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Geothermal Power Generation and Direct Use in Japan

Seiki Kawazoe [1] and Noriyuki Shirakura [2]

[1]Thermal and Nuclear Power Engineering Society, 23-11,Toranomon 1-chome, Minato-ku , Tokyo 105-0001, Japan

[2]New Energy Foundation , Shuwa Kioi-cho Park Building , 3-6, Kioi-Cho, Chiyoda-Ku, Tokyo 102-8555, Japan

[1] kawazoe@tenpes.or.jp, [2] shirakura@nef.or.jp

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ABSTRACT

This report describes the update data of geothermal power generation and direct use in Japan. 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, twenty geothermal power plants were in operation at 18 locations nationwide. Most are located in the Tohoku and Kyushu districts. Total net output from all geothermal power plants reached 535.25 MWe in FY 2000, making Japan the sixth largest producer of geothermal electricity worldwide.

The total installed geothermal power capacity is 0.2% of total power generation facilities in Japan in March 2003. The electricity produced by geothermal energy was 3,467.3 GWh in FY 2002 (April 2002 - March 2003), which was 0.3% of the annual electricity produced during the corresponding period in Japan.

In these years, there haven't been large developments of geothermal power plants in Japan. However, a 2MWe power unit was established at the Hatchobaru geothermal power station in February 2004.

The installed capacity of direct use facilities is approximately 413 MWt and the annual energy use is approximately 5,161 TJ (in FY 2002). The average utilization factor of the facilitates calculated from these figures is about 40%. Compared to the report at the WGC2000, the capacity of direct use facilities has increased mainly in snow melting facilities, but the annual energy utilization has not changed significantly.

1. INTRODUCTION

1.1 Power Genaration

The installed capacity of geothermal power generation is 535.25 MWe with the generated electricity of 3,467.3 GWh in FY 2002 in Japan. It is only a little portion among the electricity sources as shown in Table 3. Table 2 and Figure 1 show geothermal power stations in operation as of March 31, 2003. The number of geothermal wells drilled from 2000 to 2003 are shown in Table 1.

The Japanese government started the deregulation of power generation in the electricity market in March 2000 to reduce medium and long-term electricity development costs, as a part of the structural reform of the national economy. In this situation, electric power companies have changed their policies on the investment for developments of new power plants.

Table 1. Geothermal wells drilled for power generation from April 1, 2000 to December 31, 2003 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled		Total Depth (km)
		Electric Power	Other	
Exploration	(all)	12	0	23.4
Production	>150° C	16	0	31.6
	150-100° C	0	0	0
	<100° C	0	0	0
Reinjection	(all)	13	0	19.5
Total		41	0	74.5

On the other hand, power companies now have a responsibility to generate or purchase a designated volume of renewable energy or its equivalent under the renewable portfolio standard (RPS) system promulgated by the national government in April 2003.

1.2 Direct Use

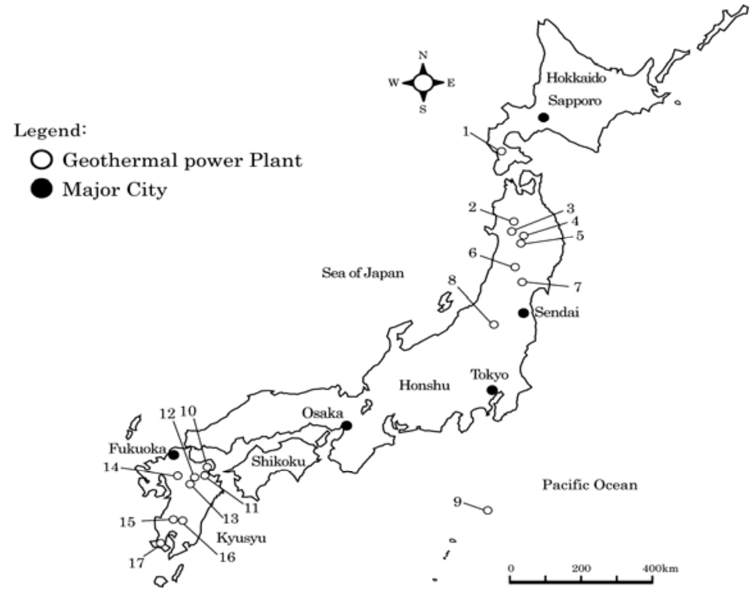
Geothermal energy has been directly used in the form of hot springs since long ago. Currently, there are approximately 27,000 hot springs in the country. Despite the availability of this accessible means of using geothermal energy, the people have a low awareness of the uses of hot springs other than for bathing.

