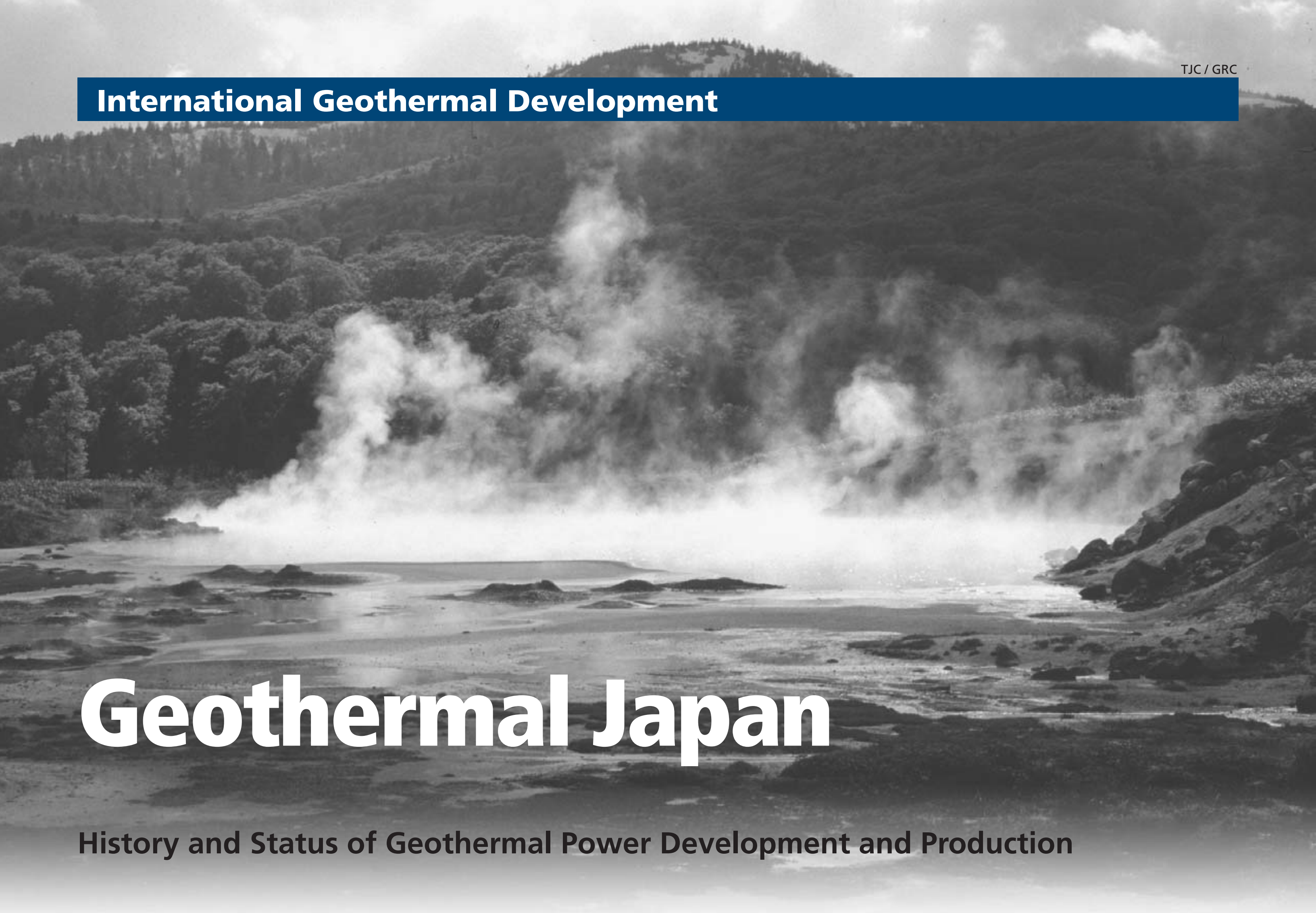

TJC / GRC

Geothermal Japan

History and Status of Geothermal Power Development and Production

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Japan is one of the world's most tectonically active countries, with nearly 200 volcanoes and the blessing of tremendous geothermal energy resources. In 2003, 20 geothermal power plants were in operation at 18 locations nationwide (Fig. 1). Most are located in the country's Tohoku and Kyushu districts. Total net output from all geothermal power plants is 535.25 megawatts (MW), making Japan the sixth largest producer of geothermal electricity in the world.

