4. Overseas Cases

4.1 Heat utilization and geothermal power generation in the world

4.1.1 Heat utilization

Figure 4-1 shows the usage ratio of the world heat utilization as of the end of December 2014. 55% of the direct use of geothermal energy is used for geothermal heat pumping (GHP); 20% is for baths and swimming pools, and 15% is used for heating (half of which is regional heating). The direct use rate per population is high in northern European countries such as Iceland, Sweden, and Norway. The direct use rate per area is the highest in Switzerland. The recent rate of increase is high in Thailand and Egypt. The most common usage is in 70 countries for bathing and pools, 45 countries for GHP, and 31 for greenhouses. The utilization rate is 20.7% for GHP; others are slightly higher, late 20's of overall average while average usage in industry use exceeds 50%. For direct use as a whole, 26.2 TOE/year (TOE: Tons of Oil Equivalent), geothermal power generation is 52.2 TOE/year, and direct use is equivalent to about half of geothermal generation as the annual oil replacement amount.

【References】

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, pg.101-117
https://www.jstage.jst.go.jp/article/grsj/37/3/37_101/_pdf/-char/ja

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

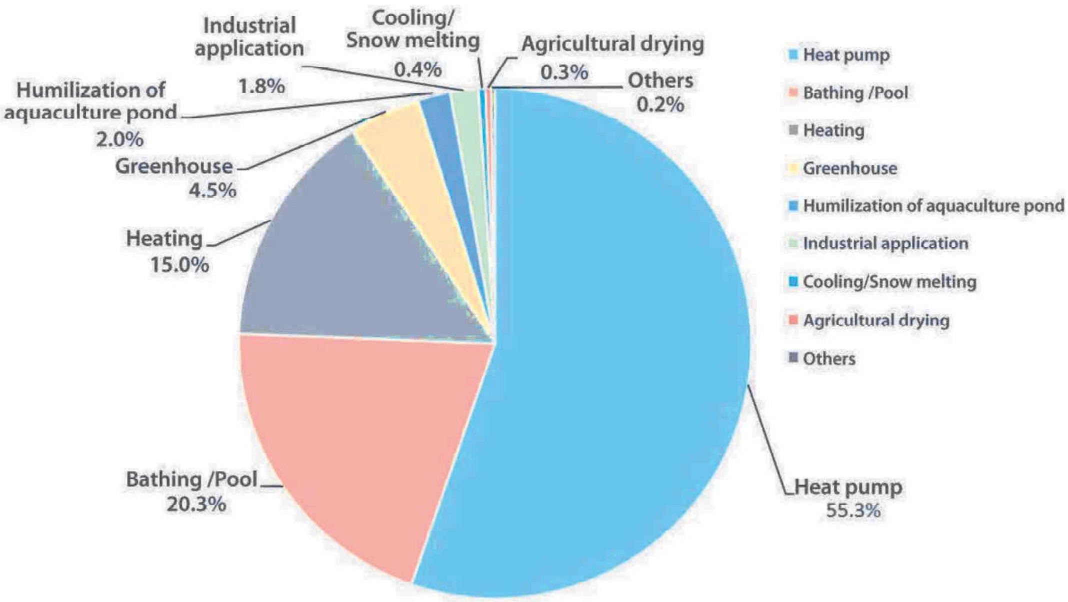


Figure 4-1 Ratio of Heat Utilization by Worldwide Applications
【As of the end of December, 2014】

【 Created based on the world heat utilization data of Lund and Boyd (2015) (Total: 587,786 TJ / yr)】

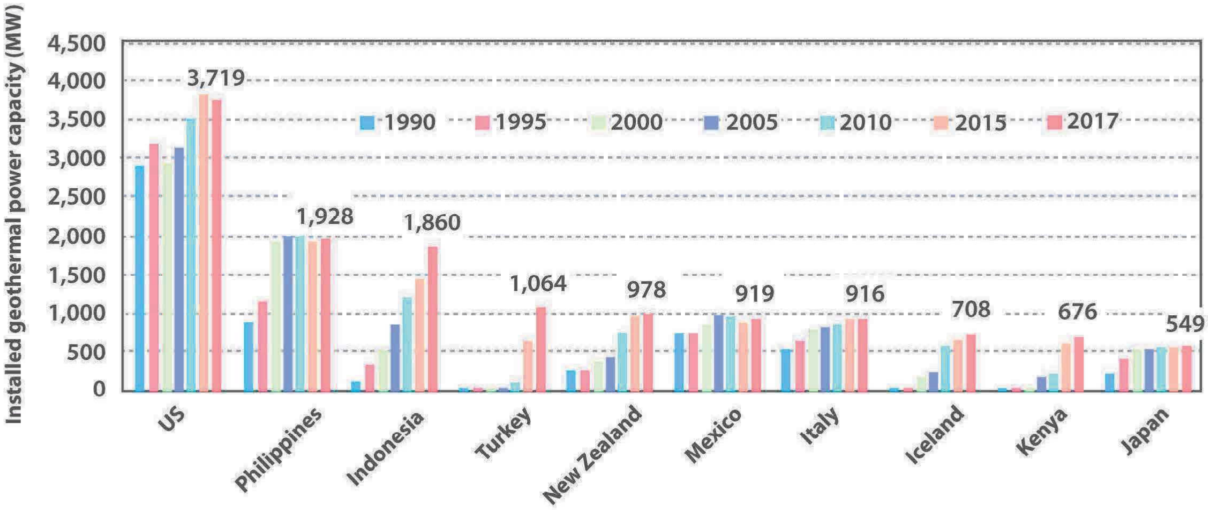
Source: John W. Lund and Tonya L. Boyd (2015): Direct Utilization of Geothermal Energy 2015 Worldwide Review, Proceedings World Geothermal Congress 2015

4.1.2 Geothermal power generation

Changes to installed geothermal power capacity in each country are shown in **Figure 4-2.** The capacity of the global geothermal power generation of 2017 reached 14.3GW. The growth of geothermal development in Indonesia, New Zealand, Iceland, and Kenya has been remarkable in recent years.
Japan's share of world installed geothermal capacity is around 4%, which is the tenth largest in the world after Iceland. The share of geothermal power generation in the total power generation of the whole world is very small (0.3% in 2017), but it plays an important role in some countries. For example, the ratio of geothermal power generation to total power generation capacity is over 40% in Kenya, over 25% in Iceland, and 18% in New Zealand.