One of the characteristics of the survey conducted this time on the geothermal direct use is the addition of the use of ground heat, including the heat at shallower depths, which is available by using heat pumps.

2. SITUATION OF GEOTHERMAL POWER GENERATION

2.1 Geothermal power plants and development sites

Geothermal areas with high-enthalpy resources related to Quaternary volcanoes are mainly located along the two volcanic fronts: one volcanic front runs from north to south in eastern Japan (from Hokkaido, via eastern half of Honshu Island, to Izu Islands), and the other from Kyushu Island to Southwestern Islands.



□ Mori
□ Sumikawa
□ Onuma
□ Matsukawa
□ Kakkonda I, II
□ Uenotai
□ Onikobe
□ Yanaizu-Nishiyama
□ Hachijojima
□ Suginoi
□ Takigami
□ Otake
□ Hatchobaru I, II
□ Takenoyu
□ Ogiri
□ Kirishima Kokusai Hotel
□ Yamagawa

Fig. 1. Geothermal power stations in Japan

2.2 Situation of geothermal power generation

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

Table 2. Utilization of geothermal energy for electric power generation as of December 31,2003.

1) N = Not operating (temporarily)
2) 1F = Single Flash B = Binary Cycle
2F = Double Flash
3F = Triple Flash
D = Dry Steam
3) Data in 2003, unless otherwise specified.

Locality	Power Plant Name	Year Com-Missioned	No. of Units	Status[1)]	Type of Unit[2)]	Installed Capacity (MWe)	Annual Power Production in 2003[3)] (GWh/yr)	Total Under-constr. or Planned MWe
Hokkaido	Mori	1982.11.26	1		2F	50.0	184,794	
Akita	Onuma	1974.6.17	1		1F	9.5	59,378	
	Uenotai	1994.3.4	1		1F	28.8	205,679	
	Sumikawa	1995.3.2	1		1F	50.0	353,498	
Iwate	Matsukawa	1966.8.8	1		D	23.5	171,651	
	Kakkonda	1978.5.26	2		1F	50.0	230,414	
		1996.3.1			1F	30.0	242,310	
Miyagi	Onikobe	1975.3.19	1		1F	12.5	80,643	
Fukushima	Yanaizu-Nishiyama	1995.5.25	1		1F	65.0	399,661	
Tokyo	Hachijyojima	1999.3.25	1		1F	3.3	14,964	
Oita	Otake	1967.8.12	1		1F	12.5	93,234	
	Hatchobaru	1977.6.24	2		2F	55.0	333,697	
		1990.6.22			2F	55.0	450,987	2.0
	Suginoi	1981.3.6	1		1F	3.0	9,383	
	Takigami	1996.11.1	1		1F	25.0	215,165	
	Kujyukannko Hotel	1998.4.1	1		1F	2.0	5,368	
Kumamoto	Takenoyu	1991.10.19	1	N	D	0.05	0	
	Kirishima Kokusai Hotel	1984.2.23	1		1F	0.1	611	
Kagoshima	Yamagawa	1995.3.1	1		1F	30.0	153,504	
	Ogiri	1996.3.1	1		1F	30.0	262,369	
Total			20			535.25	3,467,310	2.0

Table 3. Present and planned production of Electricity (Installed capacity) as of March 31, 2003

