FROST & SULLIVAN

# JAPAN ONSEN POWER

## New Horizons for Clean Power Generation from Low Temperature Geothermal Energy

A Frost & Sullivan Whitepaper

# TABLE OF CONTENTS

# EXECUTIVE SUMMARY

1

Japan's energy policies have faced unprecedented changes following the 2011 Great East Japan earthquake and subsequent Fukushima nuclear disaster which saw the shutdown of 54 nuclear reactors in the country. As a result, since 2011, the country has become largely dependent on imported coal, natural gas, and oil to satisfy its energy demands. Given the fact that Japan has extremely limited domestic fuel resources, the development of renewable power was earmarked as a key initiative to reach the country's self-sufficiency goals. In support of this, the Ministry of Economy, Trade and Industry (METI) devised a strategic plan in 2014 where it outlined the "3Es" for the energy industry; namely, energy security, environment mitigation, and economic efficiency. METI has furthermore rolled out the "Best Energy Mix plan in 2030" which aims to reduce greenhouse gas (GHG) emissions by 26% by 2020 and increase the share of renewable energy over 20% by 2030. This is an ambitious target which is expected to drive growth in renewable power in the coming years.

Currently, renewable power accounts for 15% of total electricity generation in Japan. Together hydro and solar power contributes 12% due to attractive subsides provided by the government for these technologies. Geothermal, on the other hand, only contributes a meagre 0.3% of total electricity generation, despite the country possessing the third largest geothermal resource in the world. Leveraging the potential for this technology represents a promising energy source to help achieve the country's power security and emission reduction goals.

Although total geothermal energy potential in Japan is 23 GW, current geothermal installed capacity is only 523 MW, a mere 2% of its total potential. While the government has been proactive in recent initiatives to identify potential areas for exploration and support the education of local residents and businesses, there has not been any significant development of geothermal power in the country in the last decade. Japan's ineffectiveness to take advantage of its geothermal resources can be largely attributed to: (i) a lack of government incentives ii) stringent regulations to protect national parks where 80% of the high and medium temperature geothermal reserves are located (iii) negative social perception around geothermal generation affecting the quality of hot springs.

However, despite the stagnation of geothermal power development, increased investment and technological innovation targeting low temperature geothermal power, historically used primarily for heating purposes, are expected to significantly increase the addressable market potential for these technologies and represent a new growth market in the country. Historic geothermal power developers and equipment providers have not given much attention to low-temperature geothermal heat <120°C in the past, as plant output is typically much smaller than medium to high-temperature plants and the efficiencies achieved with existing technologies at low temperatures (<100°C) is too low, in the range of 4-6%. This, combined with proportionately high capital costs, has led to low temperature geothermal power being seen as economically unfeasible for many projects.

However, technological innovations, decreasing costs and, doubling efficiencies at these low temperatures are expected to accelerate the broad based adoption of the technology. This, combined with multi-application benefits for hot spring owners, attractive feed-in-tariffs and grant financing offered by government, relaxation of development restrictions in national parks, lack of environmental assessment requirements, and improved cooperation at the community level is expected to set up low temperature geothermal power as a potential game changer in the exploitation of the country's geothermal potential, providing access to a market potential of 7.5 GW from 28,000 hot springs.

Frost & Sullivan expects the development of the low temperature geothermal industry in Japan to represent a significant contributing step in the establishment of a stable, low emission power industry in the country.

# TECHNOLOGY DEFINITION

2

Traditionally, geothermal technology refers to the production of electricity from high temperature sources above 300°C, and is typically found in high tectonic activity areas such as volcanic belts. Low temperature geothermal technology refers to the utilisation of resources below 120°C to generate electricity, usually through the use of a secondary fluid. The energy obtained from low temperature geothermal sources can be used for a myriad of applications including spas, animal husbandry, cold storage, drying of agricultural products, space heating, and power generation among many others. These renewable resources are capable of generating baseload power 24 hours a day.

Table 1 gives an overview of geothermal resource temperature ranges and the primary applications for each.

Table 1: Geothermal Resource Qualification, 2016

| Resource Type | Depth (in meter) | Temperature | Application |
|---|---|---|---|
| Very low enthalpy | <1000 | 0-30°C | Heating |
| Low enthalpy | 1000-3000 | 50-120°C | Heating & Electricity |
| Medium enthalpy | 500-1500 | 120-150°C | Electricity |
| High enthalpy | 500-1500 | 150-350°C | Electricity |
| Deep geothermal energy | > 3000 | >200°C | Electricity |

*Source: Electrical Research Institute (IEE); Frost & Sullivan*

# OVERVIEW OF THE CURRENT STATE AND STRUCTURE OF THE JAPANESE POWER MARKET

3

Resource-poor Japan relies on imported fuel for 94% of its primary energy supply. Following the Fukushima nuclear disaster in 2011, the country had to decommission 54 nuclear reactors. The resulting high dependence on fossil fuel imports led to a rapid diversification of the country's generation mix, particularly into renewable power, in order to maintain energy security, prevent cost inflation, and honour commitments to emission reductions.

