Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

2010 Country Update for Japan

Hiroki SUGINO [1] and Toshihiro AKENO [2]

[1]Thermal and Nuclear Power Engineering Society, Hokkaishiba Bldg, 31-15,Shiba 2-chome, Minato-ku, Tokyo 105-0014, Japan

[2]New Energy Foundation, 13-2, Higashiikebukuro 3-chome, Toshima-Ku, Tokyo 170-0013, Japan

[1] sugino@tenpes.or.jp , [2] t-akeno@nef.or.jp

Keywords: Japan, geothermal power generation, direct use, geothermal heat pump, update data, current status

ABSTRACT

This report describes the update data of geothermal power generation and direct use in Japan. Japan is one of the most tectonically active countries in the world, with nearly 200 volcanoes and the blessing of tremendous geothermal energy resources. In 2009, twenty geothermal power plants were in operation at 17 locations nationwide. Most are located in the Tohoku and Kyushu districts. Total net output from all geothermal power plants reached 535.26 MWe in 2006.

The total installed geothermal power capacity is 0.2% of total power generation facilities in Japan in March 2009. The electricity produced by geothermal energy was 3,063.5 GWh in FY 2007 (April 2007 - March 2008), which was 0.3% of the annual electricity production during the corresponding period in Japan.

In these years, there haven't been large developments of geothermal power plants in Japan. However, a 2 MWe power unit was established at the Hatchobaru geothermal power station in February 2004, and started its operation in April 2006. And a 220 kW domestic binary geothermal power unit started its operation at the Kirishima Kokusai Hotel in August 2006.

The installed capacity of direct use facilities is approximately 2,086 MWt and the annual energy use is approximately 25,630 TJ in FY 2006 (April 2006 - March 2007). The average utilization factor of the facilitates calculated from these figures is about 39% including bathing. Compared to the report at the WGC2005, the capacity of direct use facilities and the annual energy utilization except for bathing has not changed significantly.

1. INTRODUCTION

1.1 Power Generation

The total installed capacity of geothermal power plants is 535.26 MWe with the generated electricity of 3,063.5 GWh in FY 2007 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, 2008. The numbers of geothermal wells drilled from 2005 to 2008 are showed 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.

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.

Table 1. Geothermal wells drilled for power generation from April 1, 2005 to December 31, 2008 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled		Total Depth (km)
		Electric Power	Other	
Exploration	(all)	20	0	27.0
Production	>150^o C	13	0	20.9
	150-100^o C	0	0	0
	<100^o C	0	0	0
Injection	(all)	14	0	15.6
Total		47	0	63.5

1.2 Direct Use

Geothermal energy has been directly used in the form of hot springs for bathing since long ago. Currently, there are approximately 28,000 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.

Geothermal Energy Development Center of New Energy Foundation (NEF) has been conducted nationwide survey on the geothermal direct use since 1990. One of the characteristics of the survey in recent years is the addition of the use of ground heat, including the heat at shallower depths, which is available by using heat pumps (NEF, 2006).

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.

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 533.20 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.

The total installed power capacity in Japan at the end of FY2008 (March 2009) was 242,509 MWe, of which thermal power accounted 59.4%, hydroelectric power 19.1%, nuclear power 19.8%, and geothermal power 0.2%, as shown in Table 3. And the total annual electricity production in FY2008 was 1,001,700 GWh/yr, of which thermal power accounted 66.2%, hydroelectric power 7.6%, nuclear power 25.6%, 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.