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables		total	
	Capac-ity MWe	Gross prod. GWh/yr	Capac-ity MWe	Gross prod. GWh/yr	Capac-ity MWe	Gross prod. GWh/yr	Capac-ity MWe	Gross prod. GWh/yr	Capac-ity MWe	Gross prod. GWh/yr	Capac-ity MWe	Gross prod. GWh/yr
In operation in March 2003	535.25	3,467	172,889	706,500	46,545	91,800	45,907	295,100	277 □wind power	0.4	266,153.	1,097,200
Under construction in March 2003 (include fund-committed plans)	2		15,110		5,220		3,838		242		24,412	
Total projected use by 2010	537.25		187,999		51,765		49,745		519		290,565	

The total installed power capacity in Japan at the end of FY2003 (March 2004??) was 266,153 MWe, of which thermal power accounted 65.0%, hydroelectric power 17.5%, nuclear power 17.2%, and geothermal power 0.2%, as shown in Table 3. And the total annual

electricity production in FY2003 was 1,093,404 GWh/yr, of which thermal power accounted 64.6%, hydroelectric power 8.4%, nuclear power 27.0%, and geothermal power 0.3%.

Typically a high utilization factor is an advantage of geothermal power generation. Japan's highest value, 80.7 %, was achieved in FY 1997. Though the factor decreased to near 70 % in FY 2000, it recovered to 73.9 % in FY 2002.

During the past decade, the majority of the tasks at Japan's geothermal power facilities has been focused on efficiency increase for both resources and the facilities. These tasks include the following. Turbine scale prevention in 1995 and increased steam production from formerly idle wells to increase power output in 1997 both at Uenotai. Modifications to lower rating inlet pressure of the Hatchobaru No.1 steam turbine proved to be an effective countermeasure for declining wells, improving electrical output and saving the cost ofsupplemental wells. In addition, a hydrogen sulfide abatement system was installed at Yanaizu-Nishiyama in 1998 to prevent an environmental problem. It was the first such system at a geothermal power plant in Japan.

2.3 Estimated Resources

The estimated amount of geothermal resources is 24.6 GWe, which was estimated from a volume of geothermal water laying up to a depth of 3 km and its temperature is more than 200°C (NEDO, 1994).

2.4 Deregulation of Electricity and Geothermal Power

The 10 privately-owned electric power companies in Japan were exclusively responsible for providing local operations from power generation to distribution and supplying their respective service areas with electricity. And, each of 10 electric power companies maintained a monopoly of the retail power supply in its respective region. In March 2000, the power supply was partially liberalized to allow power producer and suppliers (PPS) to sell electricity to extra high-voltage users whose demand is approximately over 2 MWe. Regional power companies were also allowed to begin selling power to large customers outside their designated area in the liberalized market. The minimum demand of each user for the liberalized market will be lowered from 2 MWe to 50 kWe in 2005. In these situations, 10 major electric power companies have changed their policies by shifting to more economical thinking. They have shrunken their investment to a new geothermal power plant, which involves a higher risk and lower return as compared with fossil energies.

2.5 Renewable Portfolio Standard (RPS)

In April 2003, the Special Law Concerning the Use of Renewable Energy by Electric Utilities came into force, establishing a renewable portfolio standard (RPS) system in Japan. The RPS system is intended to accelerate further development of renewable energy sources by requiring the electric power utilities to supply electricity generated from renewable energies with a target amount specified by the government in proportion to their total electricity sales.

The renewable energy sources included in the RPS system are solar, wind, hydroelectric (1,000 kWe or less), biomass and geothermal. For geothermal, however, practically only binary-cycle power plants are applicable to the RPS system.

Under the RPS system, each electric power utility must hold a certain number of Green certificates in proportion to its retail volume at the end of each fiscal year. The Green certificates are issued by the national government to green electricity producers based on kWh injected into the grid. They can be traded among the electric utilities in the Green certificates market.

