Table 4-2 Installed Capacity of Geothermal Power Plants in Indonesia

Area	Unit	Installed capacity (MW)
Sumatera	93	122
Java	71	1,134
Bali-Nusa Tenggara	33	5
Kalimantan	12	
Sulawesi	70	80
Maluku	30	
Papua	3	
Total	**312**	**1,341**

【As of the end of 2012; excerpt from Surya Darma, et al. (2015)】

Source: Surya Darma, Tisnaldi and Rony Gunawan(2015): Country Update: Geothermal Energy Use and Development in Indonesia, Proceedings World Geothermal Congress 2015

4.4 Kenya

Kenya has the world's fourth-largest geothermal resource after the United States, Indonesia, and Japan as shown in **Table 2-3.** Its geothermal resource development was undertaken in the 1950s, and as shown in **Figure 4-2,** the capacity of geothermal power generation facilities has remarkably increased since 2005.

4.4.1 Geothermal resources

There are 14 Quaternary volcanoes in Kenya, as shown in **Figure 4-11**, around where geothermal resources are located.

【Reference】

Peter Omenda and Silas Simiyu(2015): Country Update Report for Kenya 2010-2014, Proceedings World Geothermal Congress 2015

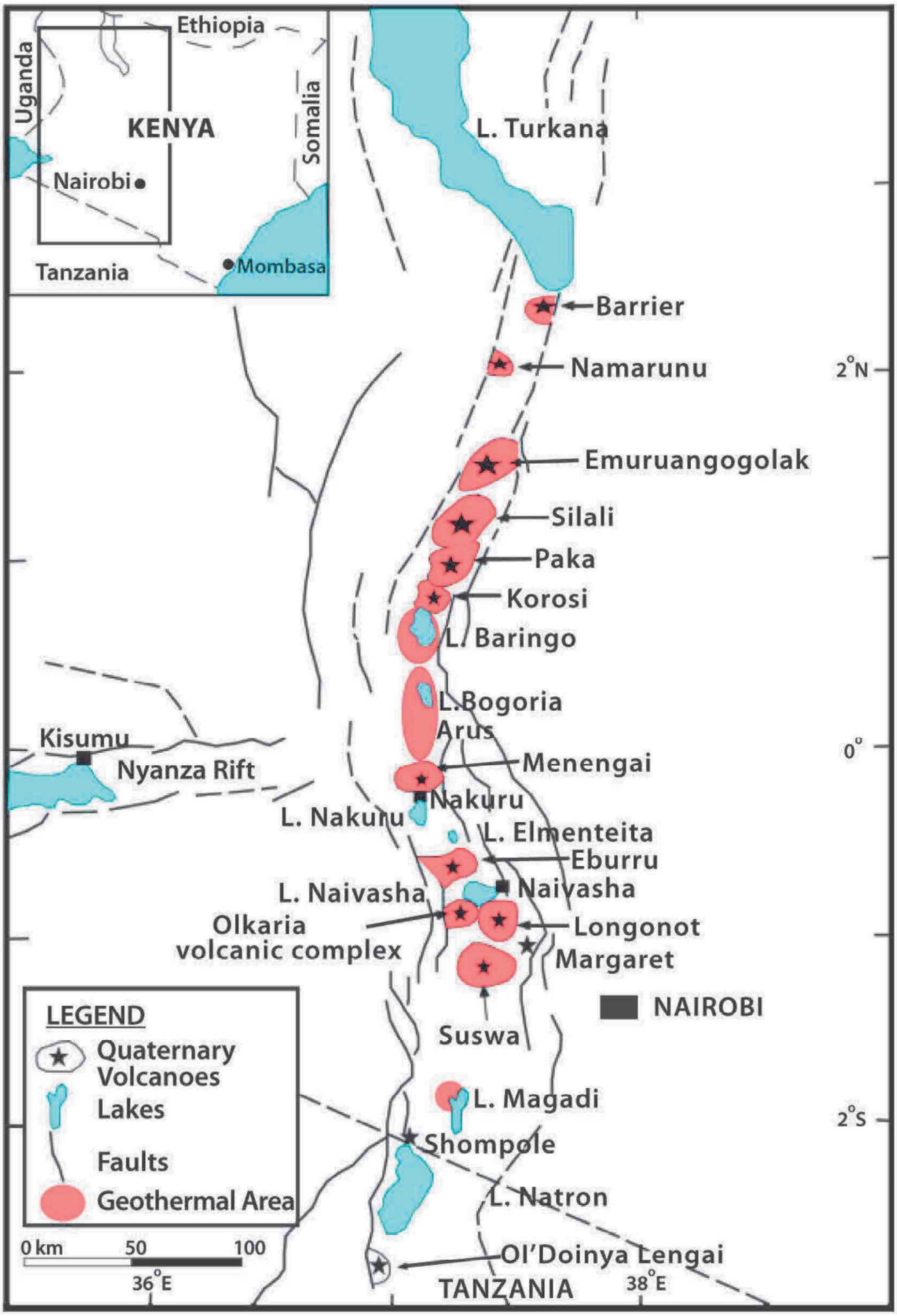


Figure 4-11 Distribution of volcanoes and geothermal resources in Kenya

Source: Peter Omenda and Silas Simiyu(2015): Country Update Report for Kenya 2010-2014, Proceedings World Geothermal Congress 2015

4.4.2 Heat utilization

The installed capacity of the direct use of geothermal resources in Kenya as of December 2014 is shown in **Table 4-3.** At the Oserian flower farm, 10 MW_t is used for heating greenhouses and fumigating soil. It has an additional heat utilization facility with 4 MW for their own use.

【Reference 】

Peter Omenda and Silas Simiyu(2015): Country Update Report for Kenya 2010-2014, Proceedings World Geothermal Congress 2015

Table 4-3 Heat Utilization in Kenya

Use	Installed capacity (MW_t)	Annual energy use (TJ/yr)
Greenhouse	16.0	126.6
Bathing/Pool	5.4	46.0
Agricultural drying	1.0	10.0
Total	**22.4**	**182.6**

【As of the end of December, 2014】

Source: Peter Omenda and Silas Simiyu (2015): Country Update Report for Kenya 2010-2014, Proceedings World Geothermal Congress 2015

4.4.3 Geothermal power generation

Geothermal development resource in Kenya is estimated to be 10,000 MW. Their plan is to expand the 676 MW power generation facilities as of 2017 (World No. 9) to 5,000 MW by 2030 (**Table 2-3**). Geothermal development is being promoted in the Olkaria region, where construction of geothermal power plants has been in progress since the 1950s. So far 300 wells have been drilled in this area. (Kaieda, 2018)

The Olkaria geothermal power plant is the largest production field with a capacity of 573 MW combined with the five power plants (463 MW) owned by Kenya Electricity Generating Company (KenGen) and Orpower 4 (110 MW). (Kaieda, 2018)

【Reference】

Hideshi Kaieda (2018): Trend of Geothermal Power Generation abroad, Geology and Survey, No. 2, 2018, pp. 41–46
https://www.zenchiren.or.jp/geocenter/geo-se/pdf/jgca152.pdf

4.5 The Philippines

The Philippines is the country that is in fifth place after the United States, Indonesia, Japan, and Kenya in terms of its geothermal resources, and it is in second place worldwide in terms of its cumulative installed capacity for geothermal power (1,928MW) (See **Table 2-3**). The introduction of geothermal power had been stagnant in the Philippines since 2000, but the enactment of a bill on renewable energies in 2009 has set things in motion once again through the adoption of preferential legal and economic measures for the introduction of renewable energies (including geothermal power). In its roadmap of the National Renewable Energy Plan (2010 - 2030) it planned to adopt 15,236 MW of geothermal power by the year 2030. **Table 4-4** shows the installed capacity of geothermal power plants in the Philippines and the amount of electricity generated as of the end of 2013.

Source: New Energy Foundation Asian Biomass Office: Added and modified "Current situation of geothermal power generation in the Philippines"
https://www.asiabiomass.jp/topics/1311_03.html（Japanese）
https://www.asiabiomass.jp/english/topics/1311_03.html（English）

Table 4-4 Installed Capacity and Generated Electricity of the Power plants in the Philippines

Area	**Installed capacity (MW)**	**Generated electricity (GWh/yr)**
Mak-Ban	458.8	1,931
Tiwi	234.0	1,130
Albay-Sorsogon	131.5	323
Tongonan	722.7	4,031
Southern Negros	192.5	1,489
Mindanao	108.5	743
Total	**1,848.0**	**9,647**

【As of the end of December, 2013】

Source: Ariel D. Fronda, Mario C. Marasigan and Vanessa S. Lazaro (2015): Geothermal Development in the Philippines: The Country Update, Proceedings World Geothermal Congress 2015
http://large.stanford.edu/courses/2016/ph240/makalinao1/docs/01053.pdf

4.6 Mexico

Mexico has the fifth largest geothermal resource in the world alongside the Philippines. Mexico has the sixth largest cumulative geothermal installed capacity as of 2017 (919 MW) (See **Table 2-3**).

There have been no geothermal zones added in Mexico since 2015. Four geothermal fields have been in operation: Cerro Prieto, Los Azufres, Los Humeros, Las Tres Vírgenes (see Figure 4-12) with the installed capacity as of 2015 of 1,017.4 MW. The net capacity at the time of operation is 839.4 MW. Two binary cycle units (1.5MWx2) are in operation in Los Azufres. The geothermal power plant in the Los Azufres region shown in **Figure 4-13** is located on a plateau at an altitude of about 3,000m near the San Andres volcano in the central part of the Mexican volcanic belt. There is a steam-dominant geothermal reservoir 600~2,000m underground.

【References】

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

Luis C.A. Gutiérrez-Negrín, Raúl Maya-González3 and José Luis Quijano-León (2015): Present Situation and Perspectives of Geothermal in Mexico, Proceedings World Geothermal Congress 2015

Figure 4-12 Geothermal Resource Region in Mexico

Source: Luis C.A. Gutiérrez-Negrín, Raúl Maya-González3 and José Luis Quijano-León (2015): Present Situation and Perspectives of Geothermal in Mexico, Proceedings World Geothermal Congress 2015

Figure 4-13 Geothermal Power Plant in the Los-Azufres Field

Source: Japan Agency for Natural Resources and Energy Homepage: Home> About Policy> Fuel> Geothermal Resource Policy/Geothermal Power Generation> Geothermal Page> Geothermal Power Generation Mechanism> Geothermal Power Plant Introduction> World Geothermal Power Plant
http://www.enecho.meti.go.jp/category/resources_and_fuel/geothermal/explanation/mechanism/plant/foreign/

The installed geothermal power capacity of Mexico as of 2013 is shown in **Table 4-5**, and the installed capacity of direct utilization is shown in **Table 4-6.** For direct use, bathing/pool accounts for nearly 100%.