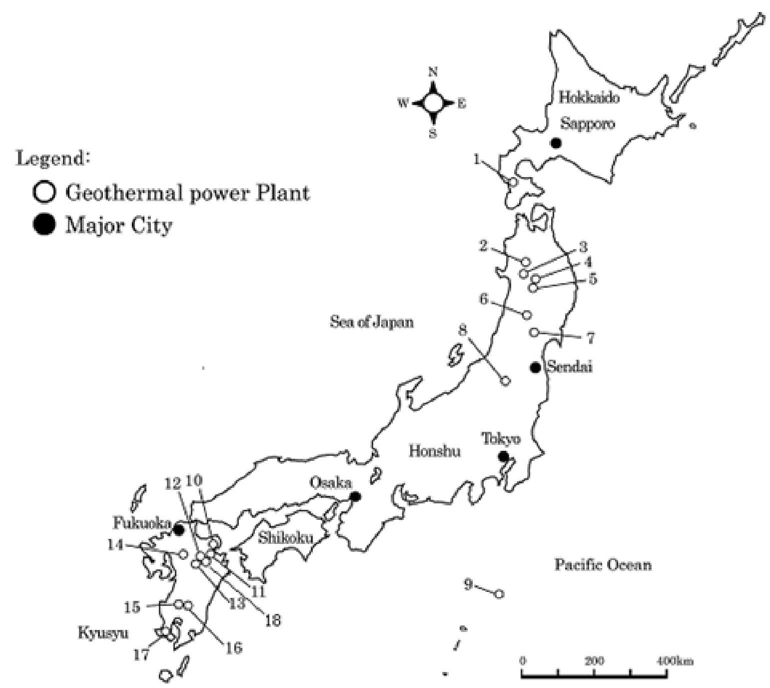
During the past decade, the majority of the tasks at Japan's geothermal power facilities has been focused on efficiency increase for both resources and the facilities. These tasks include the following. Turbine scale prevention in 1995 and increased steam production from formerly idle wells to increase 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 of supplemental 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 potential of hydrothermal resources is 23.5 GWe, which was estimated from a GIS-base volumetric method of hydrothermal resources above the Pre-Tertiary basement units (roughly shallower than 3 km) and at the resource temperature 150°C or higher (Muraoka et al., 2008).

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



1.Mori	7.Onikobe	13.Hatchobaru I, II, Binary
2.Sumikawa	8.Yanaizu-Nishiyama	14.Takenoyu
3.Onuma	9.Hachijojima	15.Ogiri
4.Matsukawa	10.Suginoi	16.Kirishima Kokusai Hotel
5.Kakkonda I, II	11.Takigami	17.Yamagawa
6.Uenotai	12.Otake	18.Kujyukannko Hotel

Fig. 1. Geothermal power stations in Japan

power supply in its respective area. 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 was 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.

Table 2. Utilization of geothermal energy for electric power generation as of March 31, 2008.

1) N = Not operating (temporarily)
2) 1F = Single Flash; D = Dry Steam; 2F = Double Flash; B = Binary Cycle; 3F = Triple Flash
3) Data in 2007, unless otherwise specified.

Locality	Power Plant Name	Year Com-Missioned	No. of Units	Status[1]	Type of Unit[2]	Installed Capacity (MWe)	Running Capacity (MWe)	Annual Power Production in 2007[3] (GWh/yr)	Total Under-constr. or Planned MWe
Hokkaido	Mori	1982.11.26	1		2F	50.0	19.0	114.6	
Akita	Onuma	1974.6.17	1		1F	9.5	7.4	59.9	
	Uenotai	1994.3.4	1		1F	28.8	25.5	170.1	
	Sumikawa	1995.3.2	1		1F	50.0	46.2	337.9	
Iwate	Matsukawa	1966.8.8	1		D	23.5	16.4	124.7	
	Kakkonda	1978.5.26	2		1F	50.0	28.3	200.1	
		1996.3.1			1F	30.0	17.5	122.4	
Miyagi	Onikobe	1975.3.19	1		1F	12.5	12.5	104.0	
Fukushima	Yanaizu-Nishiyama	1995.5.25	1		1F	65.0	49.4	362.8	
Tokyo	Hachijyojima	1999.3.25	1		1F	3.3	2.5	14.2	
Oita	Otake	1967.8.12	1		1F	12.5	11.6	82.7	
	Hatchobaru	1977.6.24	3		2F	55.0	53.2	351.0	
		1990.6.22			2F	55.0	55.0	425.8	
		2006.4.1			B	2.0	2.0	10.7	
	Suginoi	1981.3.6	1		1F	1.9	1.8	11.7	
	Takigami	1996.11.1	1		1F	25.0	24.7	215.8	
	Kujyukannko Hotel	1998.4.1	1		1F	0.99	1.0	8.4	
Kumamoto	Takenoyu	1991.10.19	1	N	D	0.05	0	0	
Kagoshima	Kirishima Kokusai Hotel	2006.8.17	1		B	0.22	0.2	0.7	
	Yamagawa	1995.3.1	1		1F	30.0	18.3	121.7	
	Ogiri	1996.3.1	1		1F	30.0	29.8	224.3	
Total			21			535.26	422.3	3,063.5	0