In July 2001, the government set a target for the introduction of renewable energy sources by FY2010 of about 1.4 times the amount actually used in 1999.

2.6 New geothermal power unit

The recent startup of a new 2-MWe unit at Hatchobaru geothermal power station in February 2004 marked the inauguration of the first binary-cycle geothermal power plant in Japan. Many geothermal engineers in Japan are paying attention the performance of this binary-cycle unit.

3. SITUATION OF DIRECT USE

Direct use of medium- and low-enthalpy geothermal water is dominant in the areas around the high-enthalpy geothermal areas, where hot springs resources are also abundant. On the contrary, use of ground heat in shallow layers is available nationwide.

The capacity of facilities using ground heat is merely 1% of all direct use, and has yet to reach the stage of proper installation.

Many hotels and Japanese-style inns utilize hot spring water. This bathing utilization, however, was excluded from the

survey on direct use, because it would mislead the evaluation of actual situation of effective energy use.

Table 4 shows the latest data on direct use in Japan. However, because there are more or less inaccurate numbers reported in the survey on many direct use facilities, many assumed values are included.

Table 4. Installed thermal power, thermal energy used of geothermal energy as of March 2002, and ground heat uses as of January 2003.

G: Greenhouse Heating	B: Hot water supply and swimming pool
F: Fish breeding	C: Snow melting and air conditioning (cooling)
I: Industrial process heat	P: Ground heat uses, including heat pump
H: Space heating	O: Others

Prefecture	G	F	I	H	B	C	P	O	Total (MWt)	Total (TJ/y)
Hokkaido	12.07	4.40		15.31	10.62	15.78	0.15	0.02	58.35	816.68
Aomori	0.13	1.31	0.44	0.94	3.55	2.57	0.55		9.49	149.79
Iwate	2.51	1.21	0.00	0.12	9.27	5.52	0.62		19.25	117.69
Miyagi	4.57					0.82			5.39	67.55
Akita	1.38			1.99	0.74	3.25	0.03		7.39	111.67
Yamagata	0.03	0.42		0.58	0.68	2.44	0.08		4.23	30.61
Fukushima	0.20			0.98	0.40	0.33	0.03		1.94	32.43
Tochigi		0.00		0.31	2.11		0.03		2.45	72.24
Gunma	0.05			20.77	16.27	3.17			40.26	793.55
Saitama							0.03		0.03	0.41
Chiba							0.00		0.00	0.04
Tokyo	1.74						0.03		1.77	12.98
Kanagawa				3.49	9.93		0.03		13.45	320.26
Niigata			0.12	1.92	0.66	83.72	0.01		86.43	93.32
Toyama				0.10		0.49			0.59	5.78
Ishikawa	0.08			0.03	0.02	1.36			1.49	16.91
Fukui				0.11	0.11		0.95		1.17	4.33
Nagano	0.53			7.54	11.95	12.73	0.03		32.78	504.80
Gifu		8.49	0.10	6.64	3.46	2.00	0.01		20.70	239.18
Shizuoka	0.06				10.33		0.02		10.41	239.60
Aichi							0.00			0.04
Mie							0.02		0.02	0.17
Kyoto							0.07		0.07	0.35
Osaka							0.01		0.01	0.12
Hyogo				0.47			0.18		0.65	4.19
Nara							0.01		0.01	0.12
Wakayama				0.03	0.07				0.10	0.43
Tottori				0.09	4.80				4.89	107.97
Shimane							0.00			0.04
Okayama				0.42	0.16		0.14		0.72	9.17
Hiroshima				0.02	0.18		0.19		0.39	5.44
Yamaguchi							0.25		0.25	3.83
Kagawa							0.34		0.34	0.81
Ehime					0.01				0.01	0.10
Kochi							0.01		0.01	0.09
Fukuoka							0.08		0.08	1.22
Nagasaki					0.12				0.12	0.59
Kumamoto		0.42							0.42	9.24
Oita	11.80		0.44	19.69	18.40		0.01		50.34	988.44
Miyazaki							0.04		0.04	0.22
Kagoshima	7.96	0.66		22.04	2.63	3.99	0.04		37.32	398.66
Total (MWt)	43.11	16.91	1.10	103.59	106.47	138.17	3.99	0.02	413.36	
Total (TJ/y)	428.50	212.34	27.34	1409.98	2583.68	476.49	22.35	0.38		5161.06
Capacity Factor	0.32	0.40	0.79	0.43	0.77	0.11	0.18	0.60		0.40