Driven by the Action Plan for a Low Carbon Society constructed by 35 electricity utility companies across the country, Japan is investing heavily in hydroelectric, geothermal, photovoltaic, wind and biomass energy in order to meet emission targets set by the Japanese government under the Intended Nationally Determined Contribution (INDC) following the adoption of the Paris Agreement at COP21 in 2015.

According to 2016 data published by the Federation of Electric Power Companies of Japan, fossil fuels dominated electricity production for the year, contributing 84.6% of generated electricity (31.6% from coal, 44% from LNG and 9% from oil, liquefied petroleum gas (LPG) and other gas). 1.1% was contributed from nuclear sources, 9.6% from hydroelectric sources, and only 4.7% from other renewable sources.

However, the target set by METI to increase the renewable power share of generation from 11-12% in 2016 to 22-24% by 2030 (amounting to annual generation of approximately 250 TWh) is a step in the right direction. In support of this, METI has set a mandate for electricity retailers to procure 44% or more electricity from generators using non-fossil fuel sources to encourage the use of renewable energy.

## Chart 1: Japan Electricity Generation by Technology, 2016

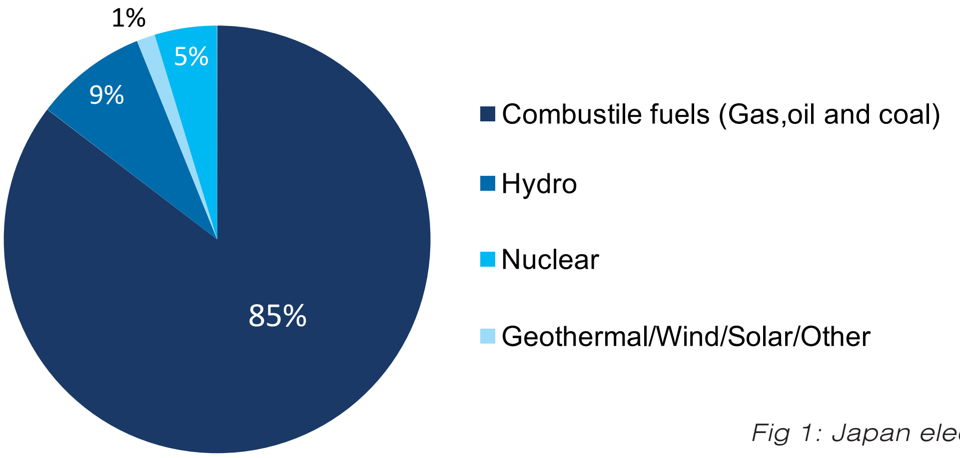
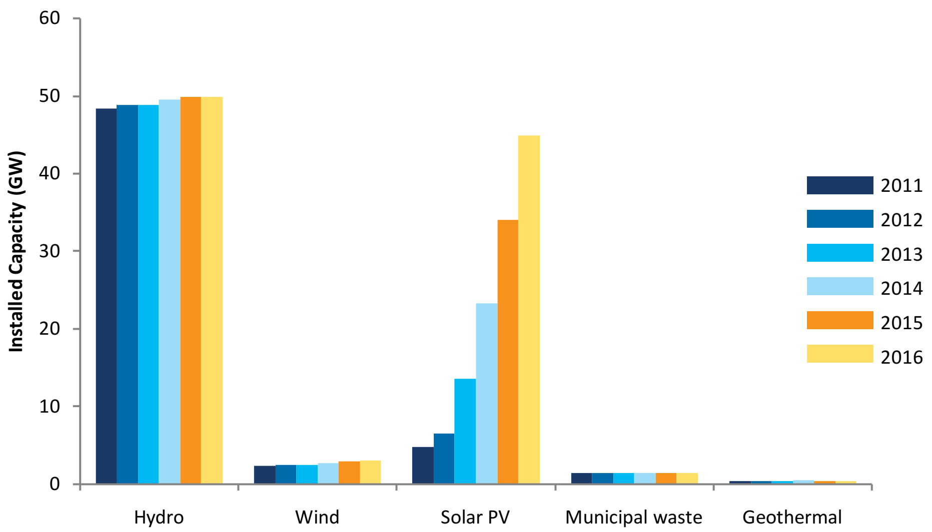



*Fig 1: Japan electric mix Source: International Energy Agency (FY2016)*

As part of this development programme, the government has set a target for the development of 1 GW of geothermal power by 2020, an approximate doubling of the existing 2016 capacity. Driving this development, and the development of the renewable power sector as a whole, is the "Act on Purchase of Renewable Energy Sourced Electricity by Electric Utilities" which establishes a FiT scheme introduced in 2012 for renewable power technologies.