【Reference】

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



【Created based on BP(2018)】

Figure 4-2 Changes in Installed Geothermal Power Capacity

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

The following sections show the utilization of geothermal energy, including heat utilization and geothermal power generation, in the order of the largest amount of geothermal resources in major countries.

4.2 USA

4.2.1 Geothermal resources

Geothermal resources in the United States are distributed in western areas where volcanic activities and orogenesis activities abound. The San Andreas fault from California's Imperial Valley to the San Francisco region, the subduction zone off the coast of northern California, Oregon, Washington, and Cascade Volcanism are the sources of much of the geothermal activity in the United States.

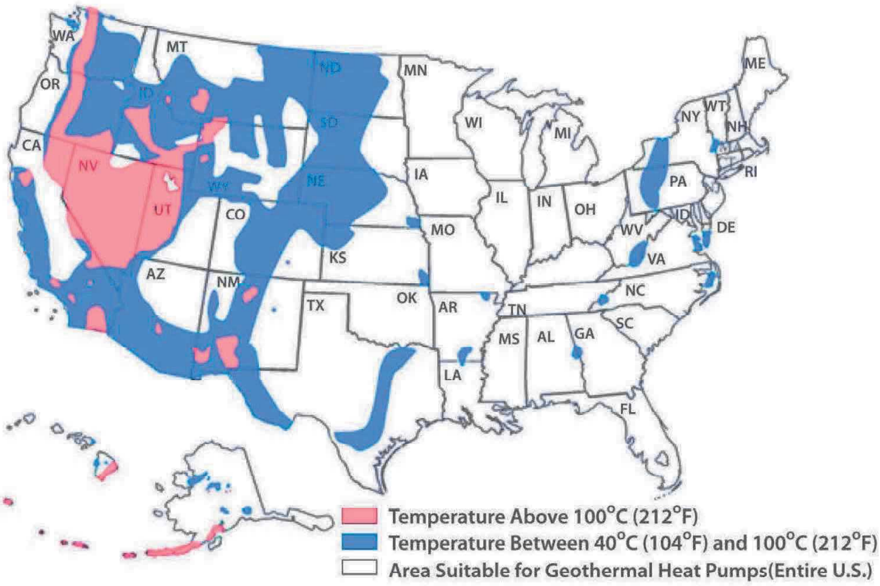


Figure 4-3 Geothermal Resource Map of the United States

Source: Tonya L. Boyd, Alex Sifford and John W. Lund (2015): The United States of America Country Update 2015, Proceedings World Geothermal Congress 2015

4.2.2 Heat utilization

The United States is one of the world's leaders in direct-use applications of geothermal resources. Its direct utilization of geothermal energy includes the heating of pools and spas, greenhouses and aquaculture facilities, space heating and district heating, snow melting, agricultural drying, industrial applications, and ground-source heat pumps. The installed capacity is 17,416 MW_t and the annual energy use is 75,862 TJ or 21,074 GWh. The largest application is ground-source (geothermal) heat pumps (88% of the energy use), and the next largest direct-uses are fish farming and swimming pool heating. The geothermal heat pumps have been operated at an annual growth rate of 8% with 1.4 million units (12 kW size) in operation. Energy conservation, through the use of all geothermal energy, is the fuel oil (74.7 million barrels) equivalent of approximately 11.2 million tons annually, reducing air pollution (about 10 million tons of carbon) and 28 million tons of CO2 (compared with fuel oil.)

【References】

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

Tonya L. Boyd, Alex Sifford and John W. Lund (2015): The United States of America Country Update 2015, Proceedings World Geothermal Congress 2015
https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2015/01009.pdf

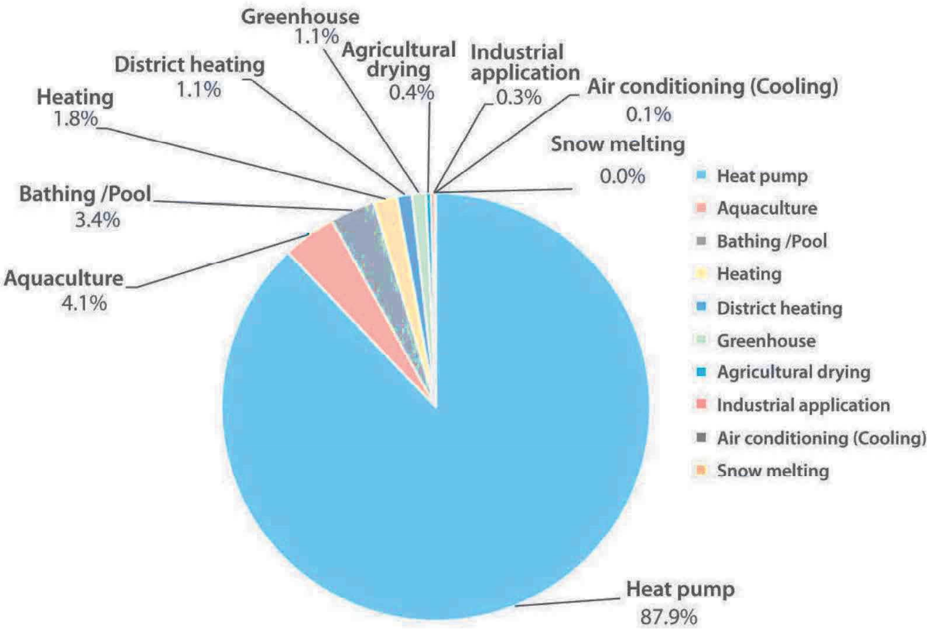


Figure 4-4 Ratio of Heat Utilization by Application in the United States

【As of the end of December, 2009】

【 Create based on Boyd et al. (2015) (Total: 75,862 TJ/yr)】

Source: Tonya L. Boyd, Alex Sifford and John W. Lund (2015): The United States of America Country Update 2015, Proceedings World Geothermal Congress 2015 https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2015/01009.pdf

Table 4-1 shows the breakdown of heat utilization by application, excluding the geothermal heat pumps, as of the end of December 2014. Aquaculture fishery is top in both installed capacity and heat utilization whose utilization rate is as high as 69%. Next comes the bath/pool and the amount of heat utilization is large. Its utilization rate is extremely high at 72%. The installed capacity of heating buildings is the second largest, but due to its low utilization rate, the amount of heat used is about half that of bath/pool.