History of Geothermal Power Development in Japan

The first experimental geothermal power generation in Japan took place in 1925 at Beppu, Oita Prefecture, in southern Japan. Though interrupted by World War II, geothermal research and development (R&D) projects proceeded after 1947. The Geological Survey of Japan started surveys and research to select geothermal energy development areas. Power production from Matsukawa—the country's first full-scale geothermal power plant—commenced in 1966. This was the beginning of the era of geothermal power development in Japan. Ensuing geothermal installations were developed in three distinct generations:

First Generation (mid-1960s to mid-1970s). During these years, there were many unknowns in geothermal exploration, resource assessment, power facility design and maintenance. Thus, Japan's first geothermal power stations were also full-scale demonstrations. Following the installation of the Matsukawa power plant in 1966, these early geothermal facilities included Otake, Onuma and Onikobe. The electrical output of each plant was added gradually as operating and other conditions were better understood.

Second Generation (mid-1970s to mid-1980s). In this decade, high-efficiency geothermal power stations in the 50-MW class were built based on the experience of the preceding generation. They included the Hatchobaru, Kakkonda (No.1 Unit), and Mori. The world oil crises of this era intensified the demand for alternative energy as technological progress from exploration to operations accelerated geothermal development. The Nationwide Geothermal Resources Exploration

Japan's reverence for nature has resulted in setting aside large areas as national parks. Many are rich in geothermal manifestations, such as the Goshogake Hot Springs at Mount Hachimantai (above). Japan's most promising geothermal fields for development are located near its national parks and/or hot springs used for bathing and recreation. To develp a new facility for geothermal energy utilization, careful steps must be taken to preserve the scenic beauty of these areas.

Project started during this decade (NEDO - see below).

Third Generation (mid-1980s to present). During the past 20 years, even small geothermal power facilities became economical thanks to improved exploration, successful drilling efforts with sophisticated technologies, and accurate resource evaluation. Thus, the geothermal power units installed during this period were smaller (20 to 30 MW) compared to their predecessors. Refined design and improved operations and maintenance (O&M) were additional factors of success as the Yamagawa, Kakkonda (No. 2 Unit), and Ogiri geothermal power plants commenced commercial operations. In 1996—thirty years since the inauguration of the Matsukawa facility—electrical output from Japan's geothermal power plants exceeded 500 MW.

Japan's Most Recent Geothermal Developments

Yamagawa Power Station (Kyushu Electric Power Co., Inc. / Japex Geothermal Kyushu Co., Ltd.). Commenced operations in March 1995. Output: 30 MW. While most geothermal power stations in Japan reside in mountainous volcanic regions at approximately 500 m to 1,000 m above sea level, the Yamagawa facility is situated near the coast on flat land. Because the reservoir temperature is high, so is the facility's turbine inlet pressure (10 kg/cm^2).

Sumikawa Geothermal Power Station (Tohoku Electric Power Co., Inc. / Mitsubishi Materials Corp.). Commenced operations in March 1995. Output: 50 MW. The first stage nozzle of the steam turbine is equipped as a cooling device to prevent turbine scale. The system was designed for easy O&M. Sumikawa is very cold area, with snow accumulating to more than 4 m during the winter, snowmobiles are essential to the power plant operators.