Table 4-5 Installed Geothermal Power Capacity of Mexico

Area	**Installed capacity (MW)**
Cerro Prieto	720
Los Azufres	194
Los Humeros	42
Las Tres Vírgenes	93.4
Cerritos Colorados	10
Total	**1,017.4**

【As of the end of December 2013; extracted from Luis C. A., et al. (2015) 】

Source: Luis C.A. Gutiérrez-Negrín, Raúl Maya-González3 and José Luis Quijano-León (2015): Present Situation and Perspectives of Geothermal in Mexico, Proceedings World Geothermal Congress 2015

Table 4-6 Installed Capacity of Direct Utilization of Mexico

Use	**Installed capacity (MW_t)**	**Annual energy use (TJ/yr)**	**Capacity factor (%)**
Bathing/Pool	155.347	4,166.512	85
Individual space heating	0.460	4.397	33
Agricultural drying	0.007	0.067	30
Greenhouse	0.004	0.028	21
Total	**155.819**	**4,171.004**	**85**

Source: Luis C.A. Gutiérrez-Negrín, Raúl Maya-González3, and José Luis Quijano-León (2015): Present Situation and Perspectives of Geothermal in Mexico, Proceedings World Geothermal Congress 2015

4 .7 Iceland

4.7.1 Geothermal resources

Iceland is a volcanic island on the Atlantic mid-ocean ridge that runs north and south in the center of the Atlantic Ocean. There are over 200 volcanoes in this area with at least 20 high-temperature zones in the volcanic zone, reaching 200°C at depths less than 1,000m. Approximately 250 separate low-temperature areas with temperatures not exceeding 150°C at a depth of less than 1,000 m are mainly located in areas adjacent to active volcanic zones. There are over 600 hot spring areas (temperatures of 20°C or more) in these areas **(Figure 4-14).**

【Reference】

Árni Ragnarsson(2015): Geothermal Development in Iceland 2010-2014, Proceedings World Geothermal Congress 2015

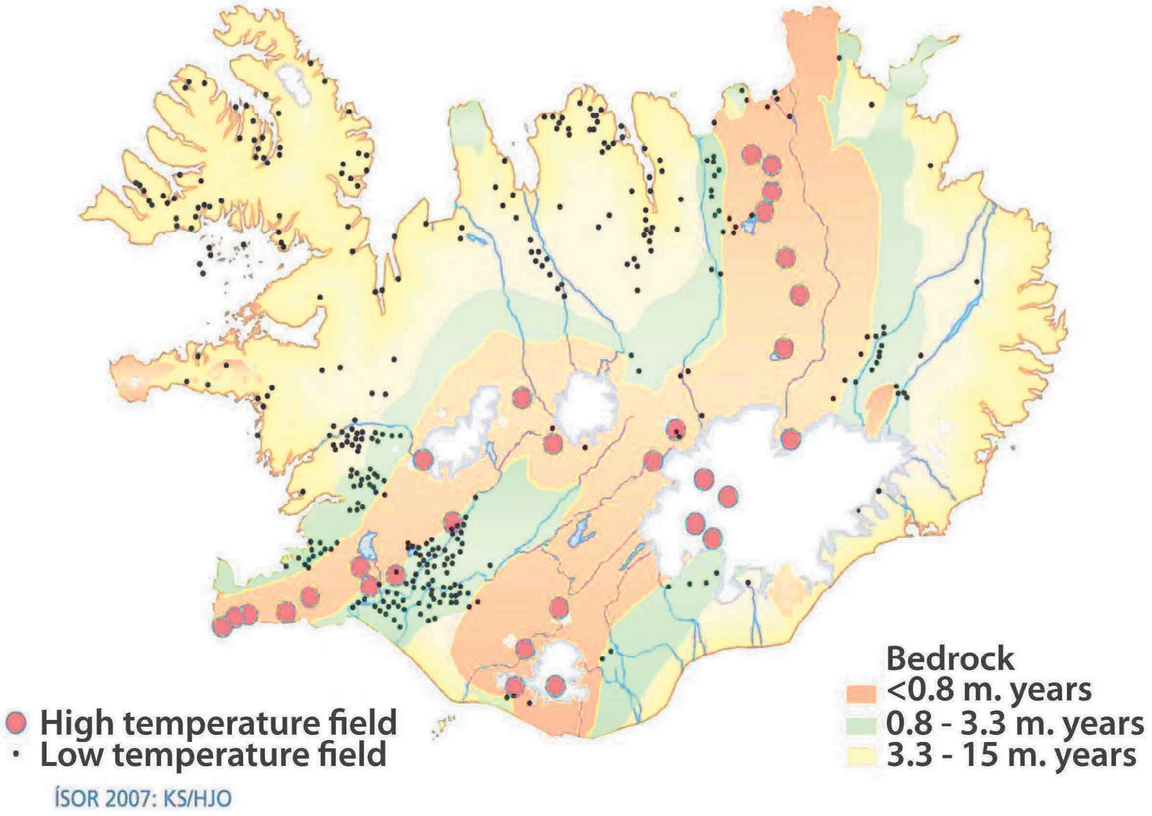


Figure 4-14 Volcanic Zones and Geothermal Areas in Iceland

Source: Árni Ragnarsson(2015 : Geothermal Development in Iceland 2010-2014, Proceedings World Geothermal Congress 2015

4.7.2 Heat utilization

Iceland ranks 8th in the world in terms of installed geothermal capacity as of 2017 (708 MW), but moreover, it is a world leader in direct utilization of geothermal energy. In the 1940s and 1950s, geothermal power replaced coal and became the largest primary energy source. Currently, 42.6% of total energy utilization is heating and 41.4% is electricity generation, but geothermal energy accounts for more than 90% of heating use **(Figure 4-15).**

The amount of heat usage as the end of December 2014 is shown in Table 4-7, and the heat utilization by application is shown in **Figure 4-16.**

The annual energy use is as much as 1.4 times the geothermal power generation. As much as 70% is used for district heating, and the remainder is used for a wide variety of applications such as aquaculture fishery, snow melting, bathing/pool, industrial use, and greenhouse. Most of the pools are open to the public throughout the year. Swimming lessons are compulsory in elementary schools. The well-known Blue Lagoon is one of the most popular tourist spots, where 700,000 tourists visit a year.

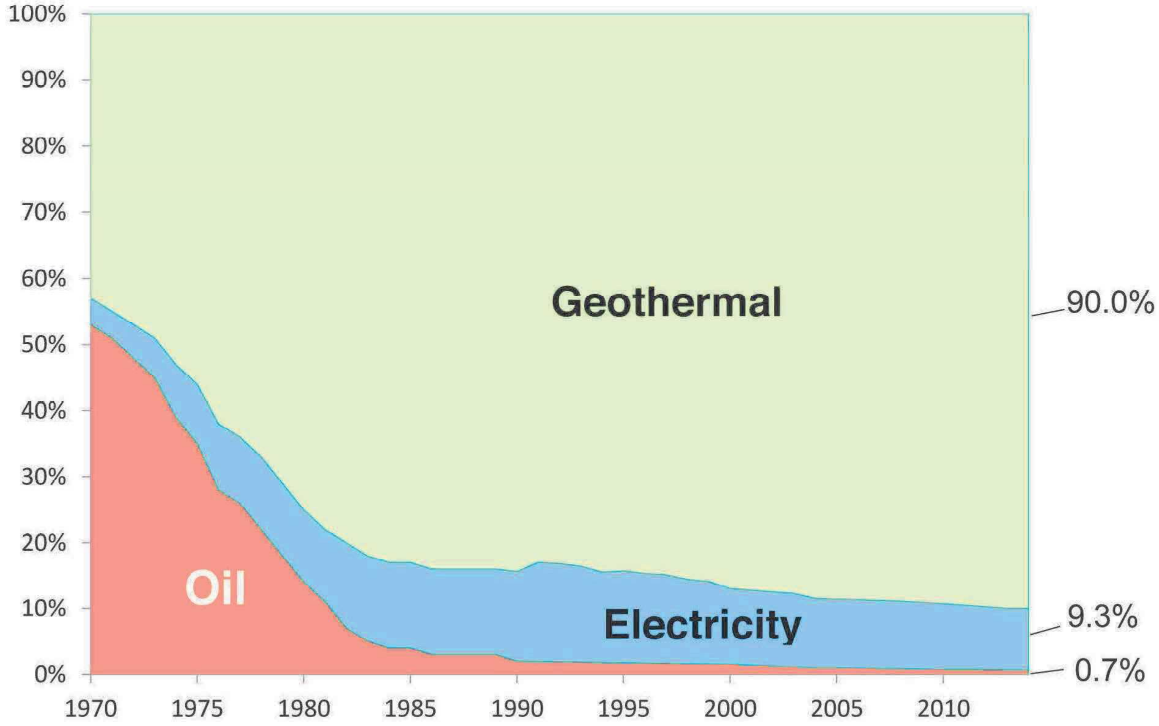


Figure 4-15: Energy Sources Used for Space Heating in Iceland

Source: Árni Ragnarsson (2015): Geothermal Development in Iceland 2010-2014, Proceedings World Geothermal Congress 2015

Table 4-7 Heat Utilization in Iceland

Use	Installed capacity (MW_t)	Annual energy use (TJ/yr)	Capacity factor (%)
Direct use	2,035	26,700	42
District heating	1,550	19,400	40
Greenhouse	45	660	47
Aquaculture fishery	85	2,230	83
Industrial use	70	910	41
Snow melting	195	1,900	31
Bathing/Pool	90	1,600	56
Geothermal power generation	663	18,882	
Total	2,698	45,582	

[As of the end of December 2014; created based on Árni Ragnarsson (2015)】

Source: Árni Ragnarsson (2015): Geothermal Development in Iceland 2010-2014, Proceedings World Geothermal Congress 2015

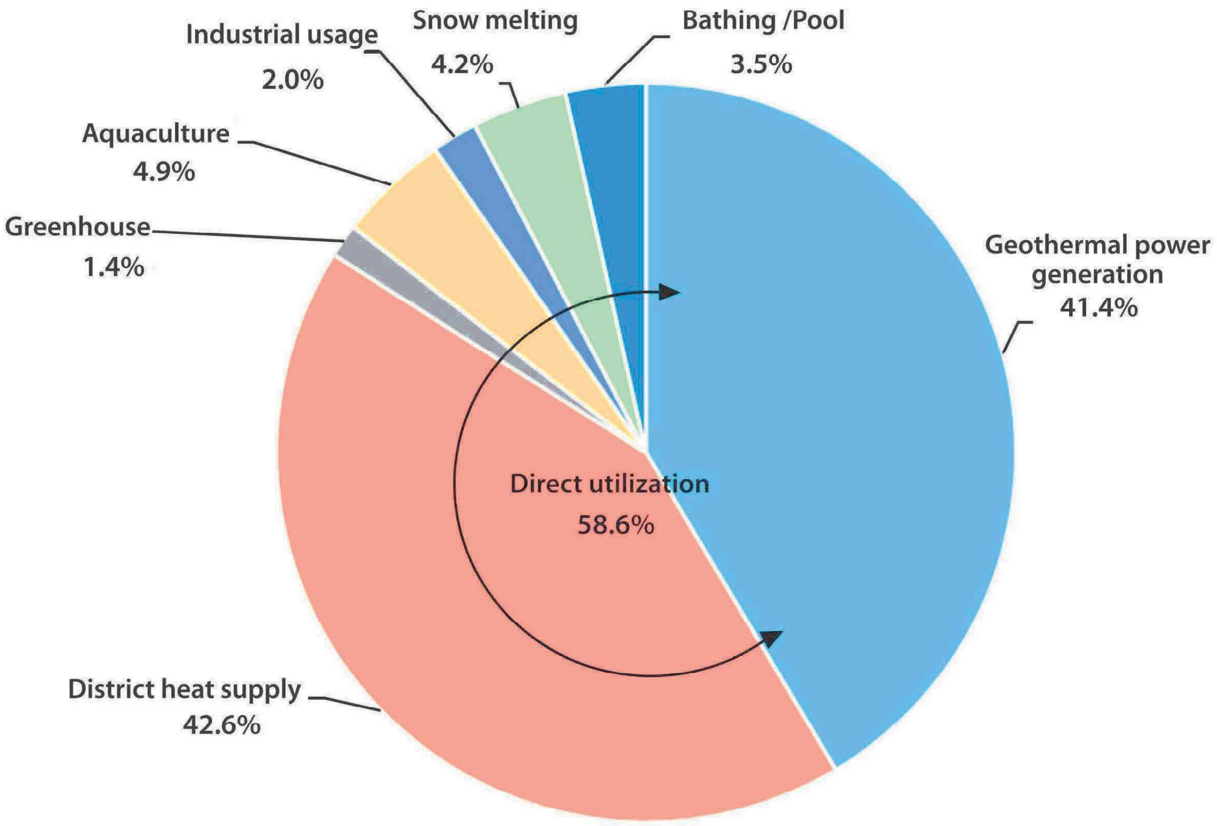
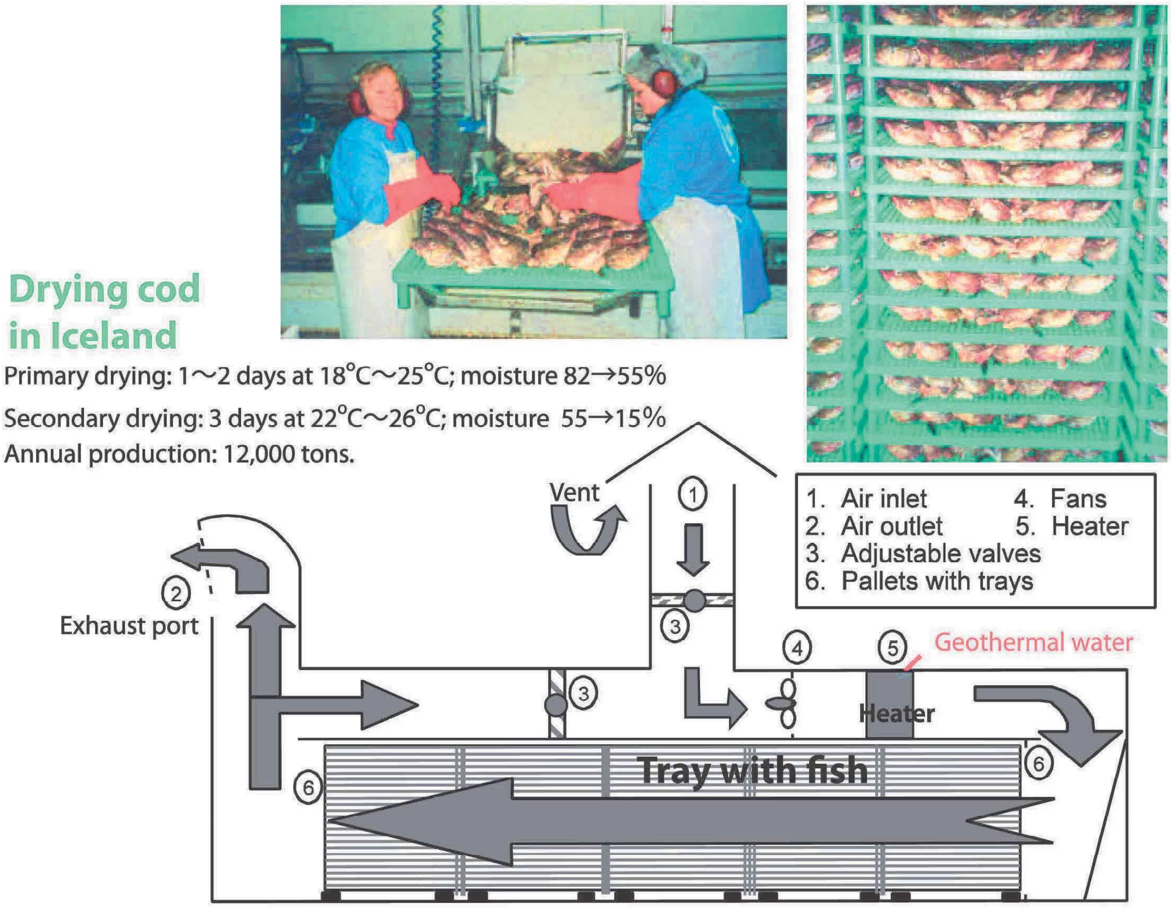


