Case Studies in Hot Spring Use for Sustainable Energy

March 2019

Oita Prefectural Government
Oita Prefecture Energy Industry Organization

Greetings

The International ONSEN summit was convened based on the expectation that getting people from around the world to begin using ONSEN and understand its charm will lead to further development of the world's ONSEN areas. Leaders from ONSEN areas in 17 regions and 16 countries around the world were welcomed to the summit. There, they were joined with more than 1,000 representatives of municipalities that are home to ONSEN in Japan along with other related organizations, making for a very fruitful international conference.

Based on a theme of the "Possibility of Regional Development by Worldwide ONSEN Locations: Diverse Ways to Utilize Local Resources Connected with ONSEN," the summit was divided into three areas: Tourism, Medical · Health · Beauty, and Energy. In addition to sharing examples of regional best practices in utilizing ONSEN culture and ONSEN resources, there was also a lively discussion on new possibilities for ONSEN. The result of these discussions has been summarized in the Summit Declaration.

The Energy Subcommittee centered on the coordinators sharing various opinions on the theme of "utilization of hot springs as a sustainable energy source". As a result of those discussions, the International ONSEN Summit Declaration was adopted. Regarding the utilization of hot-spring energy, it states:

> *Hot springs are expected to be further utilized as an energy source. With the approaching era of energy diversification, we will promote energy use in various fields including power generation, district heating/cooling, and heat utilization combined with the agriculture and fishery industries, while harmonizing with the protection of hot spring resources and the natural environment.*

Accordingly, Oita prefecture decided to publish and disseminate a collection of case studies to introduce and explain examples from Japan and relevant worldwide areas in relation to ONSEN resources. To help realize the agreed upon declaration and to make the information shared at the summit more widely available, both a written publication and a website are being used. We sincerely hope that by utilizing this information through a wide variety of venues the use of hot springs as a sustainable energy source will be advanced.

March 2019

Katsusada Hirose
Governor of Oita Prefecture

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1. Oita Prefecture ♨ International ONSEN Summit

1.1 Outline

The World's first hot-spring summit, "International ONSEN Summit" was held at the Beppu International Convention Center (B-Con Plaza) in Beppu City, Oita Prefecture for three days from Friday, May 25th to Sunday, May 27th, 2018. The participants included leaders and researchers from ONSEN areas in Japan and around the world. They exchanged information and engaged in discussions on the use of ONSEN resources and the potential for regional development. Following a keynote speech and case-study speeches, more in-depth discussions in three distinct areas were held by the separate working groups on ① Tourism, ② Medical・Health・Beauty, and ③ Energy. As a final result of that debate, the International ONSEN Summit Declaration was adopted.

Source: International ONSEN♨Summit Record (2018)

Summit dates	May 25 (Fri) – 27 (Sun), 2018
Location	Beppu City, Oita Prefecture Beppu International Convention Center (B-Con Plaza)
Organizer	**International ONSEN Summit Organization Board Committee** Chairman Katsusada Hirose (Governor of Oita Prefecture) Vice Chairman Yasuhiro Nagano (Mayor of Beppu City) Vice Chairman Koji Yukishige (President of Tourism Oita (Oita Prefectural Tourism Association)) Auditor Shoji Himeno (Chairman of Oita Association of Corporate Executives) 14 Other Committee Members (see P51 for list of members)
Supporters	Ministry of Economy, Trade and Industry (METI) / Ministry of Land, Infrastructure and Transport (MLIT) / Japan Tourism Agency (JTA) / Ministry of the Environment (MOE) / Ministry of Foreign Affairs (MOFA) / Japan External Trade Organization (JETRO) / Japan National Tourism Organization (JNTO) / Japan Travel and Tourism Association (JTTA) / The Japan Foundation / Japan International Cooperation Agency (JICA)
Theme	Possibility of Regional Development by Worldwide ONSEN Locations: Diverse Ways to Utilize Local Resources Connected with ONSEN
Working Groups	◆ **Working Group (1) Tourism:** New Possibilities of ONSEN Tourism ◆ **Working Group (2) Medical, Health & Beauty:** Vision of ONSEN Use for Healthy Life Expectancy and Healing - From Kur to Wellness - ◆ **Working Group (3) Energy:** Use of ONSEN as a Sustainable Energy Source
Participating Countries and Regions	**17 Regions in 16 Countries (listed in alphabetical order based on United Nations nomenclature)** 1. People's Republic of China: Xianning 2. People's Republic of China: Yantai 3. Czech Republic: Hodonin 4. French Republic: Vichy 5. Federal Republic of Germany: Bad Krozingen 6. Republic of Hungary: Budapest 7. Republic of Iceland: Grindavik (Blue Lagoon) 8. Italian Republic: Abano 9. Hashemite Kingdom of Jordan: Ma'in 10. Mongolia: Bayankhongor Province 11. New Zealand: Taupo 12. Republic of Korea: Busan 13. Kingdom of Spain: Madrid 14. Kingdom of Thailand: Chiang Mai Province 15. United Kingdom: Bath 16. United States of America: Hot Springs (Arkansas) 17. Socialist Republic of Viet Nam: Tuyen Quang Province
Summit in Figures	**1. Summit Participants: 1,039** Participants from overseas: 86 Participants from Japan: 953 (Local Government: 272, Societies and Companies, etc.: 262, other: 419) **2. Registered Media Representatives: 46** Overseas Media: 18 Representatives from 6 Countries (France, Germany, Italy, Spain, United Kingdom, United States) Japanese Media: 28 Representatives from 20 Media Companies **3. Administrative Staff: 185** Prefectural and Municipal Staff: 152 Student Volunteers: 33

Source: International ONSEN♨Summit Record (2018)

Program

May 25 (Fri)

14:00–16:30	3rd Japan ONSEN Summit (Organizer: Ministry of the Environment)
17:45–20:00	Welcome Reception for the International ONSEN Summit & 3rd Japan ONSEN Summit

May 26 (Sat)

9:00-12:00	International ONSEN Summit Plenary Session Organizer Greetings Katsusada Hirose, Governor of Oita Prefecture Chairman of the International ONSEN Summit Organization Board Committee Guest Greetings Masaharu Nakagawa, Minister of the Environment, Japan Introduction Speech from Overseas Participants **I. Keynote Speech** Sustainable Tourism & Possibility of Further Development of Hot Spring Locations in the World [Spain] Yolanda Perdomo, Former Director, UNWTO Affiliate Members Programme **II. Case Study Speeches** (1) Tourism Attracting Tourists Utilizing ONSEN Hot Springs in France [France] Jérôme Phelipeau, CEO, Compagnie de Vichy (2) Medical, Health & Beauty Situation of Hot Spring Medical Treatment in Italy and New Vision for Hot Spring Medical Treatment Pursuing Health and Beauty [Italy] Massimo Sabbion, Former Manager, Abano-Montegrotto Hotel Association (3) Energy Energy and Tourism: Multiple Use of Geothermal Power and Resources at Blue Lagoon in Iceland [Iceland] Ása Brynjólfsdóttir, Director of Research and Development, Blue Lagoon Ltd.
12:00-13:00	Lunch Break * Standing Buffet
13:00-16:00	**III. Working Group Session** Working Group (1) Tourism Theme: New Possibilities of ONSEN Tourism Working Group (2) Medical, Health & Beauty Theme: Vision of ONSEN Use for Healthy Life Expectancy and Healing - From Kur to Wellness - Working Group (3) Energy Theme: Use of ONSEN as a Sustainable Energy Source
17:00-18:00	Working Group Summary & Summit Declaration
18:10-18:40	Press Conference
19:00-21:00	Farewell Dinner

May 27 (Sun)

	Excursions
9:30-13:20	(1) Tourism Course (Beppu City)
8:15-13:20	(2) Medical, Health & Beauty Course (Beppu City)
9:30-13:20	(3) Energy Course (Beppu City)
9:00-16:20	(4) ONSEN & Gastronomy Walking Tour Course (Nakatsu City)

Related Events

International ONSEN Tourism & Products Exhibition

May 26 (Sat) – 27 (Sun), 2018: Convention Hall, B-Con Plaza

Features include booths showcasing the countries and local governments participating in the Summit, booths selling produce from different parts of Japan, refreshments booths, and stage events.

ONSEN & Gastronomy Walking Tour

May 26 (Sat) 2018: Beppu, May 27 (Sun): Nakatsu

Walking around these ONSEN areas will take participants along routes of rich nature, history and culture unique to each community. Participants will be able to **savor** the delicious foods and *sake* (rice wines), **soak** in the ONSEN waters, and **experience** the charms of the particular ONSEN areas.

Source: International ONSEN summit record (2018)

1.2 Case study speeches

Presentations were given in the three fields: ① Tourism, ② Medical · Health · Beauty, and ③ Energy. Ásá Brynjólfsdóttir, from Iceland, gave a case study speech in the field of energy.

(3) Energy

Energy and Tourism: Multiple use of Geothermal Power and Resources at Blue Lagoon in Iceland

Ása Brynjólfsdóttir

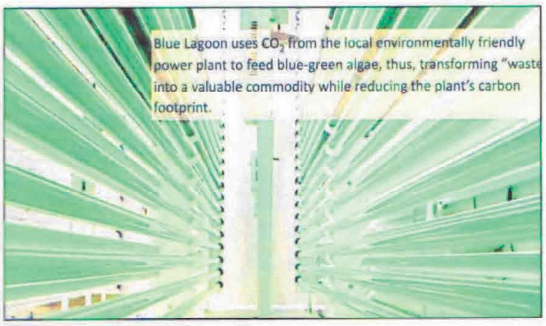
[Iceland] Director of Research and Development, Blue Lagoon Ltd.

Ása Brynjólfsdóttir holds a master's degree in pharmacy from the University of Iceland. Since joining the Blue Lagoon Ltd., a company engaged in researching the healing properties of geothermal seawater, she has spent many years researching the geothermal seawater of the Blue Lagoon and its constituent elements, and subsequently a range of skin-care products has been developed. She has been one of the key personnel in the management team, helping to elevate the Blue Lagoon Ltd. into one of Iceland's leading firms in health tourism.

Geothermal energy has been utilized extensively in Iceland, where (similar to Japan) there are many active volcanoes. Director of Research and Development at the Blue Lagoon Ltd., Ása Brynjólfsdóttir, presented specific examples regarding multiple use of geothermal energy at the Blue Lagoon, sizeable hot spring facilities that capitalize on geothermal resources from a nearby geothermal power plant.

- The Blue Lagoon was listed by National Geographic as one of the Wonders of the World.
- The lagoon's geothermal seawater flows from volcanic aquifers 2000 meters within the earth, emerging at the surface enriched with algae, silica and minerals.
- Studies suggest that the unique elements of the lagoon have healing properties and are especially effective for psoriasis.

- Silica is a characteristic element of the lagoon and gives it its blue color. It precipitates to form the white iconic Blue Lagoon silica mud mask available to all guests.
- Blue Lagoon is a venture company, leading in health tourism and skin care.
- It represents both a destination and a unique brand on a global base.



- The company's philosophy is to utilize local geothermal resources in a sustainable manner.
- A photobioreactor system uses CO_2 emitted from the geothermal plant to cultivate algae. Thus, transforming a resource, otherwise discarded, into a valuable commodity while reducing the plant's carbon footprint.

- Capital is currently being invested into a new luxury hotel, The Retreat at Blue Lagoon Iceland. The hotel has 62 suites, and the beautiful buildings have been designed to fit the surrounding volcanic landscape.
- Blue Lagoon is now known the world over, and is a destination that everyone wants to visit. The Blue Lagoon is to provide guests with an unforgettable experience.

Source: International ONSEN Summit Record (2018)

1.3 Working groups

In the subcommittee meetings, each venue was divided into three categories, ① Tourism, ② Medical · Health · Beauty, and ③ Energy, and participants engaged in deeper discussions within each field. In the energy group, discussions were held in a symposium format with the theme of "utilization of hot springs as sustainable energy". The coordinator was Dr. Kasumi Yasukawa of the National Institute of Advanced Industrial Science and Technology.

ONSEN Working Group (3) Energy

Date: May 26 (Sat), 2018
Location: Conference Room, B-Con Plaza

Theme: Use of ONSEN as a Sustainable Energy Source

Coordinator: **Dr. Kasumi Yasukawa** (Deputy Director, Renewable Energy Research Center, Fukushima Renewable Energy Institute, National Institute of Advanced Industrial Science and Technology)

Panelists: **Mr. Kouichi Fukuda** (General Manager, Geothermal Power Department, Thermal Power Division, Energy Service Headquarters, Kyushu Electric Power Co., Inc.)

Mr. Shigeto Yamada (General Manager - Geothermal Power Thermal & Geothermal Power Plant Engineering Department, Power Plant Division, Power & New Energy Business Group, Fuji Electric Co., Ltd.)

Dr. Greg Bignall ([New Zealand] Head of Department, Geothermal Sciences, GNS Science)

Ms. Ása Brynjólfsdóttir ([Iceland] Director of Research and Development,Blue Lagoon Ltd.)

Issues

(1) How should geothermal energy be utilized?
(2) How should we promote sustainable energy use in ONSEN area?

