'binary method'. A geothermal power plant with the "Flash method" takes high-pressure hot water from deep inside the earth and convert it to steam to drive generator turbines, while a plant with the "binary method" or a binary cycle power plant transfer the heat from geothermal hot water to another liquid. The heat causes the second liquid to turn to steam, which is used to drive a generator turbine. In the flash method, geothermal fluid is separated from high-temperature steam and hot water and the turbine rotates to generate electricity. In the binary method, relatively low-temperature hot water such as hot spring water is used as a heat source to heat and evaporate intervening substance with a low boiling point. The Japan Geothermal Association is proud that Japanese manufacturers have developed the manufacturing technology for geothermal power generation equipment from an early stage and have led the world in this regard. Geothermal power generation turbines, which can be said to be the heart of a geothermal power plant, are made by three Japanese manufacturers (Toshiba Corporation, Fuji Electric Co., Ltd., MHPS-Mitsubishi Hitachi Power Systems), which account for nearly 70% of the global market share (Bertani, 2015). Ormat, which has a 10% global share in binary power generation, was acquired by a Japanese company, Orix in 2017. Orix owns 27% of Ormat. Since the global share is small., it does not appear in such statistics, but Kobe Steel Ltd., Several Japanese heavy machinery manufacturers such as Kawasaki Heavy Industry and IHI manufacture various types of binary turbines and are competing for their share of business in Japan.

In Japan, hot water, after being actively used for power generation, can be used for multiple purposes not only in hot spring facilities but also in greenhouse cultivation and aquaculture projects, which also contributes to the promotion of local production and efficient consumption of energy. The Agency for Natural Resources and Energy, as part of Japanese Ministry of Economy, Trade and Industry (METI) is also working to promote the introduction of the geothermal power generation system by 2030 to increase the installed capacity of geothermal power generation to three times the current level (from the current 500 MWe into 1,500 MWe) by funding exploration and development of new geothermal development subsidizing up to three fourth of the entire cost. The ministry also offers risk money to invest in new geothermal power plant entities to hedge new developers risks. The budget plan for geothermal power generation in 2019 was about 23 billion yen (approx. NZD$ 330 million). Those budgets are distributed to and funded by several government organizations such as METI's regional branches, JOGMEC (Japan Oil, Gas and Metals National Corporation), NEDO (National Institute for New Energy and Industrial Technology Development), etc. the power generation business support is being promoted.

In this way, against the backdrop of the support measures of the Japanese government, companies other than those engaged in producing electric power, such as oil companies, mining companies, construction companies, trading companies, property companies and financial service companies have also started to work in the geothermal power generation business.

Table 1: Changes in the ratio of renewable energy to total power generation in Japan

Power Source	2014	2015	2016	2017
Hydro	8.0%	8.6%	7.6%	7.6%
Biomass	1.5%	1.5%	1.9%	1.5%
Geothermal	0.2%	0.2%	0.2%	0.2%
Wind	0.5%	0.5%	0.5%	0.6%
Solar PV	1.9%	3.0%	4.4%	5.7%
Renewable Energy Total	**12.1%**	**13.8%**	**14.7%**	**15.6%**

Table 2: Estimated results of power generation costs using the 2014 model plant

Power Source	Hydro	Geothermal	Wind	Small Hydro	Biomass	Solar PV
NZD$/kWh	0.16	0.24	0.30	0.33 – 0.38	0.18 - 0.42	0.42

Exchange rate: NZD$ 1 = JPY 70

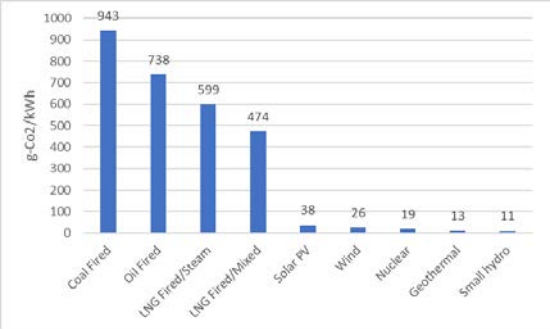

Figure 1: Life cycle CO_2 emissions by power source

3. GEOTHERMAL HEAT DIRECT USE AND BINARY POWER GENERATION IN JAPAN

Japan's geothermal resource is 23 million kW, the third-largest in the world. At the end of 2018, the installed power generation was about 554,630 kW, making it the eighth largest in the world. There are 20 power stations with an installed capacity of 1,000kw or more and the total output is 503,915kW.

