Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

COUNTRY UPDATE REPORT OF GEOTHERMAL DIRECT USES IN JAPAN

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Keywords: Direct uses and Japan

ABSTRACT

Using the new version of a database developed by the New Energy Foundation the country update report of direct uses of geothermal energy in Japan as of December 1999 is presented. Firstly, analyses are carried out for various aspects of direct uses of geothermal energy. Main results are as follows: 1) Installed thermal power is found to be 266.12 MWt, with the maximum in Hokkaido Pref. (91.71 MWt) for locality and in space heating including domestic hot water supply (136.70 MWt) for utilization type. 2) Thermal energy used is found to be 5399.59 TJ/yr, with the maximum in Hokkaido Pref. (1950.19 TJ/yr) for locality and in space heating including domestic hot water supply (2953.35 TJ/yr) for utilization type. Secondly, by comparing with other countries the economically severe condition for the use of geothermal energy as compared to fossil fuels in Japan is revealed statistically.

1. INTRODUCTION

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

On the other hand, as the Japanese enjoy natural baths, which are almost not balneotherapy but recreation, low temperature geothermal water or hot spring water is, due to its high economical value, easily delivered to hotels and inns for bathing.

Because of a volcanic country, Japan has also much beautiful scenery throughout the country. There are 15 national parks with volcanic scenery out of a total of 28. Environmental protection activities including the Environmental Agency do not necessarily approve of geothermal development for conservation of natural scenery.

These are the present background for development and utilization of geothermal resources in Japan, which have not been changed since WGC 1995.

Since most of direct use facilities are of small scale that are easily to start-up and shutdown their operations, and the data of water temperature and flow rate are frequently lacking and incomplete, thus making the systematic collection of correct information to analyze various aspects of geothermal direct uses very difficult. Recently, the New Energy Foundation (NEF) has updated the database of geothermal direct uses in Japan to promote direct uses in local communities. This effort makes it possible to investigate more completely various aspects of direct uses.

As was mentioned above, investigation is not definitive and leaves much to be desired, but the present report is the best version as of December 1999. Based on the NEF database analyses are carried out as follows.

2. Analyses

2.1. Installed thermal power

Installed thermal power (ITP) is defined as the maximum flow rate multiplied by the difference between inlet and outlet temperatures of facilities or the potential value of direct uses. Many uncertainties as was described in the Introduction makes accurate evaluation of the ITP difficult. Nevertheless, accumulating those data an estimate of ITP is attempted and the result is summarized separately in each Prefecture and each use as shown in Table 1. It can be found that the total is 266.12 MWt and the maximum ITP is 91.71 MWt for Hokkaido Pref. which has a cold climate, followed by 63.74 and 22.94 MWt for Oita and Kagoshima Prefs., respectively, blessed with much geothermal resources.

Space heating including domestic hot water supply has the maximum ITP of 136.70 MWt, followed by 34.58 MWt of greenhouses.

2.2. Thermal energy used

Multiplying ITP of each facility by its own capacity factor (the rate of the number of full load days to total calendar days), the thermal energy used (TEU) can be computed for each facility. Similar to Table 1, TEU is listed separately in each Prefecture and each use in Table 2. The total TEU is 5399.59 TJ/y and the maximum is also 1950.19 TJ/y for Hokkaido Pref. followed by 1159.58 TJ/y for Oita Pref. Because of low capacity factors in Kyushu district due to a mild climate, the TEU of Kagoshima Pref. is not the third largest consumers. The third, 409.02 TJ/y, is found in Nagano Pref. which is a mountainous and cold region.

For applications, also the maximum of 2953.35 TJ/y is found in space heating including hot water supply, followed by 652.80 TJ/y of greenhouse heating.

It must be noted that Type B in Tables 1 and 2 includes only swimming pool and not bathing. The reason why bathing is excluded in both Tables is as follows. Since Japanese likes bathing of hot springs, many hotels and inns in spas, responding to requirement of visitors, flow thermal water continuously in night and day into huge bathtubs similar to small swimming pool regardless of whether it is used by the visitors or not. On the other hand, in some spas in short supply of thermal water, hotels and inns circulate frequently thermal water in bathtubs after its filtering. Additionally, for example, well water of only 17^{o}C is classified into hot spring water by the Law of Hot Springs, due to its containing

sodium bicarbonate ($NaHCO_3$) of 454 mg/kg and metasilicic acid (H_2SiO_3) of 58.8 mg/l. Thus, evaluation of thermal energy consumed in such fashions may be meaningless to include in ITP and TEU in Tables 1 and 2, respectively.