Table 3. Present and planned production of Electricity (Installed capacity) as of March 31, 2009

	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 2008	535.26	3,000	144,060	663,600	46,380	76,600	47,940	256,300	3,594 (wind + solar power)	7,000	242,509	1,001,700
Under construction in March 2009	0		10,320		4,530		3,670		10		18,530	
Funds committed, but not yet under construction in March 2009	0		11,520		60		16,550		110		28,240	
Total projected use by 2013	535.26		151,000		47,480		50,130		3,714		252,859	

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.

The Japanese Government has set the target to be 12,200 GWh (1.35% of total electricity) by 2010 and 16,000 GWh (1.65% of total) by 2014.

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. The plant was experimentally operated for about 2 years of its initial operation, and put into commercial operation since April 2006. This plant was certified as a RPS unit, which is the first RPS geothermal unit in Japan. A 220kWe binary-cycle geothermal unit has been experimentally operated at Kirishima Kokusai Hotel since September 2006. Many geothermal engineers in Japan are paying attention the performance of these binary-cycle units.

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 such as heat pump is merely 0.3% of all direct use, and has yet to reach the stage of proper installation.

Although many hotels and Japanese-style inns utilize hot spring water, this bathing utilization was excluded from the survey on direct use in the report for WGC2005 (Kawazoe and Shirakura, 2005) because of its difficulty in the evaluation of actual energy use. However in this paper, energy use of bathing is included to be consistent with world wide data for direct use.

Table 4 shows the latest data on direct use in Japan. Since there are more or less inaccurate numbers reported in the survey on many direct use facilities, many assumed values are included. Bathing is shown as “others” in this table (Muraoka et al., 2008).

3.1 Use of geothermal water

NEF’s survey in 2006 shows that the capacity of the facilities that utilize geothermal water excluding bathing is 401 MWt, and annual energy use is 4,900 TJ/y. The average rate of utilization factor of the facilities calculated from these figures is about 38 %. Adding bathing, these numbers rise to 2,086 MWt and 25,630 TJ/y, respectively, with a utilization factor of 39 %.

Compared to the report at WGC2005 (Kawazoe and Shirakura, 2005), both installed capacity and used energy are five times bigger because bathing is added to Table 4. Although total capacity without bathing has hardly changed since 2005, hot water supply and swimming has increased by 10 % while space heating has decreased by 30 %. The annual energy use excluding bathing has decreased by about 4 %.

From the previous survey in 2002, 141 new direct use facilities were included in the database, while 136 facilities were excluded from the database, including 58 facilities that were dismantled or stopped the operation. Major reasons of the dismantle (stop) include economical problem, switch to oil fuel and scaling.

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

Similarly, the quantity of energy utilization by type of use is the largest 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 2006 shows that the capacity of the facilities for ground heat utilization is about 13 MWt, and annual energy use is about 68 TJ/y. The average utilization factor of the all facilities was about 16% and that of only for households was about 45%.

Since facilities for ground heat utilization are difficult to differentiate from their external appearance, information was collected from the construction service 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 116 cases, whose total capacity is about 6.8 MWt.

Snow-melting facilities have larger percentage in the installed capacity and 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 23.5 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. However, the amount of government supports greatly decreased several years ago and at a low level in recent years.

