Country Update Report of Geothermal Direct Uses in Japan

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ABSTRACT

Combining the data Sekioka, one of the authors, has collected with the database recently developed by the NEW ENERGY FOUNDATION (NEF), the country update report of direct uses of geothermal energy in Japan as of July 1994 is presented. Firstly, as a background the present State of sources of geothermal energy. reinjection of geothermal water and acquisition of fresh water for heat-exchanging are explained to point out problems in further Promotion of direct uses. Secondly. analyses are carried out for various aspects of direct uses of geothermal energy, Finally, the recoverable energy of low temperature geothermal resources, the total heat discharge from existing wells In the 120 big spas, the extractable heat from it and the annual mean thermal energy used are compared, including effect of the oil-saved,

1. Introduction

Japan has about 200 volcanoes including 83 active *ones,* which are 4 and 10% of those in the world , respectively, in her narrow territory of only 0.27 % of the land area of the world. Therefore, Japan is blessed with much geothermal resources including hot springs. Moreover. hot water carried up from sedimentary basins is also abundant. They are possible sources both for production of electricity and the direct-use of geothermal energy.

On the other hand, as the Japanese enjoy natural baths, which are almost not balneotherapy, the businesses of hotels and inns in spas offer frequently opposition to the development of high temperature geothermal energy for the production of electricity, because they are afraid of drying UP of hot spring wells, while low temperature geothermal energy or hot spring water is easily delivered to hotels and inns for bathing.

Because of a volcanic country, Japan has also much beautiful scenery over the country. There are 15 national parks with volcanic scenery out of a total of 28. The whole area of national Darks is 2,051,400 ha, which is 5.4% of the domain of 37,773,771 ha, Environmental protection activities including the Environmental Agency do not necessarily approve geothermal development because of conservation of natural scenery.

This is the present background for development and utilization of geothermal resources in Japan.

Since most of the direct use facilities are of small scale that are easy to start-up and shutdown of operations, and because of frequently the lack and incomplete measurements of water temperature and flow, the systematic collection of information to analyze various aspects of direct uses of geothermal energy is very difficult. But, making an endeavor to collect the data of geothermal direct uses, Sekioka has published Several statistical papers in the GRC Annual Meeting (Sekioka, 1984, 1986, 1989. 1990, 199'2 and 1993).

Recently the New Energy Foundation (NEF) has started to produce a database of geothermal direct uses in Japan for the purpose to promote direct uses in local communities. Synthesizing the data Sekioka has collected and the NEF database, it became possible to investigate more completely various aspects of direct uses.

As the NEF database is in progress, however, investigation is not definitive and leaves much to be desired, but the present report is the best available as of July 1994.

A part of analyses will be separately tabulated to present Separately to the WGC 1995 In December 1994.

2. Basic situation of geothermal direct uses

2.1. sources

One of the geothermal resources for direct uses is water from hot springs. which are located within spas having many tourists. Another source is hot water gushing with steam from production wells of geothermal Power Plants. Supply of the hot water is due to get harmony with locals in and around the developing site of the plant which has relatively sparse population (Sekioka and Higo, 1994).

Hot water carried UP from sedimentary basins overlying cities and towns is relatively abundant, but its utilization is limited to small scale, to protect the land from subsidence.

Moreover, waste hot spring water from hotels and inns in spas are sources of snow melting systems in many spas after filtering,

2.2. Reinjection of geothermal water

As geothermal fluid frequently contains arsenious and the other noxious ingredients as well as corrosive and scale-depositing ones, for conservation of environment and protection from plugging of pipes. fresh water is supplied to direct use facilities after transferred the heat is from the geothermal water through heat exchangers. Then, the geothermal water from the power plants must be reinjected back into the earth. Indeed, reinjected water serves as recharging of reservoirs.

Although reinjection wells with good

injectivity are desirable, the ability of wells is lowered year by year by means of plugging with deposition of silica and calcium carbonate. For prevention of Silica Scale deposition, pH adjustment of geothermal water has been tried by adding sulfuric acid before its reinjection.

when a heat exchanger station accompanied by reinjection wells is settled near consumers remotely from a geothermal power Plant, cool-ed geothermal water reinjected through wells into the earth can not frequently return back to reservoir. because fissures connecting the wells with the reservoir are not suffi-cient. Thus, the success rate of reinjection wells is not necessarily 100 %.