Figure 4-16 Ratio of Heat Utilization by Application in Iceland
【As of the end of December 2014; created based on Árni Ragnarsson (2015)】

Source: Árni Ragnarsson (2015): Geothermal Development in Iceland 2010-2014, Proceedings World Geothermal Congress 2015

(1) Examples of fish drying

Figure 4-17 shows an example of drying cod using geothermal water as a case of direct utilization. Primary drying is carried out at 18°C to 25°C for 1 to 2 days, reducing moisture from 82% to 55%. Secondary drying is carried out at 22°C to 26°C for 3 days, reducing moisture from 55% to 15%. Annual cod production is 12,000 tons.


Drying cod in Iceland

Primary drying: 1～2 days at 18°C～25°C; moisture 82→55%

Secondary drying: 3 days at 22°C～26°C; moisture 55→15%

Annual production: 12,000 tons.

1. Air inlet
2. Air outlet
3. Adjustable valves
4. Fans
5. Heater
6. Pallets with trays

Figure 4-17 Example of Geothermal Utilization in Iceland (Drying Fish)

Source: Kasumi Yasukawa (2018) International ONSEN summit materials

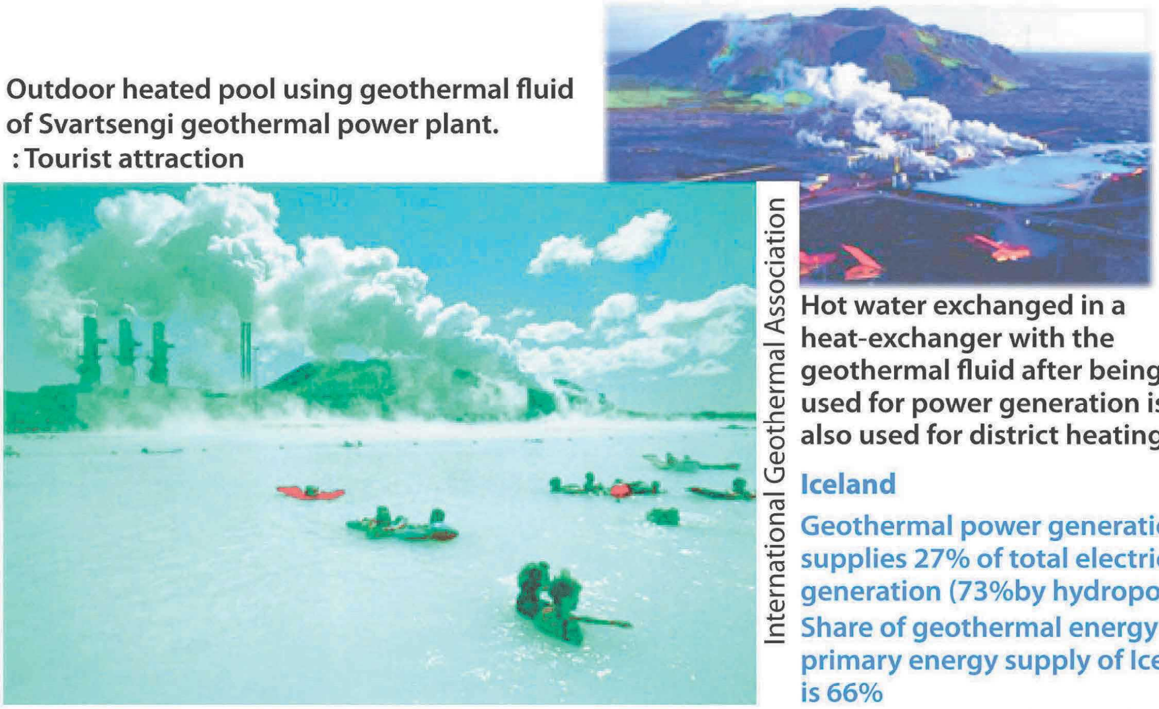
(2) Examples of outdoor heated pool

Figure 4-18 is "the Blue Lagoon" and the Svartsengi Geothermal Power Plant in Iceland. The Blue Lagoon, a tourist attraction, is an outdoor heated pool using geothermal fluid from the Svartsengi geothermal power plant. The hot water is exchanged in a heat-exchanger with the geothermal fluid after being used for power generation. It is also used for district heating.

【Reference】

Kasumi Yasukawa et al. (2015): WGC 2015 Report 1 (Keynote, Recent State, Social Aspects, Drilling, EGS, Sustainability, Software, Innovation, Geothermal Heat Pump), The Geothermal Society of Japan, Vol. 37, No. 3, pp. 101-117
https://www.jstage.jst.go.jp/article/grsj/37/3/37_101/_pdf/-char/ja

Source: Kasumi Yasukawa (2018) International ONSEN summit materials



Outdoor heated pool using geothermal fluid of Svartsengi geothermal power plant.
: Tourist attraction

Hot water exchanged in a heat-exchanger with the geothermal fluid after being used for power generation is also used for district heating.

Iceland

Geothermal power generation supplies 27% of total electricity generation (73%by hydropower)

Share of geothermal energy in the primary energy supply of Iceland is 66%

The population of Iceland is 320,000

Figure 4-18 “The Blue Lagoon" and the Svartsengi Geothermal Power Plant in Iceland

Source: Kasumi Yasukawa (2018) International ONSEN summit materials

4.7.3 Geothermal power generation

In Iceland, 70% of electricity is hydropower. The remaining 30% is covered by geothermal power generation. Iceland ranks eighth in the world in installed capacity of geothermal power generation as of 2017(708MW) (See **Table 2-3**). Hot water produced at the geothermal power plant is transported to urban areas and is utilized for district heating and for heated pools. 69% of domestic primary energy is geothermal, and utilization of hot water after power generation also plays a large role.

【Reference】

Hideshi Kaieda (2018): Trend of Geothermal Power Generation abroad, Geology and Survey, No. 2018 2, pp. 41– 46
https://www.zenchiren.or.jp/geocenter/geo-se/pdf/jgca152.pdf

4.8 New Zealand

4.8.1 Geothermal resources

The major geothermal resources in New Zealand are concentrated in the geothermal zone along the Taupo Volcano Zone extending from the Bay of Plenty to Lake Taupo in the northeastern part of the North Island (See **Figure 4-19**).

Figure 4-19 Taupo Volcanic Zone in New Zealand

Source: GNS Science Materials
https://www.gns.cri.nz/Home/Learning/Science-Topics/Earth-Energy/Geothermal-Energy/Maori-korero

4.8.2 Heat utilization

Several New Zealand companies have invested significantly in large scale industrial direct geothermal energy applications in the last five years including; heat supply to the tissue plant in Kawerau and steam supply to the milk powder processing plant in Mokai. Despite these new developments, there has been a reduction in geothermal direct heat use mainly as a consequence of Norske Skog Tasman closing down one of the paper production lines at its Kawerau facility in January 2013.

Table 4-8 shows the direct use of geothermal resources by application in New Zealand as of the end of December 2014. Most used is the industrial application (not including drying and dehydration for agriculture), followed by a great variety of applications such as bathing/pool, others (irrigation, frost protection, park for tourists etc.), greenhouse, district heat supply, heating, and aquaculture fishery.

【Reference】

Brian Carey, Mike Dunstall, Spence McClintock, Brian White, Greg Bignall, Katherine Luketina, Bridget Robson, Sadiq Zarrouk, Anya Seward (2015): 2015 New Zealand Country Update, Proceedings World Geothermal Congress 2015

Table 4-8 Heat Utilization in New Zealand

Use	Installed capacity ($\mathrm{MW_t}$)	Annual energy use (TJ/yr)	Capacity factor (%)
Industrial use	284	5,043	56
Bathing/pool	58	1,375	75
Others（Irrigation, frost protection, park for tourists, etc.）	33	992	95
Greenhouses	24	366	48
District energy supply	31	289	30
Heating	31	289	30
Aquaculture fishery	17	196	37
Heat Pump	9.32	69	23
Animal farming	0.13	2	49
Total	**487.45**	**8621**	

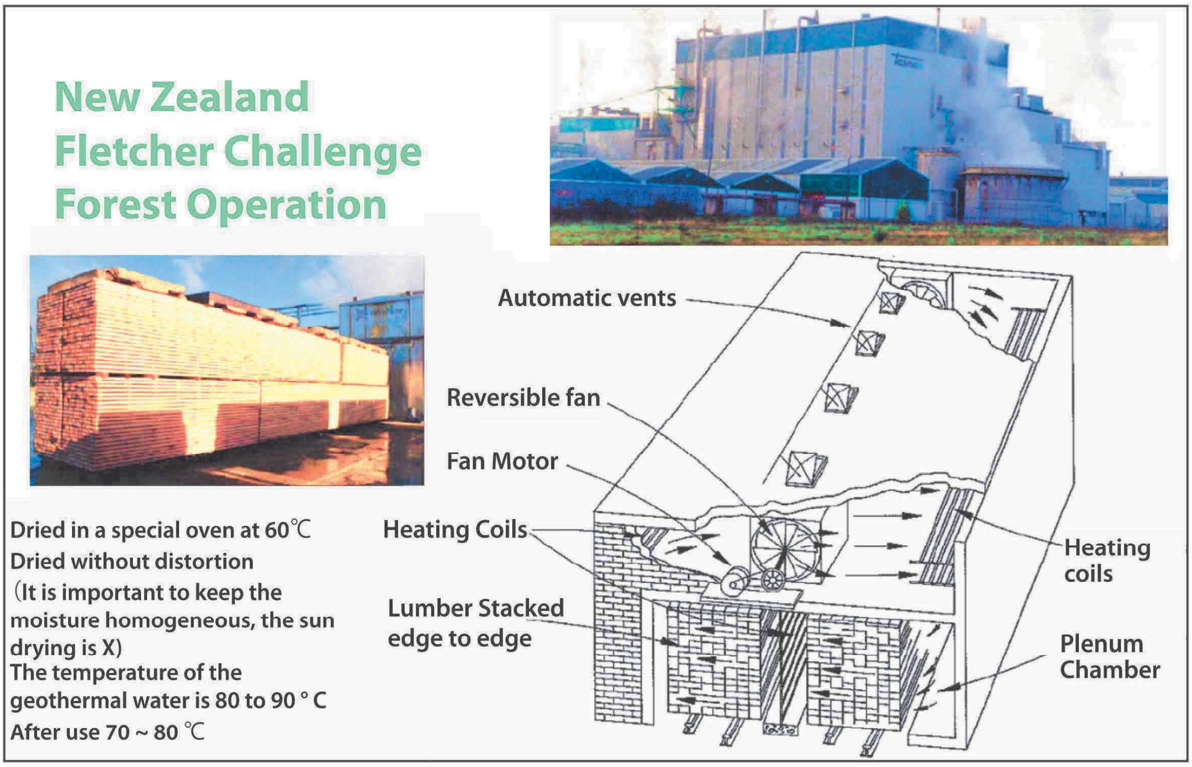
【As of the end of December, 2014】

Source: Brian Carey, Mike Dunstall, Spence McClintock, Brian White, Greg Bignall, Katherine Luketina, Bridget Robson, Sadiq Zarrouk, Anya Seward (2015): 2015 New Zealand Country Update, Proceedings World Geothermal Congress 2015

(1) Examples of wood drying

Figure 4-20 is an example of direct use of geothermal energy. Using warm water at 80°C to 90°C, wood is dried in a special oven, without distortion at 60°C by keeping moisture homogeneous.