Table 4. Installed thermal power, thermal energy used of geothermal energy and ground heat uses as 2006.

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

Prefecture	G	F	I	H	B	C	P	O*	Total (MWt)	Total (TJ/y)
Hokkaido	13.88	5.29		11.52	29.34	18.25	1.64	178.42	258.34	3196.05
Aomori	1.36	0.23	0.38	1.18	5.02	2.38	0.94	156.44	167.93	2101.20
Iwate	2.36	1.15		0.11	6.29	14.29	0.62	60.81	85.63	879.95
Miyagi	4.47					0.89	0.41	19.76	25.53	313.00
Akita	1.38		0.16	0.92	0.82	1.67	0.68	59.20	64.83	790.91
Yamagata	0.03	0.42		0.10	0.31	1.72	1.42	56.39	60.39	716.54
Fukushima				0.65	1.48		0.75	24.46	27.34	338.49
Ibaraki							0.01	2.96	2.97	36.64
Tochigi		0.00			1.95		0.02	44.04	46.01	603.44
Gunma	0.05			20.92	16.52	2.83	0.01	32.67	73.00	1061.42
Saitama							0.03	4.08	4.11	50.56
Chiba							0.30	1.69	1.99	22.80
Tokyo	1.74						0.10	11.64	13.48	156.65
Kanagawa				3.49	11.19		0.01	22.02	36.71	686.14
Niigata			0.17	0.12	0.09	84.60	0.19	51.69	136.86	665.56
Toyama				0.10		0.49	0.00	35.33	35.92	440.38
Ishikawa	0.08				1.89		0.02	25.67	27.66	366.58
Fukui					0.09		1.64	3.75	5.48	52.15
Yamanashi							0.00	19.90	19.90	244.78
Nagano	0.47		0.43	6.89	11.40	16.92	0.14	92.95	129.20	1646.09
Gifu			0.10	5.74	2.84	6.29	0.04	47.56	62.57	787.02
Shizuoka	0.59			0.03	3.67		0.02	60.48	64.79	835.83
Aichi							0.05	12.51	12.56	154.68
Mie							0.02	40.46	40.48	497.84
Shiga							0.09	0.00	0.09	1.01
Kyoto							0.19	8.30	8.49	103.46
Osaka							0.02	20.12	20.14	247.73
Hyogo					3.68		0.45	24.32	28.45	340.56
Nara							0.01	3.18	3.19	39.24
Wakayama					0.10			19.38	19.48	238.62
Tottori					1.40		1.41	13.26	16.07	213.71
Shimane							0.01	5.87	5.88	72.35
Okayama	0.00	0.00		0.08	0.07		0.15	1.79	2.09	27.02
Hiroshima							1.15	0.30	1.45	9.55
Yamaguchi							0.21	1.08	1.29	16.46
Kagawa							0.36	0.94	1.30	12.60
Ehime					0.01		0.00	3.66	3.67	45.14
Kochi							0.02	0.57	0.59	7.19
Fukuoka							0.10	10.43	10.53	129.81
Saga							0.00	6.82	6.82	83.92
Nagasaki					0.43		0.01	21.63	22.07	278.48
Kumamoto					0.21		0.00	34.38	34.59	424.76
Oita	5.42	0.00		22.99	21.39		0.01	297.60	347.41	4749.79
Miyazaki					1.03		0.05	14.23	15.31	193.62
Kagoshima	5.09	0.82		2.53	3.51	2.21	0.06	130.14	144.36	1786.47
Okinawa								2.58	2.58	31.75
Total (MWt)	36.92	7.91	1.24	77.37	124.73	152.54	13.36	1685.46	2099.53	
Total (TJ/y)	451.73	141.86	30.92	969.49	2790.11	516.27	67.86	20729.70		25697.94
Capacity Factor	0.39	0.57	0.79	0.40	0.71	0.11	0.16	0.39		0.39

* Others：hot springs for bathing, referring from a web page http://sustainable-zone.org/

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 64 areas by the end of FY 2008. 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℃, steam rate 67 t/h) at Wasabizawa, N9-AY-3 (292℃, 68 t/h) at Akinomiya, N13-AP-2 (267℃, 45 t/h) at Appi, and N12-SZ-2 (261℃, 113 t/h) at Shiramizugoe in the C Survey.