【Reference】

Tonya L. Boyd, Alex Sifford and John W. Lund (2015): The United States of America Country Update 2015, Proceedings World Geothermal Congress 2015 https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2015/01009.pdf

Table 4-1 Heat Utilization in the USA (Excluding Geothermal Heat Pumps)

Use	Installed capacity (MW_t)	Annual energy use (TJ/yr)	Capacity factor (%)
Aquaculture fishery	141.95	3074.0	69
Bathing/Pool	112.93	2557.5	72
Heating (Buildings)	139.89	1360.6	31
District heating	81.55	839.6	33
Greenhouse	96.91	799.8	26
Agricultural drying	22.41	292.0	41
Industrial process heat	15.43	201.1	41
Cooling	2.31	47.6	50
Snow melting	2.53	20.0	25
Others	0.0	0.0	-
Total	**615.91**	**9,192,2**	**47**

【As of the end of December, 2014】

Source: Tonya L. Boyd, Alex Sifford and John W. Lund (2015): The United States of America Country Update 2015, Proceedings World Geothermal Congress 2015
https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2015/01009.pdf

(1) Examples of aquaculture fishery

The main geothermal zone in the United States is located in the West Coast and Hawaii, but geothermal heat is used directly in the Midwest as well. Various types of cultivation using geothermal energy is carried out at 12 places in Idaho and in the Midwest. The most common example is tilapia, and other examples are catfish, snails, tropical fish, edible frogs, coral, and the like, among which the edible crocodile is famous (Neely, 2007). In **Table 4-1**, crocodiles are also classified as aquaculture fishery (original text: fish farming).

An example of cultivation of edible crocodiles is shown in **Figure 4-5**, and a case of tilapia aquaculture is shown in **Figure 4-6.**

【Reference】

Neely, K. (2007): Geothermal resources in Idaho -A consumer's guide.
https://www.idahogeology.org/.../Geothermal/Geothermal_book.pdf

【Photo provided: Boyd, T.】

Figure 4-5 Aquaculture of Edible Crocodiles Using Geothermal Heat in Idaho

Figure 4-6 Aquaculture of Tilapia near Klamath Falls, Oregon

Source: Geothermal Resources Council Homepage
http://geothermalresourcescouncil.blogspot.com/2017/09/usa-oregon-geothermal.html

(2) Examples of agricultural drying

Figure 4-7 shows examples of direct utilization of geothermal energy. Onions and garlic are dried utilizing geothermal energy in Nevada. 4.5 - 6.8 tons of onions per hour are dried with hot water at 99°C, reducing moisture from 85% to 5%.

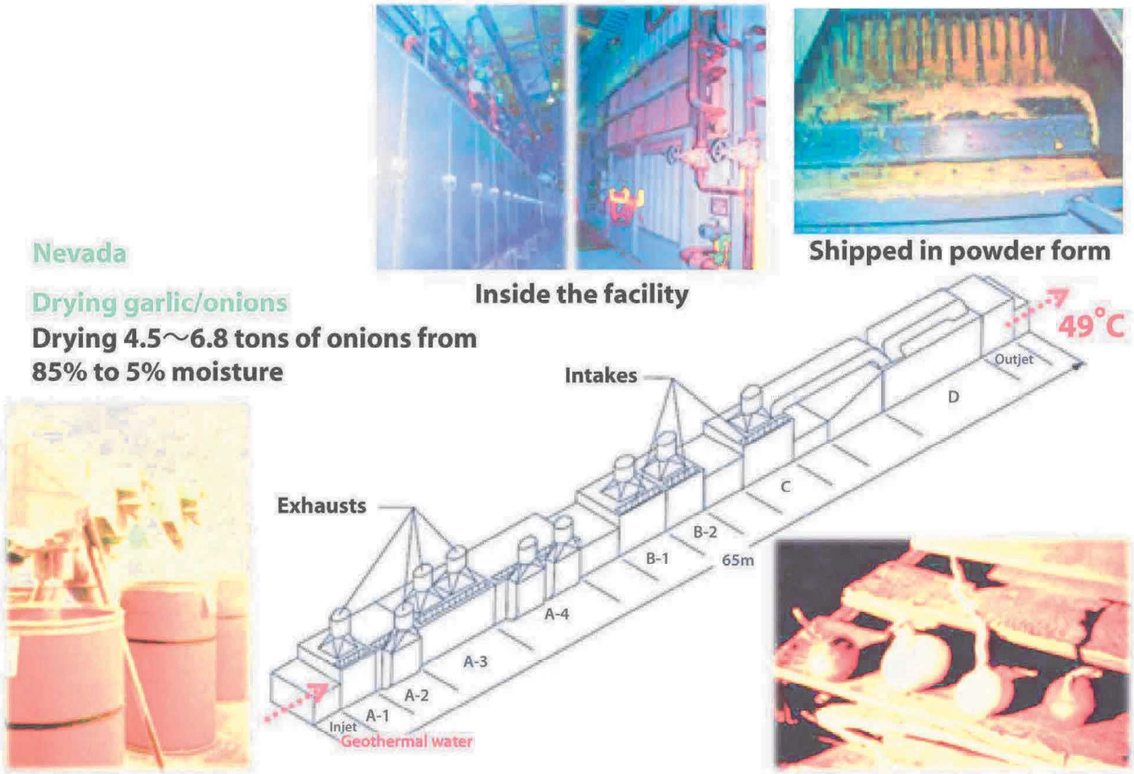


Figure 4-7 Example of Heat Utilization in the United States (Crop Drying)

【Kasumi Yasukawa (2018) International ONSEN summit materials】

(3) Examples of other uses

Although quantitatively small, there are some interesting cases of industrial utilization of geothermal in the United States, such as heating for heap leaching in which metal is eluted from ore and heating for catalytic reaction to produce sulfur from hydrogen sulfide (Bakane, 2013).