Table 1 Installed thermal power of direct uses of geothermal energy

December 1999 (Unit: MWt)

H: Space heating including hot water supply
C: Air conditioning (cooling)
G: Greenhouse heating
F: Fish breeding
I: Industrial process heat
S: Snow melting
B: Swimming pool
O: Others

Pref.	H	C	G	F	I	S	B	O	Total
Hokkaido	29.28	0.2	12.03	14.1	0.1	19.14	16.9		91.71
Aomori	0.97		0.25	1.08	0.1	2.23	1.37		6.01
Iwate	5.88		3.21	0.17			1.52		10.78
Miyagi			0.04						0.04
Akita	2.33		1.84		0.7	1.96	0.69		7.55
Yamagata	1.24			0.42		1.71	2.09		5.46
Fukushima	4.17		0.20			0.25	0.16		4.78
Tochigi	1.70						0.05		1.75
Gunma	5.01					3.57	0.13		8.71
Tokyo			0.25						0.25
Kanagawa	1.25								1.25
Niigata	0.21			0.08	0.12		0.01		0.42
Toyama	0.10		0.42	1.40		0.49			2.41
Ishikawa	0.03		0.08	0.05		1.36	0.10		1.62
Fukui	0.24								0.24
Nagano	5.21		0.14		0.42		1.13		6.90
Gifu	11.55		0.05	2.49		1.15	0.10		15.34
Shizuoka	5.34			0.12			0.22	1.72	7.40
Hyogo	0.35								0.35
Wakayama	0.03			0.12					0.15
Tottori	4.89								4.89
Okayama	0.14			0.01			0.08		0.23
Hiroshima	0.02						0.18		0.20
Kumamoto	0.17			0.42			0.41		1.00
Oita	40.69	1.26	13.62	2.81	0.66		3.65	1.05	63.74
Kagoshima	15.90	3.99	2.45	0.50			0.10		22.94
Total	136.70	5.4	34.58	23.8	2.1	31.86	28.90	2.8	266.12

Table 2 Thermal energy used for direct uses (Annual utilization)

December 1995 (Unit: M Wt) For H to O, see Table 1.

Pref.	H	C	G	F	I	S	B	O	Total (MWt)	Total (TJ/y)
Hokkaido	22.63	0.06	9.11	9.14	0.06	11.00	9.84		61.84	1950.19
Aomori	0.73		0.10	1.05	0.11	0.90	0.88		3.77	118.89
Iwate	1.75		0.74	0.10			1.31		3.90	122.99
Miyagi			0.00						0.00	0.01
Akita	1.09		1.39		0.07	0.67	0.59		3.81	120.15
Yamagata	0.61			0.18		0.29	0.70		1.78	56.13
Fukushima	3.87		0.20			0.12	0.16		4.35	137.18
Tochigi	1.25						0.03		1.28	40.37
Gunma	4.25					1.74	0.08		6.07	191.42
Tokyo			0.14						0.14	4.41
Kanagawa	1.25								1.25	39.42
Niigata	0.16			0.08	0.12		0.00		0.36	11.35
Toyama	0.06		0.31	1.40		0.20			1.97	62.13
Ishikawa	0.02		0.06	0.05		0.45	0.03		0.61	19.24
Fukui	0.24								0.24	7.57
Nagano	5.09		0.10		0.42		1.12		6.73	212.24
Gifu	10.14		0.05	2.39		0.32	0.07		12.97	409.02
Shizuoka	5.34			0.06			0.22	1.72	7.34	231.47
Hyogo	0.12								0.12	3.78
Wakayama	0.01			0.12					0.13	4.10
Tottori	4.89								4.89	154.21
Okayama	0.06			0.01			0.03		0.10	3.15
Hiroshima	0.01						0.18		0.19	5.99
Kumamoto	0.17			0.42			0.25		0.84	26.49
Oita	23.00	0.25	7.79	2.81	0.58		1.91	0.43	36.77	1159.58
Kagoshima	6.91	1.55	0.71	0.50			0.10		9.77	308.11
Total(MWT)	93.65	1.86	20.70	18.31	1.36	15.69	17.50	2.15	171.22	
Total(TJ/y)	2953.35	58.66	652.80	577.42	42.89	494.80	551.88	67.80		5399.59
Capacity Factor	0.69	0.34	0.60	0.77	0.64	0.49	0.61	0.78	0.64	

2.3. Capacity factor

The average capacity factor of each application is shown on the last line of Table 2, with the whole average of 64%. It is seen that nearly all year-around fish farming and hot water supply included in space heating show high capacity factors of 77 and 69%, respectively.

The results of Subsections 2.1 to 2.3 are summarized in Table 3.

2.4. Geothermal heat pump

With the low value of TEU (only 1% of the total), the use of heat pumps is concentrated in cold snowy Prefs. except for Okayama Pref. as shown in Table 4. As was mentioned 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.

Table 3 Summary table of geothermal direct heat uses December 1999

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/y)	Capacity Gactor (%)
Space heating including hot water supply	136.71	2953.32	0.69
Air conditioning (Cooling)	5.43	58.50	0.34
Greenhouse heating	34.59	653.77	0.60
Fish breeding	23.76	576.99	0.77
Industrial process heat	2.12	42.78	0.64
Snow melting	31.85	494.71	0.49
Bathing and Swimming	28.89	551.83	0.61
Others (Tourism)	2.78	67.74	0.78
SUBTOTAL	266.12	5399.63	0.64
Heat pumps	4.28	55.57	0.41
GRAND TOTAL	270.40	5455.20	0.64

Table 4 Geothermal heat pumps December 1999

Prefecture	Equivalent full load (Hr/y)	Thermal energy used (TJ/y)
Hokkaido	3325	8.41
Apmori	2529	6.75
Yamagata	2946	17.20
Fukushima	2925	2.45
Tochigi	4380	2.20
Gunma	8640	1.16
Nagano	5678	8.98
Okayama	6484	8.41
Total	36,907	55.27

Table 5 Wellhead price of natural gas in the U.S.