Since the introduction of the policy, investments have been predominantly targeted toward solar PV, as investors felt the technology was a safer bet given its maturity, faster development times, rapidly declining costs, and attractive feed-in tariffs (42 JPY/kWh for <10kW projects and 40 JPY/kWh for >10 kW projects). Consequently, solar PV has dominated renewable energy growth in the country since feed-in-tariff inception.

## Chart 2: Japan's Renewable Energy Generation Capacity




*Source: IEA and Frost & Sullivan*

Despite significant geothermal reserves, geothermal power has not shown significant growth in the country, primarily due to the high upfront costs and strong opposition from the hot spring industry on economic and environmental grounds. Large-scale geothermal projects in particular, subjected to arduous environmental assessment requirements, have seen limited investment opportunities resulting in a decreasing trend in project development. However, small scale, low temperature geothermal power is expected to represent a future growth market, due to: attractive FiTs of 42 JPY/kWh, significant low temperature geothermal resources; technological advancements able to achieve higher efficiencies from resources below 120°C, no environmental impact assessment (EIA) requirements, relaxation of development restrictions in national parks; government finance support, and multi-application benefits to onsen owners in heating and electricity production.

Table 2: Feed-in-tariff for geothermal power

| Electricity generated | Large Scale (More than 15,000 kW) | Small Scale (Under 15,000 kW) |
|---|---|---|
| Procurement price | 27.3 JPY/kWh | 42 JPY/kWh |
| Eligibility period | 15 years | 15 years |

*Source: Ministry of Economy, Trade and Industry and Frost & Sullivan*

# POTENTIAL FOR LOW TEMPERATURE GEOTHERMAL ENERGY IN JAPAN

4

There are approximately 28,000 hot springs throughout the country which are potential sites for low temperature geothermal energy, with major hotspots found in the hilly regions of East Japan and Hokkaido prefecture. These hot-springs release a cumulative 3 million litres of hot spring water every minute that can be tapped for electricity generation or direct use.

However, 80% of these resources lie in areas designated as national parks, where exploration and development have been restricted by the Ministry of Environment. These restrictions have historically largely blocked the development of the market as a whole. While these regulations were relaxed by the Ministry of Environment in March 2012, significantly increasing the available sites for project development, high upfront costs and strong opposition from the hot spring industry due to the perceived risk to the balneological value of the country's hot springs have led to a slow uptake of low-to-medium temperature geothermal projects in the country to date.

However, recent technological advancements have made it possible to generate electricity from low temperature geothermal resources below 120°C, traditionally exploited primarily for heating purposes due to low conversion efficiencies of existing technologies for power generation. This has expanded the potential geothermal sites available for electricity production and simultaneously decreased the environmental impact risk for onsen owners. Furthermore, at hot springs, these technologies are able to utilise geothermal heat to generate electricity before transferring the heat to the spa water.

Presently, onsen operators often have to cool the water for it to be suitable for bathing; however, these technologies allow cooling of the onsen water while simultaneously producing electricity, maximising the value of the stored heat. This creates a win-win situation for power producers and onsen owners. Such advancements have the potential to contribute greatly to domestic electricity generation in the country by significantly increasing the untapped generation potential of hot springs.

Frost & Sullivan estimates that using these technologies, there is an existing market potential of up to 7.5 GW of low temperature (<120°C) geothermal power in the country. In addition to this geothermal potential from hot-springs, there are also a large number of unused geothermal reservoirs in oil and gas prospecting wells or old geothermal wells in Japan. These reservoirs are no longer in production and can be targeted for low temperature geothermal power development.

## Low Temperature Geothermal Technology Overview

Conventional technologies available to the market for converting low and medium temperature geothermal resources for power generation involves a binary cycle and Organic Rankine Cycle (ORC) technology which employs an appropriate thermal medium as the working fluid according to the hot water temperature. A single binary unit has a capacity range from 1 kW to several MW. The existing manufacturers of ORCs have not given much attention to low-temperature heat because plant output is typically much smaller than medium to high-temperature plants but the costs have still been fairly high. For conventional binary power cycle plants, efficiencies achieved at low temperatures (<100°C) is low, in the range of 4-6%. Due to low output efficiencies and high maintenance costs, partly resulting from the technology operating at high pressure levels, it has not been considered as economically feasible to pursue such projects.

