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WORLD USES OF LOW-TEMPERATURE (<150°C) GEOTHERMAL RESOURCES IN 1980

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ABSTRACT

The results of a recent world survey of low-temperature geothermal energy utilization are reported. It was found that 44 countries have low-temperature geothermal resources, 24 countries are involved in exploration, 12 countries are utilizing low-temperature geothermal energy and 9 countries have carried out assessment studies. The survey showed that about 8700 MW-thermal (above 15°C reference temperature) were installed at the end of 1980.

INTRODUCTION

In recent years the main goal of geothermal exploration and development projects in the world has been the generation of electric power. With few exceptions these projects have been undertaken in areas of known surface manifestations typical for high-temperature resources. At the same time an increased interest has been shown in the less noticeable low-temperature resources, particularly in countries where space heating is necessary for a good part of each year. In a few countries low-temperature resources have been utilized for decades on a commercial scale while elsewhere geothermal waters have traditionally been considered little more than a novelty. Recently, however, several countries have come to appreciate the great energy potential of low-temperature geothermal resources and are translating their interest into exploration and field developments for direct use applications.

In August 1981 the United Nations convened a Conference on New and Renewable Sources of Energy in Nairobi, Kenya. To prepare for this conference its preparatory committee formed several panels of experts to address issues concerning the principal renewable energy sources, including geothermal energy. The Geothermal Division of Orkustofnun (Iceland Energy Authority) was asked by this panel to carry out a World Survey of Low-Temperature Geothermal Energy Utilization (Gudmundsson & Palmason 1981). The survey was carried out in 1980 and in early 1981 the detailed results were sent for comment to all who contributed information. At the same time they were asked to update the information to the status of geothermal utilization in their country at the end of 1980. The main purpose of this paper is to report the findings of the world survey and the updated information.

A survey similar to the one reported here was carried out for high-temperature geothermal resources. This was done by the Ministry of Works and Development in New Zealand (Bolton 1981). For the purpose of the two surveys the technical panel decided to use 180°C as the temperature limit dividing high- and low-temperature geothermal fields. The utilization reported in the low-temperature survey, however, was mainly in fields with much lower reservoir temperatures, usually below 100°C. The reservoir temperature limit dividing high- and low-temperature geothermal fields in Iceland has traditionally been 150°C where most high-temperature fields are above 200°C and low-temperature fields below 100°C. There are important generic differences between the two types, but these will not be discussed here. In the United States the temperature limit of 150°C is now used for differentiating between high- and intermediate-temperature geothermal fields. In view of the above it seems appropriate to use 150°C as the arbitrary reservoir temperature defining the scope of the survey reported in this paper. It should be noted that the utilization reported here does not include any direct or nonelectrical uses in high-temperature fields. The temperature limit of 150°C represents the resource temperature but not the temperature of utilization.

PREVIOUS REVIEWS

A widely quoted review reference on non-electrical applications within various countries is that of Howard (1975a). It reported that in 1975 about 400 MW-thermal were used for residential and commercial applications, 5500 MW-thermal in agricultural applications and 200 MW-thermal in industrial applications, mainly from high temperature fields. These values were based on a 35°C discharge temperature. About 5000 MW-thermal for agricultural applications was reported as being associated with a large acreage of greenhouses in the Soviet Union. However, in the survey reported

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here (Gudmundsson & Palmason 1981) it was shown that the above 5000 MW-thermal was grossly overestimated. At the same time all the low-temperature waters used in Japan (estimated as 4475 MW-thermal above 15°C in the present survey) were omitted by Howard (1975a). A more detailed presentation of the same study is that of Howard (1975b). Barbier & Fanelli (1975) updated and expanded the above study and showed that the total capacity associated with nonelectrical application was about 6200 MW-thermal. By assuming that nonelectrical applications have an efficiency of 85% this value was raised to 7300 MW-thermal. Again, the Barbier & Fanelli (1977) study was faulted because of the anomalous high value for the Soviet Union.

The most recent available review of geothermal energy is that of Fanelli & Taffi (1980). Although they give no new information on the amount of geothermal energy used in direct use or nonelectrical applications, they review the status of exploration and exploitation in the world. Other relevant material includes an extensive list of thermal springs of the world given by Waring et al. (1965).

METHOD OF SURVEY

The survey was conducted by sending a questionnaire to all the countries known or thought to have low-temperature geothermal resources. The information requested was the following:

"1. Present utilization. A list showing uses of low-temperature geothermal energy in various fields. Specify flowrates and temperatures (entering and leaving installation) of the geothermal waters used and give information about the type of installation (district heating, greenhouses, baths, etc.) utilizing the waters. Information on the available (but not used today) geothermal waters should also be included.

"2. Past and future utilization. A list showing uses of low-temperature waters in recent years and scheduled expansion (where financing is available or being arranged) of present and future uses in the next few years. Specify flowrates and temperatures (entering and leaving installation) of the geothermal waters and give information about the type of installation utilizing the waters.