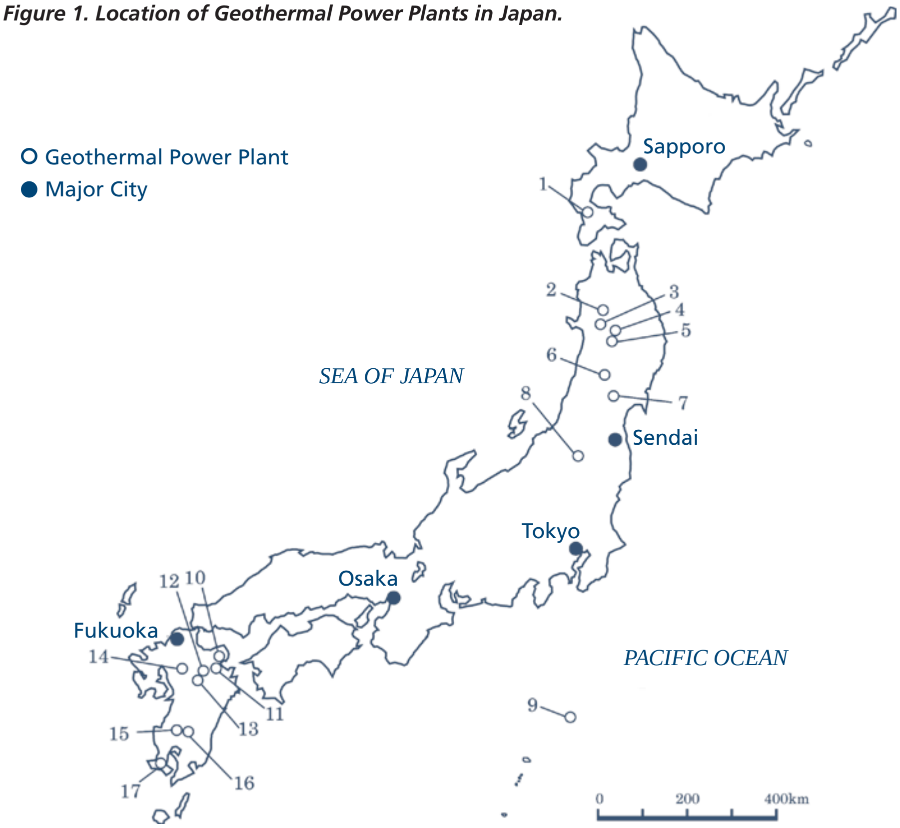
Yanaizu-Nishiyama Geothermal Power Station (Tohoku Electric Power Co., Inc. / Okuaizu Geothermal Co., Ltd.). Commenced operations in May 1995. Output: 65 MW. This power station is the largest geothermal unit in Japan. The municipal government built greenhouses near the complex, using warm water from the power plant condenser to demonstrate cascaded use of geothermal energy.

Kakkonda Geothermal Power Station No. 2 Unit (Tohoku Electric Power Co., Inc. / Tohoku Hydropower & Geothermal Energy Co., Inc.). Commenced operations in March 1996. Output: 30 MW. The unit utilizes a geothermal reservoir deeper than the reservoir tapped by the Kakkonda No.1 Unit. All control valves are motor-driven like those at Sumikawa and Yanaizu-Nishiyama, so no air compressor is necessary. This system also prevents freezing of control air tubing in cold weather. The cooling tower is a concentrated type, to help diffuse the exhaust plume. It can also operate in dry mode to prevent icing of surrounding trees during the winter.

Ogiri Power Station (Kyushu Electric Power Co., Inc. / Nittetsu Kagoshima Geothermal Co., Ltd.). Commenced operations in March 1996. Output: 30 MW. To reduce equipment costs, the unit has a module turbine and a cooling tower design common to Kyushu Electric Power Co.'s other geothermal power stations (Otake, Hatchobaru and Yamagawa). The Ogiri geothermal power plant was built within a national park.

Takigami Power Station (Kyushu Electric Power Co., Inc. / Idemitsu Oita Geothermal Co., Ltd.). Commenced operations in November 1996. Output: 25 MW. This geothermal power plant employs a module turbine like the one at Ogiri. The facility is located in the Kuju-

Figure 1. Location of Geothermal Power Plants in Japan.



1) Mori
2) Sumikawa
3) Onuma
4) Matsukawa
5) Kakkonda I, II
6) Uenotai
7) Onikobe
8) Yanaizu-Nishiyama
9) Hachijojima
10) Suginoi Hotel
11) Takigami
12) Otake
13) Hatchobaru I, II
14) Takenoyu
15) Ogiri
16) Kirishima Kokusa
17) Yamagawa

Table 1. Japanese geothermal power plant operations (March 31, 2002).