In a direct uses project, the success rate is up to 80 %, while another project is up to 63 %.

On the other hand, discharge of waste hot spring water into rivers are traditionally permitted, even if the water contains some of the chemicals typical of geothermal water.

2.3. Acquisition of fresh water

since agricultural and fishing associations, waterworks and hydroelectric power plants have already invested in various water rights on almost all the rivers in Japan with a large population in her limited area, it is frequently difficult to get water from those rivers to exchange heat with geothermal water, particularly to large scale projects. Extracting underground water for heat ex-change is also not good from the viewpoint of ground subsidence.

In a system, during phases of water shortage, beverage and irrigation take precedence over direct uses. In another case. water from some slender mountain streamlets are gathered to transport over about 7 km to the heat exchangers. A way to solve such difficulty, a closed circulation system of fresh water is selected in the enow-melting, though the piping cost became twice.

There is a snow-melting system which has been operated with hot spring water without heat exchange, because of its good water Quality.

3. Analysis

3.1. The year online

The total number of geothermal direct use facilities to be analyzed is 208 in this item. It is found in Table 1 that the facili-ties Concentrate on Hokkaido and Tohoku dis-tricts in the snowy cold climate where demand for heat is Strong and to Kyushu which is blessed with an abundant geothermal resources.

Table 1 also shows a distribution of the year when the facilities went on line. The oldest one is the tropical botanical garden of Kagoshima University in Ibusuki, Kagoshima Pref., which was established in 1918.

Moreover. Table 1 reveals that the number of the facilities is more than doubled every 10 years, i.e., 10 before 1960, 20 in the 1960's, 52 in the 1970's and 121 in the 1980's. Particularly. a rapid increase is found in the 1970's, which reflects the oil crises.

3.2. Administrative system

There are many kinds of administrative system for geothermal direct use facilities. Syn-thesizing those systems. Table 2 Shows that the number of public systems including three national government ones (a National Hospital, Hokkaido Pref., a national project of supplying hot Water, Akita Pref. and a tropical botanical garden affiliated to National University, Kagoshima Pref.! is more than half or 123 out of 244, followed by private systems of 115.

A body corporate, which provided capital from local governments and private enterprises, is 2.5 % or 6 out of 244.

Predominance of public Systems may character-ize direct uses of geothermal energy in Japan.

3.3. Distance between source and delivering Station

Since geothermal power plants are generally located In remote and secluded places among the mountains, long delivery pipelines of hot water make economics to unprofitable. For example, distance between the Matsukawa Geo-thermal Power Plant (GPP) and Matsuo, Iwate Pref.. the consuming community, is 12.8 km. In case of the Hatchobaru GPP. Oita, and the Onuma GPP. Akita Pref.. the distance is 3.9 km and 1.5 km, respectively. Exceptionally, as a greenhouse complex was newly built near the Mori GPP, zero distance was obtained.

In contrast, pipelines for the Water of hot springs are frequently short. Minase, Akita Pref.. Naruko, Miyagi Pref., Higashi-Izu, Shizuoka Pref., Kokubu, Kagoshima Pref,, and Ibusuki, Kagoshima Pref.. have zero distance. In general the distance may be less than 2 km.

Using the NEF database, a distribution of distance between the hot spring Wells or the production wells and the hot water delivering station with or Without heat exchangers is investigated and Shown in Table 3. Far dis-tances less than 1000 m, about 81% provides generally an economically reasonable cost for direct uses. Contrarily, the great parts or 72 % of the distances more than 1001 m are found in depopulated Hokkaido and Tohoku district. The distance less than 100 m gives profitable circumstances in only about 50 %. Because the database does not contain the distance between the station and the consumer, the total length of pipeline may be beyond these data.