Source: Kasumi Yasukawa (2018) International ONSEN summit materials



New Zealand
Fletcher Challenge
Forest Operation

Dried in a special oven at 60℃
Dried without distortion
（It is important to keep the moisture homogeneous, the sun drying is X）
The temperature of the geothermal water is 80 to 90 ° C
After use 70 ~ 80 ℃

Figure 4-20: Example of Heat Utilization in New Zealand (Drying Wood)

Source: Kasumi Yasukawa (2018) International ONSEN summit materials

(2) Examples of shrimp farming

Figure 4-21 shows shrimp farming as a case of direct heat utilization. The current manager purchased the aquaculture facilities from the former owner in 1991. The new management’s focus shifted use from only the aquaculture business and succeeded in raising income through the use of the tourism industry. Tourists can enjoy the attractions of shrimp fishing, river play, and restaurants. Of the 80 staff members working at the facility, 75 are engaged in the tourism industry, and only 5 are engaged in aquaculture. Sixty thousand tourists visit each year and revenue is about NZ$500,000 (approximately JP¥38,000,000).

In a breakdown of operating costs, the electricity fee from the hot water circulation pump is about NZ$120,000 per year. If the same amount of hot water was sourced from a regular boiler, the cost would be about NZ$350,000 per year. Additionally, the neighboring Taupo geothermal power plant supplies hot water at the annual cost of NZ$20,000 to help maintain high profitability.

Besides the tourism industry, the technology transfer of shrimp cultivation know-how has provided another source of income in recent years.

【Reference】

Result of the local interview survey of November 2017 by Kasumi Yasukawa

Figure 4-21 Example of Heat Utilization in New Zealand (Shrimp Farming)

4.8.3 Geothermal power generation

New Zealand was the second country in the world to use geothermal power generation, after Italy. The power generation capacity as of 2017 is the fifth largest in the world (978 MW) (See **Table 2-3**). The capacity of major geothermal power plants as of the end of December 2014 is shown in **Table 4-9.**

Table 4-9 Installed Capacity of Geothermal Power Plants in New Zealand

Area	Unit	Installed capacity(MW)
Wairakei	15	394
Kawerau	5	140
Reporoa	2	58
Rotokawa	6	174
Northland	3	35
Mokai	12	111
Tauhara	2	26
Ngatamariki	4	82
Total	**49**	**1020**

【As of the end of December 2014 】

Source: Brian Carey, Mike Dunstall, Spence McClintock, Brian White, Greg Bignall, Katherine Luketina, Bridget Robson, Sadiq Zarrouk, Anya Seward (2015: 2015 New Zealand Country Update, Proceedings World Geothermal Congress 2015

New Zealand succeeded in 6.5 MW of geothermal power generation at Wairakei geothermal power plant in 1958 by isolating only steam from the reservoir where mixed boiling water and steam were produced. Previously, geothermal power could be generated only in the geothermal area where steam is dominant. It used to be considered difficult to generate electricity in an area like Japan where both steam and hot water were ejected. However, the Wairakei case overturned the idea and greatly influenced subsequent geothermal development in Japan. Development in New Zealand is progressing in many places such as Rotokawa, Kawerau, and Mokai. The total installed capacity of the country is 978 MW as of 2017(World 5th.)

The country currently produces about 75% of its electricity from renewable energy sources and is strategically targeting 90% renewable electricity by 2025. However, domestic geothermal electricity construction has been paused since 2013, and the electricity demand is flat.
Wairakei power plant shown in **figure 4-22** is the second geothermal power plant built worldwide, after the Larderello power plant in Italy; however, the Wairakei power plant is the world's first hot-water-dominant geothermal power plant. Cooling water for the condenser is taken from the Waikato River, and geothermal water is discharged to this river.

【References】

Hideshi Kaieda (2018): Trend of Geothermal Power Generation abroad, Geology and Survey, No. 2, 2018 pp. 41 - 46
https://www.zenchiren.or.jp/geocenter/geo-se/pdf/jgca152.pdf

Brian Carey, Mike Dunstall, Spence McClintock, Brian White, Greg Bignall, Katherine Luketina, Bridget Robson, Sadiq Zarrouk, Anya Seward (2015): 2015 New Zealand Country Update, Proceedings World Geothermal Congress 2015

Figure 4-22 Wairakei Geothermal Power plant

Source: Japan Agency for Natural Resources and Energy Homepage: Home> About Policy> Fuel> Geothermal Resource Policy/Geothermal Power Generation> Geothermal Page> Geothermal Power Generation Mechanism> Geothermal Power Plant Introduction> World Geothermal Power Plant http://www.enecho.meti.go.jp/category/resources_and_fuel/geothermal/explanation/mechanism/plant/foreign/

4.9 Italy

4.9.1 Geothermal resources

The main geothermal field in Italy is the area shown in **Figure 4-23.**

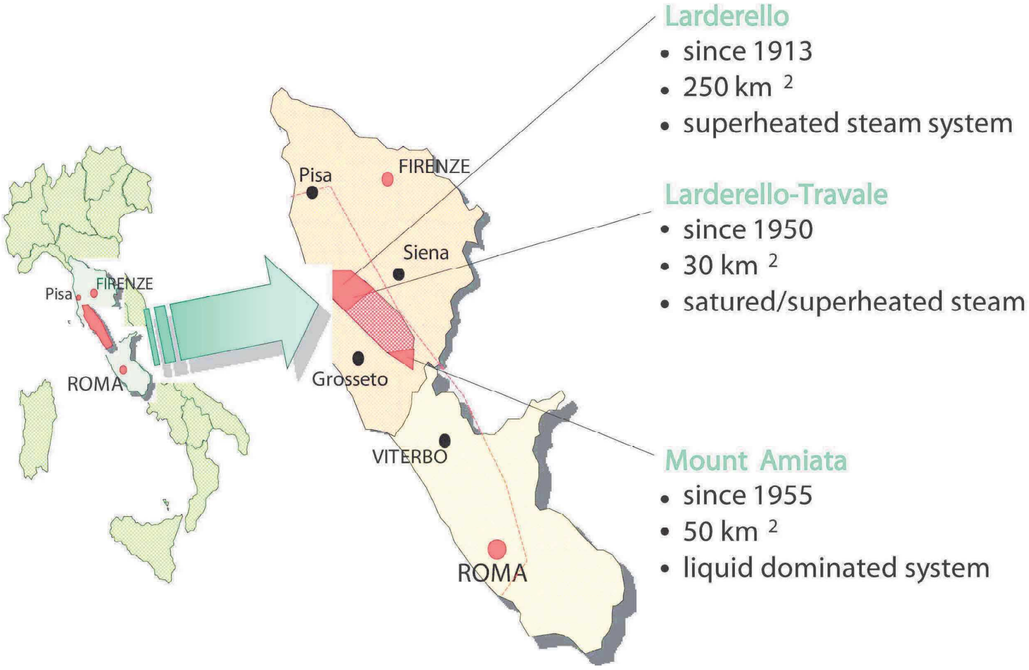


Figure 4-23 Main Geothermal Fields in Italy

Source: Francesco Razzano and Maurizio Cei (2015): Geothermal Power Generation in Italy 2010-2014 Update Report, Proceedings World Geothermal Congress 2015

4.9.2 Heat utilization

In Italy, heat from the geothermal / hot spring areas has historically been used for industry.

The name of Larderello, famous as being the home of world's first geothermal power generator, derives from Francois Jacques de Larderel, a Frenchman who invented a way of extracting boric acid from volcanic mud by using steam to heat cauldrons to separate the two. The town of Larderello was established to honor Larderel’s work and was founded to house the workers in the boric acid production factory in the first half of the 19th century. At that time, boric acid was very expensive and was used as an ophthalmic medicine in Europe; therefore, Mr. Larderel's business was very successful (Unione Geotermica Italiana, 2007).

Figure 4-24 shows the distribution of major geothermal utilization in Italy although it is an older document (Allegrini et al., 1995). Since Italy's geothermal resources are concentrated in the central peninsula mainly around Larderello and Monte Amiata, many cases of direct use are seen in this area as well as in the hot springs area in the north. One of the interesting cases is eel aquaculture. As larvae and young fish have different suitable growth temperatures, larvae are grown in Castelnuovo where hotter spring water is obtained. They are brought to Rodigo as young fish and grown to adulthood until being shipped. Although extra shipping costs are added into the pricing, the overall cost performance is better than providing separate facilities with different temperatures in one location.

Also, Abano Terme in the north is famous as a spa resort. Hot spring heat is used in various ways besides bathing. As shown in **Figure 4-25**, special mud taken here is used for mud therapy by maturing ingredients with hot spring heat (Yasukawa, 1998).

Figure 4-26 shows the present state of a large greenhouse facility in Monte Amiata. Hot spring heat is used to cultivate flowers with high commercial value.

【References】

Unione Geotermica Italiana (2007): “La Geotermia - Ieri, oggi, domain”
https://www.unionegeotermica.it/la-geotermia-pubblicazione.asp

Allegrini, G., Cappetti, G., Sabatini, F. (1995): Geothermal development in Italy: country update report, Proceedings, World Geothermal Congress 1995, 201-208

Kasumi Yasukawa (1998): Research and utilization situation of hydrothermal water and low temperature geothermal resources in Italy, geothermal, 35, pp. 111-127

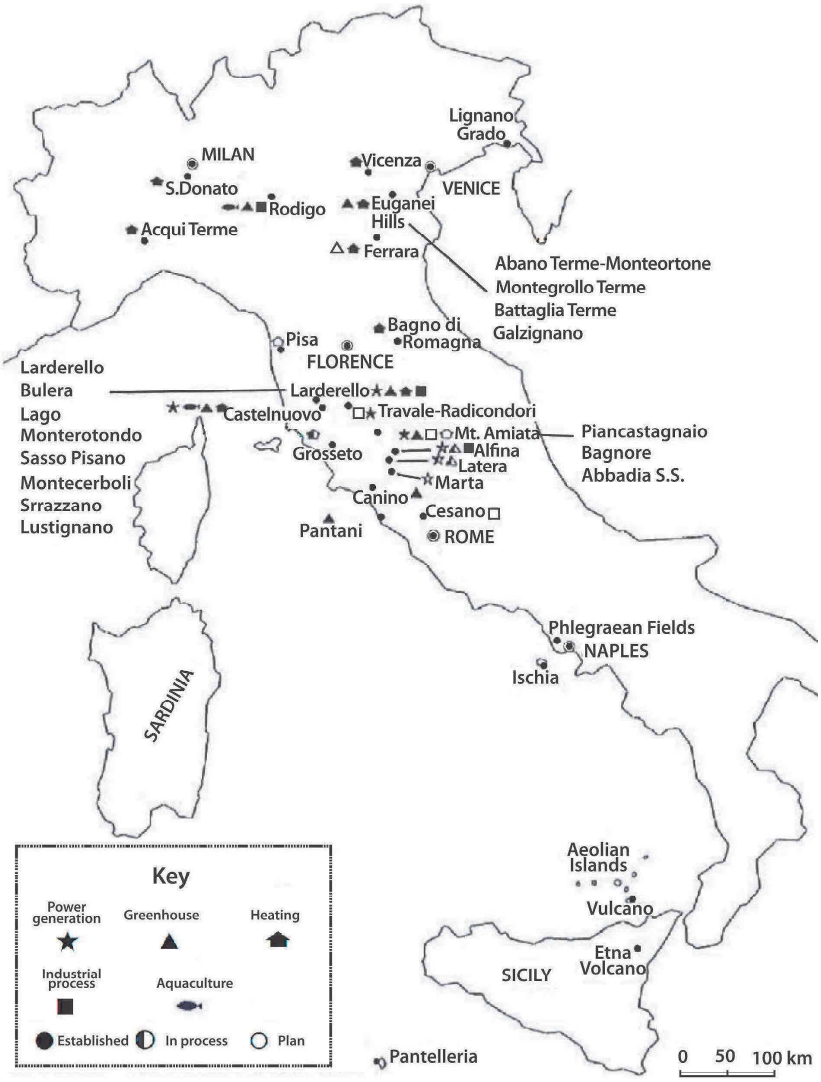


Figure 4-24 **Major** Geothermal Utilization in Italy

Source: Allegrini, G., Cappetti, G., Sabatini, F. (1995): Geothermal development in Italy: country update report, Proceedings, World Geothermal Congress 1995, pp.201-208