3.1 Use of geothermal water

The survey in 2002 shows that the capacity of the facilities that utilize geothermal water is 409 MWt, and annual energy use is 5,140 TJ/y. The average rate of utilization factor of the facilities calculated from these figures is about 40 %.

Compared to the report at WGC2000 (Sekioka and Yoshii, 2000), the installed capacity increased by about 51% and the annual energy use increased by about 14%.

Though efforts to expand the scope of survey served as the main factor for the increase, increase in snow-melting facilities is also conspicuous. However, because the utilization factor of snow-melting facilities is low, the annual energy use has not risen to a considerable extent.

The capacity of facilities by type of use is the greatest for snow-melting and air-conditioners (cooling), hot water supply and swimming pool, and space heating in this order.

The quantity of energy utilization by type of use is the greatest for hot water supply and swimming pool, space heating, snow-melting and air-conditioners (cooling) in this order.

3.2 Use of ground heat

The survey in 2003 shows that the capacity of the facilities for ground heat utilization is about 4 MWt, and annual energy use is about 22 TJ/y. The average utilization factor of the all facilities was about 18% and that of only for households was about 48%.

Since facilities for ground heat utilization are difficult to differentiate from their external appearance, information was collected from the construction industry companies.

We estimated the utilization factor of facilities using ground heat based on the type and scale of facility, when we had insufficient data about it.

Ground heat is mostly utilized by directly supplying heated/cooled binary fluid at the ground heat exchanger. Geothermal heat pump was used only in 41 cases, whose total capacity is about 1.7 MWt.

Snow-melting facilities have larger percentage in the installed capacity, while household facilities have larger share in the annual energy utilization..

4. MEASURES FOR SUPPORTING GEOTHERMAL DEVELOPMENT

The potential of geothermal resources for power generation in the country is estimated as approximately 24.6 GWe. However, the installed geothermal power capacity is merely around 535 MWe as mentioned in the previous section. One of the factors hindering the development is a lack of appropriate techniques which is necessary to reduce the uncertainty of underground geothermal structure at the exploration stage. Another factor is that geothermal development takes a long period and requires substantial pre-investment. Therefore, even an ambitious company cannot always start a project. Furthermore, most of the geothermal resources immediately available for power generation have been already developed. Thus a technical break-through to develop unused geothermal resources is crucial.

To promote geothermal energy development, the Japanese government provides various kinds of technical and financial assistance, from resource exploration to construction of power plant facilities.

4.1 Geothermal Resources Survey and Technology Development

NEDO has 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.

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 at the Shiratori, Shiramizugoe and Kirishima-Eboshidake areas on Kyushu Island.

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

Table 5. Total investment in geothermal in (2003) US$.

Period	Research & Development Incl. Surface Explor. &Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Funding Type	
	Million US$	Million US$	Private %	Public %
1990-1994	217.0	460.6	0	100
1995-1999	162.3	412.0	0	100
2000-2003	63.0	183.8	0	100

note JPY is converted to US$1=JPY110

4.2 Promotion of Geothermal Development

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. In case of this subsidy, it is need to pay back all many when its well have produced steam. 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.

5. SUPPORTS BY OTHER ORGANIZATIONS

5.1 National Institute of Advanced Industrial Science and Technology (AIST)

The AIST, part of which were formerly Geological Survey of Japan (GSJ) and National Institute of Resources and Environment (NIRE), is conducting a wide scope of geothermal researches, including regional resource mapping, geochemical and geophysical exploration techniques, reservoir modeling and management techniques, and hot dry rock.