Summary of Panelist Remarks

Mr. Kouichi Fukuda

- At Kyushu Electric Power's Hatchobaru and Otake power plants located in Kokonoe Town, Oita Prefecture, the hot water and steam used to generate geothermal power is utilized in heating facilities and in the greenhouse cultivation of roses and gypsophila.
- Kyushu Electric Power adopted binary cycle power generation systems in 2006, 2015 and 2018. It has further expanded its use and application of geothermal energy, carrying out geothermal power generation in Indonesia, too, since May 2018.
- To protect ONSEN areas, it is important to undertake regular monitoring and prescribed environmental assessment for preserving nature. That alone though is not enough. Mutual understanding, communication, and building trusting relationships based on these are also important.
- As a form of communication and in order to increase understanding about geothermal power generation, an open day event has been held once a year at the Hatchobaru Power Plant since the start of its operations, opening the plant premises up to the public. A permanent exhibition center has also been set up, visited by 22,000 people throughout the year.

Mr. Shigeto Yamada

- According to data on capacity (power generation capacity) of the world's geothermal power plants, there has been considerable growth in Iceland and Turkey. Developing a wide range of businesses and actively utilizing geothermal energy is commendable.
- Geothermal power generation is not just about heat. There is potential to expand business in a variety of ways.
- Some people think that geothermy is not beneficial to primary industry. In addition to using energy for ONSEN, it is vitally important that there be people in each region who can examine and plan broader energy uses best suited to the region.
- Although expanding geothermal power generation is important, so too is widening opportunities for the use of ONSEN resources. A good idea would be for consultants and companies to come to the fore, leading to broader use.

Source: International ONSEN Summit Record (2018)

Dr. Greg Bignall

- In New Zealand, geothermal energy accounts for about 19–20% of power. This presents an opportunity to close the fossil fuel power plants. In the medium term, I would like to consider future investment in, and future expansion of, the geothermal power generation.
- What is important is how the community wants to use geothermy. The position of the Maori people is that they want to protect nature, rather than own it. Whether it be hot springs or geothermal energy, it is important to have a conviction and sentiment of protecting—not owning.
- Even if the power plant is very small in scale, it supplies power to greenhouses and dairy factories, creates jobs, and generates profits. In this respect, it is a big positive for regional economic development.
- When pumping hot water up from underground, we need to balance the lost water and the replenishment rate, that is, replenishing water to nature. There was a time in New Zealand when that rate was wrong, and we placed a burden on the planet. However, as long as we keep that balance, geothermal resources will be a renewable energy.

Ms. Ásà Brynjólfsdóttir

- At Blue Lagoon, we view the hot springs, hotel, skin care shop and restaurant as a single enterprise group (Resource Park), and we utilize the hot springs in a variety of ways, such as having the hot water produced in generating power utilized by each of the facilities in a sustainable manner.
- Monitoring is crucial in order to promote sustainable energy use. Education, communication, and the building of relationships of mutual trust lead to sustainable development.
- We are striving to generate energy using natural resources wherever possible in order to improve the quality of life for the local people.
- Through the hot springs, being able to create and supply jobs in various industry sectors is also important. It is imperative to proceed with development collaboratively while considering the potential in sector.

Panel exhibition of initiatives by participating organizations

Booklet of initiatives by participating organizations

Working Group Summary

Dr. Kasumi Yasukawa

- Regarding the point on how geothermal energy should be utilized, there are industrial applications. In utilizing geothermal energy in industrial settings, it is important to consider the characteristics of local resources and to also take the social environment into consideration when planning.
- Regarding new possibilities for power generation using ONSEN, particularly on islands and in remote locations, since power transmission is sometimes cut during times of disaster, a power plant that uses hot springs—even a small-scale plant—would be extremely effective.
- Regarding the point on how sustainable energy use should be promoted in ONSEN areas, many in the conference room are of the view that development of large-scale geothermal power generation would perhaps have an impact on ONSEN, and so it is necessary to consider whether there is a separate way of successfully using ONSEN in ONSEN areas and using the energy without adversely affecting the ONSEN.
- In examining energy use that does not affect the source of an ONSEN, it is important to conduct effective numerical modeling based on monitoring data to make forecasts for the future. Furthermore, it is also important to produce technical guidelines that can also be understood by non-specialists, and to develop a social environment for building management systems that avoid wanton development.
- Regarding harmony with the natural environment, the landscape and the living environment, it is important to have a design that meets with the approval of the community. Rather than just hiding the plant from view, there also needs to be facilities on show from the perspective of environmental education and tourism.
- Regarding sustainable development based on consensus-building with local stakeholders, it is important to build consensus in close communication with the local community, and to consider ways of using ONSEN for multiple purposes, which will contribute to sustainable development of the region.

Source: International ONSEN♨Summit Record (2018)

1.4 Summit declaration

Summit Declaration

Date: May 26 (Sat), 2018
Location: Philharmonia Hall, B-Con Plaza

The working group coordinators presented a summary of discussions from the three working groups, and lastly, the Summit Declaration was announced by Ms. Yolanda Perdomo, former Director of the UNWTO Affiliate Members Programme. The Summit Declaration included an affirmation by leaders from ONSEN areas around the world to contribute to development of ONSEN areas by utilizing the knowledge and networks gained at the Summit, and to promote uses for ONSEN in the three areas of tourism; medical, health & beauty; and energy. In addition, the leaders declared to continue the Summit as a forum for ongoing information exchange and discussion. The Summit Declaration was approved with great applause by Summit participants.

Source: International ONSEN♨Summit Record (2018)

Declaration for the International ONSEN Summit

We, the leaders of the world's ONSEN, gathered information on and actively discussed the theme of the "Possibility of Regional Development by Worldwide ONSEN Locations" at the "International ONSEN Summit" held in Beppu City, Oita Prefecture, Japan. In the future, we hope that people from across the world will begin to use ONSEN and understand its charm. In order to further develop the world's ONSEN, we will make appeals to the world on the following points to declare our intent to implement them.

1. Contribution to Developing the World's ONSEN Locations

We will use the examples of practical applications for ONSEN culture and ONSEN resources, the specialized knowledge concerning the natural blessings that are ONSEN resources, and the networks we gained with various organizations at this Summit to the fullest extent. In addition to endeavoring to create an ONSEN related database, we will contribute to the world's ONSEN locations while creating new values for ONSEN and striving for mutual exchange.

2. ONSEN and Tourism Promotion

Tourism is a transformative tool, and has the capability of reducing poverty, wealth and gender inequality, preserving culture, protecting of tangible and intangible heritage. It can also promote environmental, social, and economic progress and sustainability.

ONSEN are an important natural and cultural resource in the tourism field. In addition to working to improve environmental awareness and preserving the natural blessings that are ONSEN resources, we will aim to enhance charms of each region by differentiating the regional specialties, and create ONSEN tourism even more people can enjoy.

3. Medical, Health, and Beauty Uses for ONSEN

ONSEN are an incredibly beneficial resource in the medical, health, and beauty fields. We will propel research via industrial, academic, and government cooperation and promote use of ONSEN in these fields as a resource for all humanity while conveying information about the new possibilities and charms of ONSEN. Especially, it is notable that the use of ONSEN has expanded to wellness field (health promotion and beauty) in addition to cure (medical treatment).

4. Use of ONSEN Energy

ONSEN are a resource whose application as an energy source is expected to grow. As we enter into the age of energy diversification, we will continue to advance sustainable use and application of ONSEN, including protecting ONSEN resources, using ONSEN energy in a variety of fields such as power generation, local air conditioning, and thermal use with agriculture and fishery while aiming for harmony with the natural environment.

5. Continuation of the International ONSEN Summit

We, with the purposes mentioned, will continuously hold the Summit in order for leaders of the world's ONSEN to share information and discuss with each other.

We declare the above.

May 26th, 2018

Source: International ONSEN♨Summit Record (2018)

2. Hot Spring (Geothermal) Heat Energy Utilization

A hot spring consists of groundwater heated by geothermal energy. Hot spring heat and geothermal have the same heat source. The methods of utilizing these heat sources are divided into two uses: a method of direct use as heat and a method of generating electricity by using hot spring heat/geothermal heat.

2.1 Use as hot springs

The most widely used method of utilizing hot spring(geothermal) heat energy is for bathing.

2.1.1 Distribution of world hot springs

Hot springs are located worldwide, especially in Europe and the Pacific Rim countries. There are many located in North and South America, New Zealand, China, and in eastern and southern African countries. These hot springs are frequently found in the new orogenic zones where volcanic activity and crustal movements are active, such as the Alps, the Himalayan Orogenic Belt, and the Ring of Fire which stretches out from the Japanese Archipelago through the Rocky and Andean Mountains to the South Pacific Ocean. On the other hand, high-temperature hot springs may sometimes be found in volcano-free areas such as the Himalaya / Tibetan Highlands; China and Siberia around Lake Baikal; and in the northwest and the south of the African Continent. It is well-known that these hot springs are located along faults. In addition, hot springs are also located in places called hot spots where high-temperature magmas penetrate the plate and appear on the surface, such as on Hawaii Island and in Yellowstone in North America.

Since hot springs exist on a global scale in places where crustal deformation is thriving, it can be said that hot springs are a "gift from the earth." The worldwide hot spring distribution is shown in **Figure 2-1**, and the world plates are shown in **Figure 2-2.**

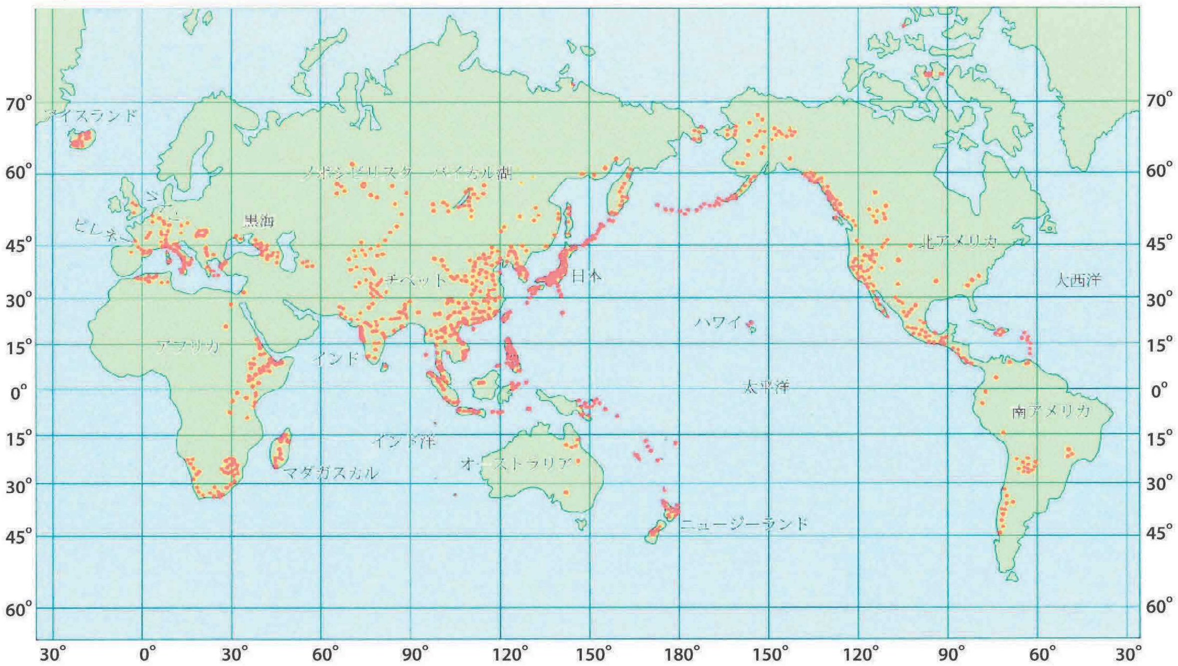


Figure 2-1 Distribution of Worldwide Hot Springs

Source: The Japan Hot Spring Association (2006): Onsen nature and culture, distribution of hot springs in the world (Yuhara · Seno /original drawing)