【Reference】

Bakane, P. (2013): Uses and advantages of geothermal resources in mining. GHC BULLETIN, 31 (4), 30-33. https://oregontechsfstatic.azureedge.net/sitefinity-production/docs/default-source/geoheat-center-documents/quarterly-bulletin/vol-31/art7.pdf?sfvrsn=6d18d60_4

4.2.3 Geothermal power generation

Regarding the capacity of geothermal power generation facilities as of 2017, the USA is the world's No. 1 (3,719 MW, see **Table 2-3**). Major geothermal electric power plants are located in California, Nevada, Utah, and Hawaii with recent installation in Alaska, Idaho, New Mexico and Oregon. The two largest concentrations of plants are at The Geysers in northern California and the Imperial Valley in southern California. The lowest temperature installed plant is at Chena Hot Springs in Alaska, where binary cycle plants use 74°C geothermal fluids to run three units for a total of 730 kW (gross). The location of major geothermal power plants in the US geothermal resources is shown in **Figure 4-8**.

Figure 4-8 Major Geothermal Power Plants Distributed in the Western United States

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/

As an example of a geothermal power plant, the power plant in the Geysers area is shown in **Figure 4-9.** Located near the San Andreas fault, it is the world's largest dry steam geothermal field with an area of about 80 square kilometers. Geothermal energy comes from plutonic rocks related to the activities of the Clear Lake Volcanics.

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/

Figure 4-9 Example of Geothermal Power Plants in the Geysers Area (Calpine Unit)

4.3 Indonesia

Geothermal resources in the country are associated with volcanoes in Sumatra, Java, Bali, and the islands in the eastern part of Indonesia.

4.3.1 Heat utilization

Geothermal resources have been used directly as hot springs and pools for hundreds of years in Indonesia. Prior to the 20th century, geothermal fluid (geothermal) was used only for bathing, washing, and cooking, but the use of geothermal fluids in recent years is very diverse. For example, the Indonesian Technology Evaluation and Application Agency (BPPT: Badan Pengkajian dan Penerapan Teknologi) is conducting research on utilizing geothermal energy in the agricultural field, especially on the use of sterilization of the growth medium used for mushroom cultivation.

Geothermal uses in agriculture are increasing. Examples of this usage are copra drying at Lahendong, Mataloko, Wai Ratai Lampung; cultivation of mushrooms at Pengalengan; drying and low-temperature sterilization of tea at Pengalengan; and direct use of geothermal energy for growing large catfish at Lampung.

In Lampung County, traditional freshwater large-catfish farming is being carried out by mixing natural geothermal water (outflow water) and fresh river water. This mixture of geothermal fluid and freshwater increases fish growth rates.

Figure 4-10 shows an example of mushroom cultivation using the bactericidal action of geothermal carried out in Camomoan, Indonesia.

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

Figure 4-10 Example of Mushroom Cultivation Using the Bactericidal Geothermal Action (Kamojang, Indonesia)

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

4.3.2 Geothermal power generation

The installed electrical capacity as of 2017 is 1,860 MW, ranked as world No 3 (**Table 2-3**). Indonesian geothermal resources are estimated at 30,000 MW. Operation of the first geothermal power plant began in 1984. Since then, geothermal power plants have been constructed in Gunung Salak (377 MW), Darajat (260 MW), and Kamojang (200 MW). The government has set a goal of 7,100 MW for geothermal power plant construction by 2025, and development is expected to continue to accelerate in the future. Japanese companies are participating in geothermal development in Indonesia, and Kyushu Electric Power Co., Ltd., and ITOCHU Corporation are taking part in the construction of power plants with a total output of 330 MW in Sarulla, North Sumatra (Kaieda, 2018).

The installed capacity of power generation facilities in each region of Indonesia is shown in **Table 4-2.**

【Reference】

Hideshi Kaieda (2018): Trend of geothermal power generation overseas, geology and survey, No. 2018 2, pp. 41- 46
https://www.zenchiren.or.jp/geocenter/geo-se/pdf/jgca152.pdf