"3. Exploration projects. A list showing national and local programs and activities in the exploration of low-temperature fields which are still in the predrilling stage. Indicate present status of exploration.

"4. Regional assessment. A list showing resource base or total potential of low-temperature fields in your country if such assessments have been made."

The questionnaire was sent to 41 countries and replies were received from 29. Information was gathered from 7 other countries through meetings. The literature was consulted for data on 10 additional countries and where no reply had been received. The total number of countries was 58. The data gathering exercise proved on the whole to be successful although almost no information was received on past and future utilization. The replies reported mainly on present utilization and exploration.

In the survey the main countries utilizing low-temperature geothermal energy were dealt with in more detail than some others. And because new extensive data were being presented for several of these countries it was decided to write special notes on China (People's Republic), France, Hungary, Iceland (Gudmundsson 1982), Japan and the U.S.S.R. These include sections on geography, utilization, exploration and assessment. A short bibliography was also included. Information on other countries than the six mentioned above was written as individual sheets in the same manner but more concisely. Over 100 references were consulted in the survey (Gudmundsson & Palmason 1981). After the survey was completed, updated information was received from China (Xin Kuide), Hungary (Tibor Boldizsar), U.S.A. (Marshall Reed) and Yugoslavia (Neven Miosic). At the same time the results of the survey were confirmed by many of the other countries. The information presented here should show the status at the end of 1980.

RESULTS OF SURVEY

An overall view of the results of the survey is presented in Table 1. It shows in alphabetical order the 58 countries covered by the survey. The table shows what countries are known to have low-temperature geothermal resources and indicates the presence or absence of utilization, exploration and assessment within the following restrictions or definitions:

Utilization. This term is used if low-temperature geothermal waters are used for other purposes than simple bathing and washing at natural hot springs. This restriction is necessary to demonstrate which countries have put effort into drilling and distribution systems to serve a thermal market. Of the 44 countries known to have low-temperature resources, only 12 are reported to utilize them.

Exploration. This term applies if other measurements than heat flow have been carried out in prospective geothermal fields. The contention here is that only explicit geothermal prospecting or drilling constitutes exploration. Table 1 shows that 24 countries are involved in exploration work for low-temperature geothermal resources.

Assessment. This term is more difficult to define than utilization and exploration. For the purpose of the survey an assessment was said to have been carried out in a country if the hot water resources of a major geothermal region had been estimated. The table shows that 9 countries had carried out such assessment studies.

In the questionnaire, countries were primarily asked to report the flowrate and inlet/outlet temperatures of geothermal water presently being used. These data were to give the useful thermal power associated with all known geothermal installations and in turn the thermal energy used, if the load

TABLE 1.
An overview of the countries included in the world survey of low-temperature geothermal energy utilization (Gudmundsson and Palmason, 1981).

	Countries	Resources	Utilization	Exploration	Assessment
1	Algeria	+	-	-	-
2	Argentina	+	-	+	.
3	Australia	+	-	-	-
4	Austria	+	+	+	-
5	Bolivia	+	-	.	.
6	Brazil	+	-	.	.
7	Canada	+	-	-	-
8	China	+	+	+	.
9	Colombia	+	-	+	-
10	Costa Rica	.	.	.	.
11	Czechoslovakia	+	+	+	+
12	Denmark	-	-	-	-
13	Djibouti	.	.	.	.
14	Ecuador	+	-	.	.
15	Egypt	+	-	.	.
16	Eire	+	-	+	.
17	El Salvador	.	.	.	.
18	Fiji	+	-	+	-
19	France	+	+	+	+
20	Germany, East	.	-	-	-
21	Germany, West	+	.	+	.
22	Greece	+	-	-	-
23	Guatemala	.	.	.	.
24	Haiti	.	.	.	.
25	Honduras	.	.	.	.
26	Hungary	+	+	+	+
27	Iceland	+	+	+	+
28	India	+	-	+	.
29	Indonesia	+	-	-	-
30	Israel	+	-	.	.
31	Italy	+	+	+	+
32	Jamaica	.	.	.	.
33	Japan	+	+	+	+
34	Kenya	.	.	.	.
35	Korea, North	+	.	+	-
36	Korea, South	+	-	.	.
37	Mexico	+	-	-	-
38	Netherlands	+	-	+	-
39	New Zealand	+	-	-	-
40	Nicaragua	+	-	-	.
41	Nigeria	.	.	.	.
42	Panama	.	.	.	.
43	Peru	+	-	.	.
44	Philippines	.	.	.	.
45	Poland	+	-	+	-
46	Romania	+	+	+	+
47	Solomon Islands	+	-	-	-
48	Sweden	+	-	-	-
49	Switzerland	+	-	+	.
50	Tanzania	+	-	.	.
51	Thailand	+	-	+	.
52	Turkey	+	-	-	-
53	Uganda	+	.	.	.
54	USSR	+	+	+	+
55	UK	+	-	+	-
56	USA	+	+	+	+
57	Venezuela	.	.	.	.
58	Yugoslavia	+	+	+	.
	Total	44 +	12 +	24 +	9 +

+ = Known (Present) - = Unknown (Absent) . = No information

factor was known. It would then take a simple calculation to arrive at the tonnes oil/coal equivalent. When the replies were received, however, it became clear that this kind of information was not available except in rare instances. It could therefore not form a common basis for a worldwide survey.