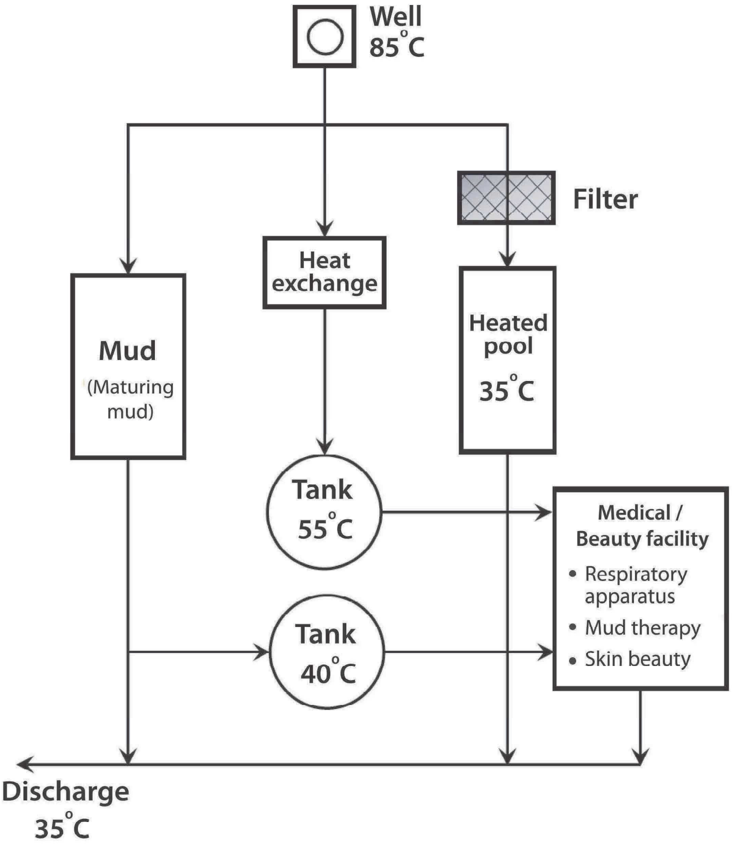


Figure 4-25 Geothermal Direct Usage Flowchart of Trione Hotel in Abano Terme

Source: Kasumi Yasukawa (1998): Research and utilization situation of hydrothermal water and low temperature geothermal resources in Italy, geothermal, 35, pp. 111-127

Figure 4-26 Greenhouse Flower Cultivation Using Hot Spring Heat in Monte Amiata

Source: Floramiata HP
https://www.floramiata.it/

4.9.3 Geothermal power generation

In Italy, geothermal resources are mainly used for power generation and all of the power plants in operation are located in Larderello-Travale and Mount Amiata in Tuscany. Their installed capacity in 2017 is the 7th largest in the world. (916 MW, See **Table 2-3)**

Table 4-10 shows the installed capacity of geothermal power generation in major Italian regions.

Table 4-10 Installed Capacity of Geothermal Power plants in Italy

Area	Unit	Installed capacity （MW）
Larderello	22	595
Larderello-Travale	8	200
Mt. Amiata	5	81
Total	**35**	**876**

【As of the end of December 2014】

Source: Francesco Razzano and Maurizio Cei (2015): Geothermal Power Generation in Italy 2010-2014 Update Report, Proceedings World Geothermal Congress 2015

Construction of a geothermal power plant took place in Larderello in 1913. Geothermal power use was promoted in the area through 1942. The installed capacity reached 120 MW. Many Italian power generation facilities were destroyed in the Second World War, but the construction of power plants progressed thereafter. The output of steam began to decline in the 1950s because the amount of hot water in the reservoir was decreasing. Therefore, condensed water from power generation was re-injected into ground wells and as a result, the output of steam has recovered since the 1970s. Construction of facilities for district heating with direct hot water use has recently begun. Facilities with 1,300 MW_t were constructed in 2015 (Kaieda, 2018).

In 2013, Enel Green Power set up the first binary power plant in Italy (Gruppo Binario Bagnore 3: 1 MW), where the liquid phase after the primary flush of geothermal fluid in Bagnore Geothermal Field (Mount Amiata) is used. (Francesco and Maurizio, 2015)

【References】

Hideshi Kaieda (2018): Trend of Geothermal Power Generation abroad, Geology and Survey, No. 2018 2, pp. 41– 46
https://www.zenchiren.or.jp/geocenter/geo-se/pdf/jgca152.pdf

Francesco Razzano and Maurizio Cei(2015): Geothermal Power Generation in Italy 2010-2014 Update Report, Proceedings World Geothermal Congress 2015

4.10 Turkey

4.10.1 Geothermal resources

The main geothermal field in Turkey is the Western Anatolia area shown in **Figure 4-27.**

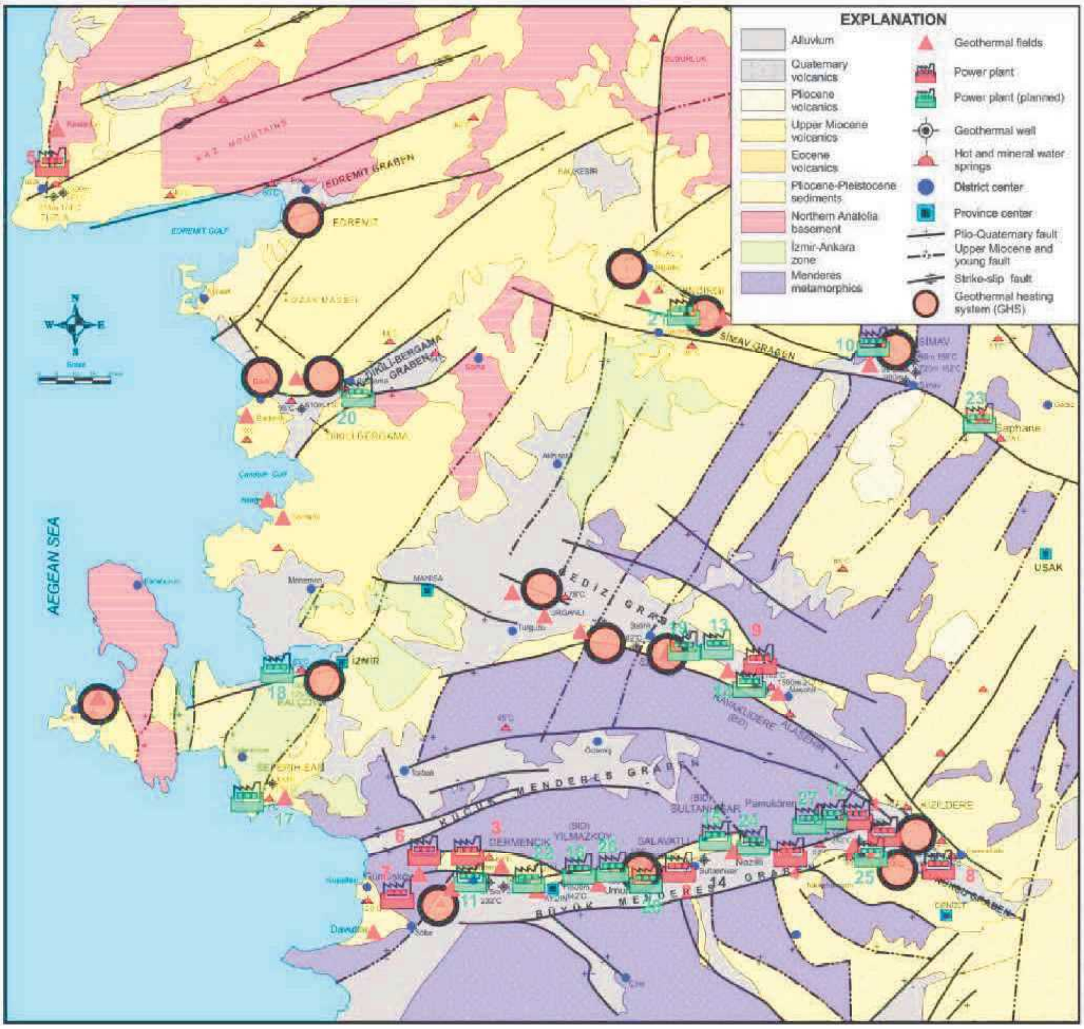


Figure 4-27 Geothermal Field in Western Anatolia, Turkey

Source:Orhan Mertoglu, Sakir Simsek, Nilgun Basarir(2015): Geothermal Country Update Report of Turkey (2010-2015), Proceedings World Geothermal Congress 2015

4.10.2 Heat utilization

The installed capacity of geothermal direct-use applications is at 2,886.3 MW$_t$. This figure is composed of 805 MW$_t$ for district heating, 420 MW$_t$ for individual space heating (mostly thermal facilities and hotels), 612 MW$_t$ for greenhouse heating (nearly 3 million m2), 1,005 MW$_t$ for hot-spring use and 42.8 MW$_t$ for the geothermal heat pumps.

The proportion of direct use of geothermal resources at the end of December 2014 is shown in **Figure 4-28**, and the direct usage is shown in **Table 4-11.** Annual heat utilization is as much as 45,126 TJ/yr, which is the second largest energy use in the world after the United States.

【Reference】

Orhan Mertoglu, Sakir Simsek, Nilgun Basarir(2015): Geothermal Country Update Report of Turkey (2010-2015), Proceedings World Geothermal Congress 2015

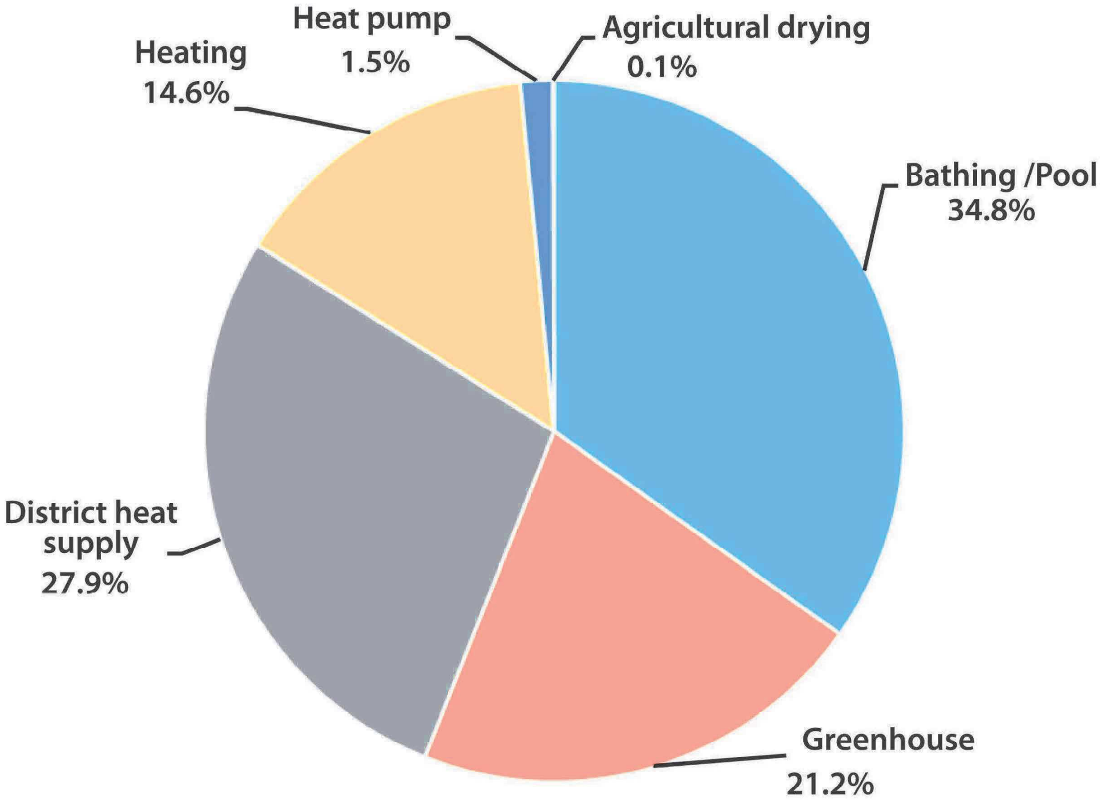


Figure 4-28 Ratio of Heat Utilization by Application in Turkey

【As of the end of December 2014; prepared based on Mertoglu et al. (2015)】

Source: Orhan Mertoglu, Sakir Simsek, Nilgun Basarir (2015): Geothermal Country Update Report of Turkey (2010-2015), Proceedings World Geothermal Congress 2015

Table 4-11 Heat Utilization in Turkey

Use	Installed capacity (MW_t)	Annual energy use (TJ/yr)	Capacity factor (%)
Bathing/Pool	1005	19,016	60
Greenhouse	612	11,580	60
District heating	805	8,885	35
Heating	420	4,635	35
Heat pump	42.8	960	70
Agricultural drying	1.5	50	30
Total	2886.3	45,126	

【As of the end of December, 2018】

Source: Orhan Mertoglu, Sakir Simsek, Nilgun Basarir (2015): Geothermal Country Update Report of Turkey (2010-2015), Proceedings World Geothermal Congress 2015

An example of heat utilization in Turkey is shown in **Figure 4-29**. In this area, tomatoes and paprika are grown in greenhouses covering a total area of 4 million square meters, using 4 wells at depths of 400m with hot water at 95°C as protection from winter frost. Geothermal district heating and power generation are also growing rapidly.