5.2 Geothermal Research Society of Japan (GRSJ)

The GRSJ is an academic association mainly comprising university people and researchers and engineers in geothermal companies. The GRSJ is holding scientific conferences and seminars, and publishing journals consisting of research papers in geothermics and related science and engineering.

5.3 Japan Geothermal Energy Association (JGEA)

The JGEA, established in 1960, is the oldest geothermal organization in Japan. 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.

Table 6. Membership of JGEA and GRSJ

(1) Individual member of JGEA
(2) Corporate member of JGEA
(3) Individual member of GRSJ
(4) Corporate member of GRSJ

Year	Professional Person-Years of Effort			
	(1)	(2)	(3)	(4)
2000	399	97	702	93
2001	389	93	692	97
2002	354	89	670	88
2003	316	84	659	82
2004	279	84	649	78

JGEA: Japan Geothermal Energy Association
GRSJ: Geothemal Research Society of Japan

6. FUTURE DEVELOPMENT AND INSTALLATIONS

6.1 Geothermal power generation

Geothermal energy development in Japan has stalled in the recent deregulation of the electricity market. To develop the geothermal power, it is important to emphasize its economical merit.

As mentioned in Section 2.6 above, the recent startup of a new 2 MWe unit at Hatchobaru is one of the symbolic trends in geothermal development. There are sufficient infrastructure at Hatchobaru, including access roads, setting space, transmission lines, production wells, reinjection wells, and operation and maintenance stuffs. Therefore, it was possible for this unit to be constructed economically. It would also be possible to reduce the production cost per kWh if this unit is operated stably for a long time.

For development of a new plant, it is recommended to target an area neighboring a currently operating geothermal field, where the characteristics of geothermal reservoir is well understood by existing drilling and other survey data. It can reduce the risk in exploration and cost of exploration as compared with a virgin field. This is one way to develop geothermal power plant in Japan.

6.2 Direct Use

Considering that most regions where geothermal water is utilized have a small population, and demand for other than hot springs is low, the use of geothermal water is expected to remain unchanged. However, use of ground heat is looked forward to as a means of resolving environment problems such as CO_2 reduction and energy saving.

Some of the reasons for the delay in launching use of ground heat are; expensive drilling cost, no specialized equipment, insufficient public acceptance activities, etc. However there are certain companies promoting technical development of low noise and highly efficient drilling machines to reduce cost, heat exchange systems in pile foundation, ground heat pumps, etc.

In large cities, heat island phenomenon is becoming an increasingly serious problem, and enthusiastic introduction of the use of ground heat is looked forward as an effective solution to the problem.

7. CONCLUSIONS

The geothermal energy is excellent clean energy with very little CO_2 discharge, a cause of global warming. At COP3 in 1998 in Kyoto, Japan, the participants recognized international coordination such as joint implementations and clean development mechanism as means to reduce CO_2 discharge.

It is very important to develop the geothermal energy as domestic resources for energy security in Japan. Therefore, new management and support system to solve these problems is needed.

To solve these situations, it is essential for geothermal development to reduce exploration risk and initial cost. Therefore, it seems to us that small-scale plants will be constructed near existing power plants, as Hatchobaru, in coming 5 years. Although a small-scale plant can reduce a risk in exploration, it is not effective from a point of the construction cost. To avoid this problem, it is recommended to construct a new plant near existing power plant to reduce the construction cost by using existing infrastructure.

Direct use of geothermal energy described in this report amounts to about 159 000 kl/y when converted to equivalent crude oil. Compared to the quantity of crude oil consumed in Japan, this is a small fraction. Continuing efforts in the use of ground heat are thus indispensable in Japan. Because this highly anticipated ground heat can be used anywhere, the public must recognize it as their own energy and make efforts to utilize it.

In such situation, Japan is expected to apply its advanced technologies in development and utilization of geothermal energy.

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