3.4. Depth of wells

A distribution of depths including production wells of GPPs which supply water for direct uses as well as hot spring wells is Shown in Table 4. The depths from 501 to 1000 m form the peak. followed by those from 101 to 300 m. The deepest well of 2000 m is for a pro-duction well of the Mori GPP, water from Which is supplied to a greenhouse complex. The depths less than 500 m including the second peak of distribution from 101 to 300 m are conventional ones in the majority of the spas.

3.5. Installed thermal power

Many uncertainties make accurate evaluation of the installed thermal power (ITP) or the maximum utilization of direct uses. difficult. Nevertheless, an estimate of the ITP is attemptad and the result is summarized separately in each Prefecture and each use as shown in Table 5. It can be found that the total is 318.80 MWt, the maximum is 102.9 MWt of Hokkaido Pref. with cold climate, followed by 34.75 and 34.67 MWt of Oita and Kagoshima Prefs.,respectively, blessed with much geothermal resources. Space heating has the maximum ITP of 182.36 MWt, because it contains hot water supply, followed by 51.56 MWt of greenhouse,

3.6. Thermal energy used

Multiplying the ITP of each facility by its own load factor (the rate of the number of workdays to the calendar days), the thermal energy used (TEU) can be computed for each facility. Similar to Table 5, the TEU is listed separately in each Prefecture and each use in Table 6. The total TEU is 6941.6 TJ/y, while the maximum is also 2319.5 TJ/y of Hokkaido Pref. Because of low load factors in Kyushu with mild climate the TEU of both Oita and Kagoshima Prefs. are not the second highest consumers. The second. 659.7 TJ/y, is found in Nagano Pref. Which is a mountainous cold region.

The maximum of 4632.3 TJ/y by use is for space heating including hot water supply, followed by 864.6 TJ/y for fish and other animal farming.

3.7. Load factor

The average load factor of each use is Shown on the last line of Table 6, with the whole average of 69 %. It is seen that nearly all year-around botanical garden, Space heating including hot water supply and fish farming have high load factors of 85, 81 and 78 %, respectively.

3.6. Rate of the oil Saved

A comparison of TEU with the fuel oil volume sold from January to December 1933 in each Prefecture and the whale country (Ministry of International Trade and Industry, 1993) is shown on the 12th column In Table 6. In this comparison, fuel oil of 10^6 kl/year or 1 Gl is converted to a TEU of 27941 TJ/y, based on the calorific value of fuel oil of 6900 kcal/l and the boiler efficiency of 0.75. The maximum rate is found 0.93 % in Nagano Pref., followed by 0.79 % of Kagoshlma Pref., which are nearly equal to 1 %, while the total TEU of 6941.6 TJ/y is not yet Only 0.11 % to the yearly fuel oil selling volume of 226.0 Gl in the whale of Japan.

3.9. Geothermal heat pump

The NEF database has only two cases, where heat pumps are used. As was mentloned already. since hot spring water with a temperature above 15°C is easily usable all over the country, there is almost no demand to use heat pumps.

3.10. Wells drilled recently for direct heat utilization

The number of wells drilled for direct use in 1990 and 1991 is nine. As was mentioned in Section 1, it is different to procure all aata in Japan at present, in spite of exerting all possible effort.

4. Low temperature geothermal resources and direct uses in Japan

Miyazaki et al. (1991) estimated low temperature geothermal resources and effective recoverable energy between 42 and 90°C to be 1.370×10^{15} MJ and 82×10^{12} MJ far the reference temperature of 15°C, respectively by means of a volume method on a nationwide scale. The effect ve recoverable energy is equivalent to 87x10' MWt x 30 Years.

NEF (1993) calculated tne total heat discharge of 2.43×10^3 MWt (for the reference temperature of 15°C) from the 6868 hot spring we115 in the 120 big spas which are selected, from 23,037 wells in 2382 spas as of March 1992, under a Standard that whole wells in a spa have heat discharge more than 5 Gcal/hr at a flow rate of 2000 l/min and over.

On the other hand, Sekioka (1993) computed an extractable heat of 1512.32 MWt for direct use from the 6868 wells mentioned above, placing emphasis on coexistence with natural bathing. The three assumptions used here was illustrated in the previous paper (Sekioka, 1990a).