Table 5. Total investment in geothermal in (2008) US$.

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. All amount of this subsidy has to be paid back 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. Since 2007, the subsidy was changed to maximum one half for "Project for promoting the Local Introduction of New Energy" and maximum one third for "Project for Supporting New Energy Operators".

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 was dissolved by the end of May 2004. A part of JGEA activities were transferred to GRSJ and TEMPES.

5.4 Thermal and Nuclear Power Engineering Society (TENPES)

The mission of the TENPES is to enhance the improvement and development of thermal and nuclear power generating technology and through this to contribute to the economic progress in Japan. The Society is now working towards these goals by focusing in three major areas, in cooperation with relevant governmental agencies, electric power companies and related manufacturers, namely;

- Study ＆ Research
- Publications
- Public Relations

Today, with a membership of over 13,000, the society is vigorously engaged in the drive to meet its objectives. TENPES took over a part of the JGEA's activities in 2004. TENPES continues educational activities for geothermal engineers, including seminars on new geothermal technologies, and discussions for promoting further geothermal development in the future. TENPES also continues the update of the statistics on geothermal power generation in Japan.

Table 6. Membership of GRSJ

Period	Research & Development Incl. Surface Explor. &Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Funding Type	
			Private	Public
	Million US$	Million US$	%	%
1995-1999	178.5	453.2	0	100
2000-2004	69.3	241.6	0	100
2005-2008	0	110.4	0	100

note：JPY is converted to US$1=JPY100

(1) Individual member of GRSJ

(2) Corporate member of GRSJ

Year	Professional Person-Years of Effort	
	(1)	(2)
2005	606	72
2006	552	66
2007	557	66
2008	554	66
2009	547	66

GRSJ： Geothermal 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.

A committee was established in 2008 in the Ministry of Economy, Trade and Industry (METI) with members from power producers, geothermal resources developers to promote further geothermal power generation. Major discussions in the committee include: 1) inclusion of all types of geothermal power generation in the RPS system, which currently only applies to binary cycle plants in geothermal sectors, and 2) increase of governmental subsidies to construction costs of geothermal power plants. Japan will soon resume its development of geothermal power plants in order to realize a low-carbon society.

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 direct use of geothermal water is expected to remain unchanged. However, use of ground heat is expected to take an important role for CO_2 reduction and energy saving.

Reasons of the delay in accelerating the use of ground heat are; expensive drilling cost, lack of 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 expected 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 1997 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.

In the “Action plan to promote low carbon society” approved by the Cabinet of Japan in July 2008, the obligation was announced to increase the ratio of electricity from the non-fossil power generation to be more than 50% by 2020.

Direct use of geothermal energy described in this report amounts to about 790,000 kl/y when converted to equivalent crude oil. It is equivalent to reduction of 1,760,000 tons of CO_2. 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.

REFERENCES

Agency for Natural Resources and Energy, Research on geothermal energy, Interim Report (draft) (2009)

Geothermal Energy Development Center, New Energy Foundation: The Current Status of Geothermal Direct Uses in Japan (2006)

Kawazoe, S., and Shirakura, N.: Geothermal Power Generation and Direct Use in Japan, *Proceedings, World Geothermal Congress 2005* (2005)

Muraoka, H., Sakaguchi, K., Komazawa, M. and Sasaki, S.: Assessment of hydrothermal resource potentials in Japan 2008, Abstracts of 2008 Annual Meeting of Geothermal Research Society of Japan, Kanazawa, B01 (2008)

Thermal and Nuclear Power Engineering Society: The situation and a trend of geothermal power generation 2008 (2009)

Thermal and Nuclear Power Engineering Society: Geothermal power (2009).