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Contribution of Geothermal Energy for Regional Innovation and Earthquake Recovery

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1 Introduction

After the Great East Japan Earthquake in March 2011, Japan has been promoting various policies like the Strategies to Revitalize Japan[1]. In particular, there has been discussion around realizing a new optimum energy mix, with the aim of strengthening and accelerating green innovation strategies. It is essential that the adoption of renewable energy be more accelerated than ever. The Energy and Environment Council[2] worked with related government ministries and agencies and other organizations to deepen the national debate and drew up a basic energy plan consisting of a new optimum energy mix. The Guideline on Policy Promotion (May 17, 2011, Cabinet Decision) discusses environmental and industrial strategies in line with this plan as well as the Innovative Strategy for Energy and the Environment consisting of green innovation strategies (which support the abovementioned plan and strategies). The guidelines state that the government will, in the short term, respond to restrictions on electricity, foster growth by, for example, creating disaster-resistant energy supply systems (including the construction of Eco-Towns, energy conservation and new energy businesses, the development of distributed energy systems), create a virtuous cycle for expanding capital demands, and implement these initiatives in the disaster-stricken region ahead of other regions. The guidelines also state that the government will, in the medium to long term, strengthen initiatives to create new energy and environmental structures that respond to requests for a safe, stable supply, efficiency, and for the environment[3].

Renewable energy does not become depleted as long as it is used within the range of nature's replenishing power and, in general, it does not cause global warming. The International Energy Agency (IEA) explains in its publication (Renewables Information), "Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar power, wind power, the ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources". As to solar power generation, a system for purchasing surplus household electricity was launched, and the use of solar power panels for households has been promoted, but improving efficiency is an issue[5]. In addition, the adoption of wind power generation, small-scale hydropower generation[6], and biofuel co-combustion (at thermal power plants)[7] have been promoted in industry in recent years.

This article reviews the current state of geothermal power generation both in Japan and the world and discusses the potential of geothermal heat as an energy source, the contributions the use of heat can make to regional communities, and related policies.

2 Current State and Issues of Geothermal Energy

2-1 Geothermal Resources

Geothermal resources can be defined as heat generated within the Earth that can be used as energy. Geothermal energy can be used both to generate power and as a direct heat source, and it is expected to reduce fossil fuel consumption and greenhouse gases[8].

Temperatures within the Earth increase with depth below the surface, and the rate of the temperature increase is called the geothermal gradient. The average geothermal gradient in Japan is about 30°C/km[8] (the global average is about 20°C/km). If depth is not an issue, underground heat resources exist everywhere. However, for heat resource usage to be economical, it is desirable to find resources at as shallow a depth as possible. As long as one uses heat moderately, the Earth will continuously replenish it, and so it is a sustainable and renewable source of energy.

As Figure 1 shows types of geothermal resources. The geothermal resources can be divided into two types depending on how the heat is replenished: 1) convection-dominated geothermal resources (heat from deep underground is transferred to groundwater and moves up through circulating water) and 2) hot dry-rock geothermal resources (there is no circulating water and the rock conducts heat). When people talk about geothermal resources, they usually mean the former. This form is easier to use, since heat is obtained as hot water or vapor, and like hot springs, hot water sometimes pours out naturally.

Figure 2 shows underground model of Geothermal Resouce. Hot water and vapor (used for power generation) are heated by geothermal heat in a groundwater reservoir (confined and pressurized under a shielding layer), which often lies 1,000 to 2,000 meters underground. Heated groundwater is brought up through a production well as pressurized vapor or hot water. Recently, it has become clear that the source of the water (hot water for either power generation or hot spring) is rainwater from the surrounding area. After it is used for geothermal generation, cooled water is usually returned underground through an injection well to maintain the underground water balance and prevent the surrounding environment from being affected by impurities from underground[10].

Japan is one of the countries that have abundant geothermal resources. Figure 3 shows geothermal power generation resources and installed power generation capacity. Japan's hot water resources (over 150°C) alone amount to 23,470 MW when converted into power output (which could supply hot water at 150°C for thirty years)[11]. Japan has the world's third largest geothermal resources (after the United States

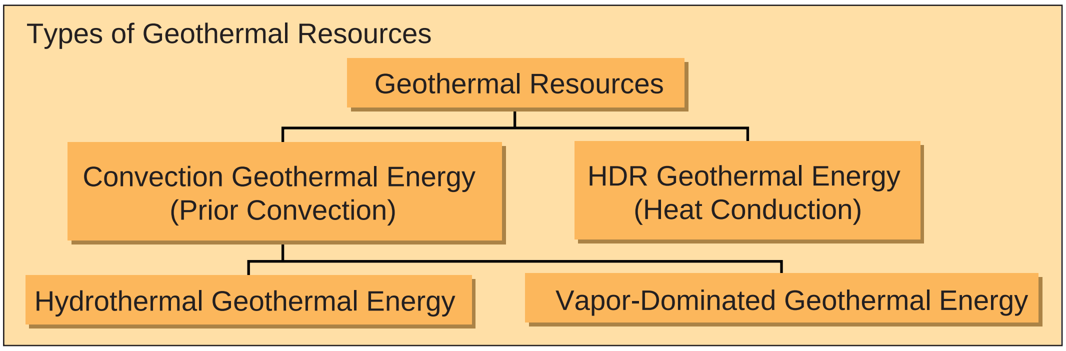


Figure 1 : Type of Geothermal Resources

Source: Reference[9]

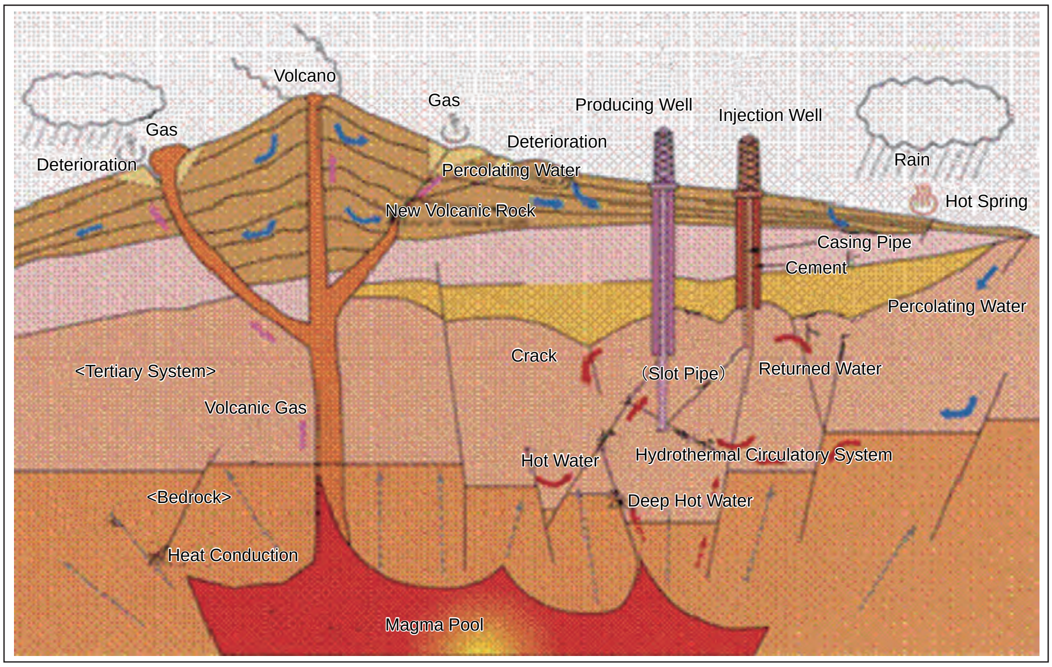


Figure 2 : Underground Model of a Geothermal Resource(Onuma-Sumikawa Geothermal System)

Source: Reference[10]

and Indonesia), and it still has abundant untapped geothermal resources.

Geothermal resources can be used not only for geothermal power generation but also as a direct heat source. Figure 4 shows how geothermal energy is used. Hot water and vapor usually come out through a well using their own pressures, and, generally speaking, it is easy to provide energy even during external power outages and other emergencies, depending on the system structure.