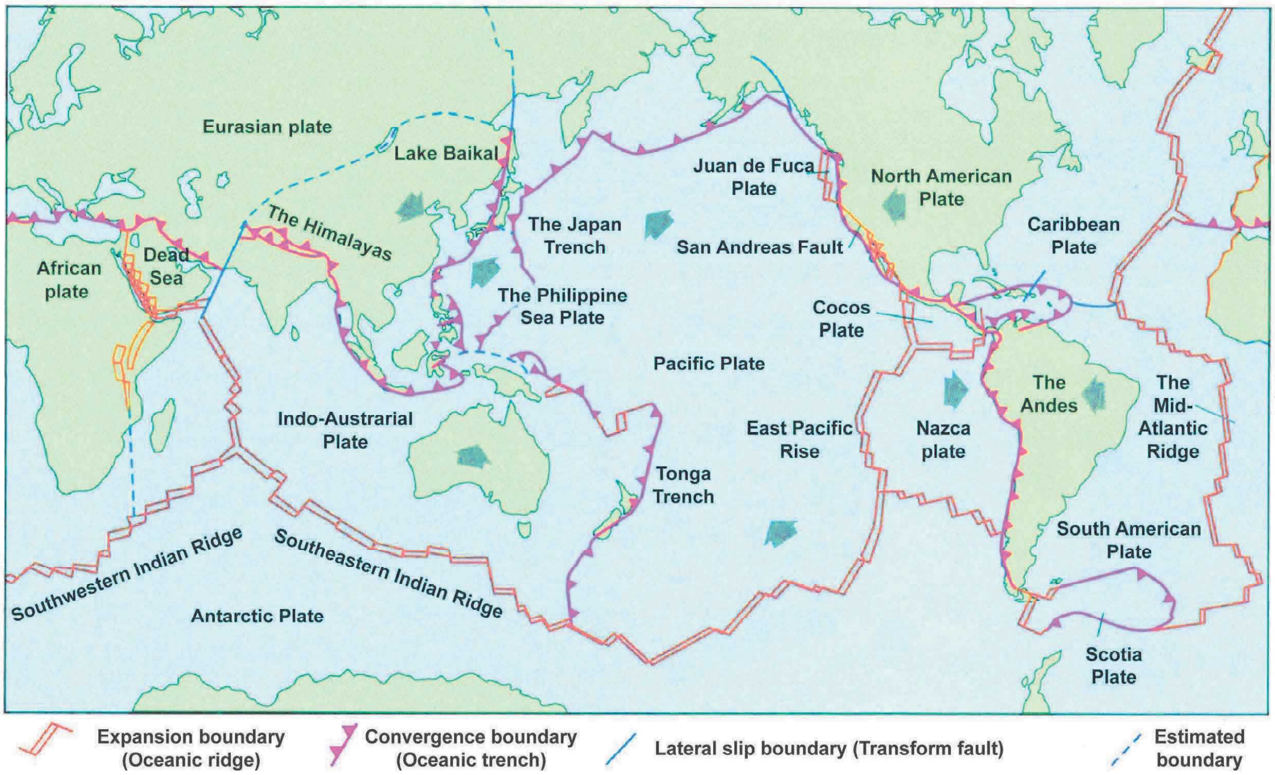


Figure 2-2 Plates in the World

Source: The Japan Hot Spring Association (2006): Onsen, nature and culture, the world's plates (Kaneoka Ichiro / original drawing)

2.1.2 Use of hot springs in the world

As shown in the hot spring distribution map above, hot springs are located all over the world, but hot-spring culture also differs from country to country due to differences in the natural environment, lifestyle, religion, and language. As there are many high-temperature hot springs in Japan, they are mostly used for "Yuami/Ofuro" or hot baths. In other countries, especially in Europe, where the amount of hot water, as well as its temperature, is low due to few volcanic zones, hot springs are often used for "pools/bathing."

A hot spring is defined as having a temperature of over 25°C in Japan. In European countries such as Germany, the UK, France, and Italy, it is defined as more than 20°C. In North America, it is defined as more than 70°F (21.1°C). Another interesting difference is seen in the symbols used to designate hot springs. In France, the image is reminiscent of a fountain whereas in Japan the symbol shows hot steam rising from water.

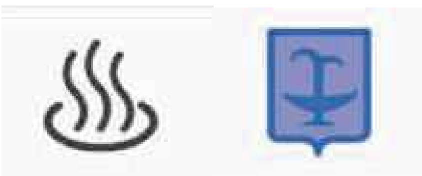


Figure 2-3 Hot Spring Symbols in Maps

【Japan】 【France】

Source: Geographical Survey Institute website: Geographical Survey Home> Children's Page>Map Symbols> Various Map Symbols> Foreign Map Symbols

http://www.gsi.go.jp/common/000206972.jpg

(1) Germany

Germany is famous worldwide as a hot spring nation. “Balneology,” the practice of using natural mineral water for treating and curing disease, has a long history and played a major role in the development of hot springs as a modern medical spa as now typified in Baden-Baden.
Unlike other countries in Europe, this area has abundant hot springs with high temperatures of 70°C. The Friedrich Therme, built in the 19th century, is a traditional bathhouse for recuperation, which offers multiple baths, saunas, and massage. Visitors follow a series of programs for bathing in which even the time to stay in the bath is set in detail. Doctors and other experts give advice according to individual health conditions.

(2) Hungary

A large number of hot spring facilities exist in Budapest, the capital of Hungary, where hot springs have been used since Roman times. Lake Hévíz is a natural thermal lake near the western end of Lake Balaton, and it is available for bathing. The water temperature is around 30°C throughout the year. People bathing with inner tubes are often seen because some places in the lake are as deep as 35 meters.

(3) Iceland

Blue Lagoon, one of Iceland's leading tourist destinations, is the world's largest hot spring lake. However, it is a hot spring lake made up of drainage from underground hot water drawn by the adjacent geothermal power plant, not as a spa originating from natural springs. As its name suggests, it is a pastel blue hot spring. Because these waters contain a large amount of silica and sulfur, skincare products utilizing mud from these hot springs are also being developed for their curative effects for various skin conditions.

2.1.3 Distribution of hot springs in Japan

The Japanese archipelago is located in the Pacific Orogenic Belt and is often hit by volcanic activities and earthquakes. Hot springs exist in all 47 prefectures throughout the country. With 27,421 hot springs nationwide, the amount of gushing hot water reaches about 2,564,123L per minute. Japan is the world's leading hot-spring country and has enjoyed abundant natural gifts from mother earth (See **Table 2-1**). Hot spring distribution around 1994 is shown in Figure 2-4.

Many of the hot springs throughout Japan are volcanic hot springs, but there are also many non-volcanic hot springs coming from heated groundwater with a geothermal heat source. These are mainly located in urban areas. Improved drilling techniques used in recent years have made deep drilling easier.

Source: Ministry of the Environment (2018): 2016 hot spring use situation
https://www.env.go.jp/nature/onsen/data/

Table 2-1 Top 5 Prefectures - Showing the Number of Hot Springs & the Amount of Discharged Hot Water

Ranking	**Number of sources of hot springs**		**Amount of hot water (L / Minute)**	
1	Oita	4,385	Oita	281,331
2	Kagoshima	2,764	Hokkaido	206,564
3	Shizuoka	2,261	Kagoshima	156,346
4	Hokkaido	2,230	Aomori	153,054
5	Kumamoto	1,352	Kumamoto	133,661
Japan Total		**27,421**		**2,564,123**

【Created based on hot spring usage in 2017.
*Source number is the sum of the number of used and unused sources 】

Source: Ministry of the Environment (2018): 2017 hot spring use situation
https://www.env.go.jp/nature/onsen/data/

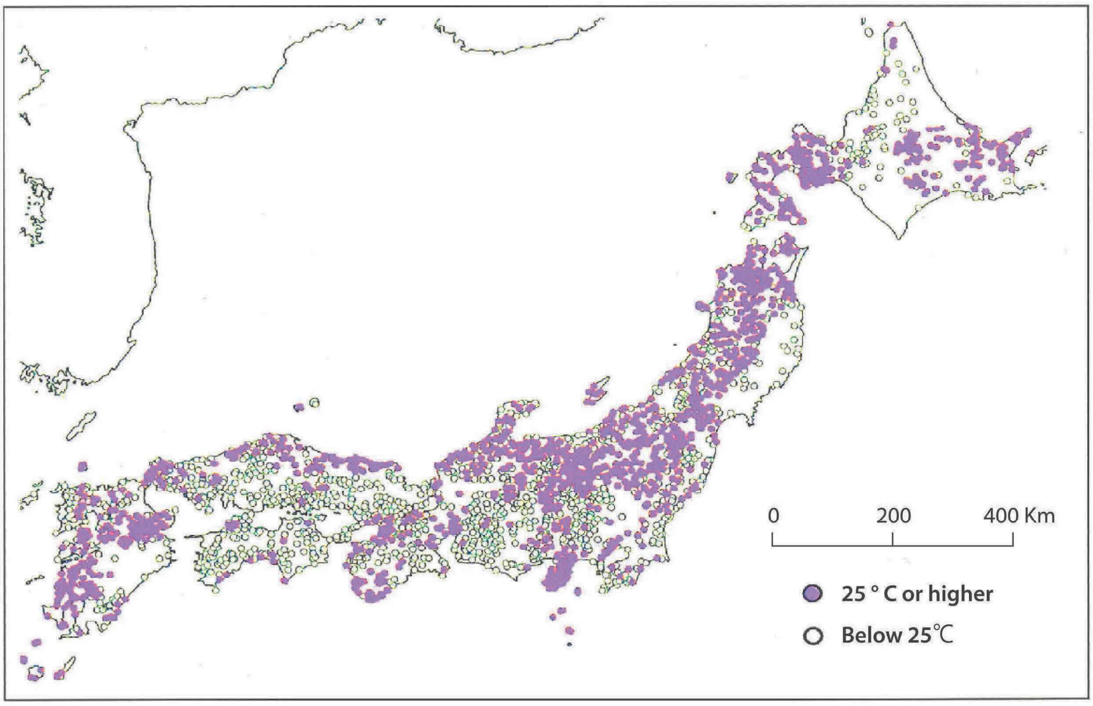


Figure 2-4 Distribution of Hot Springs in Japan (Around 1994)

Source: The Japan Hot Spring Association (2004): Hot Springs Nature and Culture, Japanese Hot Spring Distribution (Original Masao Oyama)

2.1.4 Definition and types of hot springs in Japan

According to the Japanese "Hot Spring Act" enacted in 1948, a hot spring was defined as a spring comprised of either gushing hot water, mineral water, steam, or other gasses (excluding natural gas whose main component is hydrocarbons) which rises from the ground with a temperature over 25℃ or as a hot spring that contains one of the substances listed in Table 2-2. "Temperature," "pH," "Osmotic pressure," and "Spring quality" were used as a way of classifying hot springs. A common and familiar way of hot spring classification is by using the recognized qualities of the waters and listing them on the bathhouse.

The quality of hot springs was previously classified into 11 categories with listings such as "simple hot spring," "simple carbon dioxide spring," or "iron spring." However, to be in accordance with international standards, changes were made in 1979. The terms were adjusted to listings such as "sodium-chloride spring" or "sodium-hydrogen carbonate spring" to indicate the chemical components of the spring. However, as it is generally difficult to understand the hot spring's efficacy by only using the name of the chemical ingredients, in 1982, "the name of the spring quality for posting" was decided. According to the revision in 2014, hot spring quality is now classified into 10 categories. These include: "Simple spring," "Carbon Dioxide spring," "Chloride spring," "Hydrogen Carbonate spring," "Sulfate spring," "Iron-containing spring," "Iodine-containing spring," "Sulfur spring," "Acid spring," and "Radioactive spring."

Table 2-2 Article 2 of the Hot Spring Law, Appended Table

Chemical Substance	Content (in 1 kg)
Dissolved substances (excluding gaseous ones)	Total volume of more than 1,000 mg
Free carbonic acid (CO_2)	Over 250mg
Lithium ion (Li^+)	Over 1mg
Strontium ion (Sr^{2+})	Over 10mg
Barium ion (Ba^{2+})	Over 5mg
Ferro or ferri ions (Fe^{2+},Fe^{3+})	Over 10mg
First manganese ion (Mn^{2+})	Over 10mg
Hydrogen ion (H^+)	Over 1mg
Bromide ion (Br^-)	Over 5mg
Iodide ion (I^-)	Over 1mg
Fluoride ion (F^-)	Over 2mg
Hydrocitrate ion ($HAsO_4{}^{2}$-)	Over 1.3mg
Metaphosphate ($HAsO_2$)	Over 1mg
Total sulfur (S) [corresponding to HS^- $+S_2O_3{}^{2-}+H_2S$]	Over 1mg
Metaboric acid (HBO_2)	Over 5mg
Metasilicic acid (H_2SiO_3)	Over 50mg
Bicarbonate soda ($NaHCO_3$)	Over 340mg
Radon (Rn)	20 (ten billionths of a Curie* or more)
Radium salt (as Ra)	1/100 million mg or more

【 * Unit of radioactivity, 1 Curie is 37 giga-becquerels】

【References】

Yoshimi Kawasaki (2002): Atichi's hot spring classroom - Things you need to know about hot springs, How to use hot springs, Civil Law Study Group, pg. 223

Yamamoto Masataka (2006): World Hot Spring Travel-66 Hot Springs, Kumazasa Publishing Company, pg. 199

Hiroyuki Agishi and Yuichi Iijima (2006): Walking in Hot Spring Resorts in Europe, Iwanami-shoten, pg. 162

Edited by the Japanese Society of Hot Spring Science (2005): Introduction to Hot Springs - Invitation to Hot Springs, Coronasha, pg 128

Junji Yamamura (2015): 47 Prefectural Hot Springs Encyclopedia, MARUZEN, pg 311

Ministry of the Environment HP: Outline of the hot spring law (https://www.env.go.jp/nature/onsen/outline/)

2.2 Direct utilization of hot spring (geothermal) heat

Heat utilization is the use of steam or hot water as a heat source for various applications after using it for geothermal power generation or in hot springs.