Power Plant	Operator	Authorized Output (MW)	Annual Energy Production (MWh)	Auxiliary Power Ratio (%)	Start of Operation
Mori	Donan Geothermal Energy Co.,Ltd. and Hokkaido Electric Power Co., Inc.	50.0	184,794	10.5	11/26/82
Sumikawa	Mitsubishi Materials Corp. and Tohoku Electric Power Co., Inc.	50.0	353,498	4.9	3/2/95
Onuma	Mitsubishi Materials Corp.	9.5	59,378	10.2	6/17/74
Matsukawa	Tohoku Hydropower & Geothermal Energy Co., Inc.	23.5	171,651	7.4	10/8/66
Kakkonda 1	Tohoku Hydropower & Geothermal Energy Co., Inc. and Tohoku Electric Power Co., Inc.	50.0	230,414	7.3	5/26/78
Kakkonda 2		30.0	242,310	6.0	3/1/96
Uenotai	Akita Geothermal Energy Co., Ltd. and Tohoku Electric Power Co., Inc.	28.8	205,679	4.8	3/4/94
Onikobe	Electric Power Development Co.	12.5	80,643	8.7	3/19/75
Yanauzu-Nishiyama	Okuaizu Geothermal Co., Ltd. and Tohoku Electric Power Co., Inc.	65.0	399,661	14.1	5/25/95
Hachijojima	Tokyo Electric Power Co., Inc.	3.3	14,964	14.8	3/25/99
Suginoi	Suginoi Hotel	3.0	9,383	28.0	3/6/81
Takigami	Idemitsu Oita Geothermal Co., Ltd. and Kyushu Electric Power Co., Inc.	25.0	215,165	6.5	11/1/96
Otake	Kyushu Electric Power Co., Inc.	12.5	93,234	10.3	8/12/67
Hatchobaru 1		55.0	333,697	8.2	6/24/77
Hatchobaru 2		55.0	450,987	7.4	6/22/90
Takenoyu	Hirose Trading Co., Inc.	0.05			10/19/91
Ogiri	Nitetsu Kagoshima Geothermal Co.,Ltd. and Kyushu Electric Power Co., Inc.	30.0	262,369	5.8	3/1/96
Kirishima Kokusai Hotel	Daiwado Kanko Co.,Ltd.	0.1	611	0.3	2/23/84
Yamagawa	Japex Geothermal Kyushu Co., Ltd. and Kyushu Electric Power Co., Inc.	30.0	153,504	7.5	3/1/95
Kuju	Kujyu Kanko Hotel	2.0	5,368	33.0	April 1998
Total		535.25	3,467,310		

1) Annual Energy Production is for one year, from April 1 2001 to March 31,2003.
2) Data does not include the 2-MW Hatchobaru binary cycle power plant, which commenced operations in February 2004.

Aso area, one of the most prominent geothermal zones in Japan.

Hachijojima Geothermal Power Station (Tokyo Electric Power Co., Inc. / Tokyo Electric Power Co., Inc.). Commenced operations in March 1999. Output: 3.3 MW. This is Japan's first geothermal power plant built on a small island. Like that of Matsukawa, its resource is a vapor-dominant reservoir, which is rare in the country. Geothermal energy from the operation is also effectively used for greenhouse space heating.

Current Geothermal Power Generation Status in Japan

The operational status of Japan's geothermal power plants is summarized in Table 1. Installed total capacity of 296.0 MW in March 1994 rapidly increased in the next few years to Japan's present capacity of 535.25 MW (Fig. 2). This capacity increase was brought about by the startup of the 28.8 MW Uenotai geothermal power plant in 1994, the Yamagawa (30 MW), Sumikawa (50 MW) and Yanaizu-Nishiyama power plants (65 MW) in 1995, and the Ogiri (30 MW), Kakkonda 2 (30 MW) and Takigami (25 MW) power plants in 1996. As mentioned above, the 3.3 MW Hachijojima power plant started operations in March 1999. Total geothermal power capacity in Japan has changed little since that time.