A 50 KW class Kalina cycle power generation system was field tested at Matsunoyama hot spring field in Niigata Prefecture. Kalina cycle, a type of binary power cycle, uses ammonia-water as the working fluid. However, the technology can only convert geothermal heat as low as 90°C, and has high capital costs and complexity compared to standard ORC technology. This acts as a roadblock for widespread adoption.

In order to allow for broad based adoption of low temperature geothermal power generation in Japan, there is need for technology improvements and innovation beyond these technologies to harness lower temperature heat, below 120°C, at higher efficiency and with greater economic feasibility. An example of such technological innovation is Climeon's Heat Power System.

Climeon's Heat Power system represents an economically feasible solution to utilise low temperature waste heat while achieving efficiencies up to double that of conventional binary power cycle technology. In the past, low temperature geothermal resources in the range 70-120°C have mainly been exploited for heating purposes due to the low conversion efficiencies of Organic Rankine Cycle systems at these temperatures. The current methods of converting low temperature heat below 120°C to generate electricity, such as the Organic Rankine cycle and the Kalina cycle, show low efficiencies due to large energy losses, limiting the economic viability of projects. However, Climeon's Heat Power system provides possibilities for higher efficiencies in electricity generation at these temperatures owing to their patented condensation solution and low pressure technology. Due to low operating pressure, internal energy consumption can be decreased by 90% compared to traditional ORC systems. The result is a simpler solution that makes it economically viable to produce electricity from low temperature sources starting from below 120 °C. Climeon's solution works at a low pressure of 2.5 bar making it a compact and scalable offering from 150 kW modules up to 50 MW large scale systems.

The trend of increasing low temperature geothermal project adoption in the country is evident in the renewed interest in project investment by both local and international companies. For example, Chuo Electric Power Co. collaborated with local residents at Oguni hot spring resort in Kumamoto Prefecture, Japan, to develop the first small scale geothermal plant in a decade in 2014 with a maximum output of 2 MW. These projects assist in mitigating the concerns of onsen owners regarding deeper well drilling or impacts on the quality of spring water (both of which show zero impact). Since the commissioning of this project, there have been close to 7 projects that have been in various planning stages across Japan. Low temperature geothermal has the potential to offer hot spring owners the ability to generate their own electricity through such collaborations. Currently, however, there are only a handful of low temperature geothermal projects, with major projects developed by Chuo Electric, Idemitsu Kosan and Orix, and the total added capacity of low temperature projects for 2012-2016 was only 5.5 MW. Therefore, while significant potential exists for the technology, the market in Japan is still in the nascent stage, predominantly due to technical and approval issues in project development. The lack of understanding of the benefits of the technology has been a major obstacle to get prefectural approval where hot spring owners feared the deterioration of water volume and quality. However, development is gaining momentum as more project test cases, such as the Chuo Electric project, are commissioned in collaboration with local residents, increasing end-user trust in the reliability and net benefits of the technology.

# JAPAN'S GEOTHERMAL RESOURCES

5

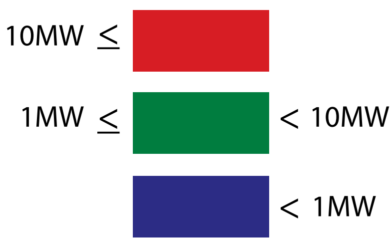
The following chart represents a breakdown of the geothermal resources in Japan made available following the relaxing of national park exploration restrictions by the Ministry of Environment in 2012.

As per the latest data obtained in 2014, around 44 prospects are currently under exploration or development. Out of which, 19 prospects have over 10 MW potential, seven prospects from 1 to 10 MW, and 18 prospects less than 1 MW. A total of 7 small binary projects (0.003 to 2 MW) were commissioned in 2013 and 2014.

The potential for geothermal exploration of all the identified sites is a cumulative 8.8 GW. Of this, small scale, low temperature geothermal projects showed the highest potential. A summary of the applicable zones for small scale, low temperature projects can be seen below.

National park special zones II and III represent zones where small scale geothermal development have exclusive rights to development with a total potential of 7.7 GW. These are expected to represent key regions for low temperature geothermal development moving forward.

## Chart 3: Map representing potential geothermal energy generation sites for exploration


### CURRENT PROJECTS

(Explorations, evaluations and installations)

- 19 prospects over 10MW
- 7 prospects 1MW-10MW
- 18 prospects less than 1MW
  (as of July 2014)

The potential for geothermal exploration of all the identified sites is a cumulative 8.8 GW. Of this, small scale, low temperature geothermal projects showed the highest potential. A summary of the applicable zones for small scale, low temperature projects can be seen below.