It is called a “multistage utilization of geothermal power generation—cascade utilization” to carry out geothermal power generation. This cascade method uses the steam or hot water from the highest temperatures and then uses the remaining heat from higher to lower temperatures in a number of stages. Direct use of geothermal heat can effectively utilize unused energy and offers great merit in terms of cost (JOGMEC, 2018).

Figure 2-5 shows the heat utilization at each stage from the highest temperature range to the lower temperature ranges (Yasukawa 2018). By utilizing geothermal energy in multiple stages, both thermal efficiency and cost efficiency can be realized, making it possible to realize a usage method without profitability alone.

【References】

JOGMEC (2018): HOME> Geothermal general information> Geothermal and hot spring> Effective utilization of hot water

Kasumi Yasukawa (2018): International ONSEN summit material

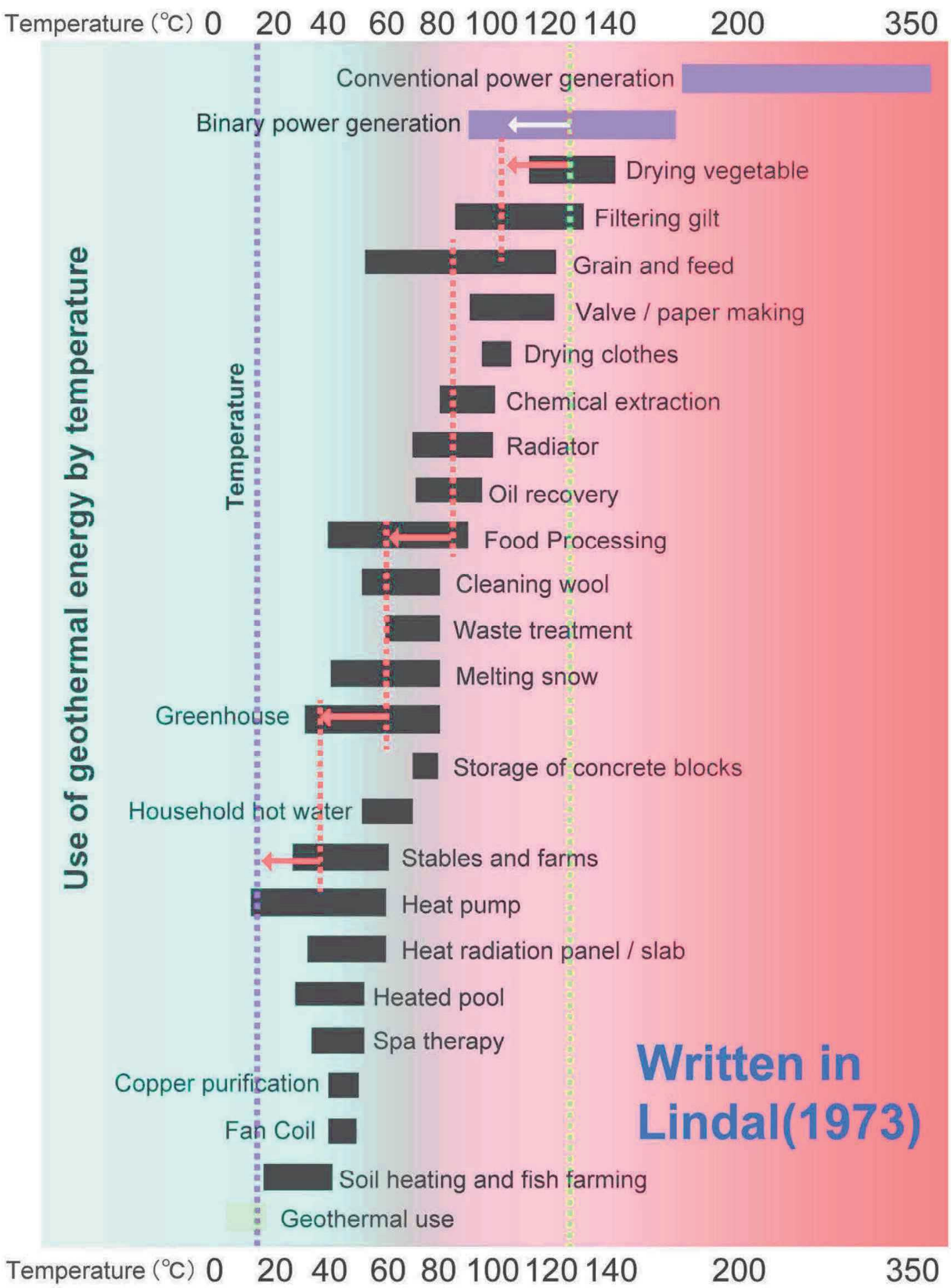


Figure 2-5 Multi-step Utilization of Geothermal Energy

Source: Kasumi Yasukawa (2018): World ONSEN summit materials (Written in Lindal, 1973) Lindal, B. (1973): Industrial and Other Applications of Geothermal Energy. Geothermal Energy, (ed.H. C. H. Armstead), Earth Science, Vol.12, UNESCO, Paris, pp.135-148.

2.2.1 Heat Utilization of Hot Springs

Hot springs produce output at a wide range of temperatures from 20°C to over 100°C. The temperature suitable for bathing is around 40°C. For this reason, hot springs gushing out at higher temperatures, suitable for bathing, are used after cooling naturally or by adding water. Hot spring water, after bathing, maintains a temperature of around 20°C, but normally it is discharged and is not reused. It is not an exaggeration to say that potential thermal energy from hot springs is being wasted.

Based on this situation, the Japan Environmental Sanitation Center organized the "Research Group on Global Warming Countermeasures for Hot Springs." This group began studying the technological feasibility of effective utilization of hot spring heat while carefully considering promoting hot spring utilization.

Source: Akio Okumura・Yasuo Kawabe・Takahiro Ohno(2010): Current Status on Utilization of Heat Sources through Hot Springs and their Effective Use, Bulletin of JESC No.37. pp.92-100
http://www.jesc.or.jp/Portals/0/center/library/shoho/H21shoho6.pdf

Ministry of Environment(2018：2017 materials of promotion seminar, Effective use of hot spring heat
https://www.env.go.jp/nature/onsen/spa/spa_utilizing.html

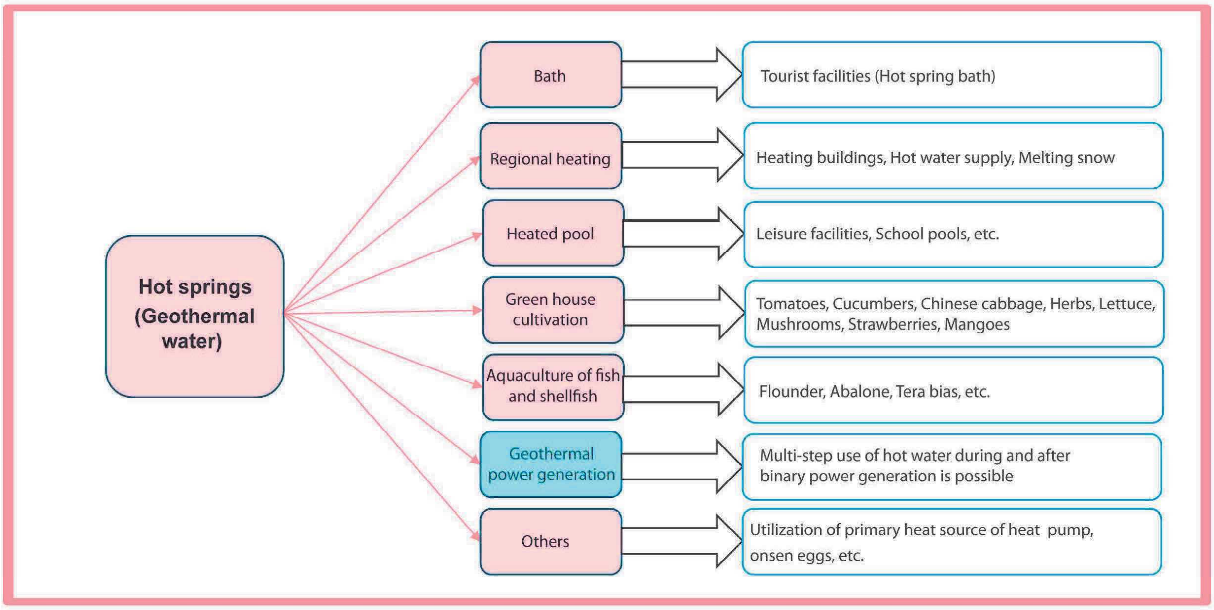


Figure 2-6 Various Hot Spring Uses

Source: Hiroshi Shinomiya (2018): Enrich region by utilizing geothermal resource ~ Treasure mountain project starting ~2017 seminar for effective utilization of thermal fever, material -3
https://www.env.go.jp/nature/onsen/spa/spa_utilizing.html

2.2.2 Heat utilization of hot springs by temperature

Various measures, as shown below, are being taken to promote the use of hot spring heat, depending on the temperature zone of the hot springs. (Hokkaido Economic Affairs Department Industry Promotion Bureau, 2017). Heat usage images are shown below.
① Binary power generation can be expected if the temperature is higher than 70°C. However, for binary power generation, it is important to have a flow rate of hot springs of 200L/min or more and cooling water of 330L /min or more at 30°C or less.
② The heat of a hot spring can be utilized directly with a heat exchanger. When the temperature of the hot spring is above 45°C, it can be used after releasing and cooling the heat through a heat exchanger because the temperature is too high for bathing.
③ Even low-temperature heat, such as from discharged hot water, can be used for preheating a hot water supply, resulting in curbed fuel consumption.
④ Discharged hot water can be used as a heat source for a heat pump. However, because the initial cost is high, it may be used as an alternative source as long as the heat source from accommodation

facilities whose operation rate and fuel consumption are high. However, it must be noted that when the flow rate is low, it cannot be used, so the scale may be reduced. The temperature range required varies depending on the purpose and the conditions of use, for example, it is sufficient to ensure a Geothermal/hot temperature at which the soil does not freeze when cultivating leafy vegetables for agricultural use.

【References】

Hokkaido Economic Affairs Department Industrial Promotion Bureau (2017): Geothermal/hot spring thermal problem-solving guide book
http://www.pref.hokkaido.lg.jp/kz/kke/kadai-gaido.pdf

2.2.3 Direct utilization of geothermal heat in Japan and in the world

The proportion of direct use of geothermal heat in Japan and in the world is shown in **Figure 2-7** and **Figure 2-8** as the proportion of the installed capacity by thermal unit (MW_t).
In Japan, uses for bathing and pools account for the majority, but on a worldwide scale, uses for bathing and pools is at 45%. This shows that geothermal resources are used for a greater variety of purposes outside of Japan. It is necessary to expand further direct use of geothermal heat in Japan.

【Unit of generation capacity and installed capacity of heat output】

Worldwide, a unit of installed capacity of a geothermal power plant is written as "MW_e (megawatt electrical): Watt Electrical is the unit of power output."
Installed capacity of direct use of geothermal heat is written as "MW_t or MW_{th} (megawatt thermal): Watt thermal is a unit of heat output."
In Japan, it is rare to distinguish between these. Installed capacity (power generation capacity) of a geothermal power plant is written in units of "W." Therefore, this case collection follows the Japanese notation.
The unit of equipment capacity for direct utilization of geothermal energy is "MW_t" (t is a half-width subscript). Note that 10,000 kW is 10 MW.