Based on the data synthesized here, the thermal energy used as of July 1994 is computed to be 220.12 MWt as Shown in Table 2. This is 14.6 % of the extractable heat, 9.1 % of the total heat discharge from the big spas and 0.25 % of the effective recoverable energy. Moreover, the heat of 220.12 MWt corresponds to 0.11 % of that desired from the fuel oil of 228.5 Gl sold in 1992 in Japan.

The oil-saved rate of geothermal direct uses will increase to 0.76 % if the extractable heat can be fully provided, to 1.2 % if the total heat discharge can be obtained and to 43 % if the effective recoverable energy can be utilized.

5. Further prospect---Combination of direct uses with small scale binary cycle electric power generation

In recent years. the New Energy and Industrial Technology Development Organization (NEDO) is developing a 100 kW and a 500 kW binary cycle electric generator (NEDO, 1994). NEDO also reported that the total potential Production of electric power from the 63 existing geothermal and hot spring wells having potential Output from 100 to 500 kW is assessed to be 15,527 kW, whlle the total potential production from existing 12 wells having potential output above 500 kW is assessed to be 11.251 kW, and thus the grand total is 23,178 kW.

On the other hand, the average temperature and flow rate of geothermal water discharged after the use of binary cycle electric power generation are 76°C and 125 ton/hr, respectively (NEDO, 1994). Those water having a total heat of about 9 MWt is Suitable for various geothermal direct uses. Direct uses of geothermal energy is expected to further evolve by combining with binary cycle electric power generation.

5. Conclusion

Although the in-Progress NEF database and the not-necessarily-sufficlenc data Sekioka has collected are used to analyze various aspect of direct uses of geothermal energy, this country update report based upon the analytical results may he the best version as of July 1994. because there is no other synthetic and quantitative data of direct uses in Japan.

It must be emphasized that a relatively large increase of the ITP and TEU obtained here from those as of April 1992 (Sekioka. 1992) is due to progress of the NEF database, not to evolution of the direct uses in Japan in only the two years.

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Table 2. Administrative System

System	Number
Public	123
Private	115
Corporation	6
Total	244

Table 1. The Year Online

	Hokkaido	Tohoku	Kanto	Chubu	Kinki-Chugoku	Kyushu	Total
Before 1960	5	1		3		1	10
1961-1970	10	5			1	4	20
1971-1980	30	17		3		2	52
1981-1990	48	39	9	9	2	14	121
1991-1992		2		3			5
Total	93	64	9	18	3	21	208

Table 3. Distance (km) between Source and Delivering Station

Distance	okkaido	lohoku	Kanto	Chubu	Kinki-chugoku	Kyushu	otal
	40	30		2		9	81
101- 300	11	6	2			5	24
301- 500	8	5	2		1		16
501- 1000	9	1		1		3	20
1001- 1500	1	1			1	1	5
1501- 2000	11	4					16
2001- 3000	1	4					6
3001- 4000	1		1				2
4001- 5000		2					2
5001- 7000		1		2			3
7001-10000	1	1					2
Total							177

Table 4. Depth of Wells

	Hokkaido	lohoku	Kanto	Chub"	Kinki-chugoku	Kyushı	Total
- 100	11	9	1	10	1	11	49
101- 300	35	19	3	6		12	15
301- 500	12	1	8	12		1	44
501-1000	43	31	2	2		4	82
001-1500	34					2	36
501-2000	3						3
Total							289

TABLC h. UTILIZATION OF GEOTHERMAL ENERGY FOR UIRECT HEAT IN DECEMBER 1994
[Annual Utilization]