The use of underground heat requires the technology to use soil or water underground (at 0-100 meters deep) as a heat source for a heat pump. The topic was previously covered in Science & Technology Trends (No. 90, September 2008). The underground temperature is roughly constant throughout the year. It is lower than the air temperature in summer and higher in winter. Therefore, if waste heat is put underground in summer, and heat is brought out as a thermal source for a heat pump in winter, one can run an air conditioner, heater, snow-melting system, or water heater using less power than if one were using the air as a thermal source[12].

2-2 Geothermal Power Generation

2-2-1 Comparison of Other Renewable Energy

Compared with other renewable energy, geothermal power generation has the following major characteristics.

- Compared with solar power and wind power generation, geothermal generation is reliable in terms of supply. A stable power supply is attainable with no need to set up a back-up power source and secondary battery. In addition, operating ratios are higher than solar power and wind power generation, and so as shown in Figure 5, geothermal generation can annually produce power energy several times higher than solar and wind power generation. Facility utilization rates are also high, and the power generation unit price is about one fifth to one third of the unit price of solar power[15].
- Heat is a byproduct and can be used for various purposes.
- The emissions rate of CO_2 over the lifecycle of the facility is about one quarter to one half of the CO_2 emissions generated from solar power and wind power generation as shown in Figure 6.

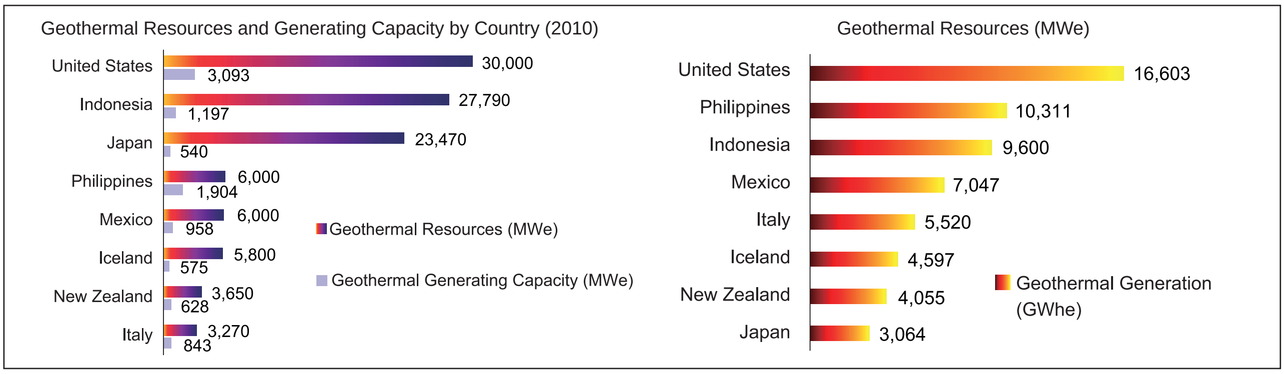


Figure 3 : Geothermal Resources, Installed Power Generation Capacity, and Geothermal Power Generation around the World

Source: Prepared by STFC based on Reference[13,14]

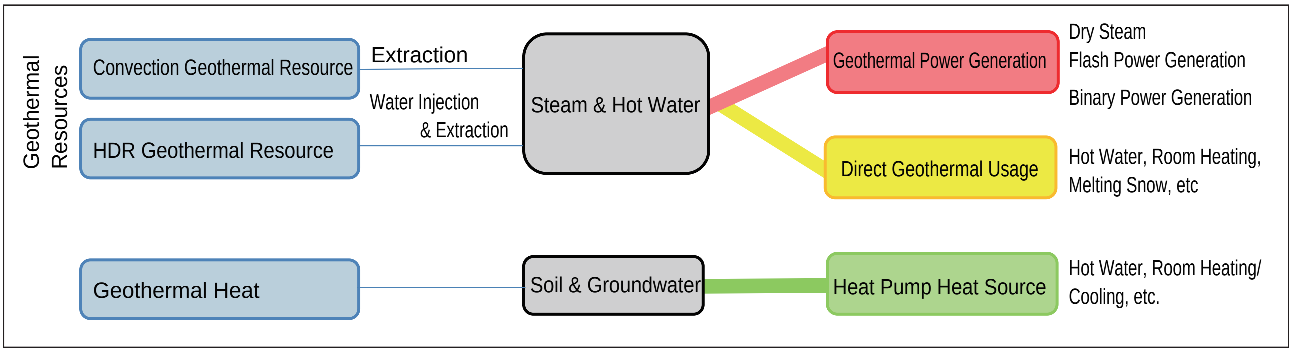
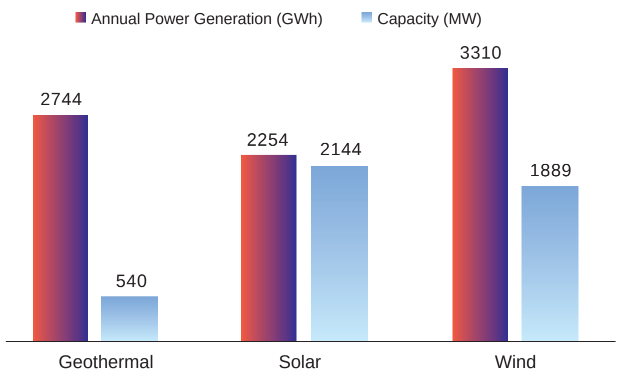


Figure 4 : Usage of Geothermal Resources

Prepared by STFC.



Generating Method	Cost (JPY/kWh)	Utilization (%)
Hydro	8.2~13.3	45
Oil	10.0~17.3	30~80
LNG	5.8~7.1	60~80
Coal	5.0~6.5	70~80
Nuclear	4.8~6.2	70~85
Solar	46	12
Wind	10~14	20
Geothermal	7.8~18.3	70

Basis for Annual Power Generation
- Geothermal: FY2008 results data (Reference [15])
- Solar: Calculated according to assumed facility utilization of 12% based on 2,144 MW currently installed as of FY2008 (Reference [16])
  Annual Power Generation = 2,144 MX x 24 hrs x 365 x 0.12 x 0.001 (GWh / MWh)
- Wind: Calculated according to assumed facility utilization of 20% based on 1,889 MW currently installed as of FY2008 (Reference [16])
  Annual Power Generation = 1,889 MX x 24 hrs x 365 x 0.2 x 0.001 (GWh / MWh)

Figure 5 : Comparisons of Annual Power Generation, Facility Capacity, Power Generation Unit Price, and Facility Utilization Rate (Fiscal 2008)

The graph was prepared by STFC. The power generation prices and facility utilization rates are based on Reference[15].
*Nuclear power generation prices are being reassessed by the Japan Atomic Energy Commission.

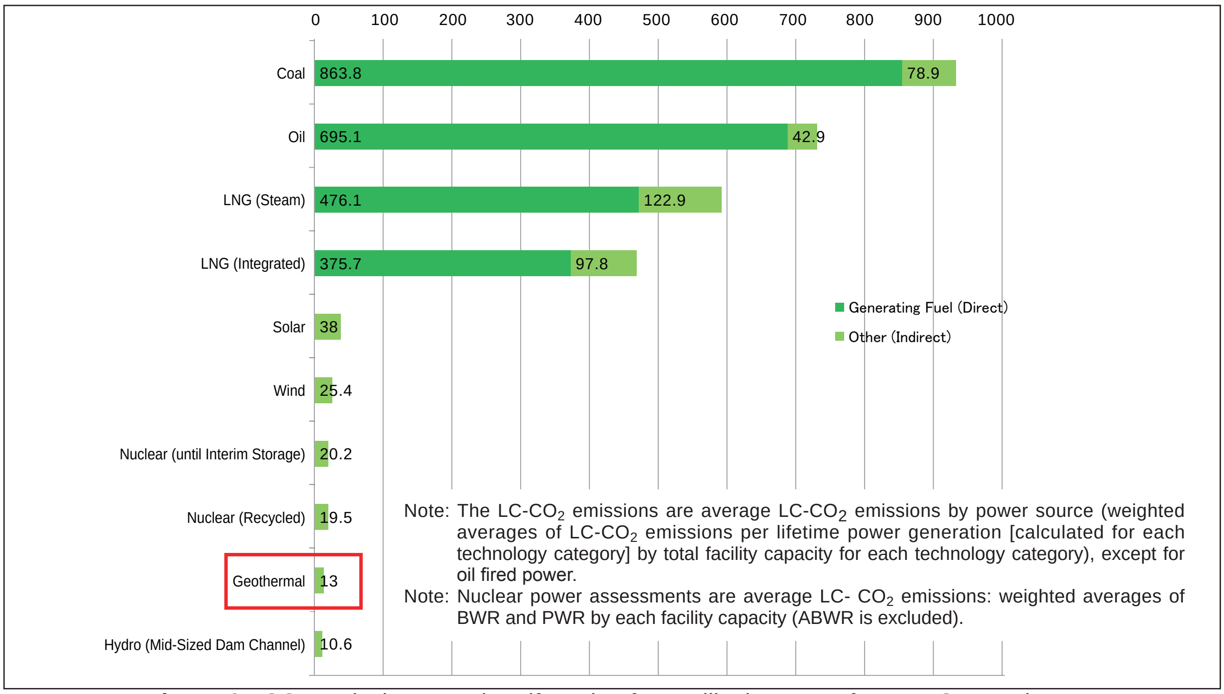


Figure 6 : CO_2 Emission over the Lifecycle of a Facility by Type of Power Generation
(Unit: g-CO_2/transmission end kWh)