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

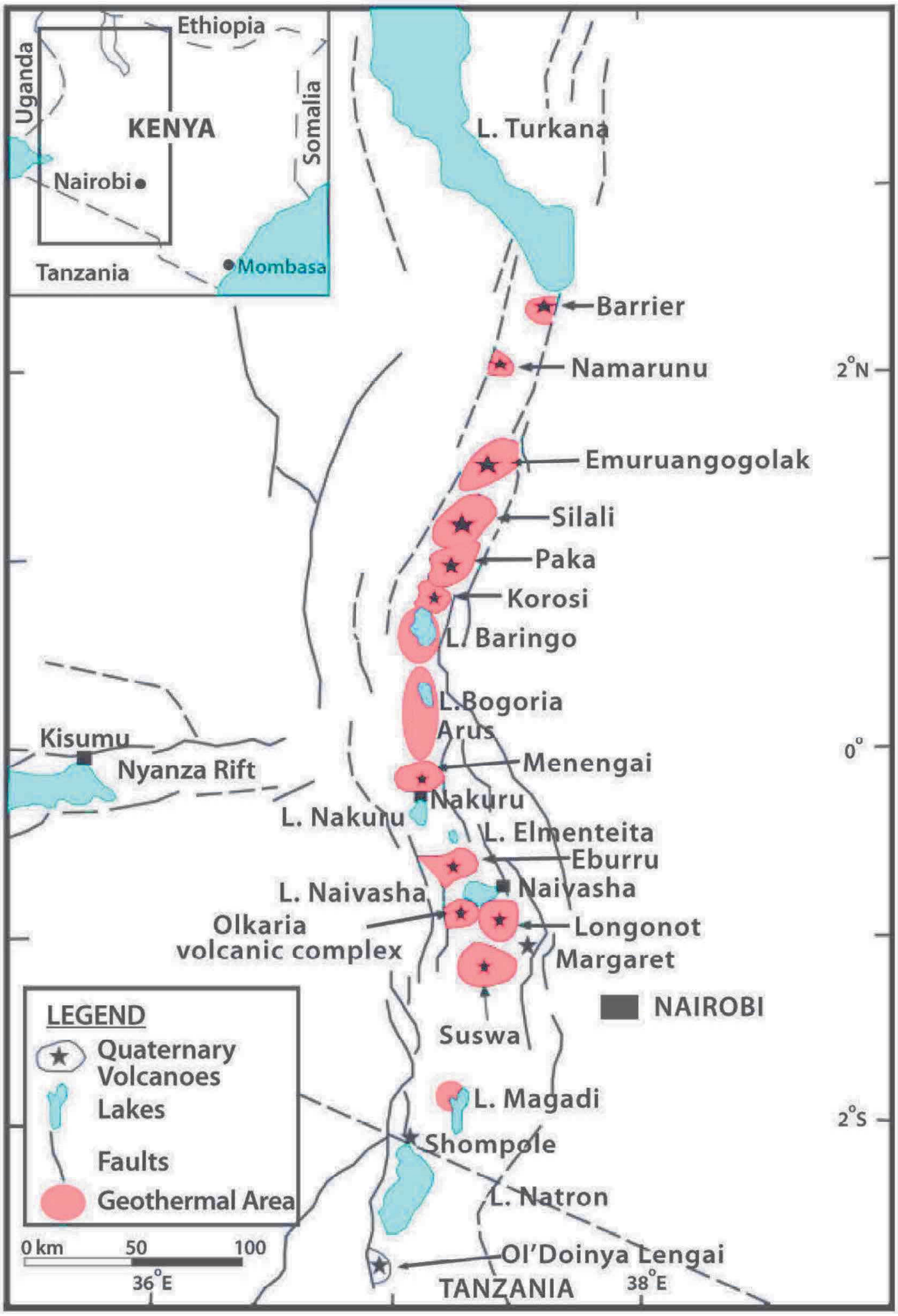


Figure 4-11 Distribution of volcanoes and geothermal resources in Kenya

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

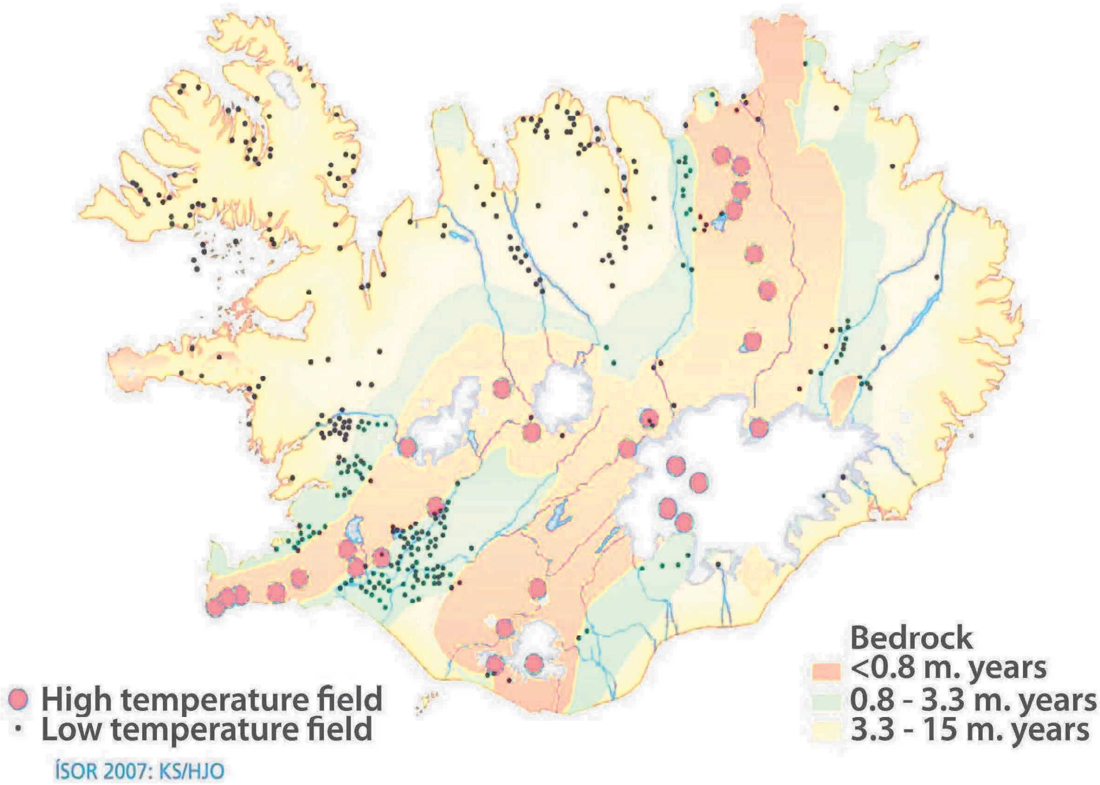


Figure 4-14 Volcanic Zones and Geothermal Areas in Iceland

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.