Year	US$/Mcal	Index
1980	0.0063	100
81	0.0079	125
82	0.0099	157
83	0.0107	170
84	0.0103	163
85	0.0095	151
86	0.0075	119
87	0.0063	100
88	0.0063	100
89	0.0063	100
90	0.0067	106
91	0.0063	141
92	0.0067	149
93	0.0079	125
94	0.0071	113
95	0.0059	94
96	0.0083	131
97	0.0087	138

3. ECONOMICAL ENVIRONMENT

The use of geothermal energy competes with the price of fossil fuels. Sekioka (1999) attempted to reveal the severe economical condition surrounding geothermal direct uses in Japan. BP Statistical Review of World Energy (abbreviated as BP in the following) and the Summary of Energy and Economical Statistics (abbreviated as EE in the following) are used to analyze the economic conditions from 1980 to 1996 or 1997 after the two oil crises in 1973 and 1978 for geothermal direct uses in Japan and other geothermal countries.

In the U.S., because the amount of domestic natural gas has been about 10 times more than that imported from Canada, the well-head price of natural gas is selected as the index by converting

Table 6 Import price of natural gas in France

Year	Fr/US$	US$/Mcal	Fr/Mcal	Index
1980	4.2	0.012	0.05	100
85	9.0	0.015	0.14	280
90	5.4	0.011	0.06	120
91	5.6	0.013	0.07	140
92	5.3	0.011	0.06	120
93	5.7	0.010	0.06	120
94	5.5	0.0089	0.05	100
95	5.0	0.0094	0.05	100
96	5.1	0.0096	0.05	100

Table 7 Imported price of natural gas in Italy

Year	Lit/US$	US$/Mcal	Lit/Mcal	Index
1980	856	0.012	10.20	100
85	1909	0.015	28.79	282
90	1198	0.011	13.31	130
91	1241	0.013	15.75	154
92	1232	0.011	13.69	134
93	1574	0.010	15.51	152
94	1612	0.0089	14.35	141
95	1629	0.0094	15.31	150
96	1543	0.0096	14.81	145

its unit from Btu to Mcal. It is seen in Table 5 that adopting the price in 1980 as 100, the cost in 1997 increases to 138. Furthermore, import of natural gas of higher price from Canada has been advantageous to geothermal direct uses in the U.S.

According to BP, natural gas consumed in France and Italy, the leading geothermal countries in Europe, was imported from the former U.S.S.R. and North Africa. Since the imported price of natural gas is expressed in US$ for whole EC in BP, the price is converted to Fr and Lit for France and Italy, respectively, based on the exchange rate in EE. In Tables 6 and 7, the two time series of the price of natural gas in both countries are provided in the unit of per Mcal with the indices standing at 100 in 1980. It reveals that the price index returns to 100 in France and increase to 145 in Italy in 1996, favorable to geothermal exploitation.

In Japan, the rival is crude oil, not natural gas. The C.I.F. and exchange rate in Japan in EE are used to compute three time series of Yen/kl, Yen/Mcal and its indices as shown in Table 8. It is seen in Table 8 that the oil price index in Japan decreased drastically from 100 in 1980 to only 23 in 1994 and 30 in 1997,

Table 8 CIF price of oil in Japan

Year	Yen/US$	US$/bbl	Yen/Mcal	Index
1980	218.67	34.63	7.14	100
81	226.14	36.89	7.86	110
82	249.66	34.09	8.02	112
83	236.81	29.63	6.61	93
84	242.97	29.17	6.68	94
85	224.05	27.21	5.74	49
86	160.86	13.81	2.09	29
87	139.18	18.03	2.37	33
88	128.05	14.79	1.78	25
89	141.91	17.92	2.40	34
90	141.95	22.76	3.05	43
91	133.33	18.83	2.37	33
92	125.47	19.28	2.28	32
93	108.31	16.76	1.71	24
94	99.98	17.26	1.63	23
95	96.29	18.26	1.66	23
96	111.94	21.72	2.29	32
97	122.48	18.77	2.16	30

inversely to the situation in the three countries. Causes of the sharp fall of oil price are easily found in the time series of both strongly growing of Yen against US$ and lowering of the oil price in US$. When the price of oil is more than Yen 3.00/Mcal, geothermal direct uses can match crude oil in Japan.

4. CONCLUSION

The NEF database is used to analyze various aspects of geothermal direct uses in Japan. This country update report based upon the analytical results may be the best version as of December 1999, because there is no other synthetic and quantitative data of direct uses in Japan. It must be emphasized that a relatively large decrease of the ITP and TEU obtained here from those as of July 1994 (Sekioka and Toya, 1995) may mainly be due to lowering of oil prices in Japan, though uncertainty included in the NEF database is undeniable.

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