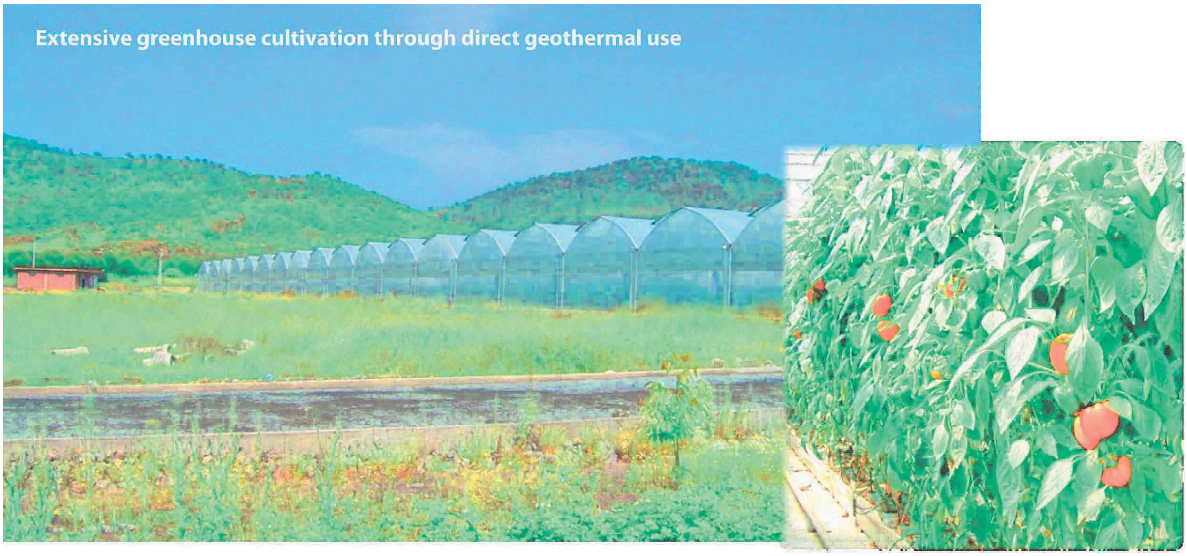


Figure 4- 29 Greenhouse Cultivation in Turkey (Dikili geothermal area)

Source: Kasumi Yasukawa (2018) International ONSEN summit materials

4.10.3 Geothermal power generation

The installed capacity of geothermal power generation of Turkey as of 2017 is the fourth largest in the world (1,064 MW) (See **Table 2-3**). As shown in **Figure 4-2**, Its greatest feature is that like Kenya, the installed capacity has been increasing rapidly since 2010.

A 15 MW geothermal power plant was constructed in Turkey in 1984, and thereafter, development has advanced rapidly with the enactment of the “Law on the Use of Renewable Energy Resources" in 2005. Furthermore, for the first time in 2007, "Law on the Geothermal Resources and Natural Mineral Waters (Law No. 5686/2007) (Geothermal Resources and Natural Mineral Water Act, No. 5686, 2007)" was enacted. Under this act, "Geothermal resources belong under the control of the state and do not belong to landowners," (Kaneko, 2016). This change has led to an increase in geothermal resource development in recent years.

【References】

Kaneko Masahiko (2016): World Geothermal Law (2), The Geothermal Society of Japan Journal Vol. 38, No. 3, pp. 85-100

4.11 Germany

4.11.1 Geothermal resources

Geothermal resources for geothermal power production were estimated in a 2002 study.
The aquifer of hot water, the distribution of the crystalline rock which becomes a geothermal resource is shown in **Figure 4-30.**

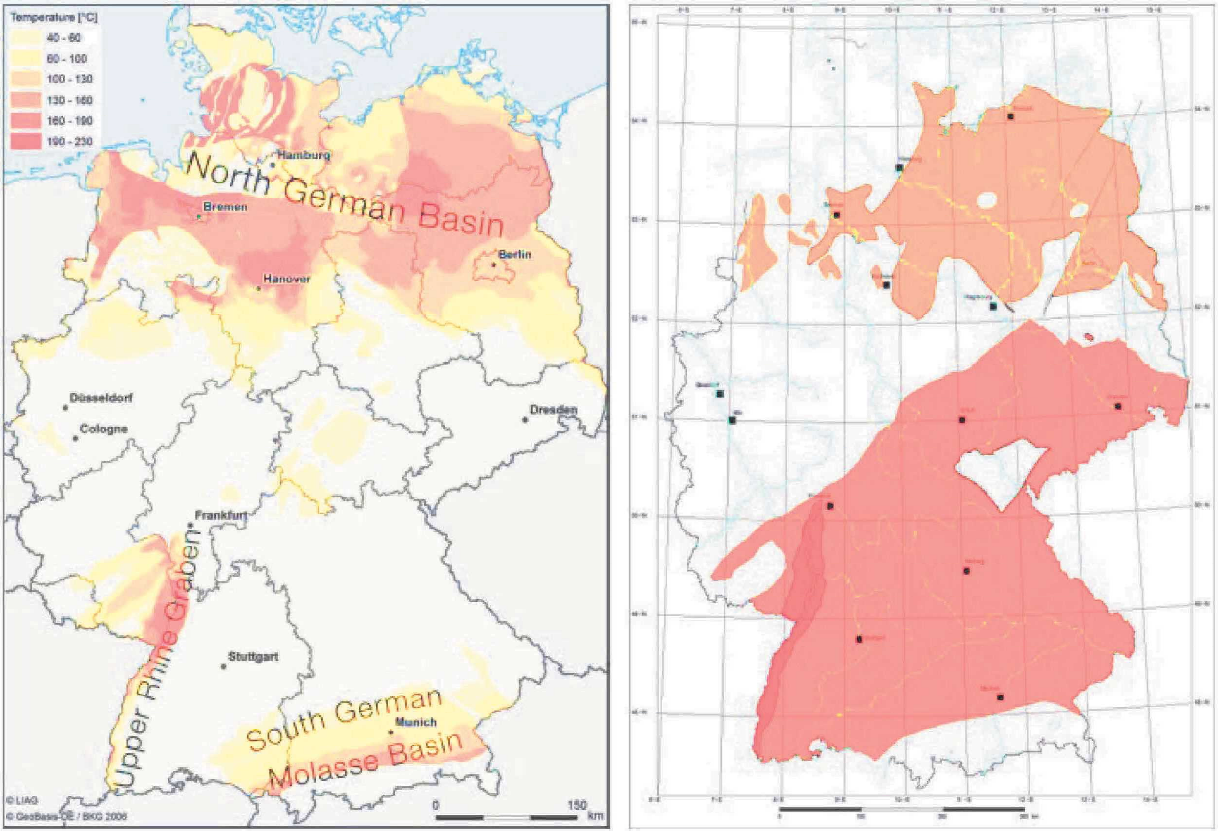


Figure 4-30 (Left) German Regions with Hydrothermal Resources & (Right) Crystalline Rock Distribution (proven and assumed)

【(Right) Crystalline rock distribution, Legend, Red: at a depth of 3 km and an average temperature of 100°C.; Dark red: Crystalline rock with upper line graven depth 3 km, temperature 130°C; Orange color: Rotliegend (Permian) volcanic rock with temperature above 100°C】

Source: Josef Weber, Britta Ganz, Ruediger Schellschmidt, Burkhard Sanner and Ruediger Schulz (2015): Geothermal Energy Use in Germany, Proceedings World Geothermal Congress 2015

4.11.2 Heat utilization

At present, 180 geothermal installations for direct use of geothermal energy are operating in Germany. The installed capacity of these plants amounts to roughly 260 (geothermal)/650 (total, including peak load capacity etc.) MW_t. The installations comprise centralized heating units (district heating), space heating in some cases combined with greenhouses, and thermal spas. Most of the plants are located in the North German Basin, the Molasse Basin in Southern Germany, or along the Upper Rhine Graben. In addition to these large-scale plants, there are numerous small and medium-size geothermal heat pump units (ground coupled heat pumps and groundwater heat pumps). Their installed capacity nearly reaches 2,600 (geothermal)/3,500 (total, including electrical energy consumed) MW_t. After a period of growth in the past decade, the number of newly installed geothermal heat pumps decreased over the last years, due to economic and regulatory shortcomings. By the end of 2013 direct thermal use of geothermal energy in Germany amounted to a total installed thermal capacity of about 2,850 (geothermal) /4,150 (total) MW_t (Weber et al., 2015).

In Germany, geothermal power is a minor contribution to overall power generation, but it is regarded as a major heat source in the heating and cooling market. The use of shallow geothermal continues to progress, and it is estimated that about 165,000 facilities are installed in individual houses and commercial buildings. Approximately 30,000 facilities are newly installed each year. In some areas, over 20% of newly constructed buildings utilize geothermal heating, most of which have vertical closed systems (Holst, 2013).

【References】

Josef Weber, Britta Ganz, Ruediger Schellschmidt, Burkhard Sanner and Ruediger Schulz (2015): Geothermal Energy Use in Germany, Proceedings World Geothermal Congress 2015

Holst RUETER (2013): Geothermal development master plan in Germany and its realization, Journal of the Geothermal Society of Japan, vol. 35, No. 1, pp. 45 - 47

4.11.3 Geothermal power generation

Geothermal power plants such as Durmhaar (7 MW), Kirchstockach (7 MW), Sauerlach (5 MW), Insheim (4.3 MW) had been built in Germany by 2015 (Kaieda, 2018). The installed capacity of these plants amounted to 39 MW as of 2017 (BP, 2018).

【References】

Hideshi Kaieda (2018): Trend of Geothermal Power Generation abroad, Geology and Survey, No. 2018 2, pp. 41– 46
https://www.zenchiren.or.jp/geocenter/geo-se/pdf/jgca152.pdf

BP (2018): Home / Energy economics / Statistical Review of World Energy / Renewable energy / Geothermal power
https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/renewable-energy.html/geothermal-power

Fully Using Geothermal Energy in Oita

Utilization in agricultural and fishery industries

- Reduce dependence on fossil fuels using warm water heated by geothermal energy
- Using clean energy cultivation to add value to products


Paprika cultivation facilities using geothermal heat


Loach fish farming using geothermal heat

Utilization in daily life

- Used for heating low recessed tables, warmed by circulating steam from hot springs


A low "kotatsu" table recessed into the floor


Beauty salon using geotehrmal heating

Place of origin of geothermal power generation in Japan in Oita prefecture

- In 1925, the world's third power generator, after Italy and the USA.
- The fumarolic hole on the north side of "Bouzu Jigoku" in Beppu

A photo of "Bouzu Jigoku" or "Buddhist Hell" in Beppu

5 Individual Interviews

At the end of the case collection, interviews with four people who are deeply involved with geothermal power generation have been included. The reasons for choosing the interviewees are as follows.