### Table 3: Potential developable sites and updated regulations for geothermal energy exploration

| Geothermal reserve zones | Potential sites | Before 2012 vregulations | After 2012 regulations | Potential (MW) |
|---|---|---|---|---|
| National parks Class 1 special zone | 11 sites | Surface survey and development is forbidden | No development is allowed but surface surveys are permitted | 2,600 |
| National parks Class 2 and 3 special zone | 11 and 22 sites | Surface survey and development is forbidden. | Only small scale development may be permitted provided it has environmental considerations | 7,700 |
| National parks Ordinary Zones | 5 sites | Development is not permitted however small scale development may be permitted provided it has environmental considerations | Both large and small scale development is admitted | 1,100 |

*Source: Frost & Sullivan*

National park special zones II and III represent zones where small scale geothermal projects have exclusive rights to development. These zones have a combined geothermal power potential of 7.7GW and represent key regions for low temperature geothermal development moving forward.

# DRIVERS AND RESTRAINTS TO LOW TEMPERATURE GEOTHERMAL POWER

6

Table 4: Summary of Market Drivers and Restraints for Low Temperature Geothermal Power

## MARKET DRIVERS

### FiTs and no environmental assessments requirements for small scale geothermal

Renewable feed-in tariffs (FiTs) established in 2012 are expected to represent the primary driver to future low temperature geothermal power development. Small scale (including low temperature) geothermal projects (<15 MW) benefit from a FiT of 42 JPY/kWh ($0.37/KW) for 15 years, significantly higher than the tariff offered for large scale projects (>15 MW) of 27.3 JPY/kWh ($0.24/kWh). These are also 25% higher than the FiT offered for solar PV and is the second highest tariff offered in the country for renewable power outside of small scale wind. Furthermore, unlike FiTs for other renewable technologies, such as solar PV which has been declining since 2012, the FiT for small scale geothermal has remained unchanged over this period. Projects with capacities less than 7 MW also do not need to undergo environmental assessments, significantly reducing project development times.

## Government loan guarantees

Supporting the adoption of low temperature geothermal projects, a special body called the Japan Oil, Gas and Metals National Corporation (JOGMEC) was formed in 2004 by the national government. Guarantees are offered by JOGMEC of up to 80% of total project loans at construction phase. These are provided for small to medium scale geothermal projects, granting a guarantee of liabilities to private companies. JOGMEC was responsible for the first loan guarantee of 600 million yen to the Onsen Binary at Tsuchiyu hot springs commissioned in 2015 along with a subsidy of 100 million yen from METI.

## Inherent features of geothermal energy increases its application viability

Low temperature geothermal offers multi-application use-cases that increase the net benefit of the system to end users. Systems offer both electricity generation as well as direct use applications such as district heating, greenhouses, fisheries, mineral recovery, and industrial process heating. Furthermore, the technology removes the need for cooling of bathing water while simultaneously providing electricity for use by onsen owners. This increases the likelihood of technology adoption by hot spring owners working in tandem with low temperature geothermal operators for mutual benefit.

## Funding toward small scale geothermal projects is encouraging private investments

Financing mechanisms such as METI funding for projects that aim to utilise heat from hot springs for electricity generation and Soft Bank's subsidiary SB Energy's loans for small scale renewable energy projects are expected to encourage project development. This scheme grants subsidies of 50% to local governments and 33% for private sector operators on total cost of development of renewable heat utilisation facilities. As of 2014, a total budget of JPY 4 billion ($351.2 M) has been allocated to this scheme.

## Increased R&D focus toward renewable energy and energy efficiency is driving the attention toward low temperature geothermal

New Energy and Industrial Technology Development Organization (NEDO) is committed to develop and promote R&D activities in the field of new energy (renewable energy, hydrogen and fuel cells) with an estimated budget of PY148.4 billion.

NEDO works rigorously to develop energy efficient technology and conduct pilot projects to reduce environmental impact and is responsible for identifying and monitoring hot spring power generation in the country. The commitment toward R&D has enabled numerous manufacturers to develop technologies that can convert low and medium temperature heat into electricity. As a direct consequence of NEDO's initiative, it has provided R&D grant to develop a small and low-temperature geothermal power generation system using Kalina cycle for feasibility study in Japan. Such measures are driving the attention toward development of low temperature geothermal projects.

## MARKET RESTRAINTS

### Lack of published technical information on low temperature geothermal power

There is limited published technical, financial, and legislative information for developers about low temperature geothermal energy, particularly in comparing business cases and the experiences and lessons learnt from various individual projects. However, this gap is being bridged by the formation of a geothermal power generation advisory expert committee within JOGMEC in 2016, which aims to understand and provide geothermal data and consultations to the local government to provide a greater understanding of its application benefits.