The rest are power generation facilities of less than 1,000 kW and as of the end of March 2018, there are 61 units of such power generation facilities in 45 power plants throughout Japan. These are owned by, for example, Geothermal World Industrial Co., Ltd. located in Beppu City, Oita Prefecture and have the smallest facility of just above 10 kW at the Kamenoi Hotel. Currently, this type of power generation method has the largest increase in the overall industry and five new power stations went online during 2018.

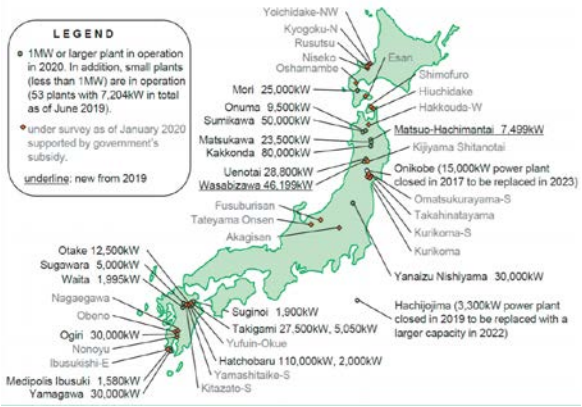

Figure 2: Geothermal Power Plants and ongoing survey projects as of January 2020 (Source: The Geothermal Researchers Society of Japan)

3.2 JOGMEC's efforts

As mentioned above, the Government of Japan and the Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry are working to promote the increase of geothermal power generation by 2030 to increase the installed capacity of geothermal power generation to three times the current level based on the long-term energy supply and demand outlook. JOGMEC, which uses a sizeable budget to promote geothermal development, is investing a large amount of subsidy in large-scale geothermal power development to promote the development of large-scale geothermal power plants to achieve this goal. On the other hand, in 2015, it commissioned ENAA to create the 'Small-scale Geothermal Power Plant Design Guidelines'.

The purpose of JOGMEC is to have the following four objectives.

1) Further effective utilisation of precious hot spring resources

2) Realise a power generation business that coexists with the region

3) Smooth operational start according to the construction plan

4) Reduction of initial and ongoing operating costs

The 'Small-scale Geothermal Power Plant Design Guideline' is open to the public and the trustee ENAA goes to METI, local governments, hot spring associations, etc. all over the country to carry out educational activities.

3.3 Geothermal potential suitable for small-scale geothermal power generation

Figure 2 shows the density distribution of domestic geothermal resources above 53°C. It is widely distributed in eastern Japan in locations such as Hokkaido, Tohoku, Kanto, Chubu, and Hokuriku regions.

It is said that the average geothermal gradient excluding volcanic areas in Japan is 0.025°C–0.03°C /m and the annual average temperature on the surface is 15°C, even if the geothermal gradient of 0.025°C/m is 65 at a depth of 2,000 m. At a depth of 3,000 m, it reaches 90°C. If power can be generated even in the so-called low-temperature geothermal temperature range of 50°C to 120°C, the areas where geothermal resources can be used will further expand.

Therefore, in regions that have not been considered geothermal areas so far and in areas where there is little impact on extant regulations, such as natural parks and existing hot springs, if low-temperature geothermal heat of 120°C or lower can be used, then only global warming countermeasures can be taken. Not only that, but it can also contribute to the stable supply of energy.

Although it does not apply to all regions nationwide, if hot springs of 50°C to 120°C are available, the amount of resources available for small-scale power generation is estimated to be 8,330 MW which is a huge resource.

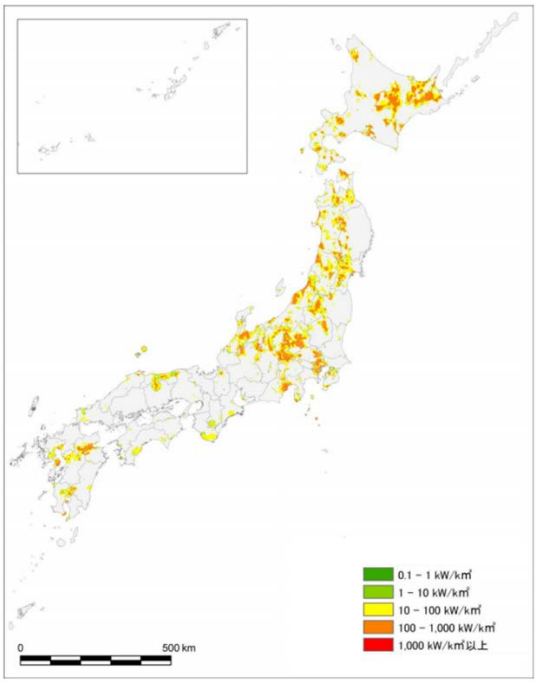

Figure 3: Distribution Map showing Potential for Introduction of Hydrothermal Resource Development (53 to 120°C)