Pl-e-fec-ture*	D**	C	G	.	F		ol		**	Total	el l iles lume	il wed ffect
	TJ/y	TJ/y	TJ/y	l/y	TJ/y	TJ/y	J/y	J/y	J/y	TJ/y	il/y	9
HK	691.9	0.3	297.1		70.0	35.6	17.3	7.3		319.5	13.0	0.64
AO	98.4		3.5		59.3	29 0	4 7			194 9	2.9	0.24
IW	69.4		22.1		0.6	7 6	0.9			100.6	2.0	0.18
MY	9.5		0.0		0.9	3.5			6.3	50.2	4.3	0.04
AK	140.0		67.2	).9	43.8	25.5	12.3	0.7		294.4	2.3	0.46
YT	107.2		0.0		03.8	23.7	3.6			248.3	1.7	0.52
FS	259.5						12.1			391.6	5.9	0.24
GM	50.8	0.3				43.5	6.3			100.9	2.9	0.12
TG	52.3	5.4			0.3	0.9				58.9	3.1	0.07
KN	102.5									102.5	13.4	0.03
NI	6.0				2.5					8.5	4.2	0.01
TY	5.7					1.9				7.6	2.1	0.01
IS			1.9			14.2				16.1	2.2	0.03
NG	825.3		18.9			9.8	5.7			859.7	3.3	0.93
SZ	51.4		8.8		86.1				4.'	200.5	6.2	0.12
GF	407.4		0.9		106.6	15.5	1.3			531.7	2.8	0.68
HY	7.6						0.3			7.9	7.0	0.00
WY					3.8					3.8	3.3	0.00
TT	14.5									14.5	1.0	0.05
SN					0.3	2.8				3.1	1.1	0.01
OK	10.4				0.3					10.1	11.0	0.00
YG			11.7							11.7	6.1	0.01
SG			0.0							0.C	1.3	0.00
KM	5.4	12.:	11.4		33.4		6.0	0.!		69 4	2.3	0.11
OI	552.8		219.2		10.7			0.(		782.1	4.2	0.67
KG	164.3	25.!	116.7		242.2		2.5	0.:		551.1	2.5	0.79
Total	1632.3	44.:	773.4	0.9	3M.6	'835	33.0	9.:	30.	5941.6	26.0	0.11
Load Fac-tor	81	41	48	8	78	32	62	25	85	69		

*) See the bottom of TABLE 5 for the abbreviation of name of Prefecture.
**) *See* the bottom of TABLE 5 for the abbreviation of name of utilization.

TABLE 5. INSTALLED THERMAL POWER OF DIRECT USES OF GEOTHERMAL ENERGY. DECEMBER 1996
[Maximum Utilization1

	D**	C	G	A	F	S	B Pool	I	0	Total
	MWt	MWt	MWt	MWt	MWt	MWt	MWt	MWt	MWt	MWt
	60.98	0.04	3.03		6.60	9.21	2.68	0.45		102.99
	4.566		0.25		1.91	2.59	0.21			9.62
	6.67		3.14		0.04	0.82	0.10			10.77
	0.36		0.04						.65	2.50
	5.18		2.31	.37	1.39	3.13	1.76	1.22		15.36
	5.35		0.00		3.29	3.42	1.76			13.82
	9.55						4.19			13.74
	4.82	0.01				3.57	0.39			8.79
	2.40	0.17			0.01	0.10				2.68
	4.22									4.22
	0.25				0.08					0.33
	0.31					0.49				0.80
			0.08			1.36				1.44
NG	26.11		1.03			1.14	0.19			28.53
SZ	1.63		0.62		3.65				.72	7.66
GF	14.56		0.05		3.48	1.57	0.21			79.87
HY	0.47						0.09			0.56
WK					0.12					0.12
TT	0.46									0.46
SN					0.01	0.35				0.36
OK	0.33				0.01					0.34
YG			0.49							0.49
SG			0.00							0.00
KM	0.17	0.96	0.69		1.06		0.35	0.70		3.93
OI	22.56		1.75		0.35			0.09		34.75
KG	11.26	2.21	8.08		13.02		0.08	0.02		34.67
Total	82.36	3.39	1,56	.37	35.09	28.17	12.01	2.48	.37	318.80

*) Abbreviation of the name of Prefectures is as follows:
HK: Hokkaido. AO: Aomori, IW: Iwate, MY: Miyagi, AK: Akita, YT: Yamagata. FS: Fukushima, GM: Gunma, TG: Tochigi, KN: Kanagawa, NI: Niigata, TV: Toyama, IS: Ishikawa NG: Nagano, SZ: Shizuoka. GF: Gifu. HY: Hyogo, WK: Wakayama. TT: Tottori, SN: Shirane. OK: Okayama, YG: Yamaguchi, SG: Saga, KM: Kumamoto, OI: Oita. and KG: Kagoshima.
**)Abbreviation of the name of utilization:
D: Space heating. C: Air conditioning. G: Greenhouses. A: Agricultural drying, F: Fish and other animal farming, S: Snow melting. B: Swimming, I: Industrial Process heat, 0: Sight seeing.