Source: Reference[17]

2-2-2 Issues Surrounding Geothermal Resource Development in Japan

In Japan, the capacity of geothermal power stations increased by 314MW between 1990 and 1996, accounting for more than half of the current capacity, 540MW. This trend coincides with efforts to develop geothermal resource exploration technology and hot water/vapor handling technology based on oil development and mine technology as well as to cultivate human resources after the launch of the “Sunshine Project” in 1974. However, since the launch of the Hachijo-jima geothermal power plant in 1999, no plants have been established except for expanded small-scale binary power generation, discussed below[18]. This is in contrast to trends in the United States, the Philippines, Indonesia, Italy, and elsewhere, where geothermal power generation is rapidly becoming popular.

Some of the reasons that Japan’s geothermal power generation is not increasing in contrast to other renewable energy or other countries are as follows:

1) A resource survey takes a substantial amount of time and, depending on the result, there is risk of giving up on commercialization in the middle of the process.
2) Many places appropriate for geothermal power generation are located in natural parks, and it is difficult to develop facilities under the current Natural Parks Law.
3) Some point out that development will affect hot springs.
4) It takes at least three years to finish environmental impact assessment procedures.
5) A secondary factor for each of the abovementioned causes is that the lead time between the launch of a development process and the beginning of actual power generation operation is more than ten years. As such, it takes a long time to recover investments, and business incentives are low.
6) Compared with other renewable energy, the government's assistance for initial investments is scarce.

In particular, items 2) to 4) are causes for concern in Japan. The Natural Parks Law regulates power generation facilities in national parks in order to protect the natural environment and landscape. National parks and hot spring areas have abundant hot water resources that can be used for geothermal power generation, but due to regulation, their development has not been promoted.

In addition, due to the budget screening in May 2010 under the Democratic Party of Japan administration, it was determined that the geothermal development promotion survey project and the geothermal power generation development project would be reviewed on the presumption that the projects may be abolished[19].

Of the geothermal development costs, excavation accounts for a substantial fraction, which has to be resolved. The key to geothermal commercialization depends on whether a sufficient supply of hot water can be secured, and there is a high risk of excavating unsuitable sites before finding a hydrothermal vein that will support a stable business. If many excavations are required, the investment for a geothermal business becomes substantial. It costs between 300 million to 400 million yen to excavate a well down to about 2,000 meters, and the risks for a private company are huge. This is one of the major reasons why geothermal commercialization has not been promoted.

The government provides initial investment support to new energy, including geothermal energy. However, the support differs considerably depending on power generation sources. The new energy introduction acceleration support project in fiscal 2011[20] sets upper limits: solar power generation may receive either up to one third of the total cost or 250,000 yen/kW, whichever is lower; wind power may, after an individual consultation, receive up to 1.5 billion yen if there is adequate cause; natural gas cogeneration and microgrid systems may receive up to 500 million yen. In contrast, geothermal power may receive up to one half of the cost of a survey and excavation project and one fifth of the establishment cost of a geothermal power generation facility[21]. This means, for example, that only up to 500 million yen may be subsidized for an excavation survey that costs about one billion yen. As discussed below, only 24 million yen may be subsidized for establishing the electric power system required for a binary power generation system 50kW (transmission end), grid connection, etc. that costs about 120 million yen[22]. As discussed in item 6), geothermal power generation is at a disadvantage when it comes to receiving government assistance.

Due to these factors, not much attention has been given to geothermal energy compared to other renewable energy. Geothermal energy has its own unique issues, but most of the issues are expected to be resolved to some extent.

3 Current State of Geothermal Energy Use in Japan

3-1 Geothermal Energy Use for Power Generation

The output (i.e., facility capacity) of individual commercial geothermal power generators currently installed in Japan is between few l MW and 112 MW. For example, some hotels and other private facilities have a capacity of 100kW. Power for commercial uses generated by geothermal energy is transmitted to a distant point of demand, and so, like thermal power and hydropower plants, it requires a concentrated power source. Roughly speaking, geothermal power generation for commercial uses needs power output equal to a large-scale wind power generator or even larger, like a small and medium-scale water power generation facility. Current typical geothermal power generation depressurizes (or flashes) extracted vapor or hot water (part of which turns into vapor), sends

Table 1 : Current State of Geothermal Power Generation (as of November 2010)

Pref.	Plant	Location	Steam Supply	Utility	Use	Rated Output	Start Year	Direct Geothermal Use
Hokkaido	Mori	Mori, Kameda	HEPCO	HEPCO	General	50MW	1982	69 greenhouses
Akita	Sumikawa	Kazuno	Mitsubishi Materials	Tohoku Electric Power	General	50MW	1995	
	Onuma	Kazuno	Mitsubishi Materials	Mitsubishi Materials	General	9.5MW	1974	
	Uenotai	Yuzuwa	Akita Geothermal Energy	Tohoku Electric Power	General	28.8MW	1994	Kurikoma Foods (food processing), Minase Heated Pool, Akinomiya Heated Pool
Iwate	Matsukawa	Hachimantai	Tohoku Hydropower & Geothermal	Tohoku Electric Power	General	23.5MW	1966	Hachimantai Geothermal Steam Dyeing Workshop, room and water heating for nearly 700 hotels, inns, guesthouses, pensions, resort houses, shops and hot spring facilities, 95 greenhouses
	Kakkonda No. 1	Shizukuishi, Iwate	Tohoku Hydropower & Geothermal	Tohoku Electric Power	General	50MW	1978	Iwate Prefecture Indoor Heated Pool (alt. name: Hotswim)
	Kakkonda No. 2	Shizukuishi, Iwate	Tohoku Hydropower & Geothermal	Tohoku Electric Power	General	30MW	1996	
Miyagi	Onikobe	Osaki	J-Power	J-Power	General	15MW	1975	Oraga Tropical Garden
Fukushima	Yanadu-Nishiyama	Yanaizuma, Kawanuma	Okuaizu Geothermal	Tohoku Electric Power	General	65MW	1995	
Tokyo	Hachijojima	Hachijo	TEPCO	TEPCO	General	3.3MW	1999	Greenhouses, mixed bathing facilities
Oita	Suginoi Hotel	Beppu	Suginoi Hotel	Suginoi Hotel	Private	1.9MW	1981	Hot springs, room heating, water heating, cooking
	Otake	Kokonoe, Kusu	Kyuden	Kyuden	General	12.5MW	1967	
	Hacchobaru No. 1	Kokonoe, Kusu	Kyuden	Kyuden	General	55MW	1977	
	Hacchobaru No. 2	Kokonoe, Kusu	Kyuden	Kyuden	General	55MW	1990	
	Hacchobaru Binary	Kokonoe, Kusu	Kyuden	Kyuden	General	2MW	2006	
	Takiue	Kokonoe, Kusu	Idemitsu Oita Geothermal	Kyuden	General	27.5MW	1996	Water heating for 40 private homes
	Kokonoe	Kokonoe, Kusu	Kuju Kanko Hotel	Kuju Kanko Hotel	Private	0.99MW	1998	Hot springs, room heating, water heating
Kagoshima	Ogiri	Kirishima	Nittetsu Kagoshima Geothermal	Kyuden	General	30MW	1996	
	Kirishima Int'l Hotel	Kirishima	Daiwabo Kanko Kirishima Int'l Hotel	Daiwabo Kanko Kirishima Int'l Hotel	Private	0.1MW	1984	Hot springs, room heating
	Yamakawa	Kirishima	Kyuden	Kyuden	General	30MW	1995	
8 Pref.	*17 Places*		*13 Companies*	*9 Companies*		*540.09MW*		

Prepared by STFC based on Reference[23]

steam into a steam turbine, and the rotating turbine generates power. Therefore, even when the amount of hot water is the same, the higher the temperature of the hot water is, the higher the power output becomes, leading to higher economic efficiency. As such, it is desirable to establish a facility at a location with high temperature hot water.