3.3 Case studies of geothermal direct heat uses in Japan

It may be argued that the effective utilisation of hot spring heat is not necessarily advanced in comparison with the high potential of geothermal utilisation. In this field, the Japanese Ministry of the Environment has developed and published guidelines, pamphlets, casebooks, etc. to promote the effective use of hot spring heat. Even in such a small number, there are many new cases compared to New Zealand, so I would like to introduce them all here.

3.3.1 Greenhouse cultivation

Okuhida Farm cultivates bananas and other greenhouse produce using hot spring water on land at an altitude of 800 m. Here hot water from a simple hot spring with an average temperature of 65°C is made to flow through the waterways in the greenhouse to adjust the temperature and humidity (the amount of hot water flows at the rate of about 25 L/min). The farm sells banana seedlings and seeds rather than bananas. It is difficult to secure business viability when selling bananas. It is more profitable to sell banana seedlings for ornamental use. The farm also sells palm seedlings and seeds, cacao trees and seedlings and plans to sell green nut oil. The feasibility is secured and the business is expanding in the future.

Adonis Co., Ltd. also cultivates shiitake mushrooms in greenhouses in the Hotta Onsen district of Beppu City. It was constructed with a subsidy from the Ministry of Economy, Trade and Industry's Geothermal Development Understanding Promotion Project. Such cases are spreading all over the country.

3.3.2 Soil disinfection with steam

At the Oita Flower Center, not only is steam used for heating, but it is also used for disinfection of test and research fields. It is a method by which steam is directed to the target field with a fire hose, an iron pipe with a hole is buried in the field and steam is used to sterilise it. The centre also disinfects soil and materials from farmers in the prefecture free of charge.

3.3.3 Aquaculture in the geothermal field

The cultivation of the giant shrimp prawns by Fukushima prefecture's *Genki Up Tsuchiyu* is a relatively well-known example in the Japanese industry. *Genki Up Tsuchiyu Co., Ltd.* uses the aquaculture facility constructed with the subsidy of the 2016 geothermal development understanding promotion project. Shrimp are cultivated by secondary use of hot water (hot spring water and cooling water) after binary power generation. There is also a service that allows mature shrimp to be put in a simply constructed fishing pond so that tourists can enjoy fishing and grill them on the spot. This seems to be a great reference to Huka Prawn Park in New Zealand.

3.3.4 Air conditioning

At *Kurodaya*, a Kan'nawa Onsen located in Beppu City, Oita Prefecture, hot spring water is used to heat and cool the inside of the inn.

It was installed with a subsidy for the geothermal development understanding promotion project in 2014. The *Kurodaya*'s absorption chiller-heater is a cooling and heating facility that enables not only heating using hot water but also cooling using the heat of vaporisation when water evaporates.

4. CONCLUSION

As argued above, Japan is far from reaching the national goal of increasing the installed capacity of geothermal power generation to three times the current level by 2030 and further measures and efforts are needed. However, the number of small-scale geothermal power generation facilities is increasing and the number of cases of geothermal direct heat use is progressing. Other than importing turbines, there are also cases that New Zealand can refer to.

Geothermal power generation in Japan is still developing, even with a mature economy and there is a strong possibility of further expansion. New Zealand should actively participate in such development and Japan welcomes the New Zealand entry to the geothermal industry as mentioned above.

Geothermal development takes time. There are good times and bad times. Through the continuous involvement of both countries, both people and things should flourish. We believe that this will also enable us to maintain our technical capabilities. We hope that many businesses in New Zealand and Japan will be actively involved. Especially, as Japanese agricultural market is huge as big as NZ$ 130 billion in 2018 (MAFF, 2020), geothermal can play significant role to support those growing big businesses leveraging with greenhouse, soil disinfection, and aquaculture, and you can be a part of those big business as well.

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ISSN 2703-4275