【Reference】

NEDO (2008): Geothermal Energy · Barometer 2007 (EU), NEDO Overseas Report, NO.1021
https://www.nedo.go.jp/content/100105395.pdf

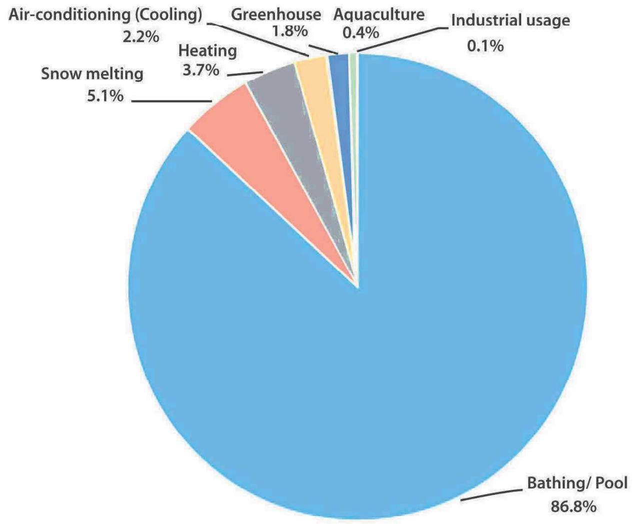


Figure 2-7 Direct Utilization of Geothermal Power in Japan
[Percentage of installed capacity as calorie; based on Japan's heat utilization data (total 2,086 MW_t) published in IGC's GEOTHERMAL POWER DATABASE (data on heat pump excluded)]

Source: IGC: GEOTHERMAL POWER DATABASE (As of February 2019)

https://www.geothermal-energy.org/explore/our-databases/geothermal-power-database/#direct-uses-by-purpose

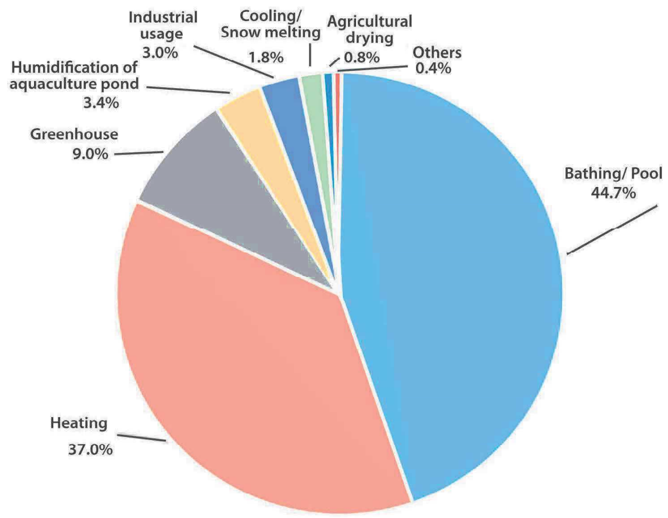


Figure 2-8 Direct Utilization of Geothermal Power in the World

[Percentage of installed capacity as calorie; based on 2015 world heat utilization data of Lund and Boyd (2015) (total 20,431 MW_t) (heat pump excluded)]

Source: John W. Lund and Tonya L. Boyd (2015): Direct Utilization of Geothermal Energy 2015 Worldwide Review, Proceedings World Geothermal Congress 2015

2.3 Use as geothermal power generation

2.3.1 Distribution of geothermal resources

This graph shows the geothermal resource volume per listed country. The United States, with the world's largest geothermal area (The Geyser geothermal area), ranked first (30 million kW); Indonesia, consisting of many volcanic islands, ranked second (27.79 million kW). Japan is the third (23.47 million kW) and is considered one of the world's leading geothermal resource countries (**Table 2-3**). As shown in **Figure 2-9**, geothermal resources have a strong correlation with the number of active volcanoes present. The geothermal power generation capacity in each country is shown in **Figure 2-10**. Large-scale geothermal power generation facilities are installed in the Pacific Rim Volcanic Zone.

Table 2-3 Geothermal Resource and the Installed Capacity in Major Countries

Country	Geothermal Resource (10,000kW)	Installed Capacity (10,000kW)
USA	3,000	372
Indonesia	2,779	186
Japan	2,347	55
Kenya	700	68
Philippines	600	193
Mexico	600	92
Iceland	580	71
New Zealand	365	98
Italy	327	92

【Geothermal resource amounts posted by Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy (2018): Overseas geothermal power generation capacity is extracted from the 2017 data of BP (2018): Japanese geothermal power generation capacity is the latest value as of February 2019 recalculated based on 2017 data of Thermal Power Nuclear Power Technical Association (2018) in accord with the information as of February 2019 by (Tohoku Electric Power Co., 2017; Japan Heavy Industries, Ltd., 2019) 】

Source: Ministry of Economy, Trade, and Industry, Agency for Natural Resources and Energy (2018): 2017 Annual Report on Energy (Energy White Paper 2018)
http://www.enecho.meti.go.jp/about/whitepaper/2018pdf/

Source: BP(2018：BP Statistical Revier of World Energy, 67th edition, Renewable energy - geothermal
https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2018-renewable-energy.pdf

Source: Thermal Nuclear Power Technologies Association (2018): Current status and trends of geothermal power generation 2017

Source: Tohoku Electric Power Co. (2017): Regarding the start of operation by changing the rated output of Yanaizu Nishiyama Geothermal Power plant, August 28, 2017
https://www.tohoku-epco.co.jp/news/normal/1195420_1049.html

Source: Japan Heavy Industries Ltd. (2019): Geothermal power plant started full-scale operation in Matsuo Hachimantai area of Iwate Prefecture, January 29, 2019
http://www.jmc.co.jp/岩手県松尾八幡平地域で地熱発電所が運転開始.html

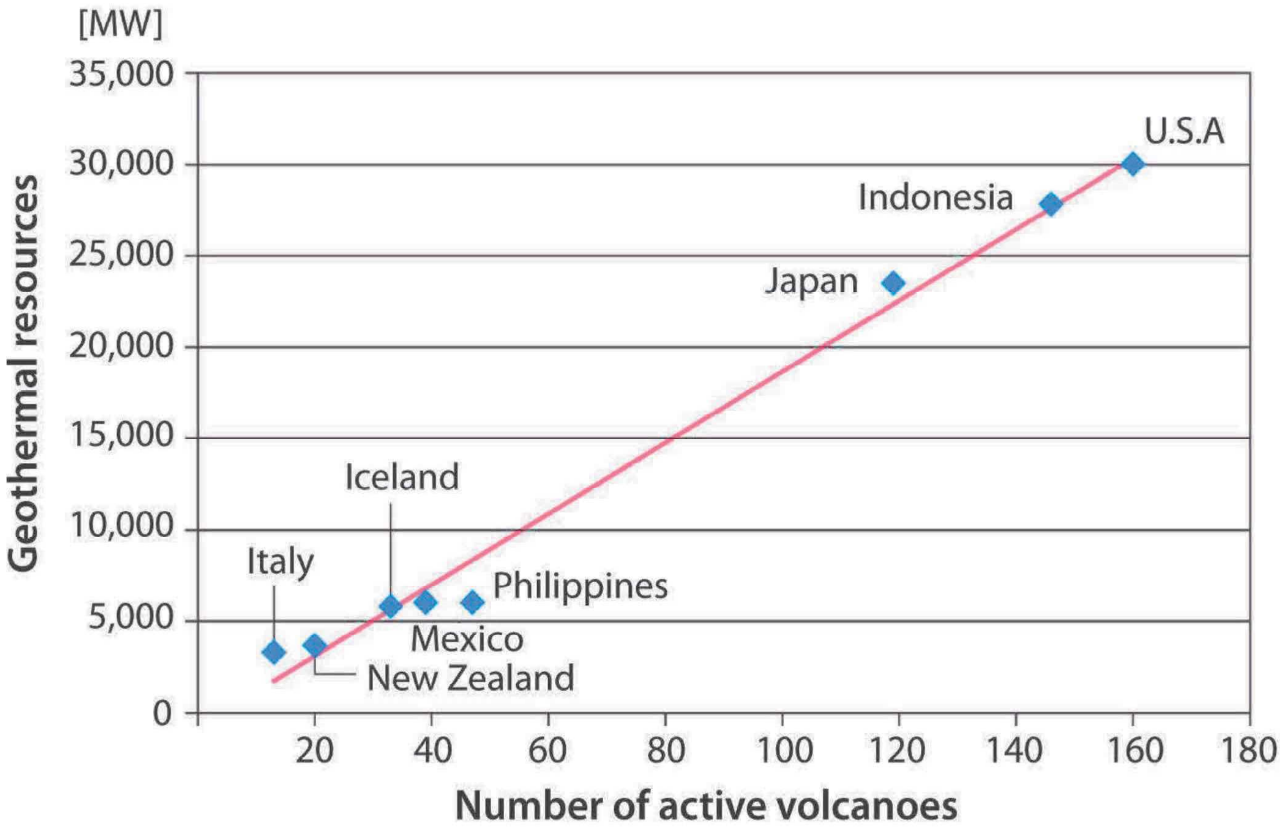
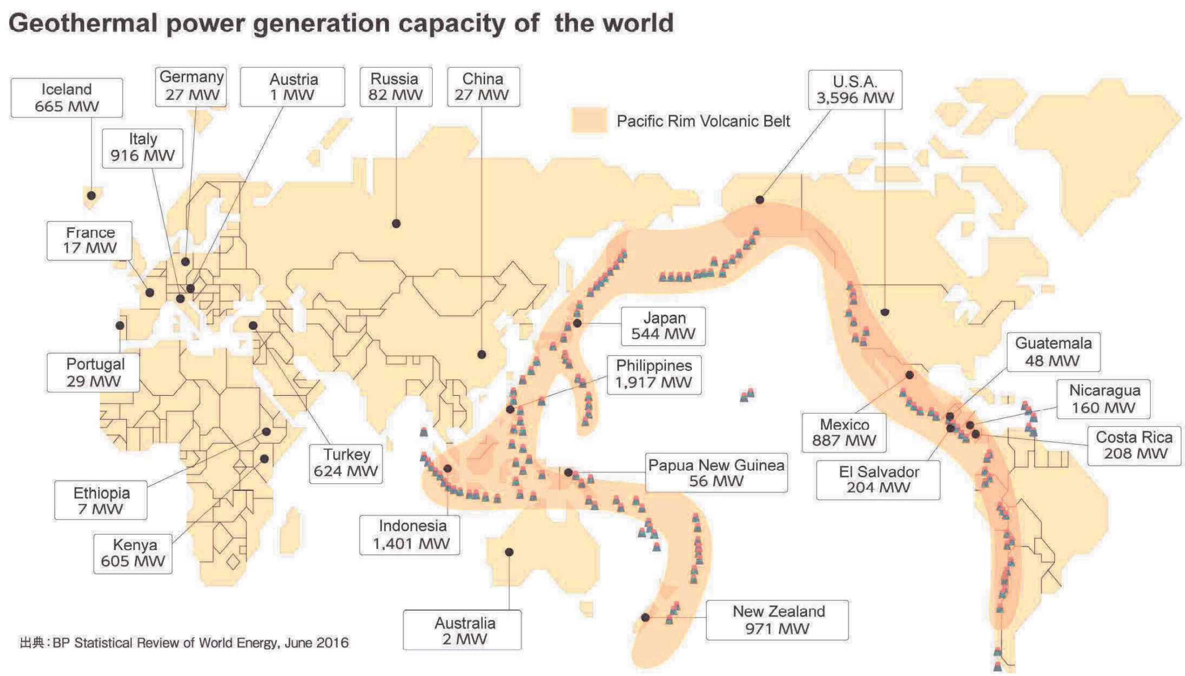


Figure 2-9 Worldwide Geothermal Resources in Correlation to Active Volcanoes

Source: NEDO (2014): Renewable Energy Technology White Paper, Second Edition, Chapter 7 Geothermal Power Generation
https://www.nedo.go.jp/content/100544822.pdf



[JOGMEC (2018) fixed geothermal power plant capacity data. Overseas-changes to the 2017 data of the BP (2018). Japan-the latest value as of February 2019 shown in Table 2-3.]

Figure 2-10 Geothermal Power Generation Capacity of Countries around the World

Source: JOGMEC (2018): Geothermal Heat, Energy living in harmony with local nature, brochure http://geothermal.jogmec.go.jp/report/file/jogmec_geothermal.pdf

Source: BP (2018): BP Statistical Revier of World Energy, 67th edition, Renewable energy - geothermal https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2018-renewable-energy.pdf

The amount of potential geothermal resources in Japan is estimated to be 23.47 million kW as output (**Table 2-3**). This is based on the results of the estimation conducted by Muraoka et al (2008) of the National Institute of Advanced Industrial Science and Technology. By using GIS, they conducted a nationwide assessment of the geothermal resources with a temperature of 150°C or higher and estimated that the total amount was 23.47 million kW. The evaluation result is shown separately under a special protection zone of the national parks, special areas, and others in **Figure 2-4.**

According to the results of this evaluation, 81.9% of the hydrothermal resources above 150°C are within the designated protected area of a National Park/Special Area. Only 18.1% of these areas do not have development restrictions. Developmental regulations within natural parks act as a barrier to geothermal development.

Table 2-4 Relationship between Hot Water Resources of 150°C and the Distribution of National Parks

Classification of calculated areas	Amount of natural resources (10,000kW×30years)	Share nationwide (%)
Total national parks	1,922	81.9
Special protection zone	780	33.2
Special areas	1,142	48.7
Others	425	18.1
Total	**2,347**	**100.0**

Source: Hirobumi Muraoka・Keiichi Sakaguchi・Susumu Sasaki (2008): Evaluation of hot spring system resources in Japan 2008, Abstracts of academic lecture of FY2008 Geothermal Society of Japan, B01
https://www.jstage.jst.go.jp/article/grsj1979/30/Supplement/30_Supplement_B01/_pdf
Source: Yusaku Yano (2008): Development possibility of geothermal power generation, H20.12.1 Study group on geothermal power generation (1st), reference 5 (data cooperation: Hirofumi Muraoka) Group on Geothermal Power Generation (1st), Reference 5 (Materials Cooperation: Hirofumi Muraoka)
http://warp.da.ndl.go.jp/info:ndljp/pid/286890/www.meti.go.jp/committee/materials2/downloadfiles/g81201a05j.pdf

2.3.2 What is geothermal power generation?

The Earth's interior is composed of four layers: inner core, outer core, mantle, crust. The temperature of the center is estimated to be over 5,000ºC. When the rock melts at the top of the mantle, magma occurs, which breaks the crust, and when they reach the surface of the earth, they cause eruptions, forming a volcano. There are magma reservoirs from several kilometers to 20 kilometers underground in the volcanic belt. Their temperatures reach as high as 1000°C. Geothermal power generation is a method of generating electricity using this heat.