Table 1 shows the current state of geothermal power generation in Japan. Currently, facilities are located in eight prefectures, and many of them are situated along the volcanic belts in Hokkaido, the Tohoku for, and the Kyushu region. The facilities provide not only electricity but also supply heat for contributing to regional businesses.

3-1-1 Dry Steam and Flash Steam Power Generation

If spew from a production well is vapor containing very little hot water, only simple moisture removal is required before transferring steam into a steam turbine to generate power. This method is called dry steam power generation. The Matsukawa geothermal power plant, Japan's first geothermal power plant, has been using this method to generate power since 1966. If a well produces mostly hot water and not so much vapor, a steam separator is used to separate (or flash) steam, which goes into a steam turbine for power generation. This method is called flash steam power generation (Figure 7). After the steam is separated, if the pressure of the remaining hot water is high enough, a second separator can be installed to depressurize the hot

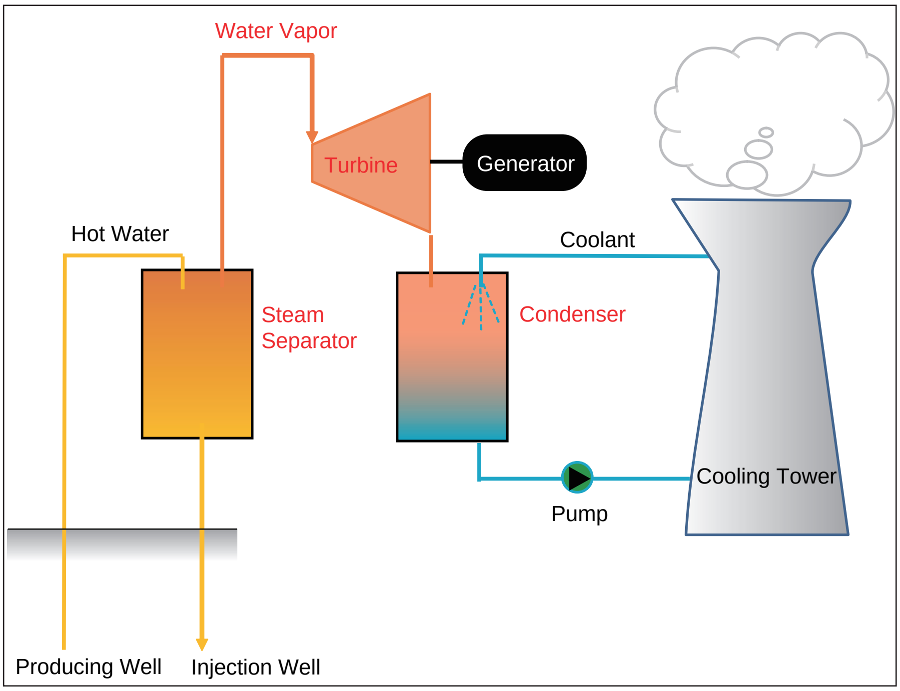


Figure 7 : Dry Steam/Flash Steam Power Generation

Prepared by the STFC

water to create more steam, which is then put into the mid-section of the turbine in order to improve power output and use geothermal energy effectively. This is called a double flash cycle and used at the Mori and Hacchobaru geothermal power plants (Table 1).

The largest output from an individual dry steam and flash steam power generator is 140MW (New Zealand). Dry steam and flash steam power generation is used as concentrated power sources and is the mainstream of geothermal power generation. These methods are mostly suitable for locations producing hot water at temperatures greater than 200°C. Three Japanese makers (Mitsubishi Heavy Industries, Toshiba, and Fuji Electric) account for 70% of the world's share of geothermal turbines for large-scale power generation. Geothermal turbines and generators are exposed to a more severe environment compared to thermal power generation because various underground materials are sent as-is to turbines. Thermal turbines used to require biennial maintenance, but Japanese makers created turbines that are more corrosion-resistant with coated rotors and stators. In addition, by installing equipment to capture moisture (water droplets) and drain it out of turbines and making other improvements, thermal turbines are now of a higher quality and can be used continuously and stably for six years without problems. These improvements are the reason for Japan's expanded market share.

3-1-2 Binary Power Generation

The steam is usually used to rotate turbines, but with binary (cycle) power generation other substances with lower boiling points than water (e.g., hydrocarbon) are heated and vaporized, and the pressurized steam is used to operate a power generation system. This method can use heat sources at temperatures lower than 150–200°C (which cannot be used with a water/steam-based system) as shown in Figure 8.

In recent years, this method has become increasingly popular. Ormat in Israel holds the world's top share in this method. Kyushu Electric Power's Hacchobaru geothermal power plant (110MW), they have been they using with a 2MW binary power generation system since 2006 that using an existing production well where the power output had declined. Normal pentane (boiling point: 36°C) is used to operate the turbine. In addition, the Kalina cycle (a kind of binary power generation) uses a solution of water and ammonia and can generate power using heat resources at even lower temperatures (less than 100°C).

Binary power generation was recognized as a new energy source by the RPS law[NOTE1]. It does

[NOTE 1] Renewables Portfolio Standard is a system that requires electric power suppliers to use a certain proportion of electricity generated from new energy, depending on the amount of energy they distribute each year, in order to promote new energy.

