ORKUSTOFNUN

World survey of low-temperature geothermal energy

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WORLD SURVEY OF LOW-TEMPERATURE GEOTHERMAL ENERGY

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INTRODUCTION

The present Survey was carried out at the request of the Technical Panel on Geothermal Energy of the Preparatory Committee for the United Nations Conference on New and Renewable Sources of Energy. At the first session of the Technical Panel in New York 10-14 December 1979 there were made several recommendations on work to be carried out before its second meeting (in Geneva 3-7 November 1980). Recommendation B was the following:

"That a survey for low-temperature fields be undertaken to include:
a) A table listing uses of low-temperature geothermal energy in various countries, based on available sources and perhaps summarized in some cases. Capacity should be included ;
b) Graphs illustrating increase with time, by countries, where available ;
c) A list of exploration projects. These are probably less well defined in many cases than those for high-temperature fields, which are more confined to limited areas. Compiling this list may therefore not be practical ;
d) An account of regional assessments of low-temperature fields, where such assessments have been made".

At the request of the Panel it was agreed by G. Pálmason, the representative of Iceland on the Technical Panel, that Iceland should carry out the above recommendation. The Technical Panel made in all 12 recommendations which the 9 countries represented on the Panel agreed to carry out.

One of the contributions of New Zealand to the preparatory work of the Technical Panel on Geothermal Energy was to carry out Recommendation A of the Panel, which was a similar survey of high-temperature geothermal fields. It was decided convenient by the Panel for the purpose of these two surveys to use 180°C as the temperature limit dividing high- and low-temperature fields. A low-temperature geothermal field in the present Survey is therefore defined as having a (measured) base or subsurface temperature below 180°C. It should be stressed that this temperature limit is only a demarcation for the two respective surveys and does not necessarily define high- and low-temperature fields.

This World Survey of Low-Temperature Geothermal Energy was carried out by the Geothermal Division of Orkustofnun, the Iceland Energy Authority. To compile the Survey has taken about 3 man-months, all staff and funds being provided by Orkustofnun. It was decided to make the Survey as complete as possible and to make the information collected easily accessible to everyone. For this reeason there were written separate Notes or Sheets on each country. It is hoped that this will enable the Technical Panel to make better use of the Survey in the preparation of its final report. All of the written material of the Survey is stored in the Orkustofnun Library. This Survey would of course not have been possible without the cooperation of numerous people in the various countries. All recipients of the questionnaire who replied are hereby thanked for taking part in the Survey. It is the intention of Orkustofnun to send all the participants a copy of the present Note and any other relevant material if requested.

PREVIOUS REVIEWS

It was not found possible in the present Survey to illustrate how the utilization of low-temperature geothermal energy has increased with time. Such data was not provided by the countries taking part in the Survey although it was requested. Any historical trend in utilization must therefore, for the time being, be based on the literature and previous reviews in particular. There are however difficulties that arise because of the frame of reference of this Survey. Most available reviews differentiate between electrical and non-electrical applications (direct uses) but not high- and low-temperature fields. In many instances these coincide but not always. An important consideration must also be the completeness of previous surveys or indeed the present one. It was felt that due to the many uncertainties involved it would be meaningless to illustrate the assumed or estimated growth in low-temperature utilization with time. This information is probably known in a few countries although not available in the present survey.

Almost 20 years have now passed since the U.N. Conference on New Sources of Energy was held in Rome in 1961. It was the first significant meeting where geothermal energy was presented as a viable resource. Within 10 years the U.N. Symposium on the Development and Utilization of Geothermal Resources was held in Pisa in 1970. In the Proceedings of the Symposium Facca (1970) presented "The Status of World Geothermal Development" and Einarsson (1970) reviewed the "Utilization of Low Enthalpy Water for Space Heating, Industrial, Agricultural and Other Uses". These two papers should be viewed as the starting point of the present Survey. Within 5 years the Second U.N. Symposium on the Development and Use of Geothermal Resources was held 1975 in San Francisco. At this Symposium the "Present Status of Resources Development" was summarized by Muffler (1975) and a paper on the "Present Status of World Geothermal Development" was presented by the United Nations, Energy Section, Centre for Natural Resources, Energy & Transport (1975). These two reviews presented the status of high- and low-temperature geothermal programmes country by country. These two above papers were updated by Meitav et. al. in 1977.