In order to generate geothermal power, a geothermal reservoir which holds steam and hot water above 150°C and is under high pressure must exist deep underground at around 2000 meters.

Three elements, ① water (precipitation), ② heat (magma), and ③ container (cap rock), are required to form the geothermal reservoir. By excavating the well (production well) in the formed geothermal reservoir layer, steam and hot water are collected to generate electricity. (See **Figure 2-11**)

The remaining hot water, after power generation, is returned to the geothermal reservoir through the reinjection well, which makes power generation sustainable.

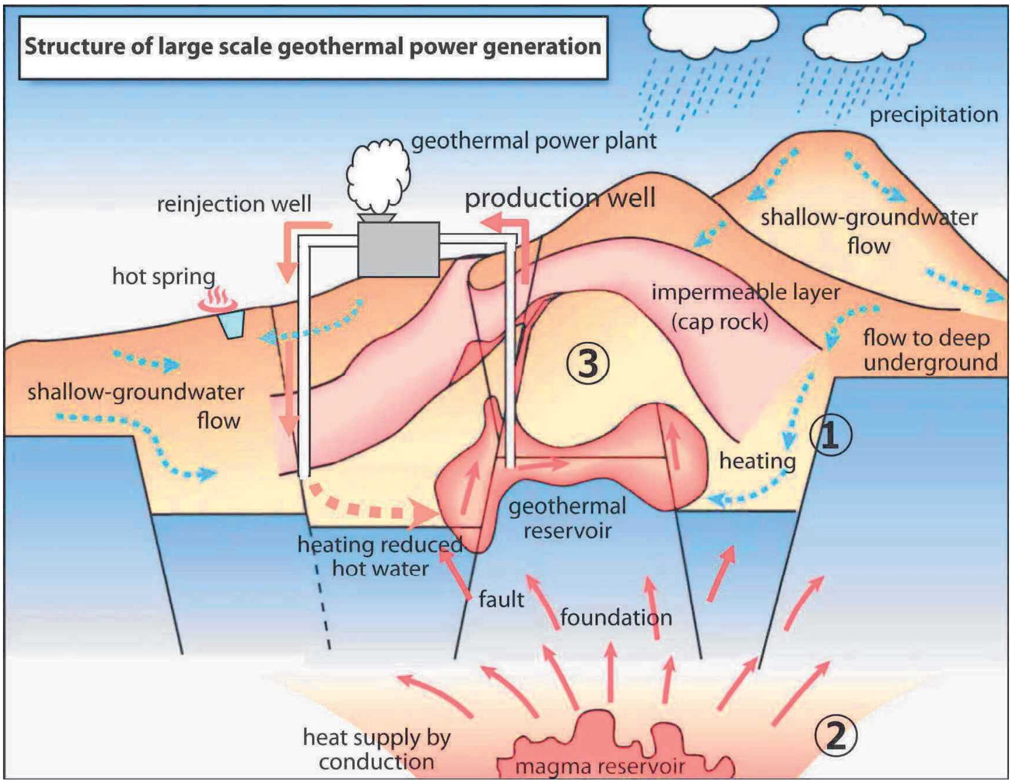


Figure 2-11 Mechanism of Geothermal Power Generation

Source: Agency for Natural Resources and Energy (2017) : On the current state of geothermal resource development Resource and Fuel Subcommittee, Total Resources and Energy Research Committee (22nd), Material - 4 June 2017
http://www.meti.go.jp/committee/sougouenergy/shigen_nenryo/022_haifu.html

Geothermal power generation is relatively clean in terms of CO2 emissions as compared to electricity generated by fossil fuels. Geothermal power is an effective clean energy source aiding in the prevention of global warming. Moreover, it has higher stability compared to other natural energies (sunlight, wind power, etc). Because hot water mixed with steam is returned to the ground, it does not harm the environment.

【Reference】

The Agency for Natural Resources and Energy (2018): The merit of geothermal power generation
http://www.enecho.meti.go.jp/category/resources_and_fuel/geothermal/explanation/development/merit/clean/

Figure 2-12 shows the life-cycle of CO2 emissions by type of power supply. Geothermal power generation, like nuclear power generation and small and medium hydropower generation, has very low CO2 emissions.

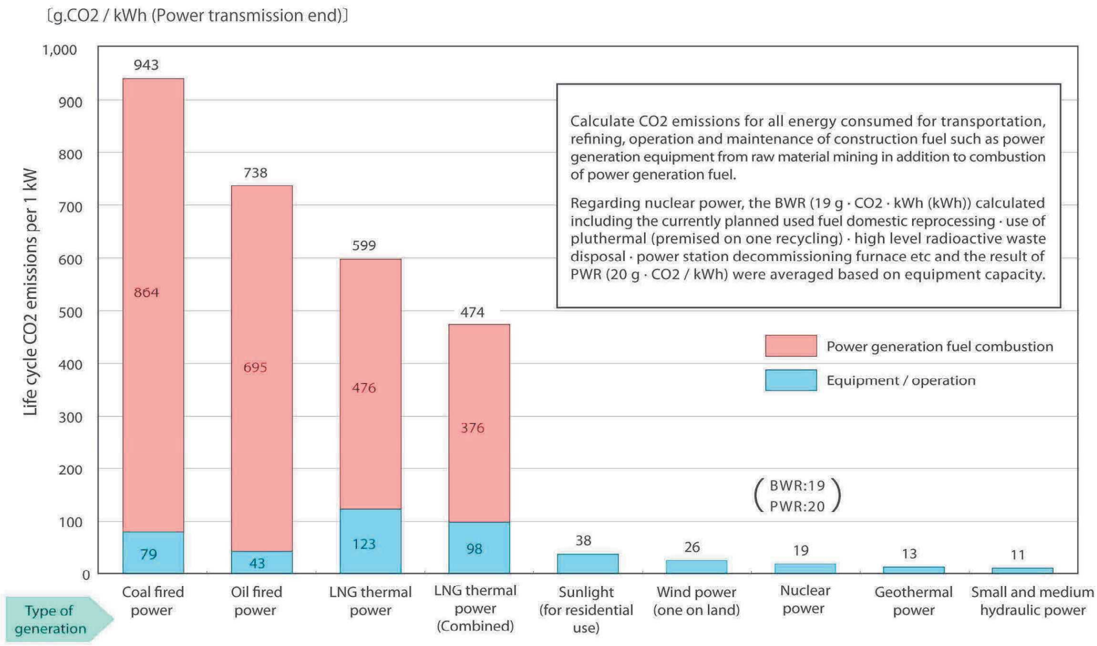


Figure 2-12 Life-cycle CO2 Emissions by Each Power Supply
Source: Japan Atomic Energy Culture Foundation (2018): Drawings of "Nuclear Energy" https://www.ene100.jp/zumen_cat/chap

2.3.3 Geothermal power generation systems

There are two types of systems for geothermal power generation that have already been put into practical use: the widely used flash steam system and the relatively new binary cycle system.

(1) Flash steam system

In the flash steam system, steam and hot water with temperatures between 200 to 350 °C in the geothermal reservoir flow upwards, through a well. The steam is then separated by a steam-water separator and used to rotate a turbine to generate electricity.

The hot water separated by the power steam-water separator is then injected back into the ground through a reinjection well. Most Japanese geothermal power plants use a single flash steam generation system (**Figure 2-13**).

There are also other systems, for example, the double flash steam system and the dry system. The double flash system separates hot water, which is then led to the flasher (low-pressure steam/water separator) and is separated into hot water and steam again. The steam is then sent to the turbine together with the primary steam. The hot water is then sent to a reduction well. Alternatively, the dry steam system draws from underground resources of steam. The steam is piped directly from underground wells to the power plant, where it is directed into a turbine. It does not require a steam/water separator and is used to power turbines.

In Japan, Hatchobaru Power Plant (Kyushu Electric Power Co., Ltd.) and Mori Power Plant (Hokkaido Electric Power Company) use the double flash system, and the Matsukawa Geothermal Power plant (Tohoku Hydroelectric Geothermal) uses the dry steam type.

(2) Binary cycle system

In the binary cycle system, generally, using medium-to-high-temperature hot water or steam of 80°C to 150°C as a heat source, a working fluid, that has a low boiling point, is heated and evaporated; consequently, the turbine is rotated and generates electricity. Working fluids with a boiling point of 100°C or lower such as pentane (boiling point 36.07°C), hydrocarbons, substitute Freon, or ammonia (boiling point -33.34°C) are used. After use, these working fluids are then liquified by a condenser and used repeatedly. This method is called a binary cycle system because hot water and working fluid with a low boiling point, together, generate electricity using two independent thermal circulation cycles (**Figure 2-14**). This system makes it possible to utilize low-temperature hot water and steam which cannot be used in flash steam power system.

【Reference】

NEDO (2014): White paper on renewable energy technology, second edition, chapter 7-Geothermal power generation
http://www.nedo.go.jp/content/100544822.pdf

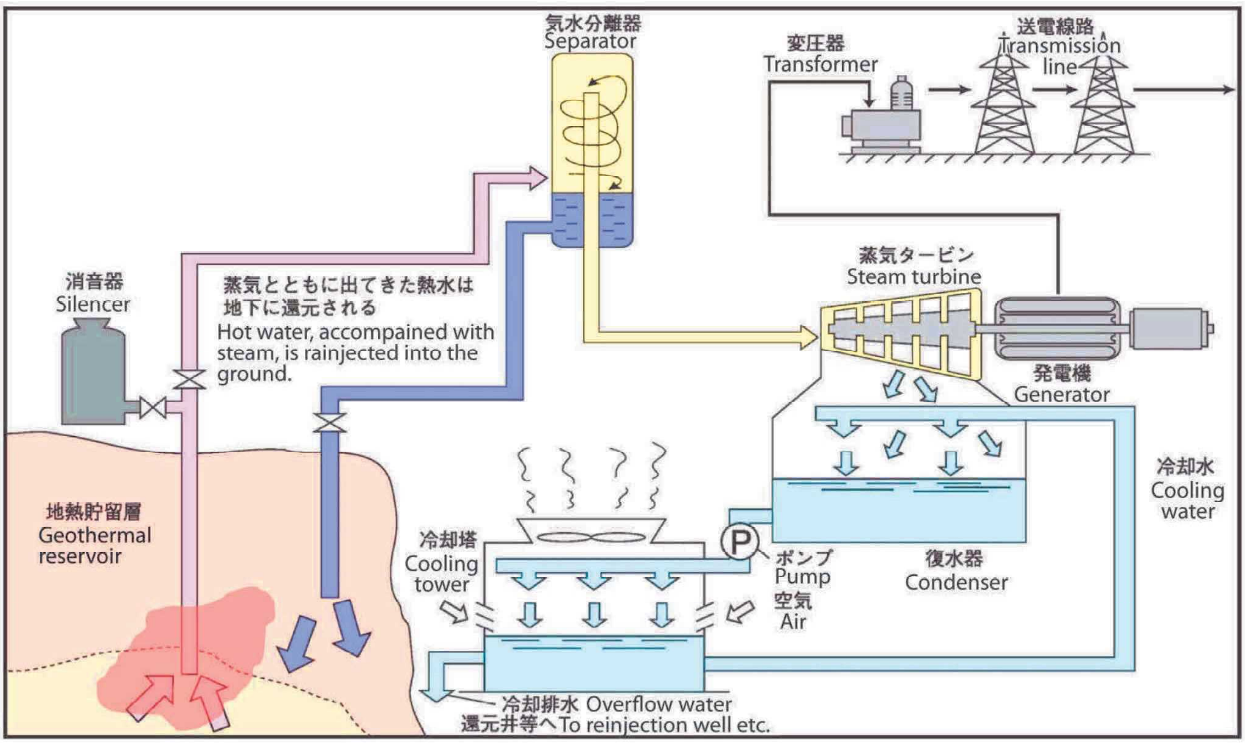


Figure 2-13 Conceptual Diagram of a Single Flash Power Generation System

Source: NEDO (2014): White paper on renewable energy technology, second edition, chapter 7-Geothermal power generation
http://www.nedo.go.jp/content/100544822.pdf