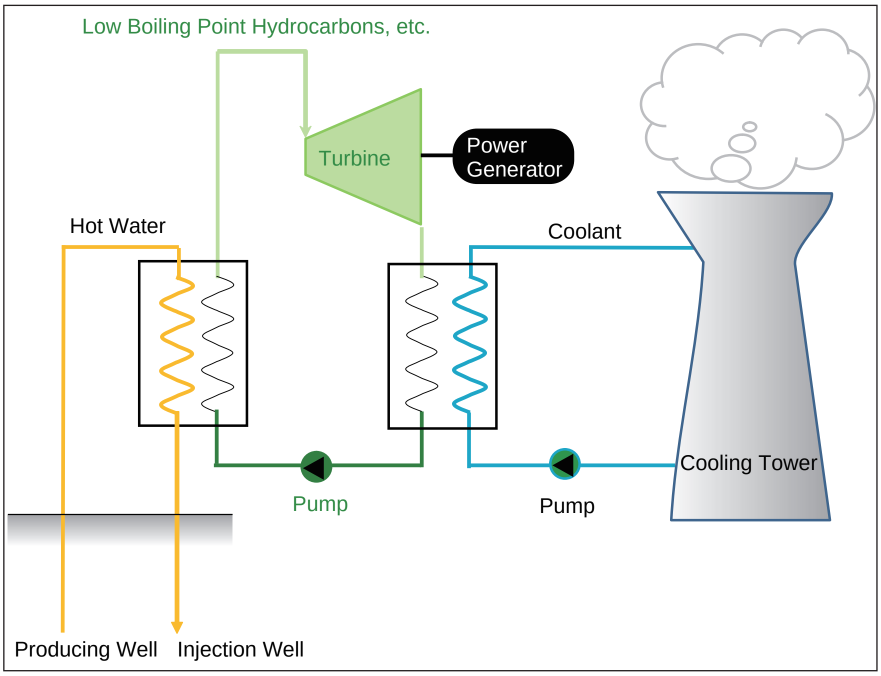


Figure 8 : Binary Power Generation

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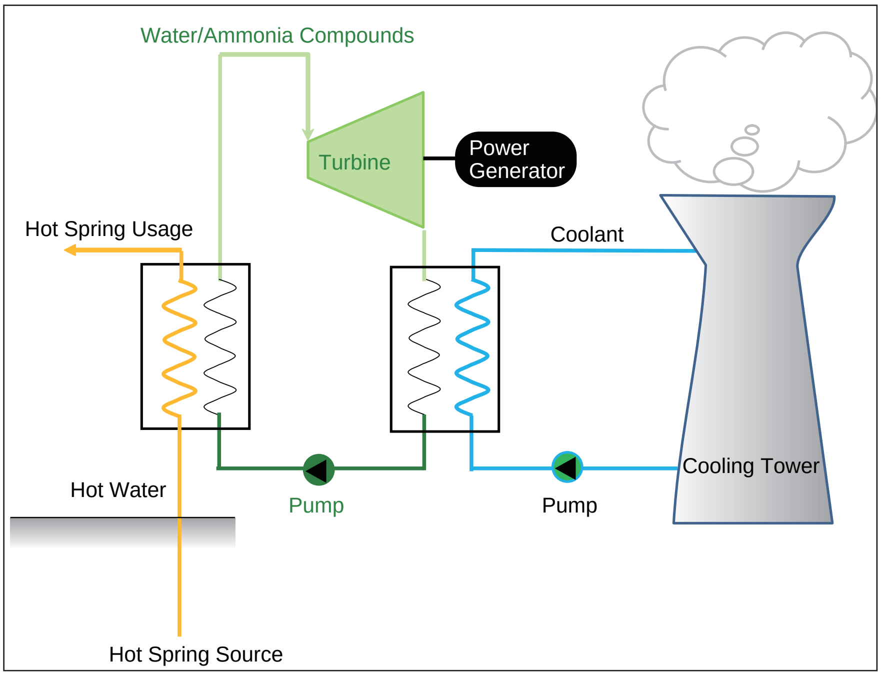

Figure 9 : Hot-Spring Power Generation

Prepared by STFC

not require high temperature heat sources like flash steam power generation, and compared to the flash steam system, many locations are suitable for the establishment of a binary power plant. Therefore, the number of binary power plants is expected to increase in Japan as well as world.

3-1-3 Hot-Spring Power Generation

An estimate indicates that the Kalina cycle system could generate approximately 722MW of power using unused heat released from existing hot springs while maintaining an appropriate temperature for bathing[24]. The system is a kind of binary power generation discussed above and is commonly called "hot-spring power generation." Characteristically, there is no need to excavate a new well, and so it can start generating power easily. Hot-spring power generation is expected additional power generation to existed Geothermal energy capacity as shown in Figure 9.

3-1-4 Enhanced Geothermal System

In Figure 10, the enhanced geothermal system (EGS)

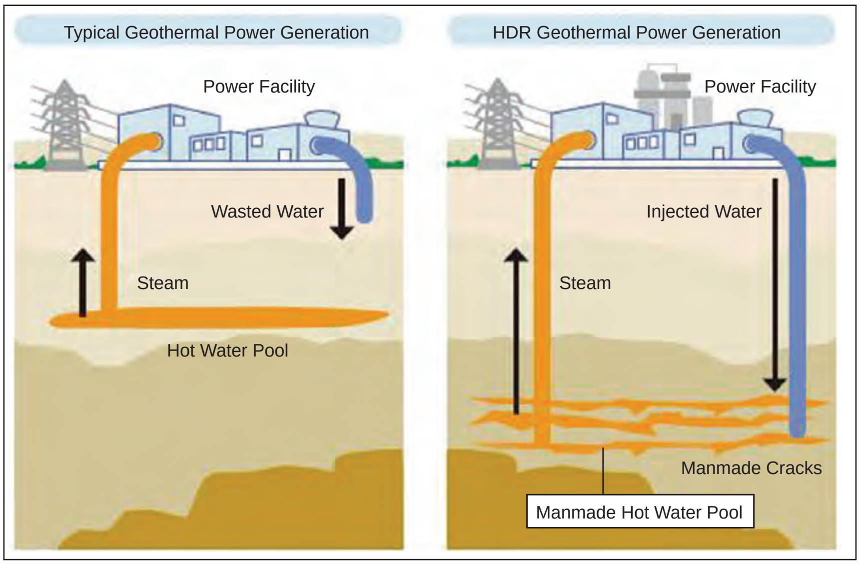

Figure 10 : Enhanced Geothermal System

Source: Reference[48]

generates power by injecting water into underground hot dry rocks, artificially creating steam and hot water, and retrieving them to turn a turbine. The EGS is a next-generation technology for places where natural vapor or hot water cannot be attained. The important technologies for this system concern the artificial creation of cracks so that water can pass through underground hot dry rocks and the injection of high-pressure water underground to collect hot water or vapor.

The Central Research Institute of Electric Power Industry (CRIEPI) and the NEDO conducted hot and dry-rock thermal resource recovery tests in Ogachi, Akita prefecture and Hijiori, Yamagata prefecture, respectively. In the latter case, a hot water recovery and circulation test was conducted for about two years, and a 50kW power generation test was conducted for about three months. The tests were completed in fiscal 2002, and no continuous tests have been conducted since[25].

3-2 Usage as Heat

More than half the energy for households is used to generate heat for, for example, making hot water or heated air. In Figure 11, there is also a variety of heat energy uses in industry.

Unlike other renewable energy, not only can geothermal energy generate electricity but it can also provide a substantial amount of heat energy to communities. In other words, by using heat energy, we can expect to save energy resources and prevent global warming.

The higher the temperature of a geothermal resource, the greater the variety of uses it has. Thermal efficient cascading use of hot water is possible since after high temperature water is used, the water can be reused for other purposes even after the temperature goes down. In addition, hot water generated in the steam separation process for flash steam power generation can be used as a heat resource before the water goes into an injection well by having it exchange heat with clean tap water to create warm water. Thermodynamically, less than 10% of hot water at a temperature lower than 120°C can be converted to electricity, but if it is used directly as heat, all of the water's heat energy can be utilized.

In recent years, the use of geothermal heat for air conditioning/heating systems has been rapidly becoming popular around the world, and it is already in practical use in many places in Japan. In this case, one does not need to excavate a well to collect hot water, and heat can be used by a simple construction method like putting a heat exchanger pile in the ground. For example, Tokyo Sky Tree and other large-scale commercial facilities have recently adopted geothermal heating systems. The coefficient of performance (COP) at Tokyo Sky Tree is expected to exceed 1.3, the highest district heating and cooling (DHC) level in Japan[26].

Unlike hot water use, geothermal heat use is not completely CO_2 free, but the energy-saving effect is great. Advantages for the widespread use of geothermal heat are the mitigation of the urban heat island effect, the reduction of electricity consumption and CO_2 emissions by reducing fire-powered heating in cold regions, and smoothing of

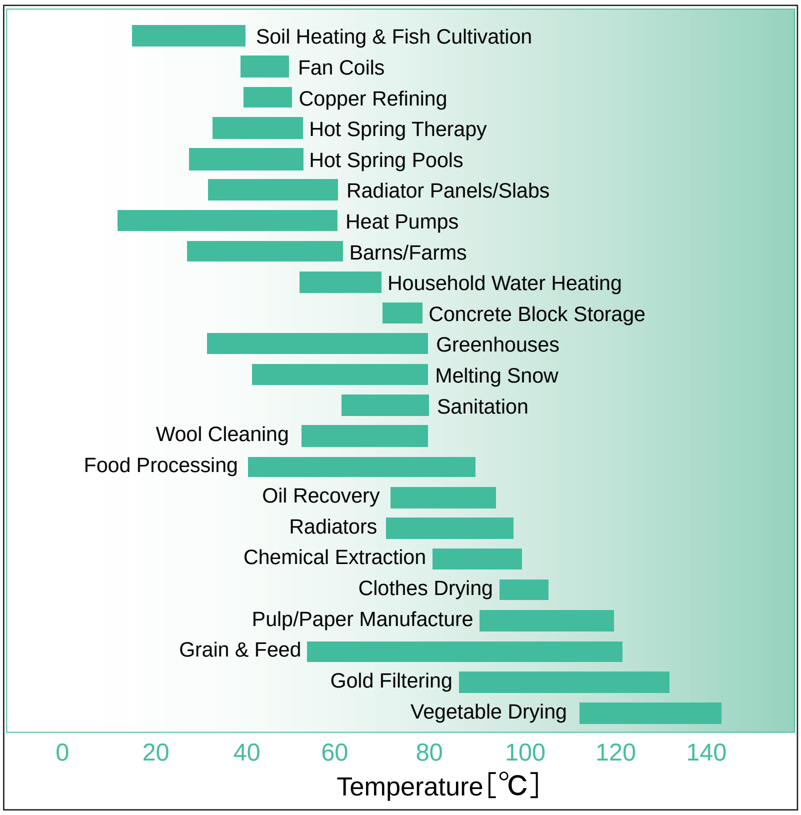

Figure 11 : Heat Energy Use by Temperature

Source: Reference[8]

electricity consumption by reducing peak electricity in midsummer and using nighttime power.