Japan's geothermal power capacity of 535.25 MW is about 0.2 percent of total power capacity in the country. Electricity produced by geothermal energy during Japan's FY 2002 (April 2002 - March 2003) is 3,467 gigawatt-hours (GWh) (Fig. 3), which is about 0.4 percent of total annual electricity production.

Typically high utilization factors are an advantage of geothermal power generation. Japan's highest value—80.7 percent—was reached in FY 1997. Though the factor decreased to near 70 percent in FY 2000 (Fig. 3), it recovered to 73.9 percent by FY 2002. This achievement can be attributed to the hard work of power plant operators based on the knowledge and experience they have gained through the years.

During the past decade, the majority of work at Japan's geothermal power facilities has been focused on efficiency for both resources and the facilities. Work has included turbine scale prevention at Uenotai (1995) and increased steam production with formerly idle wells to increase power output at Uenotai (1997). Modifications to lower rating inlet pressure of the Hatch-obaru No.1 steam turbine proved to be an effective countermeasure for declining wells, improving electrical output and saving the cost of supplemental wells. In addition, a hydrogen sulfide abatement system was installed at Yanaizu-Nishiyama in 1998 to help protect the environment. It was the first such system at a geothermal power plant in Japan.

The recent startup of a new 2-MW unit at the Hatchobaru geothermal power station in February 2004 marked the inauguration of the first binary-cycle geothermal power plant in Japan. Equipment for the project was provided by ORMAT International, Inc. (Sparks, NV).

Geothermal Resources Survey and Technology Development

Geothermal energy is renewable, clean and indigenous, with minimal environment impact. It has prominent advantages with respect to stabilization of energy supply and protection of the environment—both locally and on a global scale. Because Japan is deficient in natural resources like oil and gas, steady development of geothermal energy is of crucial importance. To cope with these problems and promote geothermal energy development, the Japanese government provides various kinds of technical and financial assistance to address issues from resource exploration of resources to construction of power plant facilities.

Since its establishment in 1980, Japan's New Energy and Industrial Technology Development Organization (NEDO) has been conducting a long-term and comprehensive exploration program—Survey for Promotion of Geothermal Development—at promising geothermal areas throughout the country. The main objective of the NEDO surveys is to evaluate the possibility of geothermal power generation.

Various surveys including exploration well drilling were carried out on 56 areas by the end of FY 2004. Under the so-called "C Survey" initiated in 1992, a number of production-size wells were drilled, and short-term production/injection tests were carried out at the Wasabizawa, Akinomiya and Appi areas in the Tohoku District and in the Shiratori, Shiramizugoe and Kirishima-Eboshidake areas on Kyushu Island.

Figure 2. Japanese Geothermal Power - Net Output (MW).