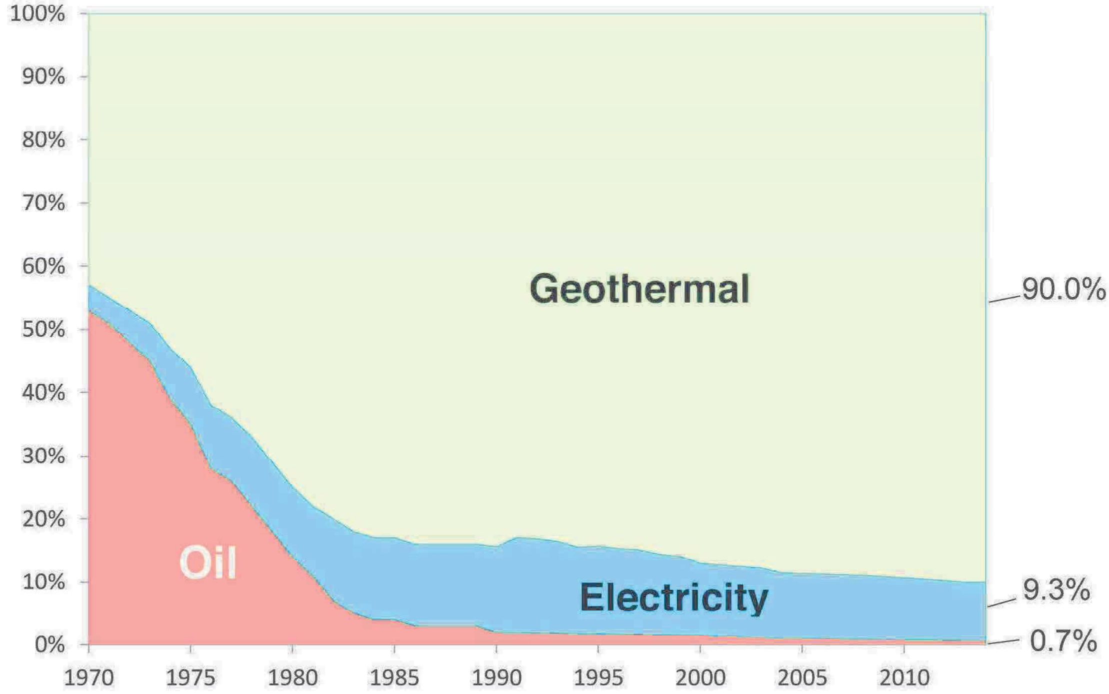


Figure 4-15: Energy Sources Used for Space Heating in Iceland

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

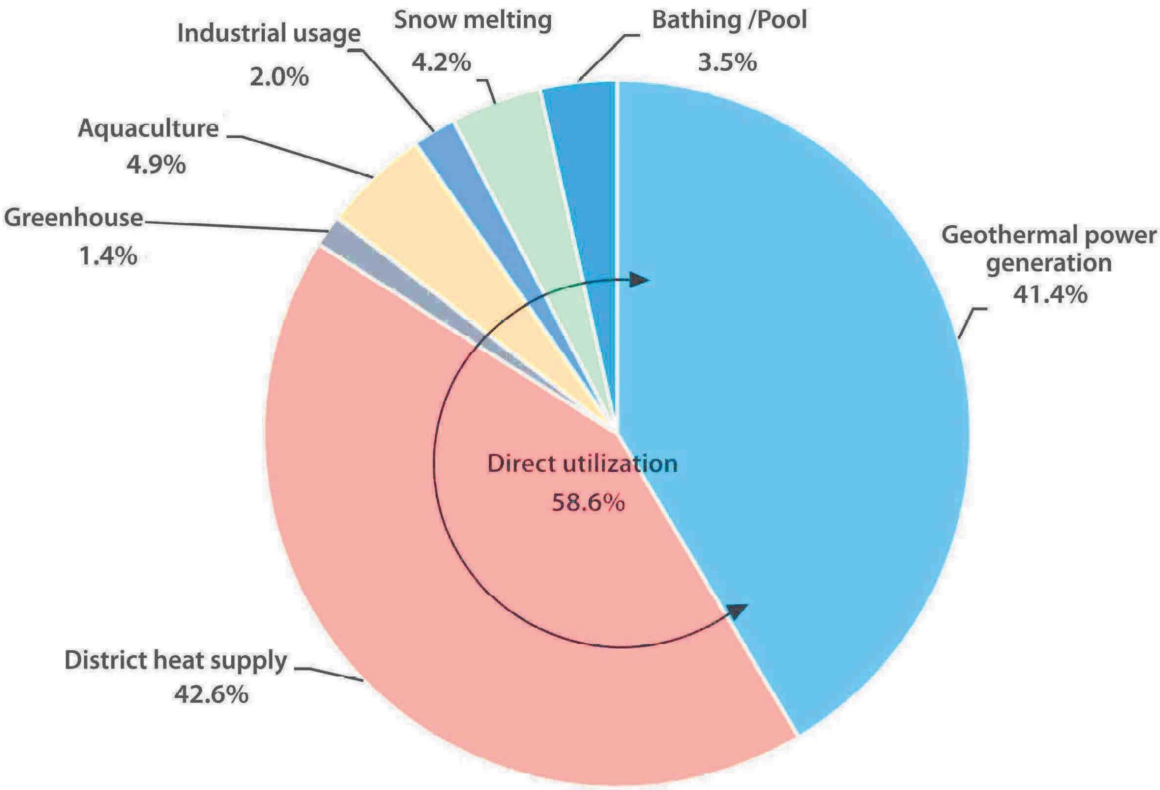


Figure 4-16 Ratio of Heat Utilization by Application in Iceland
【As of the end of December 2014; created based on Árni Ragnarsson (2015)】

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.