Thus, geothermal heat can be used to create an energy system as a power generating source, depending on regional circumstances, and also as heat, which is not affected by climate conditions. Geothermal heat also hardly doesn't depends on fossil fuels.

4 Geothermal Energy Use in the World

In contrast to Japan, geothermal power generation grew rapidly by about 30% in the decade between 1995 and 2005. In particular, the growth in the United States, Iceland, and Indonesia is notable. Especially, the federal and state governments support renewable energy in United States.

The use of geothermal heat pumps has become popular in the United States, Sweden, and, recently, China.

4-1 United States

One of the guiding principles for energy and environmental policy in the United States that called "Investing in the clean energy jobs of the future." The government aims to create 17,000 jobs by providing 2.3 billion dollars in tax credits for the clean energy manufacturing sector[27].

Currently, the Department of Energy (DOE) and other organizations are actively investing in geothermal energy. The American Recovery and Reinvestment (ARR) Act of 2009 provided 350 million dollars for verifying developing geothermal power generation and 50 million dollars for geothermal heat pumps[28]. Specifically, a National Geothermal Data System (NGDS) is aimed at reducing the risk of failure for geothermal developers by providing comprehensive information, including geothermal resource data and assessment, technological information, successes and failures in geothermal research, and policies. In addition, the Office of Electricity Delivery & Energy Reliability of the DOE has been working with other organizations on the electric grid to allow geothermal energy resources to reach distant markets.

The Geothermal Technologies Program (GTP), an industry-government-academia program launched in 2008, aims to popularize geothermal power generation and reduce power generation costs by 2020 or 2030. The GTP conducts activities organized around the five areas shown below[29]. The National Renewable

Energy Lab (NREL) estimates that enhanced geothermal power generation has a potential of 16,000 GW in the United States, and so the development of enhanced geothermal systems technology is particularly emphasized.

- Enhanced geothermal systems technology
- Hydrothermal power
- Low-temperature resources
- Strategic planning, systems analysis and geothermal data
- Technology validation

In 2008, for example, Google invested 10 million dollars in ventures including: AltaRock Energy, which works on Engineered Geothermal Systems (EGS) (6.25 million dollars); Potter Drilling (4 million dollars); and the Southern Methodist University Geothermal Laboratory, which works on the mapping of geothermal energy resources in North America (489,521 dollars). Such research and development has been ongoing[30].

4-2 Indonesia

Indonesia has huge geothermal potential some as Japan. Unfortunately, the usage rate for geothermal power generation used to be about 4.5%, making up less than 3% of Indonesia's total resources. However, in 2003, the Indonesian government adopted a Geothermal Law and drew up a geothermal power generation roadmap. According to the roadmap, the government is planning to expand by 2025 the capacity of geothermal power facilities to about 1 GW (5% of primary energy), which will be about eight times greater than the current level. To achieve the plan, it is essential to promote Independent Power Producers (IPPs)[NOTE2], which raise private funding, and a total of 20 billion yen (including 10 billion yen of credit) will be funded for exploratory drilling for geothermal energy. JICA, JBIC, consulting companies, and trading firms from Japan are planning to provide financial and technological assistance to develop geothermal energy[31]. Indonesia does not have a natural park law like Japan, and geothermal development is expected to proceed more easily. It is also interesting that Indonesia is trying to develop geothermal energy even though the country has abundant fossil resources such as oil, natural gas, and coal.

4-3 Iceland

The population of Iceland is about 320,000. In the 1930s, the capital Reykjavik was suffering from smog from coal power generation and began shifting to oil. However, the 1970s oil crisis forced Iceland to reexamine this policy, and the use of geothermal energy has become more popular. Geothermal energy was developed primarily for community air heating, and now, 90% of the population has been using on geothermal heat for air heating. Geothermal energy is used primarily as a heat source, with excess energy being used for power generation. Iceland has abundant renewable energy such as hydro and geothermal energy. In 2009, renewable energy accounted for 85% of primary energy. In addition, 100% of electricity is supplied by renewable energy (about 30% by geothermal and 70% by hydro energy)[32]. Notably, Iceland did not have many industries other than fishing, but, taking advantage of electricity generated from 100% renewable energy, Iceland attracted multi-national aluminum smelting plants, which consume 70% of the country's electricity. Iceland's clean electricity is then exported to the world as a form of aluminum. In addition, the Svartsengi geothermal power station uses geothermal seawater (taken up for power generation) to operate Blue Lagoon, the world's largest open-air hot spring resort for the public.

4-4 Germany

Germany is enthusiastic about using renewable energy and has actively been promoting the use of geothermal energy. The government is expected to increase geothermal power generation capacity by 2020 to about 280 MW, 40 times higher than the current level. This equals to 1.8 TWh/year of power. A total of 8.2 TWh of heat is also expected to be supplied by deep geothermal energy by 2020 (3.4 TWh from geothermal power stations and 4.8 TWh from heat from geothermal facilities that do not generate power and only provide heat). In addition, 850 MW of power generation capacity is expected to be added by 2030[33].

Currently, there are three geothermal power

[NOTE 2] Independent Power Producer (IPP) is also called a "wholesale power provider" in Japan. The 1995 revision of the Electricity Business Act allowed general businesses to supply wholesale power to electric power companies.

stations and 167 heat supply facilities (which use deep geothermal energy and do not generate power). For example, hot-water-based binary power generation is in operation in Landau and Unterhaching (south of Munich). They each recover hot water at around 120°C from a depth of 3.3 to 3.4 km deep. Germany does not have volcanic hydrothermal systems. But despite this disadvantage compared to geothermal power plants abroad, geothermal power generation is in operation, showing the country's serious willingness to develop geothermal energy[34]. In 1999, a comprehensive geothermal energy facility was established in Erding, north of Munich. This facility obtains 80t/h of warm water at 65°C from a depth of 2,300 meters, and the water is then heated up to about 100°C through a heat exchanger and heat pump. The hot water is used for community air heating and industries, and groundwater cooled via the heat exchanger and heat pump is used for an artificial hot spring and drinking. As such, all the heat and water resources obtained from underground are effectively used[35].

To promote geothermal power generation projects, Germany created policies that give preferential treatment to geothermal projects and reduce related risks. The Renewable Energy Law adopted in January 2009 raised compensation prices for purchasing geothermal power and also adopted a special bonus system. As such, the fixed-rate purchasing system and other systems have been effective. For example, a new geothermal power station (up to 10 MW) established in 2009 received a fixed purchasing rate of 16 euro cents/kWh compared to 14 euro cents before the revision, and until 2015, 4 euro cents will be added as a bonus. In addition, if the station provides heat, 3 euro cents are added. However, the fixed purchasing rate will be reduced every year by 1 euro cent per year. Therefore, a power provider who establishes a facility sooner receives more funding, and it is profitable to excavate a depth of more than 3 kilometers. In addition, the Renewable Energies Heat Law adopted in January 2009 requires new buildings to use renewable heat, which has been promoting the use of geothermal energy[33].

The Federal Environment Ministry made 60 million euros available in financing for deep geothermal drilling projects, and this credit program reduces the risks associated with drilling in particular. The KfW Bank Group provides loans for deep underground drilling through commercial banks, and the upper limit is 80% of all the costs necessary for drilling. If no hot water reservoir is found, the investor will not have to pay the remaining amounts once the project is considered a failure[36]. The government also continues to provide grant funding for research and development and tries to reduce technological and geological risks. In this way, Germany has been active in making national policy to develop geothermal energy.

4-5 Australia

Australia is also promoting renewable energy policy and is planning to invest at least 35 billion Australian dollars by 2020. Australia is expected to accelerate the use of renewable energy through the current tax credit system for electricity prices and the federal government's Small-scale Renewable Energy Scheme (SRES).