### Historic lack of efficient technology for low temperature geothermal power

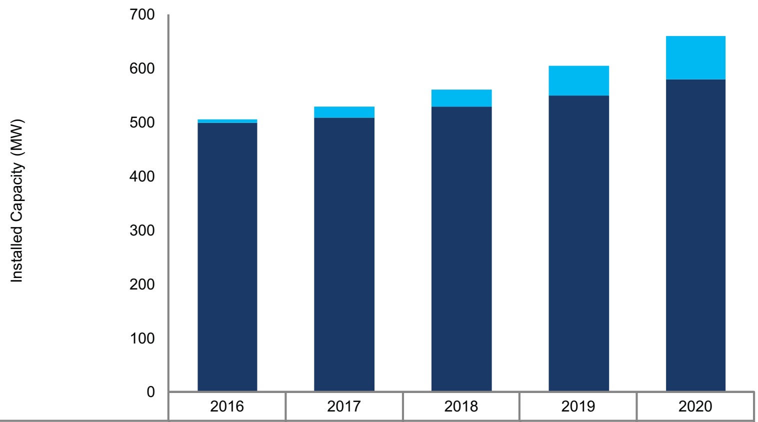
Major Japanese technology leaders such as Mitsubishi Heavy Industries (MHI), Fuji Electric and Toshiba have extensive expertise in geothermal power generation equipment. However, while these companies have strong technology portfolios in direct-type (flash) steam turbines for large scale geothermal projects, they have limited technology presence in low temperature binary systems. The lack of local technological leadership and integrated modular solutions for low temperature geothermal energy has been a major restraint for large scale deployment in the country.

### Public opposition for low temperature geothermal projects at hot springs

Limited knowledge on the potential and benefits of low temperature geothermal projects is restricting market acceptance in the country by hot spring owners and restraining market growth. Onsen owners strongly believe that construction of geothermal projects in hot springs depletes water volume and affects the quality of water for bathing.

*Source: Frost & Sullivan*

## Chart 4: Geothermal Installed Generation Capacity Forecast, Japan, 2016-2020




| | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|
| Low temperature Geothermal energy installed operational capacity | 5.5 | 20 | 32 | 56 | 80 |
| Geothermal energy installed operational capacity | 500 | 510 | 530 | 550 | 580 |

*Source: Frost & Sullivan*

Frost & Sullivan forecasts the installed capacity of low temperature geothermal technology to grow from 5.5 MW in 2016 to 80 MW in 2020, showing a 95% compound annual growth rate for the period. This is expected to be primarily driven by major low temperature geothermal projects planned for commissioning over this period. Market factors driving new project development include: the lack of required environmental assessments for small scale geothermal projects reducing project development time; increasing investments in low temperature geothermal projects with improved cooperation at the community level; government focus on improving energy security through issuing attractive FiTs and grant financing; and a government focus on identifying low temperature geothermal reserves and relaxing exploration and development restrictions in national parks. Considering these factors, the future of low temperature geothermal looks promising, provided tariffs and governing policies are established and clearly defined in the country.

### Table 5: Key developers of Low-to-Medium Geothermal Electricity Production Suitable for the Japan Market

| | |
|---|---|
| Orix | JFE Engineering |
| ElectraTherm | TLuxe power |
| Climeon AB | Fuji Electric |
| Ormat Technologies Inc., | Kobelco* |
| Kawasaki Heavy Industries* | Turboden |
| IHI plant construction Co.,Ltd.* | |

** Companies Involved In micro binary system development.*

*Source: Frost & Sullivan*

The market competition for low temperature geothermal energy is dominated by local companies; however, there has been a recent influx of international players leveraging their global expertise in geothermal equipment. Japan offers some of the most technically advanced equipment for geothermal exploration, development and monitoring and is the world leader in the development of geothermal turbines and generators. Kawasaki heavy industries, Fuji electric, and Toshiba contribute to 70% of the world market for the supply of sophisticated geothermal equipment and Kawasaki, KOBELCO, IHI and Fuji Electric are involved in the development of 50-100 kW generators for small binary plants. However, despite its superiority in supplying geothermal equipment, these suppliers have only recently started supplying geothermal binary power generating systems as integrated modular solutions. To date, there exists a clear technology gap in the country to realise the potential of energy generation from low temperature geothermal resources. Technological innovation by international market players represents a key vehicle to close this technology gap.