Masanori Hayashi of Turbo Blade Co., Ltd. has developed the world's first hot-water generator that uses a two-phase flow of steam and hot water from a geothermal well in a turbine by utilizing public funds for development. From the testing generator, he then developed a practical generator. The practical generator used by the Oita Prefectural Agricultural Research Division Floriculture Group was well covered and publicized by mass media, and many people have visited the center. This was selected as a successful case that led to the revitalization of the local community by power generation technology based on hot spring energy.

Mr. Katsuichi Kato of Genki-up Tsuyuki Co., Ltd., suggested revitalizing Tsuchiyu hot springs with renewable energy after the Great East Japan Earthquake of 2011 had devastated the area. Hot-spring inns suffered a great deal of damage, resulting in a sharp decline in tourists. The locals worked together and gained national subsidies, completing small-scale hydroelectric power generation, binary power generation, and the aquaculture business of raising freshwater prawns. This case was selected as a successful example that activated the local economy, utilizing hot spring energy.

Mr. Nobuyasu Nishikawa of JOGMEC promotes grant projects for geothermal resource surveys nationwide. He also conducts airborne surveys to support nationwide policies to increase the geothermal power generation capacity of Japan by 1 million kW by 2030. He was selected as one of the leaders at the forefront of the development of hot spring and geothermal energy.

Mr. Greg Vignal has been contributing to the development of geothermal energy in New Zealand by developing analytical techniques to clarify the structure of underground resources in New Zealand. His selection as an interviewee is based on his being one of the most advanced engineers in the world in the field of geothermal energy.

5.1 Yukemuri power generation (Mr. Masamoto Hayashi, CEO of Turbo Blade Co., Ltd.)

Yukemuri Power Generation Plant

Interview with Mr. Masamoto Hayashi, CEO of Turbo Blade Co. Ltd

[Company Profile]

1999.2	Established Turbo Blade Inc. in Oita
2013.6	Earned subsidies from Oita Developed Yukemuri Power Generation system Completed then began operation of the 1st, 2nd, and 3rd (3 kW) experimental plants (World's first)
2014	Completed then began operations of practical 1st plant (10 kW) <Geothermal World Industry Inc. and Kamenoi Power plant>
2015	Completed and started operation of practical 2nd plant (22 kW × 2 units) <Oita Prefectural Agricultural Research Division Floriculture Group>

Photo-1 CEO of Masamoto Hayashi and Yukemuri Power Generation Plant

[Interview]

Q: How did you invent the Yukemuri Power Generation system that uses both steam and hot water to generate electrical power?
Hayashi: About 25 years ago, we had an opportunity to invent a steam turbine and a hot water turbine that generate electricity. It came about because there was no power supply for sensor research when Mr. Yukio Ehara, emeritus professor from Kyushu University, tried to study steam and hot water use at Jigokudani National Park. After that, we received a subsidy related to renewable energy from Oita prefecture. Then we learned about geothermal wells from Geothermal World Industry, Inc. and developed the world-first Total Flow Power Generation that is also called the Yukemuri Power Generation system. This unique system generates power utilizing both steam and hot water. In Japan and the United States, they knew that electric power generation with steam and hot water would produce 1.6 times more power than steam alone; however, it was inefficient and was not put into practical use. In fact, Total Flow Power generation has more than 70% efficiency. After the Great East Japan Earthquake disaster, Prime Minister Abe visited us and was interested in our experimental Unit 3. Then, thanks to Prime Minister Abe's efforts with deregulation, we were able to develop a practical plant. Moreover, we received a request from Taiwan University to design and produce a plant for Yilan County near Taipei that generates electricity using 150°C steam and hot water. Currently, that plant continues generating electricity at 150kW.

Q: Could you tell us about the structure of the Yukemuri Power Generation System?
Hayashi: Compared to flash power generation that uses only steam, the Yukemuri Power Generation system is characterized by the structure of a turbine rotated by using a two-phase flow of both steam and hot water. Also, it has production considerations that affect the structure of the turbine. Variations may occur depending on the flow of the steam, the temperature of the source hot water, the flow amount, and various other ingredients.

Q: What have you struggled with in developing Yukemuri Power Generation system?
Hayashi: Steam turbines were being studied for use with flash power generation while research on energy from hot water was only minimally being studied. Additionally, the Total Flow Power system did not have a supersonic nozzle to convert hot water to steam. That was the most important part of our development. It was the most difficult challenge to design the shape of the rotating blade and the thermal fluid design of the nozzle for hot water energy generation.

Q: Could you tell us about your co-developers for the world- first generator?
Hayashi: We appreciate that Oita Prefecture provided us subsidies for research. In fact, the Total Flow Power System was awarded 1st place in the Business Grand Prix held in Oita Prefecture. We received

a prize of about 9 million yen. Thus, we were able to develop the practical No. 2 machine (22 kW × 2 units) for the Floriculture Group. Currently, the Total Flow Power system is supported by three groups: Turbo Blade Inc. that works for design, Todaka Seisakusho that works for processing and production, and Geothermal World Industry Inc. that is in charge of sales.

Q: Was there any social reaction when the experimental plant began to operate?
Hayashi: When the 1st Experimental Plant that was developed with a subsidy from Oita Prefecture was completed, we were interviewed by three TV stations in Oita Prefecture. Then several members of Congress visited the plant and advertised it in Tokyo because Oita Prefecture and the Kyushu Bureau of Economic Industry had applied for accreditation. In the countryside of Oita Prefecture, developing the world's first Total Flow Power system that efficiently generates power with steam and hot water seemed to have had a positive social impact.

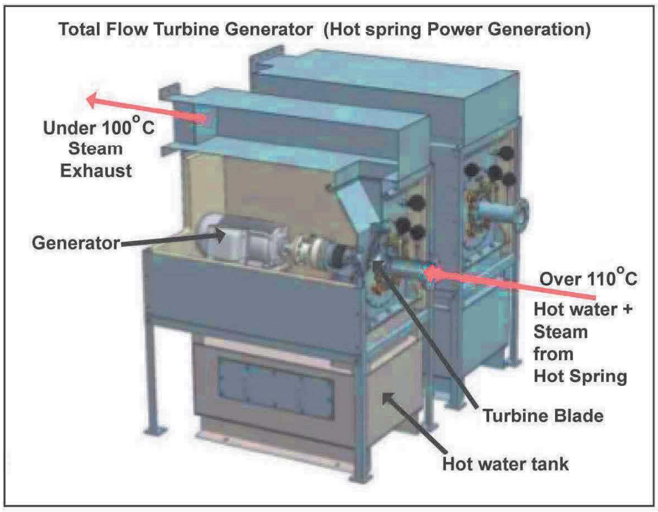


Photo-2 Structure of Total Flow Power System

Q: Could you tell us about the operation status of Practical Unit No.2 at Oita Prefectural Agricultural Research Division Floriculture Group?
A: It cannot be used for power generation from November to April. In those months the main use of the steam is for heating the greenhouse. Therefore, we only use excess steam for power generation from May to October because heating the greenhouse is not necessary then. Originally, there was no capability to generate with only one generator from the source due to pressure and flow rate. Then, as we continued, we found that sand was mixed in the two-phase flow and the blades of the turbine were being scraped and worn down. Therefore, we set up a sand separation tank before the two-phase flow enters into the power generator. Recently, we have been considering switching to only power generation for steam turbines as the volume of hot water is running low.

Q: Could you tell us about your future prospects for Yukemuri Power Generation?
Hayashi: The development of machines that effectively generate electricity using the two-phase flow of steam and hot water has begun to be applied to other industrial plants. Therefore, we would like to continue to expand this system into fields other than generators and to develop new industrial applications.

5.2 Tsuchiyu Onsen (Mr. Katsuichi Kato, CEO of Genki-up Tsuchiyu Co., Ltd)

Tsuchiyu Onsen
Interview with Mr. Katsuichi Kato, CEO of Genki Up Tsuchiyu Co. Ltd

[Company Profile]

2011.10	Established Genki Up Tsuchiyu Co., Ltd.
2014. 5	Held the *Anzen-kigan-sai* (ceremony to pray for safety) for Higashikawa River hydroelectric power plant
2014. 8	Anzen-kigan-sai for No. 16 Binary Power Plant, Tsuchiyu Onsen
2015. 5	Completed Higashikawa River hydroelectric power plant
2015.11	Completed and started operations of No16. Binary Power Plant, Tsuchiyu Onsen
2017. 5	Completed shrimp farming facility/Facility of hot-water sprinkler system for Snow-melting tour experience

Photo-1 Mr. Katsuichi Kato and Tsuchiyu hot spring No.16 well Binary Power Plant

[Interview]

Q: You work in hydroelectric power generation, binary power generation, and hot water utilization after power generation, so can you tell us about how you started these businesses?
Kato: The Tsuchiyu Onsen area was greatly affected by the Great East Japan Earthquake on March 11, 2011. Five of the hot spring hotels had to close their businesses due to major damage. On a yearly basis, there used to be about 260,000 tourists coming to Tsuchiya Onsen; however, that number decreased to less than 100,000 people after the earthquake. Therefore, we started a redevelopment by using hot spring resources. First, we began construction of a small hydropower plant that we had been planning even before the earthquake disaster. Next, we focused on binary power generation in order to utilize hot spring resources that Tsuchiyu Onsen had in abundance. Then we decided to use the binary power generation from Omart Company which was well-known world-wide, and we managed to start its construction. For funding to construct the power plant, we received a debt guarantee from JOGMEC. It was completed in November 2015 and we were able to start selling electricity.

Q: How did you get support and cooperation from local residents regarding construction of the binary power plant?
Kato: In fact, we provide hot water to the onsen hotels after adding cooling water because the temperature of the water at the source in Tsuchiyu is so high. Thus, even though the temperature drops due to binary power generation, we thought it was economical. So we explained to the residents that binary power generation could provide the same quality of hot spring water because it would work by passing through the heat exchange without touching air.

Q: What was the biggest struggle you had to overcome to get approval?
Kato: First of all, we focused on the scenery and the environment because Tsuchiyu Onsen is located in a national park and tourism is the main industry. Next, the binary power generator had to be treated as a dangerous, as N-Pentane is used. as a coolant. In case of emergency, it is necessary to set a security zone of 5 meters around the power plant.

Q: Could you give us an overview of a binary power plant?
Kato: The Source of the hot spring used is the 16th source which is owned by Yuyu Tsuchiyu Onsen Cooperative Association. The temperature is over 130°C, the flow amount is 37.2t/h, and the pressure is 0.35MP. A two-phase flow of steam and hot water is used. Cooling water is drawn from a spring about 4 km upstream. The temperature is 10°C ~12°C and the flow rate is 260t/h. The power generation system is the Organic Rankine Cycle type and has been approved with the rated output of 440kW. This is equivalent to the amount of electricity generation for approximately 800 households, and we sell the entire amount at FIT.

Q: Why did you choose to do shrimp farming with the hot water from post power generation?
Kato: We wanted to receive a subsidy somehow for Tsuchiyu Onsen since we found out that the Ministry of Economy, Trade, and Industry supports promotion projects in geothermal development. I considered land-based cultivation as I had some experience with greenhouse cultivation. Then we went to Hirosaki in Aomori prefecture. They are farming giant freshwater prawns (Macrobrachium rosenbergii) and we were able to get juvenile fish. After I raised them, experimentally, in Tsuchiyu Onsen and it went well, I applied for a subsidy for promotion projects in geothermal development. We created an interesting and fun experience for visitors. People can enjoy fishing in the pond and then grilling and eating their prawns. In 2018, the operating hours are limited to only Saturdays and Sundays from July to August. Thankfully, approximately 450 people enjoyed this outing.

Photo-2 The Onshore fish farming of Demon Prawn

Q: Has the binary power generator been producing power steadily?
Kato: Fortunately, there has been no trouble with the power generator. This June (2018), the pressure of the source dropped a little, so we cleaned the well for the first time in two years and the pressure recovered. Although there may be blackouts sometimes from electric companies, the utilization rate by calendar day is being maintained at over 91%. As a result, revenues from electricity sales also increased by approximately 20% above the plan. The revenues are being returned to the local community. For example, school meals are offered free of charge at elementary schools and high school students who have to take a bus to Fukushima city are able to go for free.