In 2010, Geodynamics, Ltd. began constructing a large-scale EGS plant. More than 40 venture companies are developing geothermal power generation in the Cooper Basin. Australia does not have volcanoes, and so, to obtain vapor and hot water, the wells must go down to a depth of over 4,000 meters, twice as deep as ordinary wells. Many companies and individuals have already invested in geothermal power generation. One of the reasons why Australia has been increasingly investing in renewable energy even though it has abundant energy resources is that it aims to actively reduce greenhouse gases[37].

5 Expanding the Use of Geothermal Energy in Japan

5-1 Geothermal Power Generation Potential in Japan

Japan's geothermal power generation has not been growing, in contrast to other renewable energy in Japan or geothermal power generation in other countries. As discussed in Chapter 2, factors include the lengthy amount of time it takes to conduct a site survey and construct a large-scale geothermal power station, and the fact that power stations cannot be built in national parks. On the other hand, we have seen progress in small-scale geothermal technologies and excavation technologies such as for binary power generation, which can help solve Japan's unique issues. NEDO created a geothermal resources map, and the risks that surround geothermal development have decreased.

In line with the progress in binary power generation technologies, the National Institute of Advanced Industrial Science and Technology (AIST) and other organizations have been investigating on distribution data for geothermal resources at temperatures lower than 150°C, which were not included in earlier surveys. For example, the Ministry of Environment considers geothermal resources between 53°C and 120°C to be suitable for Kalina cycle power generation, and as shown in Figure 12, these resources exist in places that are far from natural parks, for example, in Tokyo suburbs. Considering that hot water between 53°C and 120°C can be used for Kalina cycle power generation and hot water between 120°C and 150°C can be used for other binary power generation systems, the ministry calculated power output and estimated that the total national reserve of geothermal resources between 53°C and 150°C is approximately 9.6 GW[38]. This is different from the amount of resources (23,470 MW of power output) discussed in Chapter 2.

As mentioned earlier, most hot water resources over 150°C are located in national parks and are therefore problematic to use. However, due to the development of directional drilling, a new technology that excavates wells at an angle beginning outside a regulated natural park and extending directly underneath the park to obtain hot water, it is hoped that geothermal resources under regulated areas will be used at power generation facilities constructed mostly outside the areas. The ministry says that the geothermal development potential for hot water resources over 150°C will increase by almost three times from 2.2 GW (without national parks) to 6.4 GW (with national parks) because of the directional drilling technology.

5-2 Potential of Contribution for Regional Innovation

5-2-1 Creating a Low-carbon Society by Supplying Heat to Communities

A unique characteristic of geothermal energy is that, unlike other renewable energy, not only can it generate power but it can also supply a substantial amount of renewable heat to communities. As shown in Figure 11, there is demand for heat at a variety of temperatures, mainly for light industry, agriculture, and household use, and mostly fossil fuels such as heavy oil, kerosene, and gas are used to generate heat. More than 50% of household energy is consumed to generate heat for air heating and hot

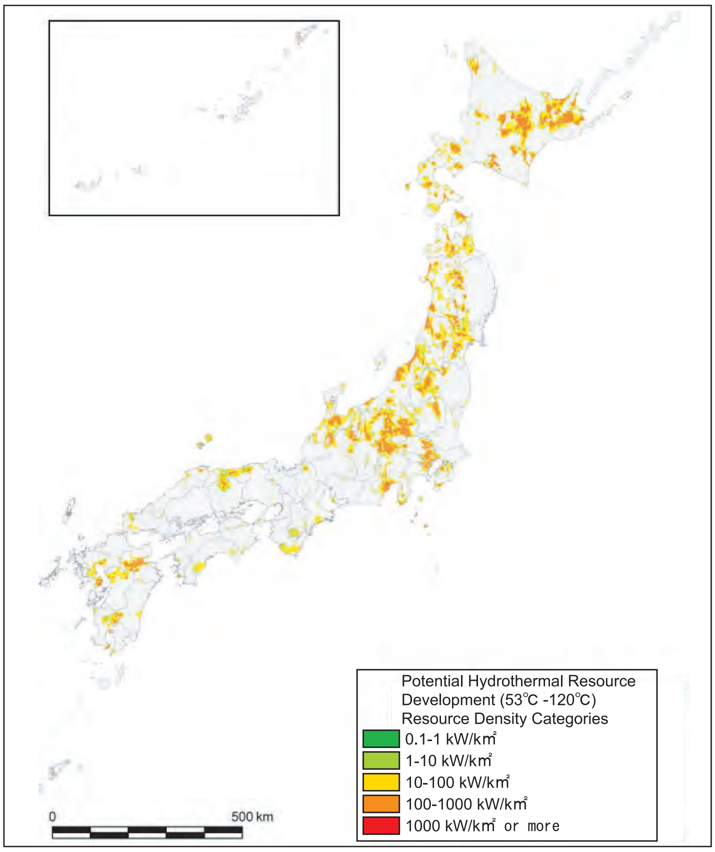

Figure 12 : Distribution Map of Hot Water (53–120°C) Resource Development Potential

Source: Reference[32]

Table 2 : Areas with High Self-sufficiency Rates (Top 10 Areas)

Pref.	Area	Self-sufficiency rate	Main Power
Fukushima	Yanaizu, Kawanuma	3290	Geothermal
Oita	Kokonoe, Kusu	2123	Geothermal
Gunma	Kuni, Agatsuma	1333	Small Hydro
Aomori	Higashidori, Shimokita	1269	Wind
Kumamoto	Itsuki, Kuma	907	Small Hydro
Miyagi	Nishimera, Koyu	774	Small Hydro
Nagano	Sakae, Shimominochi	759	Small Hydro
Yamanashi	Kayakawa, Minamikoma	717	Small Hydro
Iwate	Shizukuishi, Iwate	709	Geothermal
Hokkaido	Tomamae, Tomamae	702	Wind

Source: Reference[41]

Calculation method:
Self-sufficiency rate = renewable energy supply in a district / demand for industries and agricultural uses in the district

water systems[39,40]. To create a sustainable low-carbon society, the impact of shifting to renewable energy for generating heat is greater than the impact of shifting to renewable energy for electricity generation. The use of geothermal energy is expected to substantially contribute to the creation of a low-carbon society. Local production and consumption of energy will be realized through the adoption of geothermal power generation systems based on regional characteristics and the maximum effective use of heat.

The New Growth Strategy aims to increase the proportion of renewable energy up to 10% in the domestic primary energy supply by the year 2020. As Table 2 shows, there are communities that have become more than 100% energy self-sufficient with renewable energy alone. However, it should be noted that energy supplies such as electricity, heat, and power are converted into primary energy equivalents. Regions with geothermal resources can self-supply electricity and heat at the same time, and so, they have potential to become self-sufficient not only in calculation but also in reality.

5-2-2. Revitalizing Regional Industries

It is desirable that energy and food are produced and consumed locally to improve national security and to reduce carbon footprints. Making use of geothermal heat will lead to the creation of communities based on sustainable energy.

In recent years, much attention has been paid to ecotourism[42]. By communicating about local resources to visitors, residents can recognize the value of their own resources. It not only enhances the originality of regional tourism and vitalizes regional economies but also invigorates regional communities. In other words, by rediscovering unique regional appeal, residents can lead a lively lifestyle with confidence in and pride for their community and aim to create a more vigorous and sustainable community. Japan's oldest geothermal power plant, Matsukawa, began operating in 1966 and has been providing part of its geothermal steam to local hot spring inns for air heating. In 1971, the plant began heating steam condensate to provide hot water (60 t/h at 70°C) to the current Hachimantai City Industrial Promotion Corporation and to provide some of the hot water for vacation homes, hotels, and tourist facilities in a hot spring resort settlement in Higashi-Hachimantai. In 1981, the demand for hot water was expected to rise substantially in the settlement and other areas, and the water volume was increased to 200 t/h. Currently, Tohoku Hydropower & Geothermal Energy is providing up to 260 t/h hot water for profit to 38 hotels and inns, 25 recreation facilities, 613 vacation homes, 15 stores, a vacation rental home, a hospital, a retirement home, a one-day hot spring facility, and 95 greenhouses (only during winter) (See Table 1)[43].

Otofuke-cho in Hokkaido uses both heat from hot springs and cold energy from snow and ice to grow Miyazaki mangoes in greenhouses and harvest them during the off-season[44].