## Selected Success Story 1: Ormat Technologies installation at Tsuchiyu Onsen

Ormat technologies, an U.S based renewable energy technology provider, commissioned a 400 KW binary geothermal plant in 2015 at Tsuchiyu onsen. Tsuchiyu is located in Fukushima which was in close proximity to the nuclear power plant disaster. Ormat technologies revitalised the region with its 4,000 KW Onsen Binary Geothermal Power Plant. Capitalising on its extensive intellectual property and technology know-how, Ormat technologies were able to deploy geothermal technology to gain trust of the local community. The installation also lessened the anxiety of hot spring owners about the ill-conceived notion of the harmful effects of geothermal plants.
The company took advantage of the geographical setting in the community where two water sources were available. The existing well had a geothermal water of 100°C which was used to heat the secondary liquid to run the turbine. The other source, being the mountain water which had a temperature of 10°C, was drawn to act as a coolant. The generation cycle was able to reduce the hot spring water to 70°C while the temperature of the mountain water goes up about 20°C. The remaining mountain and hot spring water is fed back to the nearby spas creating a win-win situation.
The total cost of the project was estimated to be $5.7 million and the company received a subsidy of $812,000 from METI while receiving a loan guarantee on the remaining amount from JOGMEC. The generated electricity is then sold to Tohoku Electric Power Co., at a FiT rate of $0.32/kWh for 15 years. Such success stories have helped companies to associate with local communities and government for self-generation.

## Selected Success Story 2: Climeon AB deal to produce distributed geothermal electricity in Iceland

Sweden-based Climeon AB is a clean tech equipment vendor providing a technology that converts low temperature heat into electricity. Climeon AB has entered into collaboration with Icelandic company CP Energy Holding for the delivery of equipment and services for a two-phase, 15 MW geothermal power project in Iceland; enough to power 2,500 households. The order will include the delivery of 100 units of Climeon Heat Power modules to be installed across 10 to 15 sites over a 30-month period. Climeon's Heat Power modules generate electricity from low temperature heat, such as heat from low enthalpy geothermal wells. The collaboration targets the installation of large scale distributed geothermal energy without any subsidies. The systems will be built up of compact, flexible and 150 kW scalable units. By exploiting the temperature difference between hot and cold water and gas, the Climeon Heat Power system economically converts low temperature geothermal heat (as low as 70 °C) into profitable clean electricity with record high efficiencies of up to 14%. Climeon's new revolutionary project to produce low enthalpy distributed geothermal electricity in Iceland represents a valuable case study for the Japanese energy market to replicate, given the enormous potential of hot springs and the technologies demonstrated technological capabilities to generate clean electricity from low temperature geothermal sources.

### Table 6: 1. Overview of the Current Low Temperature Geothermal Projects in Japan

| Project Location | Stakeholder | Installed Capacity | Commissioning Date |
|---|---|---|---|
| Iwate Prefecture | Joint venture by JFE Engineering, Mitsui Oil Exploration, Japan Oil, Gas and Metals National Corp., and Japan Metals & Chemicals | 7 MW | 2018 |
| Fukushima prefecture Tsuchiyu onsen | Ormat Technologies and JFE engineering | 0.4 MW | 2015 |
| Hachijojima Island | Orix | 4.4 MW | 2022 |
| Oita Prefecture | Idemitsu Kosan | 5 MW | 2017 |
| Beppu | ElectraTherm | 110 KW | 2016 |
| Kurikoma National Park | Sumitomo Forestry and RENOVA | 2 MW | 2016 |
| Beppu Oita Prefacture | Thai Luxe Enterprises | 500 KW | 2017 |
| Obama Onsen | Kobe steel | 60 KW | 2011 |
| Beppu onsen | Anest Iwata Corporation | 5.5 KW | 2013 |
| Kumamoto Prefecture, Oguni Hot Springs | Chuo Electric Power Co | 2 MW | 2014 |

*Source: Frost & Sullivan*

The following gives an overview of the low temperature geothermal projects that have been commissioned in Japan since 2015.

**7 MW plant in Iwate Prefecture**

(Commissioning 2017)

A joint venture by JFE Engineering, Mitsui Oil Exploration, the government-backed Japan Oil, Gas and Metals National Corp., and Japan Metals & Chemicals has commissioned an approximately 7 MW geothermal plant in Iwate Prefecture in March 2017. The facility, expected to cost 8.5 billion yen ($75.8 million), is scheduled to operate in 2018.

### 4.4 MW Plant on Hachijojima Island

(Commissioning 2022)

Leasing company Orix is set to sign an agreement to build a 4.4 MW geothermal plant on Hachijojima Island as part of a replacement of an older Tokyo Electric Power facility. The expected investment is close to 5 billion yen ($44 million) with a commissioning planned for 2022. In addition, Orix has started exploring and surveying several other potential geothermal sites with 10 projects of a total capacity of 30 MW being considered. Orix currently is the fourth-largest independent power producer (IPP) in Japan to corporate customers.