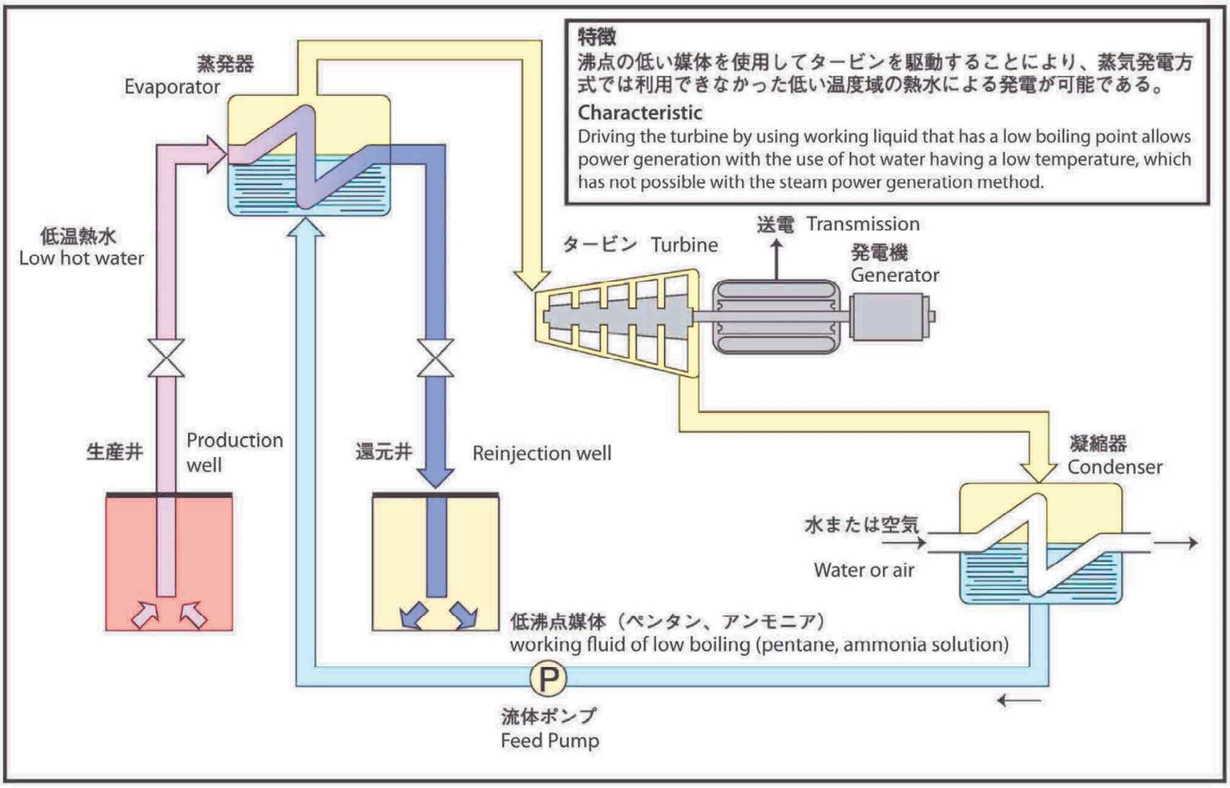


Figure 2-14 Conceptual Diagram of Binary Cycle Power Generation System

Source: NEDO (2014): White paper on renewable energy technology, second edition, chapter 7-Geothermal power generation
http://www.nedo.go.jp/content/100544822.pdf

2.3.4 History of geothermal power generation

Geothermal power generation in Japan began in 1919 when Lieutenant General Yoshihisa Yamauchi succeeded in fumarolic drilling in Beppu, Oita Prefecture. Mr. Heiji Tachikawa, director of the research center of Tokyo Denki Co., Ltd., then took over the project and succeeded in Japan's first geothermal power generation (output 1.12 kW) in 1925. Following Director Tachikawa's work, no major development was seen until the end of World War II.

Postwar Japan needed a stable supply of electric power and promoted the construction of hydropower and large-scale thermal power plants. At that time, the focus was on conducting investigative research and development for practical uses of geothermal power. These efforts finally bore fruit when, in 1966, the Matsukawa geothermal power plant in Iwate Prefecture, a vapor-dominated type plant, started operation as the first full-scale geothermal power plant in Japan. In 1967, the Otake power plant, in Oita prefecture, using the Hot Water excellence system started operations. The success of these two power plants has greatly advanced geothermal development.

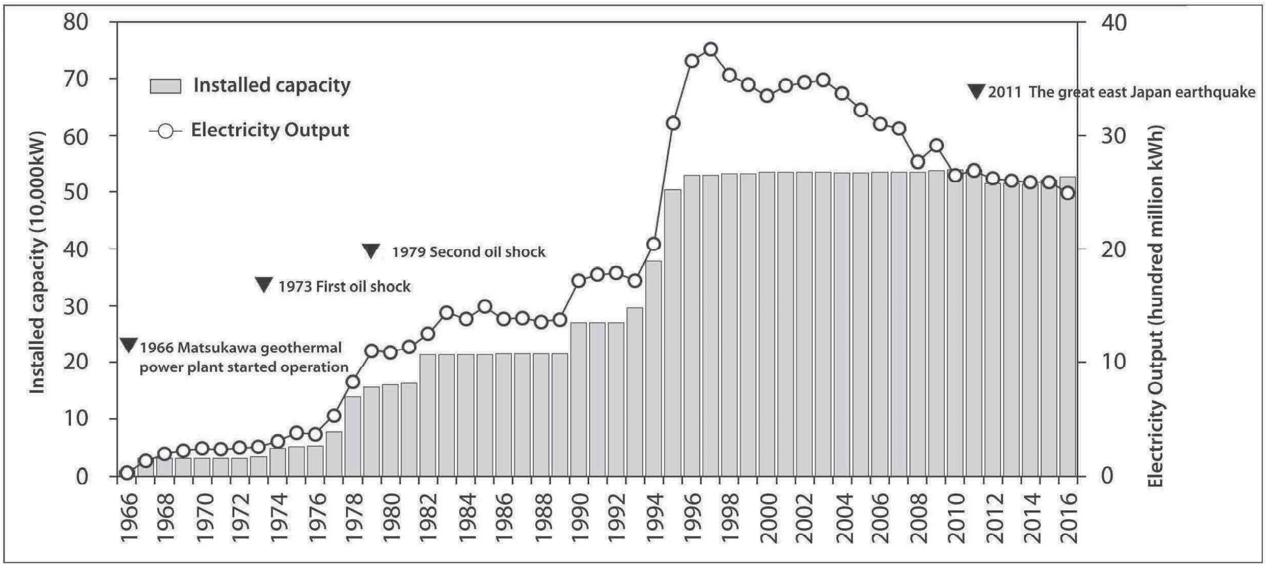
In the 1970s, triggered by two oil shocks, Japanese geothermal development was greatly advanced as the geothermal portion of the Sunshine Project that was initiated in 1974 as an alternative energy policy. In the Tohoku and Kyushu regions, the construction of power plants continued one after another, and in 1996 the installed geothermal power generation reached 500,000 kW. Japan has become one of the leaders in geothermal power generation technology.

In the 1990s, due to the stabilization of oil prices and the conversion of the energy policy in Japan, the development of the geothermal power generation leveled off. The concerns of the cost of power generation, the laws regulating natural parks and the need for harmonious coexistence with hot spring operators all affected further development of geothermal power plants. In 2002, the national technology development budget terminated. Therefore, since 2006, only the Hatchobaru power plant was constructed. However, due to the serious energy crisis caused by the Great East Japan Earthquake, in 2011, the Fixed Price Purchase System (FIT) was introduced. As a result, expectations toward geothermal power generation have increased. It is recognized as a stable power supply based on a renewable energy source.

【Reference】

Source: JOGME HOME＞Geothermal heat, general information＞History of geothermal power generation＞History to date
http://geothermal.jogmec.go.jp/information/history/history.html

Figure 2-15 shows geothermal power generation capacity and generated power. Since 1996, the capacity of power generation facilities has remained flat, but the generated electric energy has decreased due to aging facilities that have weakened power generation efficiency and declined due to scale adhesion.



{Created from Thermal Power Nuclear Power Technology Association (2018)}

Figure 2-15: Secular Change of Installed Capacity and Electricity Output

Source: Thermal Nuclear Power Technology Association (2018): Current situation and trend of geothermal power generation, 2017

2.3.5 The amount of available geothermal heat and potential for introduction by region

Figure 2-16 shows the distribution of the available geothermal heat based on the power supply by area (Source: EX Research Institute Ltd. et al., 2011). **Figure 2-17** shows the conditions of the distribution of potential geothermal heat introduction.

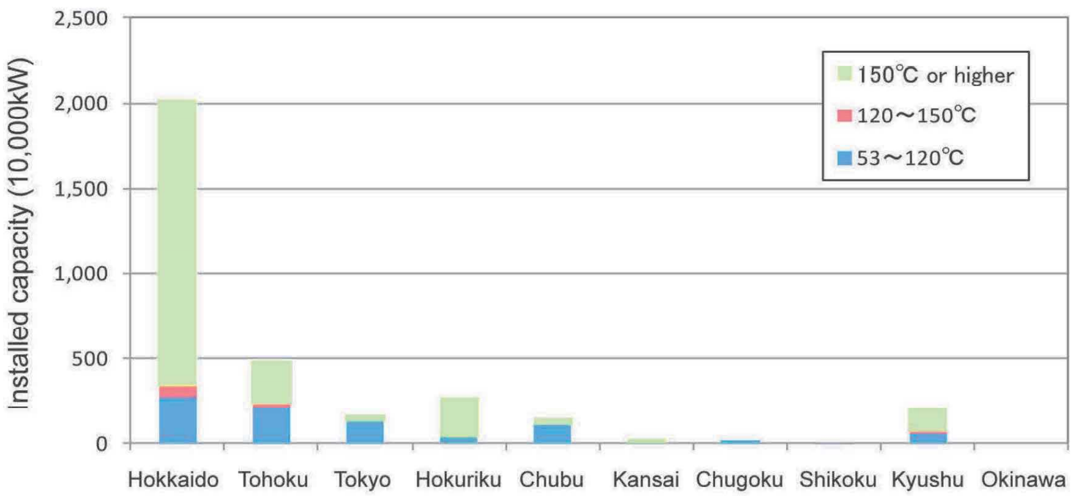
Apart from the amount of available geothermal heat, the natural conditions and social conditions (such as regional classification based on the Natural Parks Act) in individual areas have been taken into consideration.

The amount of available geothermal heat, according to each geographic power supply area, with a temperature of 150°C or more is concentrated in the Hokkaido area, accounting for 71% of the total, followed by the Tohoku area at 11%, the Hokuriku area at 9% and the Kyushu area at 6%. Supply areas with temperatures of 120°C to 150°C show similar distribution conditions.

Available geothermal heat with temperatures of 53~120°C is distributed over a relatively wide geographic range, from 32% in Hokkaido, 25% in Tohoku, 15% in Tokyo and 13% in Chubu. The distribution map for the introduction of potential hydrothermal resource development (53°C ~ 120°C) is shown in **Figure 2-18.**

【Reference】

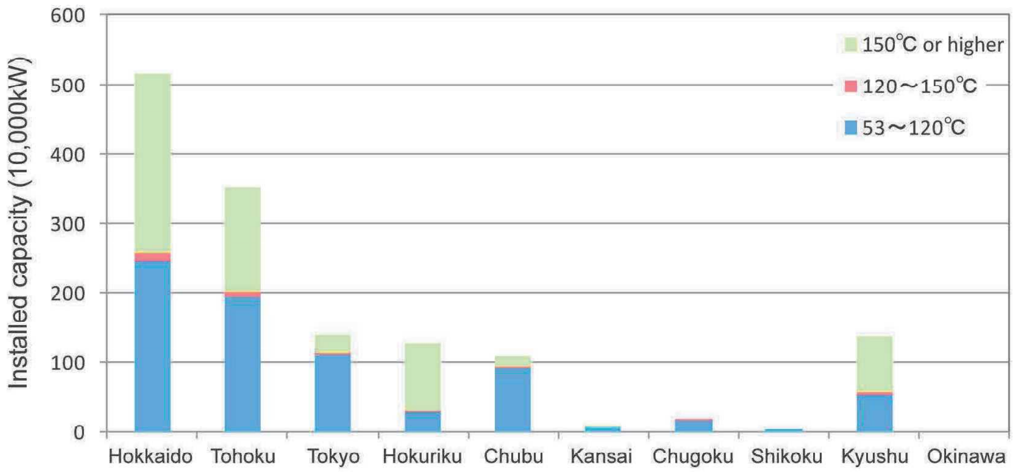
EX Research Institute Co., Ltd. · Asia Aeronautical Corporation Co., Ltd. · Pacific Consultants Co., Ltd. · ITOCHU Techno-Solutions Co., Ltd. (2011): FY 2010 Potential for introducing Renewable Energy Investigation Report, 2010 Ministry of Environment commissioned project, pp.213-225 https://www.env.go.jp/earth/report/h23-03/chpt6.pdf



Temperature	Nationwide	Hokkaido	Tohoku	Tokyo	Hokuriku	Chubu	Kansai	Chugoku	Shikoku	Kyushu	Okinawa
150℃ or higher	2,357	1,674	252	39	220	37	2	0	0	134	0
120～150℃	108	70	16	2	7	3	0	0	0	9	0
53～120℃	849	272	216	128	37	107	8	17	4	60	0
Total	3,314	2,016	484	169	264	147	10	17	4	203	0

Figure 2-16 Distribution of Geothermal Viability by Area

Source: EX Research Institute Co., Ltd. •Asia Aeronautical Corporation Co., Ltd. · Pacific Consultants Co., Ltd. · ITOCHU Techno-Solutions Co., Ltd. (2011): FY 2010 Potential for introducing Renewable Energy Investigation Report, 2010 Ministry of Environment commissioned project, pp.213-225
https://www.env.go.jp/earth/report/h23-03/chpt6.pdf