Typical data was the flowrate and temperature from one well or a field but not what was being used in installations. It was therefore found convenient to report the data in terms of thermal power available for utilization. And because most of the thermal waters are reported used, it also represents the installed thermal capacity associated with low-temperature geothermal resource utilization.

Of great interest in the survey was the total installed thermal power of the countries utilizing geothermal energy in the world. Table 2 (column A) shows the total installed capacity of the 12 countries listed in Table 1 as having utilization other than hot springs used only for bathing and washing. Japan is clearly the largest user of low-temperature waters with 4475 MW-thermal installed above 15°C. Table 2 (column A) shows also that Hungary is the second largest user with 1540 MW-thermal and Iceland third with 1127 MW-thermal. China, Italy, the United States and the Soviet Union form a group of countries using hundreds of MW-thermal while Czechoslavakia, France, Romania and Yugoslavia use tens of MW-thermal. A surprising result of the survey was the large amount of geothermal water used for bathing in Japan. Information from several sources confirmed that the bulk of low-termperature waters produced there are used for bathing. It was estimated that 81 MW-thermal are used in space and and water heating, greenhouses and animal husbandry. Also, an examination of the data from Hungary showed that 38% of the installed thermal power was used for bathing purposes. It was therefore decided to estimate the installed geothermal power in the world not associated with bathing. The result is shown in Table 2 (column B) and amounts to 3468 MW-thermal. About 60% of the total world uses of low-temperature geothermal resources is therefore used for bathing, balneology and swimming.

It is opportune at this point to explain why the temperature limit of 15°C was used in the survey. When geothermal water cools down at ambient conditions it gradually approaches the temperature of its surroundings. It follows that the maximum amount of energy that can be extracted from geothermal water corresponds to its cooling to the average ambient temperature. The average annual temperature at the surface of the earth is reported to be close 15°C. This temperature was therefore used when considering geothermal energy on a worldwide basis. The average annual temperature in each country or region would be a better reference temperature in future and more detailed surveys. A remaining problem is to estimate the useful thermal power and energy associated with geothermal applications in the absence of actual measurements. From the data used in the survey it appears that a reference temperature of 35°C would be appropriate for most low-temperature applications.

TABLE 2
World uses of low-temperature geothermal resources in 1980, expressed as thermal power above 15°C.

Country	Thermal power (MW)			
	A	(%)	B	(%)
Austria	5	(0.1)	5	(0.1)
China	346	(4.0)	329	(9.5)
Czechoslovakia	43	(0.5)	43	(1.2)
France	56	(0.6)	56	(1.6)
Hungary	1540	(17.7)	959	(27.7)
Iceland	1127	(13.0)	1096	(31.7)
Italy	265	(3.1)	73	(2.1)
Japan	4475	(51.4)	81	(2.3)
Romania	36	(0.4)	36	(1.0)
U.S.A.	225	(2.6)	221	(6.4)
U.S.S.R.	555	(6.4)	555	(16.0)
Yugoslavia	14	(0.2)	14	(0.4)
Total	8687	(100.0)	3468	(100.0)

A: All utilization as defined in text.
B: Utilization excluding bathing.

CONCLUDING REMARKS

The worldwide survey reported here is probably the first of its kind. While several surveys have been done on geothermal electric power generation, nonelectrical low-temperature uses have not received much attention. It is, however, interesting to note that about the same number (12) of countries were involved in low-temperature direct uses as in high-temperature electric power generation in 1980 (Bolton 1981). As of May 1980 the installed electric generating capacity of the world was 2462 MW-electrical.

It was found here that about 8700 MW-thermal above a 15°C reference temperature are installed in the 12 main low-temperature countries. The low-temperature geothermal fluids used for other purposes than bathing and similar uses amounted to 3500 MW-thermal (above a 15°C reference temperature) at the end of 1980. The survey has shown new data on the type of use to which low-temperature resources are used. Instead of 5000 MW-thermal used for agricultural applications in the Soviet Union, as previously reported, it reports on nearly 4400 MW-thermal associated with bathing applications in Japan. This example perhaps demonstrates that surprising aspects on the utilization of low-temperature geothermal energy may yet come to light. An important contribution of this survey is the data from the People's Republic of China. It was found that about 350 MW-thermal are installed in several locations being used in traditional applications of thermal waters.

An important result of the survey was information on the worldwide availability of geothermal resources. It was reported that 44 countries have known low-temperature resources. This is a conservative number by the nature of the survey--it appears that geothermal resources are to be found in most countries of the world. In this respect it should be noted that a large number of countries have potential geothermal resources in sedimentary basins not considered important in past years. The examples of Hungary and France are now being followed worldwide in an effort to exploit geothermal energy in such environments.

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