Q: Could you tell us about the tour program and the training program with the binary power plant, shrimp farm, and small hydropower plant as tourism resources?
Kato: We charge 4,000 yen per person to visit the binary power plant and the shrimp farm. We also receive 50,000 yen per group when custom-made tours are requested for professionals. Additionally, we recommend guests stay at Tsuchiyu Onsen during their visit. As a result, the number of tourists to Tsuchi Onsen has recovered to about 270,000 people. This is close to the number of guests before the disaster. I believe that constructing the binary power plant, the shrimp farm, and the small hydropower plant has helped to redevelop Tsuchiyu Onsen. Therefore, we are looking forward to more tourists visiting in the future.

5.3 JOGMEC (Mr. Nobuyuki Nishikawa, General manager of JOGMEC)

Japan Oil, Gas and Metals National Corporation (JOGMEC)
Metal and Mineral Resources Organization
Interview with Mr. Nobuyasu Nishikawa, General Manager of JOGMEC

Abstract of Organization

2002. 7 Independent Administrative Corporation (German law)
Japan Oil, Natural Gas, Metal and Mineral Resource Organization (JOGMEC)
Promulgation of Law
2004. 2 JOGMEC established
2012. 8 JOGMEC Law Revision
2012. 9 Added support for coal and geothermal resource development
Started support projects for geothermal resource development

Photo-1 Mr. Nobuyasu Nishikawa of General Manager of Geothermal Dep. Of JOGMEC

[Interview]

Q: The government has set a goal for increasing the installed capacity of geothermal power generation to around 1 million kW by the year 2030. JOGMEC is considered to play a major role in achieving that goal. Can you tell us what JOGMEC's main work is in relation to geothermal resource development?
Nishikawa: JOGMEC's work covers potential research, support for projects in geothermal resource development, technology development, training, publicity dissemination (information provision), and cooperation with overseas counterparts. In the support project there is a subsidy system for geological structure surveys, equity investment for exploration of resources and quantity evaluation. JOGMEC also has a debt guarantee system for power plant construction.

Q: Support projects are considered important for increasing geothermal power generation country. Can you give us some specifics?
Nishikawa: First, although there is a subsidy system, it is subject to ground survey results, well drilling surveys and hot spring monitoring. The subsidy rate varies depending on the geothermal power producer and the local geothermal corporation. Recently, the grant rate has changed depending on the scale of power generation. It focuses on giving incentives for the development of large-scale power generation. We have given grants to 66 projects (2012~2017) so far. Approximately 40% of them are for local governments and hot spring operators. And, now, survey areas are increasing in addition to the existing areas of Tohoku and Kyushu. There are now projects in Hokkaido and Chubu. This means that the base of the geothermal business is steadily spreading out into wider areas. There are currently four guarantees underway for the construction of power plants.

Among them, a project that has been drawing particular attention is a large-scale geothermal power plant in Akita Prefecture. The Yamazawa geothermal power plant is now under construction. The plant is in the city of Yuzawa and will be Japan's first geothermal plant with output of more than 10,000kW. The Yuzawa power plant will be the country's fifth-largest geothermal plant. This is a large-scale geothermal power plant and one of the biggest since the Takigami Power plant that started operation in 1996 with an output of 42,000kW.

In addition, in order to discover new projects in the frontier area, we also conduct extensive surveys using aerial physics exploration and we conduct surveys of heat holes.

Photo-2 The Airborne Geophysical Exploration

Q: What kind of technical development is being done at JOGMEC?
Nishikawa: In order to solve technical problems, we are working on reducing lead time, improving the success rate of excavation and stabilizing steam output. All of these are keys to achieving a good energy mix. We are also working on three-dimensional elastic wave exploration technology and recharging at Yanatsu Nishiyama Power plant. Additionally, we are promoting the development of PDC bits (polycrystalline diamond compact) for use in geothermal well drilling. These bits enable cheaper well drilling.

We are working to achieve practical applications in early stages, and we are actively engaged in field trials, such as demonstration tests. Going forward, we will continue to proactively develop technologies such as the development of compact high-power rigs and water permeability improvement technologies.

Q: Many of the projects being undertaken now are related to dissemination of information to the public. Can you tell us a little more about that?
Nishikawa: To promote geothermal development, it goes without saying that the understanding of the general public and the support of local residents is a major consideration moving forward. JOGMEC carries out understanding promotion activities through symposiums, special classes for elementary and junior high and high school students and exhibitions at various venues. We also conduct campaign activities for Geothermal Power Generation Day on October 8. In the future, I think that it is important for the public to understand the activities of hot spring businesses and to accept and support geothermal power generation. It is important to have a good understanding and cooperation from the public and for business operators to respect the wisdom and concerns of local stakeholders.

Q: Can you talk about the engineer training system related to geothermal development.
Nishikawa: "Geothermal Development Engineer Training" is centered on young engineers and "Geothermal Drilling Engineers Training" is carried out to solve the technical shortages in geothermal development. In particular, "Geothermal Development Engineer Training" is held at the International Resource College in Kosaka, Akita prefecture. Participants are from 30 to 40 people every year. This training is carried out to not only acquire skills but also to create networks between the trainees. I am proud that I can contribute to making a network between trainees for the future growth of geothermal development.

Q: **Can you tell us about overseas cooperation activities.**
Nishikawa: We hold workshops in both Japan and New Zealand under the MOU signed with GNS Science in New Zealand in July 2015. We also share information through technical exchanges. In September of this year (2018), three lecturers from New Zealand came to Japan to train young Japanese engineers. Also, we are building cooperative relationships with the US Electric Power Research Institute (EPRI) in the field of recharge technology.

Q: **As of fiscal 2018, what does the JOBMEC medium-term 5-year plan entail?**
Nishikawa: In order to realize the energy mix goal of 2030, we recognize that this is a critical moment in time. JOGMEC is fully prepared to mobilize all of the work we have introduced so far, and we will strive to maximize all we have done. However, there are external factors that must be worked out. For example there are system connection problems that cannot be controlled by JOGMEC and reaching consensus with hot spring operators must be carried out. And we have to address various procedural problems that have become obvious. Further cooperation with the national government and related organizations will be necessary as we move forward. We want to continue to work on all of these points and we will continue to promote geothermal resource development. We deeply appreciate everyone's strong support and continued cooperation.

Abstract: ***"The current situation of geothermal power generation in Japan and JOGMEC' approaches.***"

While JOGMEC implemented geothermal business over the past 5 years, there has been a growing recognition as to effective use of geothermal support program by JOGMEC. This is thanks to the backup measures from the government and in response to the strong gain of momentum of the companies in geothermal development. (Egashira, et al., 2014) On the other hand, in the Long-term Energy Supply and Demand Outlook, July 2015, the Ministry of Economy, Trade and Industry (METI) put geothermal power as "baseload power source," which can be produced stably and by low cost, and set a goal to increase the present geothermal power ratio in the total power generation (the energy mix) by 3 times up to 2030. Aiming for the achievement of the energy mix, JOGMEC will make efforts to enhance collaboration with all the parties concerned and accelerate geothermal development. In this report, we explain about the current situation of and the issues surrounding geothermal power in Japan, and JOGMEC's support programs, recent activities and its future prospect as well.

Source: Article *in* BUTSURI-TANSA (Geophysical Exploration) 70:81-95 · December 2017

5.4 GNS Science (Dr. Greg Bignall)

Interview with Dr. Greg Bignall; Head of Geothermal Sciences Department of GNS Science

Company History

- **1865** New Zealand Geological Survey established.
- **1992** The Geological and Nuclear Science Institute was newly established. All departments of the Geological Survey Institute and the Ministry of Science, Technology, and Research were relocated, and the organization was made public.
  The research institute studies geology, geophysics, volcanology and nuclear research.
  Research outcomes, consulting and support services are provided to outside businesses

Biographical overview

- Ph.D. (1995) from the Geothermal Institute (University of Auckland), Doctor of Science (Geology)
- After engaging in research work at Tohoku University, joined GNS Science in 2004 and is currently Director of Geothermal Science.
- Extensive experience in resource assessment, exploration and development, and geoscience (incl. New Zealand, Indonesia, Japan, Mongolia, Iran).

Photo-1 Dr. Greg Bignall of GNS Science

[Interview]

Q: Please tell us about the organizational structure and the research subjects of the GNS?
Greg: The GNS research institution is under the jurisdiction of New Zealand MBIE (Ministry of Business, Innovation, and Employment). There are more than 390 staff members in total, and over 85% of them work as researchers and technicians. The research division is classified into three categories: natural disaster system, environment/material system and the underground resource system. The Underground Resource system includes the "Geothermal Science Department," "Marine-Earth Sciences Division," "Department of Paleontology and Biology," and the "Petroleum Earth Sciences Division."
The "Wairakei Laboratory," is a research center specializing in geothermal development. There are geologists, geophysicists, geochemists, and engineers working there. Our team depicts geothermal systems by integrating the data gathered using geological, geochemical and geophysical methods and evaluates the geothermal resource quantity, chemistry, temperature and hydration levels of the reservoir. We work to understand geological structures.
In 1991, New Zealand established the Resource Management Act (RMA), which consolidates environmental conservation and nature conservation laws for the purpose of sustainable management of natural and physical resources, based on our land laws. We promote protection of the environment and focus on water and air quality. So, the GNS, as a research institution, supports these RMA policies. Many researches have long-term targets, and some research periods, even at the shortest may be 5 years long. Within these periods it is rare to change the researchers in charge, so we have a lot of continuity within the GNS.

Q: Please tell us about the current state of geothermal development in New Zealand.
Greg: A major feature of New Zealand is that the share of renewable energy in the total power supply is high. Approximately 60% of the total power generation is in hydroelectric power. That is followed by geothermal power generation at about 18%. The proportion of renewable energy, other than hydropower, is about 30%. In Japan, geothermal power generation is only 0.3% of all of the total electrical generation So there is a very big difference between the two countries.

As a result of the implementation of the aforementioned RMA, the rules for development became clear, but then the progress of geothermal development slowed down. However, since the latter half of the 1990s geothermal power generation has increased dramatically. Geothermal exploration is conducted by state-owned enterprises such as GNS and private enterprises, but consent from landowners is required. Because New Zealand's land and resources are owned by the indigenous Maori people, geothermal resource developers need to build a partnership with Maori. For that reason, we are promoting geothermal business in a way for the Māori people to be active and consenting participants. It is important to combine science and spirituality based on Maori traditions.

Q: Please give advice on how to proceed with geothermal development in Oita prefecture based on your varied experiences.

Greg: Geothermal power plants in New Zealand are mainly located in the Taupo region of the North Island, especially the Waikato region. Wairakei, Ohaaki, and Mokai are representative geothermal areas. The Beppu area is geologically similar to these areas. The big difference between New Zealand and Japan is the developmental scale. In Japan, we do a lot of small geothermal resource development, but in New Zealand, it is mainly large-scale development. The Ngatamariki power plant is a large 82MW binary power plant (Fig.-1). The site consists of 7 geothermal wells. There are 3 production and 4 re-injection wells. The re-injection wells ensure that the amount of hot water used for power generation is conserved. If the underground structure and the geothermal reservoir of the Beppu Shimabara, Graben Belt was analyzed on a large scale and very intensively, then the geothermal development in Oita Prefecture could also be greatly advanced.

Also, in New Zealand, the uses of geothermal resources are not only for electricity generation but also for direct heat for the agricultural industry. Utilization of geothermal resources in a variety of ways is very useful for regional development.

Fig.-1 Ngatamariki Geothermal Power Plant (Total reinjection of all fluids)

6. Editor’s Postscript

After the declaration of the World Hot Spring Summit held in Beppu in May 2018, a collection of case examples of hot-spring energy use was compiled. Ms. Kasumi Yasukawa of the National Institute of Advanced Industrial Science and Technology and Mr. Masato Yamada of Fuji Electric Co., Ltd., served as editorial board members and organized the editorial meetings. Together, they edited the collection of case studies.

In Japan, hot spring energy is most frequently used for hot-spring baths, but it is also utilized for power generation, thermal household greenhouse cultivation, onshore aquaculture, and building heating. These varied uses are contributing to regional revitalization. After the Great East Japan Earthquake of 2011, renewable energy attracted attention, especially geothermal power generation as a baseload power source. The country's subsidy for heat utilization post power generation has become increasingly widespread, and the number of heat utilization facilities has increased along with the increase of small-scale binary power generation.

Useful information on cases from overseas was also able to be collected with the cooperation of the New Zealand Embassy and the editorial board members.

In the individual interview section at the end of the case collection, we were able to gain useful information that we had not been aware of, and we were convinced that it will be useful in spreading hot-spring energy use in the future.

Lastly, we would like to thank the people of the Oita Prefectural Commerce and Industry Labor Division New Industry Promotion Office, the members of the editorial board, and many people who cooperated in providing information for this occasion.