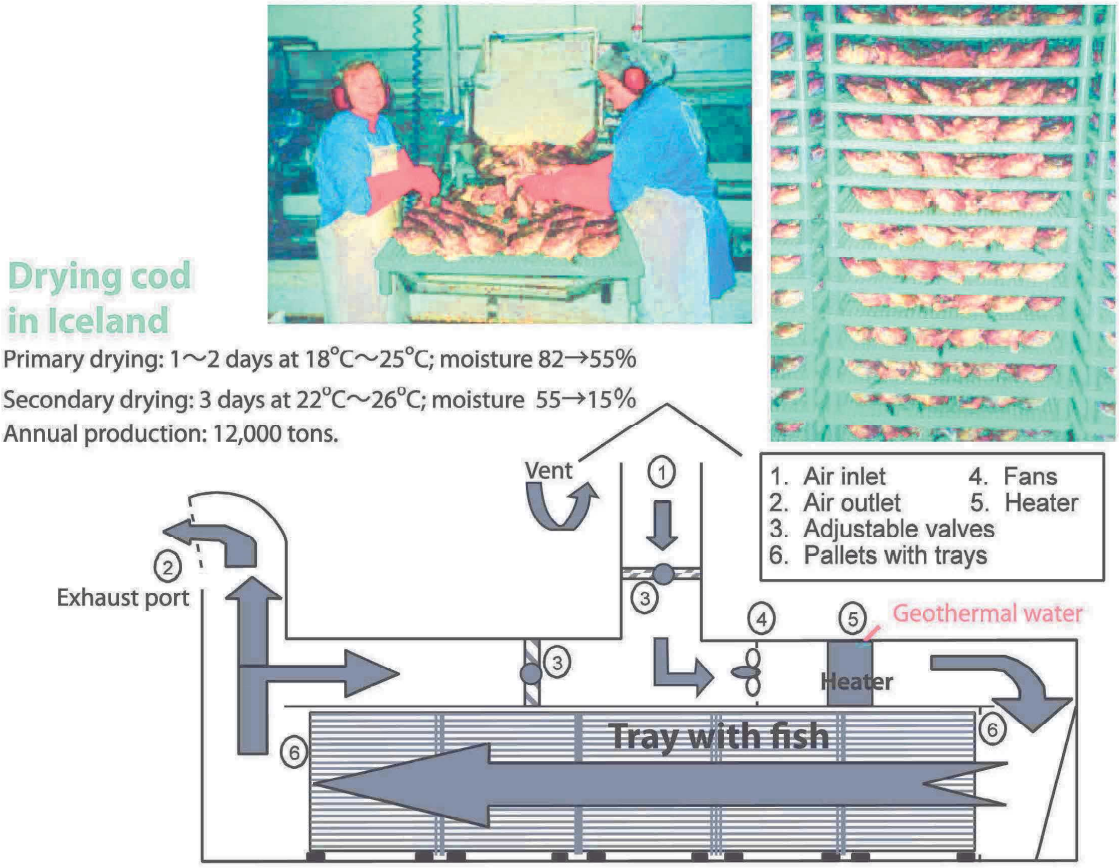


Figure 4-17 Example of Geothermal Utilization in Iceland (Drying Fish)

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

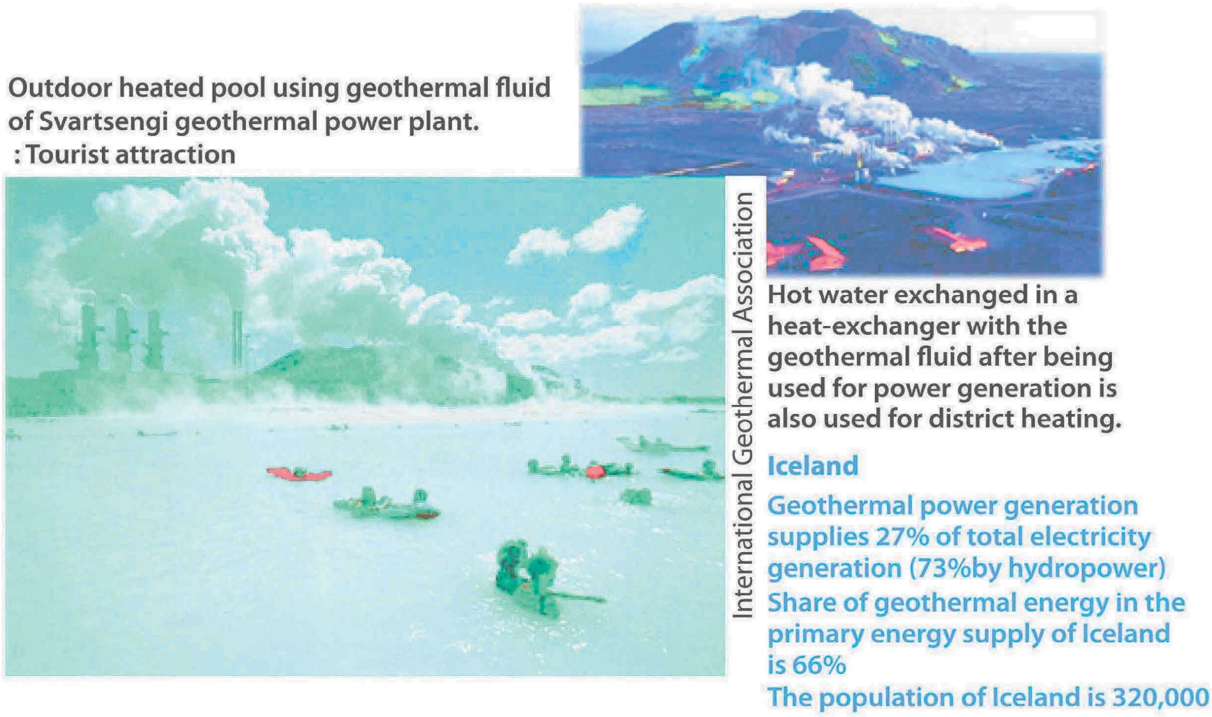


Figure 4-18 “The Blue Lagoon" and the Svartsengi Geothermal Power Plant in Iceland

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 (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