Temperature	Nationwide	Hokkaido	Tohoku	Tokyo	Hokuriku	Chubu	Kansai	Chugoku	Shikoku	Kyushu	Okinawa
150℃ or higher	636	261	150	28	99	16	0	0	0	82	0
120～150℃	33	12	9	2	3	1	0	0	0	5	0
53～120℃	751	245	194	113	28	93	8	15	4	52	0
Total	1, 419	518	353	142	129	110	8	15	4	140	0

Figure 2-17 Distribution of Potential for the Introduction of Geothermal Power Generation by Area Based on Natural and Social Conditions

Source: EX Research Institute Co., Ltd. • Asia Aeronautical Corporation Co., Ltd. • Pacific Consultants Co., Ltd. • ITOCHU Techno-Solutions Co., Ltd. (2011): FY 2010 Potential for introducing Renewable Energy Investigation Report, 2010 Ministry of Environment commissioned project, pp.213-225
https://www.env.go.jp/earth/report/h23-03/chpt6.pdf

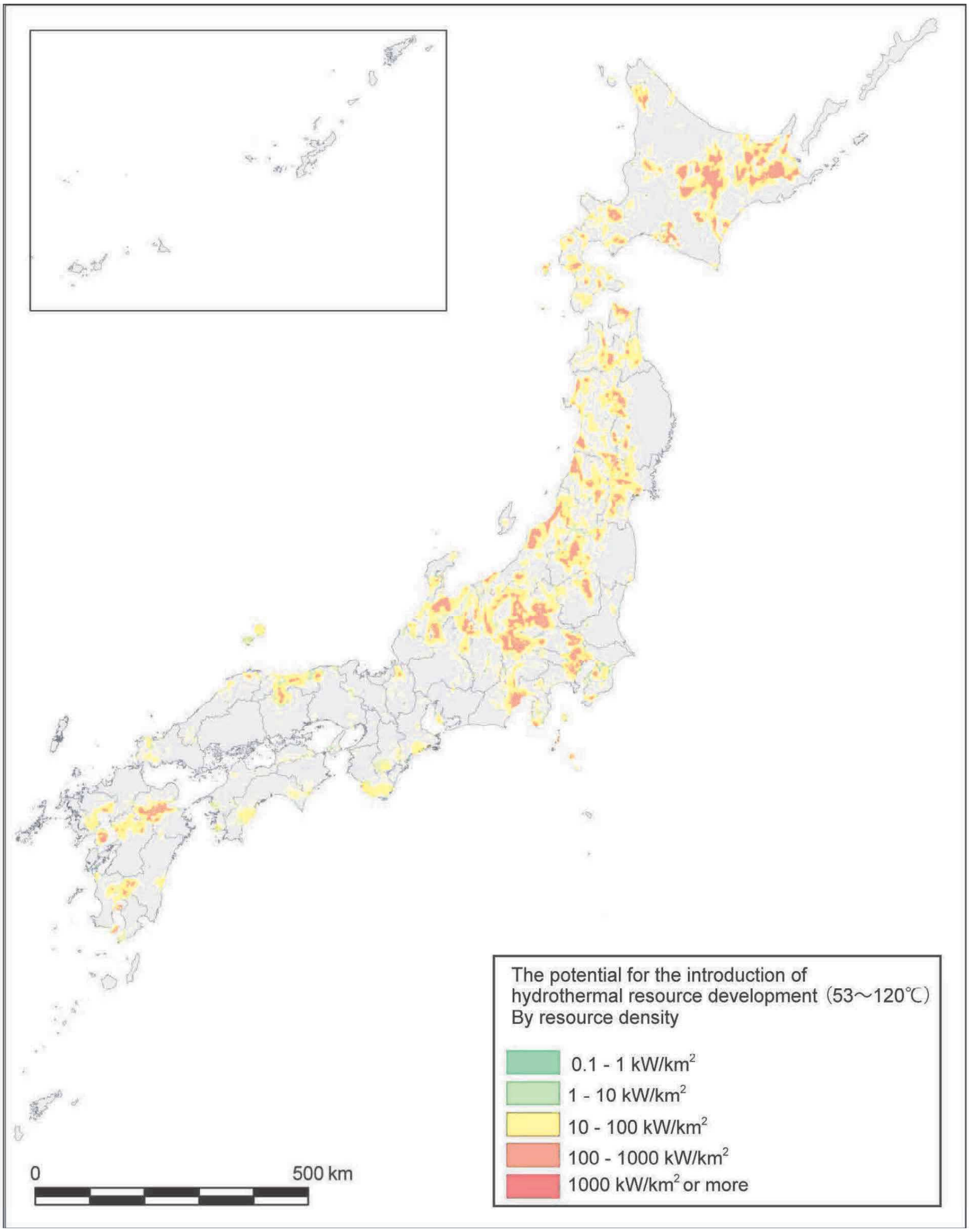


Figure 2-18: Distribution Map showing Potential for Introduction of Hydrothermal Resource Development (53°C ~ 120°C)

Source: EX Research Institute Co., Ltd. • Asia Aeronautical Corporation Co., Ltd. • Pacific Consultants Co., Ltd. • ITOCHU Techno-Solutions Co., Ltd. (2011): FY 2010 Potential for introducing Renewable Energy Investigation Report, 2010 Ministry of Environment commissioned project, pp.213-225
https://www.env.go.jp/earth/report/h23-03/chpt6.pdf

2.3.6 Geothermal power generation by institution

The geothermal power plants in Japan are concentrated in Tohoku and Kyushu due to the distribution of volcanoes and geothermal areas. The total installed capacity of power generation nationwide is about 520,000kW and the total electricity output is 2,559GWh (FY 2015), which covers roughly 0.3% of the electricity demand in Japan.

The largest power plant in Japan is Hatchobaru Power Plant in Oita prefecture, which generates 110,000kW. Other geothermal power plants, for example, are the Hachijojima Geothermal Power Plant in Tokyo, the only plant in Japan located on an isolated island, and the Matsukawa Geothermal Power Plant in Iwate Prefecture. The Matsukawa plant has a 50-year history and was started as the first commercial operation in Japan.
Figure 2-19 shows the location map of major geothermal power plants in Japan.
Table 2.5 shows power generation business operations and their authorized output, power generation systems, and operation start date.

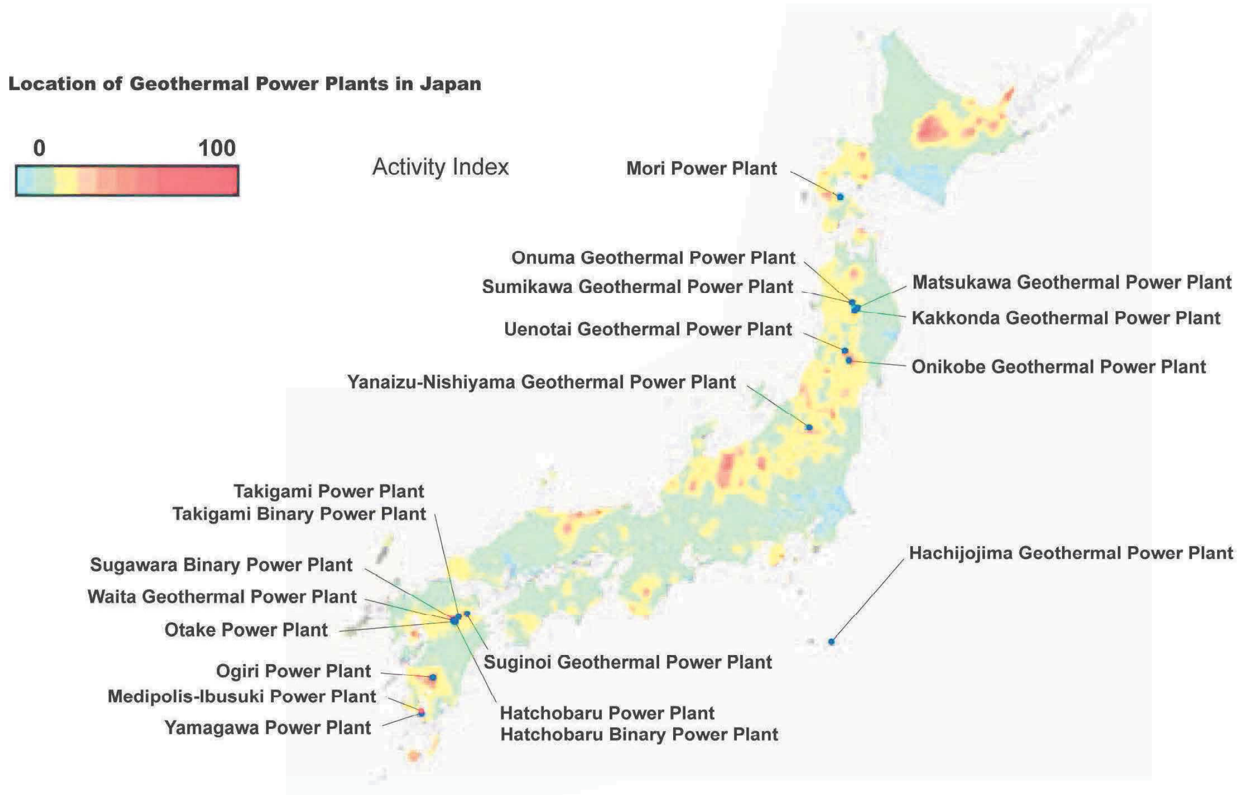


Figure 2-19 Location of Geothermal Power plants in Japan

Source: JOGMEC 2018：Geothermal Energy to Coexist with the Region and Nature, Brochure
http://geothermal.jogmec.go.jp/report/file/jogmec_geothermal.pdf

Table 2-5 Specifications of Major Power plants

	Location	Generator	Steam/Hydrothermal Supplier	Authorized Output (kW)	System	Start Date	FIT
Mori Power Plant	Mori, Hokkaido	Hokkaido Electric Power Co., Inc.		25,000	DF	1982.11.26	
The Matsukawa Geothermal Power Plant	Hachimantai, Miyagi	Tohoku Sustainable & Renewable Energy Co., Inc.		23,500	DS	1966.10.08	
The Kakkonda Geothermal Power Plant	Shizukuishi, Iwate	Tohoku Electric Power Co., Inc.	Tohoku Sustainable & Renewable Energy Co., Inc	No 1 50,000	SF	1978.05.26	
				No 2 30,000		1996.03.01	
The Onikobe Geothermal Power Plant	Osaki, Miyagi	J-Power		15,000	SF	1975.03.19	
The Onuma Geothermal Power Plant	Kazuno, Akita	Mitsubishi Materials Corporation		9,500	SF	1974.06.17	
The Sumikawa Geothermal Power Plant		Tohoku Electric Power Co., Inc.	Mitsubishi Corporation	5,000		1995.03.02	
The Uenotai Geothermal Power Plant	Yuzawa, Akita	Tohoku Electric Power Co., Inc.	Tohoku Sustainable & Renewable Energy Co., Inc	28.800	SF	1994.03.04	
Yanaizu-Nishiyama Geothermal Power Plant	Yanaizu, Fukushima	Tohoku Electric Power Co., Inc.	Oku Aizu Geothermal Co., Ltd.	65,000	SF	1995.05.25	
The Hachijojima Geothermal Power Plant	Hachijo, Tokyo	Tokyo Electric Power Co., Inc		3,300	SF	1999.03.25	
The Waita Geothermal Power Plant	Oguni, Kumamoto	Waita LLC.		1,995	SF	2014.12	F
The Suginoi Geothermal Power Plant	Beppu, Oita	Kyushu, Beppu Suginoi-Hotel		1,900	SF	2006.04.01	
The Takigami Power Plant	Kokonoe, Oita	Kyushu Electric Power Co., Ltd.	Idemitsu Oita Geothermal Co., Ltd.	27,500	SF	1996.11.01	
The Takigami Binary Power Plant		Idemitsu Oita Geothermal Co., Ltd.		5,050	B	2017.03.01	F
The Otake Power Plant		Kyushu Electric Power Co., Ltd.		12,500	SF	1967.08.12	
The Hatchobaru Power Plant		Kyushu Electric Power Co., Ltd.		(No 1) 55,000	DF	1977.06.24	
				(No 2) 55,000	DF	1990.06.22	
The Hatchobaru Binary Power Plant				2,000	B	2006.04.01	
The Sugawara Binary Power Plant		Kyuden Mirai Energy Company, Incorporated	Kokonoe-machi	5.000	B	2015.06.29	F
The Ogiri Power Plant	Kirishima, Kagoshima	Kyushu Electric Power Co., Ltd.	Nittetsu Mining Co., Ltd.	30,000	SF	1996.03.01	
The Yamagawa Power Plant	Ibusuki	Kyushu Electric Power Co., Ltd.		25,960	SF	1995.03.01	
The Medipolis Ibusuki Power Plant	Kagoshima	Medipolis Energy Co., Ltd.		1,410	B	2015.02.18	F

Power generation system FS Single Flash DF Double Flash B Binary F: Feed-in Tariff system certified power Plant among 38 geothermal power plants, the power plants with approved/certified output of 1000 kW or more are posted.

Source: JOGMEC (2018): Geothermal Energy to Coexist with the Region and Nature, Brochure http://geothermal.jogmec.go.jp/report/file/jogmec_geothermal.pdf