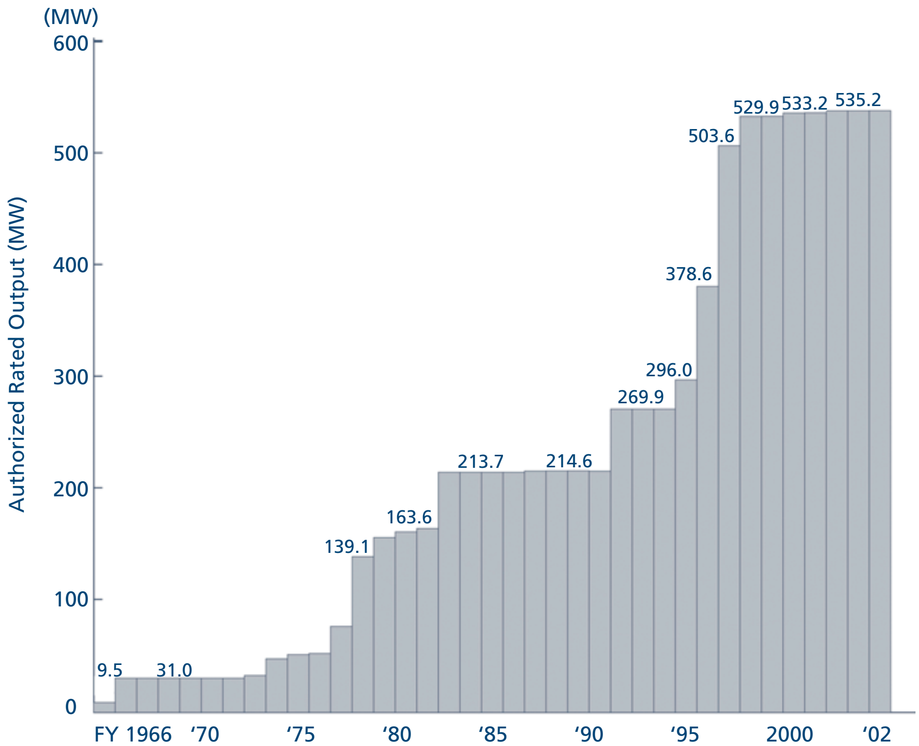


Figure 3. Japanese Geothermal Power - Annual Energy Production (GWh).

NEDO has successfully drilled several excellent geothermal production wells, including N8-WZ-9 (reservoir temperature: 278° C; steam rate: 67 tons/hr.), N9-AY-3 (292° C; 68 tons/hr.), N13-AP-2 (267° C; 45 tons/hr.) and N12-SZ-2 (261° C; 113 tons/hr.) at areas included in the C Survey.

NEDO has also been a central organization for geothermal technology development since 1980. As part of its "New Sunshine Project," NEDO carried out various R&D projects in exploration, drilling, reservoir engineering and power plant technologies during the last two decades.

Promotion of Geothermal Development in Japan

In addition to the efforts described above, the Japanese government provides financial subsidies to the private sector through NEDO. The subsidy fraction for exploratory well drilling is 50 percent. For the drilling of production and/or injection wells and construction of facilities such as pipelines related to power plants, the subsidy is 20 percent. A relatively new subsidy for construction of binary-cycle power plants is 30 percent.

The Japanese government passed Renewable Portfolio Standard legislation in 2003 that mandates utilities purchase electricity generated by renewable energy. At present, the new law is not applicable to conventional flash-type geothermal power plants, but binary-cycle power plants are covered by the scheme.

Most promising geothermal fields in Japan are located near national parks and/or hot springs used for bathing and recreation. To develop a new facility for geothermal energy utilization, careful steps must be taken to preserve the scenic beauty of these areas. In addition, it is important that new geothermal development not affect existing hot spring and fumarole facilities for bathing, which has been an indispensable facet of the Japanese lifestyle for centuries. But with efforts for cooperation with the areas and people concerned, sound development of geothermal energy can be smoothly promoted.

Finally, there are a number of problems inherent to geothermal energy development that must be solved, such as reducing costs of exploration and drilling, and developing more efficient technologies for energy conversion. To promote greater and wider utilization of geothermal energy, industry, research institutes and government must increase their efforts to address these problems.

Japan Geothermal Energy Association

Established in 1960, the Japan Geothermal Association (JGEA) is the oldest geothermal organization in Japan, and since the early 1970s has maintained an excellent relationship with the Geothermal Resources Council. The JGEA's principal activities have included surveys, research, education, publication of journals, reports and statistics, and promotion of geothermal energy development. However, due to declining membership, the JGEA will be dissolved by the end of May 2004, and its Secretariat transferred to the Thermal and Nuclear Power Engineering Society (TEMPES).

Conclusion

With over 500 MW of generation capacity, Japan is the world's sixth largest producer of electricity from geothermal energy resources. In developing those resources, Japan has made important contributions to world geothermal development, including research on geothermal environmental issues, Hot Dry Rock, and "deep-seated geothermal resources."

In addition, Japan has been an important player in providing input to international geothermal technical information exchange, including cooperative programs related to geothermal energy development. With the International Energy Agency, various governmental and private sector organizations and companies, Japan has supported geothermal utilization in the developing countries of Southeast Asia, the Pacific Rim and Latin America. Assistance has ranged from resource surveys to construction of geothermal power stations and renovations of existing geothermal power facilities.

Yet geothermal energy development in Japan has stalled. With limited energy resources, Japan must further develop its abundant geothermal potential. To do so, it will be necessary to gain new governmental support, as well as craft a new, long-range plan for development that emphasizes economics, conservation of nature, and cooperation with local communities and the country's many national parks.

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