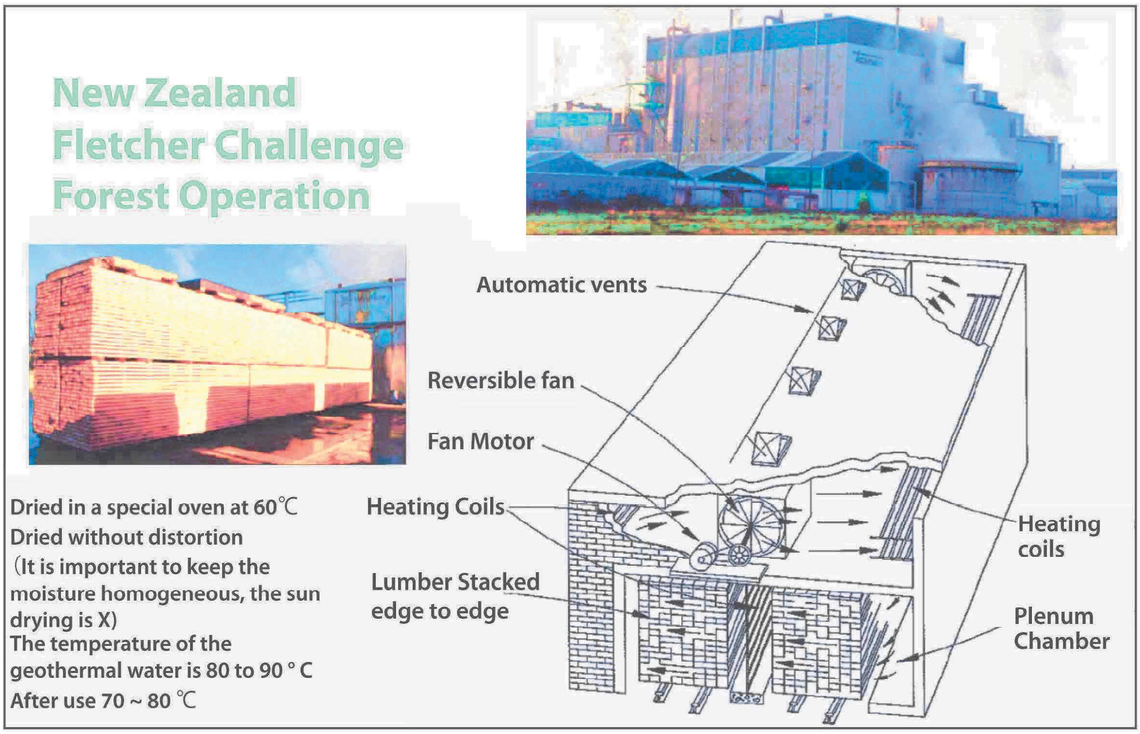


Figure 4-20: Example of Heat Utilization in New Zealand (Drying Wood)

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

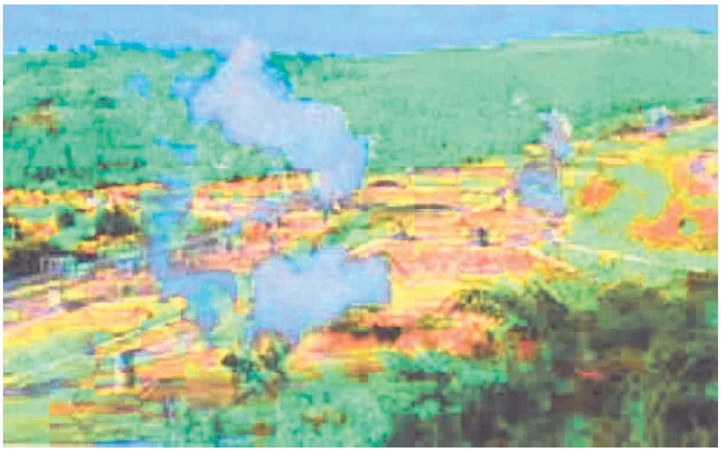


Figure 4-22 Wairakei Geothermal Power plant

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.**

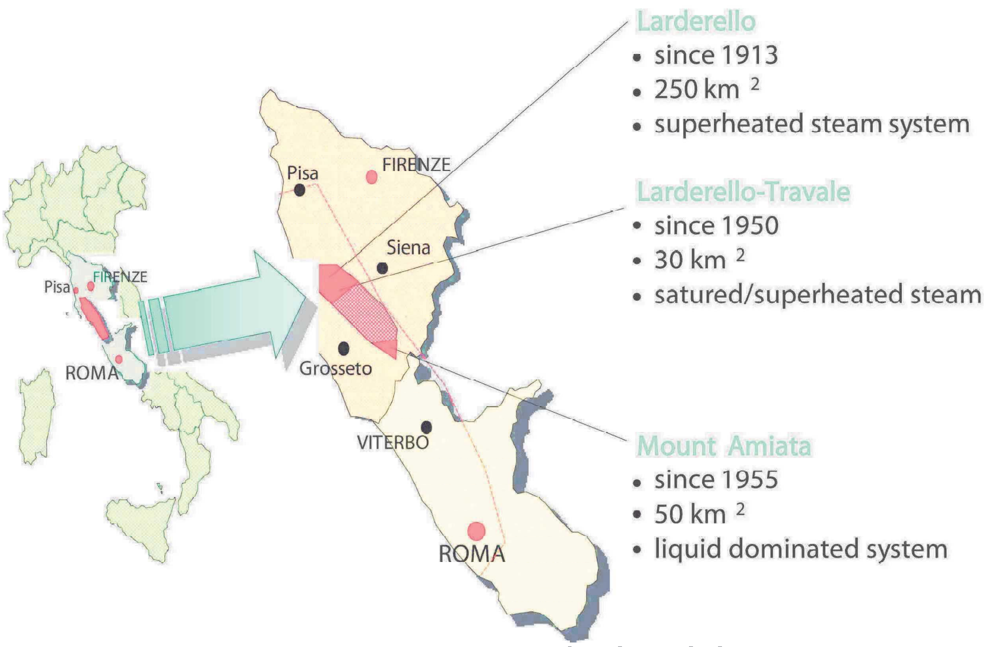


Figure 4-23 Main Geothermal Fields in Italy

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