TAULE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT IN DECEMBER 1994

[1] I = Industrial process heat D = Space heating
C = Air conditioning B = Bathing and swimming
A = Agricultural drying G = Greenhouses
F = Fish and other animal farming O = Other (please specify by footnote)
S = Snow melting

[2] Enthalpy information is given only if there is steam or two-phase flow

[3] Energy use (TJ/yr) = Annual average water flow rate (kg/s) x [Inlet temp.(°C) - Outlet temp.(°C)] x 0.1319

Locality	Type[1]	Maximum Utilization					Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2] (kJ/kg)		Average Flow Rate	Energy Use[3]	Load Factor
		kg/s	Inlet	Outlet	Inlet	Outlet	kg/s	TJ/yr	
		See Tables 5 and 6 in the text.							

TABLE 4. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES

[1] Inst. thermal power (MW$_t$) = Max. water flow rate (kg/s) x [Inlet temp.(°C) - Outlet temp.(°C)] x 0.004184

[2] Energy use (TJ/yr) = Annual average water flow rate (kg/s) x [Inlet temp.(°C) - Outlet temp.(°C)] x 0.1319

	Installed Thermal Power[1] MW$_t$	Energy Use[2] TJ/yr
Space heating	181.22	4614.3
Bathing and swimming	12.01	233.0
Agricultural drying	0.37	0.9
Greenhouses	51.56	773.4
Fish and other animal farming	35.09	864.6
Industrial process heat	2.46	19.2
Snow melting	28.17	283.5
Air conditioning	3.35	44.2
Other uses (specify)	3.37	90.5
Subtotal	317.62	6923.6
Heat Pumps	1.18	18.0
Total	318.80	6941.6

TABLE 5. GEOTHERMAL HEAT PUMPS

[1] Thermal energy used (TJ/yr)
= Annual average geothermal water flow rate (kg/s) x [Inlet temp.(°C) - Outlet temp.(°C)] x 0.1319

Locality	Heat Source °C	COP - Factor	Heat Pump Rating MW$_t$ (Output)	Thermal Energy Used in Heating Mode[1] TJ/yr
Sunagawa, HK	17		0.35	6.1
Mogami, YT	14		0.83	11.9
Total			1.18	11.9

TABLE 8. WELLS DRILLED FOR DIRECT HEAT UTILIZATION OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1990 TO DECEMBER 31, 1994
(Do not include thermal gradient wells less than 100 m deep)

[1] Type or purpose of well and manner of production
Use one symbol from column (a) and one from column (b)

(a)
T = Thermal gradient or other scientific purpose
E = Exploration
P = Production
I = Injection

(b)
A = Artesian
P = Pumped
F = Flashing

[2] Total flow rate at given wellhead pressure (WHP)

Locality	Year Drilled	Well Number	Type of Well[1]	Total Depth m	Max. Temp. °C	Fluid Enthalpy kJ/kg	Well Output[2] Flow Rate kg/s	Well Output[2] WHP bar
Kyogoku, Hokkaido	1990	S45	PA		26		0.3	
Kamikawa, ditto	1990	4	PA	61	72		1.7	
Toyakoonsen, ditto	1990	3	PP	130	57		2.7	
Abuta, ditto	1990	H3	PP	150	46		2.2	
Inakadate, Aomori	1990		PP	800	49		5.0	
Akita, Akita	1990	2	PP		36		3.3	
Ibusuki, Kagoshima	1990	1	PA	78	34		10.0	
Makisono, ditto	1990	3	PP	400	143		1.4	
Suwa, Nagano	1991		PA	1000	56		25.0	
Total 9				2619			51.6	