The use of excess hot spring water is still at a trial stage in Japan. If other regions can also provide geothermal power as well as a substantial amount of heat resources, not only can energy be produced and consumed locally but also a new large-scale industry may be cultivated.

It is important that, even though new geothermal power plants have not been developed recently, resource survey data has been updated to reduce developers' excavation risks, and small output geothermal power plants have been tested for verification. However, in addition to such bottom-up policies, it will be effective to use geothermal power in top-down policies. It is desirable that different regions compete to draw up their own sustainable and comprehensive innovation plans based on geothermal power generation, and that regions with good model cases receive financial support and be designated as special deregulation zones[45].

Geothermal power plants need to continuously undergo proper maintenance and so constantly require employment. More employment is needed when the plants go through regular inspections, equipment repairs and updates, and drilling of new wells. If we consider this an employment opportunity, it will contribute to regional employment growth. In addition, if a new industry is developed, employment growth will be even greater.

5-3 Lifestyle Innovation Potential

Locations with an abundance of geothermal resources usually have hot springs, and a community can combine both global warming prevention and health-related efforts to attract visitors for business and tourism. For example, it is reported that hotels with geothermal power generation facilities in Kyushu have more overnight guests who visit for the geothermal facilities[43].

The cancer treatment center[46] in Ibusuki city, Kagoshima (opened in 2011) is planning to use binary power generation to cover about 1.5 MW for proton therapy, and for this, the NEDO began a geothermal development promotion survey in 2007[47]. The results suggest that the potential is high, but the plan is not yet in practical use because the binary power generation does not become profitable unless the fixed purchase price is more than 20 yen/kWh in a feed-in tariff system. In Ibusuki, various efforts have been made to have hot springs and geothermal facilities co-exist and co-prosper by, for example, holding active discussion with the residents about the introduction of a geothermal power plant, publicizing the plant's system and the survey results of the well, and conducting a scientific survey showing no impact on hot springs.
These efforts involve both green and lifestyle innovation potential, and in particular in Japan where the population is aging, it is hoped that such efforts will be promoted and established as a business model in many regions.

6 Summary and Proposals

Geothermal energy is a renewable energy source and its energy resources that are equivalent to power generation are estimated to be around 23 GW (more than 10% of the current electricity capacity of general electric power suppliers in Japan). Japan has the third largest reserves in the world, and geothermal energy is one of the few unique resources for the country. However, after a little over 40 years since 1966 (when the oldest power plant, Matsukawa, began operating), the total capacity developed so far is only 540 MW, less than 0.3% of the reserves. This contrasts starkly with the situation in the United States, Iceland, the Philippines, Indonesia, and Italy, where geothermal energy has been rapidly developed. The low price of crude oil until several years ago and the economic downturn are somewhat related to the slow pace of development for geothermal power generation. However, the main factors are that, since geothermal locations often exist in natural parks, a great deal of coordination is required between the government, hot spring operators, and landowners, and numerous environment assessments and other procedures are necessary. Due to these conditions, the lead time between the launch of a development process and the beginning of actual power generation operation is estimated to be more than ten years, and as a result, companies are reluctant to invest in geothermal energy. However, in contrast to solar power and wind power generation, geothermal power generation is not affected by the weather. Therefore, a stable energy supply is possible, and the energy self-sufficiency rate could be improved and CO_2 emissions could be reduced.

Compared with other renewable energy, geothermal energy also has more potential to contribute to regional development in a variety of ways other than power generation. As a source of both renewable energy and as a source of heat, geothermal energy can be expected to greatly contribute to the economy by creating new jobs for local residents through direct and indirect factors, including more construction orders and visitors to the area. In other words, geothermal energy has great potential as a platform to vitalize regional innovation. This fits the concept of "a tourism-oriented nation and local revitalization" described in the New Growth Strategy.

Large-scale geothermal power plants are of course important, but it takes a long time to construct one. In particular, if we want to use geothermal energy for the earthquake recovery, it is desirable to begin with binary power generation and hot-spring power generation since they can be achieved quickly. In the long term, it is essential to develop policies to commercialize enhanced geothermal systems, which can be applied to locations with fewer hot water resources. To this end, the following policies and improvements are desirable.

(1) Revising Related Laws

The Ministry of Environment established an environmental study panel on geothermal power generation and a study panel on the impact of geothermal power generation on hot springs and groundwater, reviewed the guidelines of the Hot Spring Law, and began reexamining regulations. In Japan, no cases have been reported where hot spring resources were depleted due to geothermal development.[43]

(2) Shorter Environmental Assessment Process

An environmental assessment is required to establish a geothermal power plant with over 10 MW output. Currently, an assessment takes at least three years, and it takes more than ten years to begin generating geothermal power. Based on cases overseas, it is desirable to improve Japan's systems so that the assessment process will be shorter.

(3) Technological Development Support

Geothermal development requires a variety of knowledge and technologies including geology, geochemistry, environmental assessment, and simulation. In particular, for geothermal power generation, it is essential to develop technology to find geothermal reservoirs. Technology for finding geothermal resources with greater certainty has been developed based on seismic observation technology. Japan has been actively conducting earthquake-related research and development, which may be used to extend geothermal development. As discussed in section 2-2-2, the costs and risks when drilling in geothermal development are great. It is hoped that technological development in this area will be promoted because it will reduce the risks for private operators. It is also effective for the national government to take the initiative in studying underground structures in order to reduce the risks of drilling.

Impurities contained in hot water can be deposited to form scale and block pipes and heat exchangers, obstructing operation and causing performance degradation. Existing power plants ensure their operational reliability through appropriate maintenance, but the cost of removing scale is substantial. Therefore, it is essential to develop technology to remove scale at a low cost[16]. These are issues shared by power plant operators, and it is hoped that the government will provide support for technological development.

At the same time, it is important to promote technological development towards the commercialization of an enhanced geothermal system, facilitate efforts to find resources, and to improve binary power generators.

(4) Heat Management

As discussed in section 5-2-2, it is essential to consider geothermal development in a comprehensive manner by, for example, drawing up an integrated regional plan based on geothermal power generation and creating a system where the national government can support the development of a model plan. As discussed earlier, there have been many cases where geothermal power plants provide heat to local communities. However, these communities obtained benefits in return for allowing the plants to be established. Heat is used at new greenhouses and bathing facilities, but it has not reached the point where the energy structures of entire communities are sustainable. For example, while electricity is supplied to areas outside a community, kerosene is still used for heating air in the community. To create a sustainable community, it is essential to manage geothermal heat energy in an integrated manner both for industries and everyday living[49]. There is already a framework that can be used to encourage communities and geothermal power plants to coexist[50], but it is hoped that communities will make their own comprehensive plans, and that a system will be created so that the government can provide support.

(5) Subsidy for Geothermal Development

In August 2011, the Diet passed the law on "Special Measures concerning the Procurement of Renewable Electric Energy by Operators of Electric Utilities", which fixes purchase prices for electricity generated by renewable energy. This law is expected to be applied to geothermal power generation, too. However, this advantage can be obtained after the launch of plant operation, and so, it is unclear if it will be effective to reduce the risk of having a long lead time, which is typical for geothermal power generation.

The high cost and risk of drilling are key factors in private companies' reluctance to develop geothermal energy. Therefore, along with technological development support discussed in (3), it is necessary to appropriately reduce risks for individual operators. As discussed in the German case in section 4-4, it may be effective to provide loans for the drilling phase since it requires substantial funding, as well as to compensate for losses if drilling fails. Solar power generation drastically increased after a subsidy system was restored, and subsidies are essential for geothermal power generation, too.

7 Conclusion

Since the Great East Japan Earthquake, much attention has been paid to renewable energy and geothermal power generation. In July 2011, some private companies announced that they were going to construct a large-scale geothermal power plant in the Tohoku region by 2017. The Tohoku region, which is recovering from the earthquake, has an abundance of geothermal energy. Since the region has a relatively cold climate, the benefit from a sustainable heat supply is greater than it would be in a region with a warmer climate. When the earthquake hit that region, it was cold and snowing lightly, and energy was necessary to stay warm. Geothermal energy can be used both for power generation and direct heat supply, and there is no question that geothermal energy can greatly contribute not only to the people living in the earthquake-stricken area but also to the prevention of global warming.

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