### 5 MW Plant in Oita Prefecture

(Commissioning 2017)

Oil Company Idemitsu Kosan is building a 5 MW Takigami Binary Power Plant which has begun commercialisation in Oita Prefecture in March 2017. The plant uses a binary power cycle to utilise lower-temperature steam and hot water that could not be used in traditional geothermal power generation with an expected annual generation of 31GWh.

### 0.11 MW Plant in Beppu

(Commissioning 2016)

U.S based renewable energy company ElectraTherm successfully commissioned its Power+ Generator™ 4400 in Beppu in April 2016. The company now reports that its plant has exceeded 3,000 hours of operational runtime. The company uses ORC and ElectraTherm's patented twin screw power block to generate up to 110 kWe of electricity from low temperature water ranging from 77-122°C.

### 2 MW Plant in Kurikoma National Park

(Commissioning 2016)

Japanese timber and biomass firm Sumitomo Forestry entered into a strategic alliance with RENOVA (independent developer and operator of renewable power plants) to develop a 2 MW geothermal plant at Kurikoma National Park in 2016 on forestland the company owns in Japan. The generated power is then sold under Japan's FiT system to the local utility. The company plans to invest around $181 million to expand its renewable energy portfolio in the country.

### Cumulative 1.5 MW in Oita Prefecture

(Commissioning progressive)

Thai Luxe Enterprises, through its subsidiary is constructing small-scale geothermal in Oita Prefecture, Japan. Thai Luxe Enterprises is predominantly an animal feed company, but has established a subsidiary focused on its geothermal investment, called TLuxe Power. The cumulative planned investment is nearly $23 million in 8 geothermal plants. An additional three geothermal plants are being considered.

The company has plans of constructing 12 low temperature geothermal power plants with an installed capacity of 125 kW, all located in Oita Beppu, Japan. Currently four units have been installed with a total capacity of 500 kW.

### Other Examples

Other examples of low temperature geothermal power plants that have been constructed include: 60 KW installed capacity at the Obama Onsen in Unzen City, Nagasaki Prefecture by Kobe Steel; 20 KW heat recovery ORC developed by IHI Corp for power generation from hot springs; and a 5.5 KW binary generator unit developed by Anest Iwata Corporation at demonstration test facility at the Beppu Onsen.

# THE LAST WORD

7

In a post-nuclear era, it is essential for Japan to harness the potential of all domestic renewable energy resources to mitigate the risk of dependence on foreign resources and global political changes. Since 2011, there has been a paradigm shift toward renewable power development to decrease dependence on costly imports of fossil fuels, achieve a stable energy supply and reduce greenhouse gas emissions. A testament to this is the recent scrapping of the plan to build a 1 GW coal power plant in Chiba by Kansai Electric and Tonen General in lieu of rising environment concerns.

Low temperature geothermal power holds potential to greatly contribute to meeting these demands and is expected to show accelerated market adoption to 2020, due to: attractive FiTs and financial support for small scale geothermal development; reduced need for previously required environmental assessments; technological advancements and price reductions; improved cooperation at the community level; government support in guarantees, financing and identifying reserves; and relaxing development restrictions in national parks. However, new technological innovation, allowing access to geothermal reserves at temperatures below 120°C, is expected to represent the primary driver to increasing the total addressable market potential for project development and driving the market as a whole.

The full liberalisation of Japan's electricity market in April 2016 has, furthermore, created an interesting scenario for renewable energy providers to increase its customer base by providing prices lower, or on par, with conventional energy sources.

Considering this shift, utility business models are expected to become more flexible, with greater focused being placed on distributed power generation including community generation projects. Low temperature geothermal plants represent an ideal energy solution as a low carbon power supply to local communities. This market, however, is expected to be primarily driven by low temperature geothermal energy companies that can work in tandem with hot spring owners to produce electricity as well as additional value-add services; drastically increasing the attractiveness and adoption of such projects.

Japan's domestic energy crisis is opening up interesting opportunities for foreign companies to contribute to the national geothermal portfolio. However, companies will need to compete against well-established alternative technologies such as solar photovoltaic to gain a foothold in the market. Building strong local and community relations represents a key success criterion for project development, due to the strong cultural values attached to hot springs in the country and the resistance shown for fear of environmental impact.

As the market matures, the demonstration of low temperature geothermal technologies, operating at below 120°C, represents a potential game changer in the exploitation of the country's geothermal potential to contribute to stable, low emission, power generation in Japan.

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