An important paper by Howard (1975a) was presented in San Francisco on the "Principal Conclusions of the Committee on the Challenges of Modern Society Non-electrical Applications Project". This has since become a widely quoted reference (review) on non-electrical applications within various countries. It showed 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. It is understood that these values are based on 35°C discharge temperature. About 5000 MW-thermal for agricultural applications was reported as associated with large acreage of greenhouses in the U.S.S.R. However, as shown in Note JSG-80/04 of the present Survey, the above 5000 MW-thermal in the Soviet Union are grossly overestimated. At the same time all the low-temperature geothermal waters used in Japan (estimated as 4475 MW-thermal above 15°C in the present Survey) were omitted in the paper by Howard (1975a). A more detailed presentation of the same study is a Lawrence Livermore Laboratory "Present Status and Future Prospects for Nonelectrical Uses of Geothermal Resources" edited by Howard (1975b). In an excellent paper "Non-Electrical Uses of Geothermal Energy" by Barbier & Fanelli (1977) the above study is updated and expanded and shows the total capacity associated with non-electrical applications to be about 6200 MW-thermal. By assuming that non-electrical applications have an efficiency of 85% this value was raised to 7300 MW-thermal. Again, this study is faulted by the anomalous high value for the Soviet Union.

The E.P.R.I. (Electric Power Research Institute) report "Geothermal Energy Prospects for the Next 50 Years" from 1978 has useful sections on Non-electric Uses and Recent International Developments. Its table on Present Nonelectric Applications of Geothermal Energy is basically that of Howard (1975 a & b) and does therefore not differentiate between high- and low-temperature geothermal fields. The table shows, however, some additional information that was obtained by a questionnaire in the study. It is estimated in the E.P.R.I. report that the total energy use rate in non-electric applications amounts to 7000 MW-thermal. The most recent available review of geothermal energy is the paper "Status of Geothermal Research and Development in the World" by Fanelli & Taffi (1980) presented at the 26th. International Geological Congress in Paris. While it gives no new information on the amount of geothermal used in non-electric applications, it reviews the status of exploration and exploitation in the world. It also has most useful sections on geothermal areas and systems.

An extensive listing of thermal springs of the world is that of Warring et. al. (1965). In 1976 there was an "International Congress on Thermal Waters, Geothermal Energy and Vulcanism of the Mediterranean Area". Useful books on geothermal energy are "Chemistry and Geothermal Systems" by Ellis & Mahon (1977) and "Geothermal Energy" by Armstead (1978). A recent book "Geothermal Energy as a Source of Electricity" by DiPippo (1980) is an extensive worldwide survey of the design and operation of geothermal power plants.

METHOD OF SURVEY

Information for the Survey was obtained by sending a questionnaire to all the countries known or suspected of having low-temperature geothermal fields. Several countries were however unfortunately excluded because it was not known to whom to send the questionnaire. The individuals to whom the questionnaire was sent were either known to Orkustofnun staff as being responsible for geothermal matters in their country or their names were taken from papers presented at the San Francisco symposium in 1975. In several instances the questionnaire was sent to individuals not directly involved in national geothermal programmes, but that had to be done for the lack of better information. In the case of India and the Soviet Union, because it was not known who was the right recipient of the questionnaire, it was decided to contact more than one individual. For some countries there was an opportunity to meet directly with geothermal people involved in national programmes.

A covering letter was sent with the questionnaire. These letters were similar but each written specifically to address the matter of the Survey as appropriate in every country. A general covering letter was also prepared to cater for situations where Orkustofnun staff had the opportunity to meet representatives of national geothermal programmes at conferences or visits to their country.

Appendix A shows some material relevant to the method of the Survey. The first table shows a listing of the countries and individuals to whom the questionnaire was sent, including dates of sending and reply, and a very brief comment on the reply as it related to the Survey. Next in Appendix A are the covering letter and the questionnaire. The letter gives a general background to the Survey while the questionnaire spells out the specific questions. The questionnaire was of course designed to obtain the information asked for in Recommendation B of the Technical Panel on Geothermal Energy. The last item in Appendix A is a list of names and addresses of the recipients of the questionnaire and a few other individuals. It is hoped that this list will aid in further information gathering.

From the outset of this Survey it was clear that the main countries utilizing low-temperature geothermal energy had to be dealt with more fully than some of the others. It was also known that some of the main countries have good information on their geothermal involvement. For these reasons and also because new data was being presented for several of the main low-temperature geothermal countries, it was decided to write Orkustofnun Notes on China (People's Republic), France, Hungary, Iceland, Japan and the U.S.S.R. It was felt that Orkustofnun could contribute more information for these countries than some of the others. These Notes are in Appendix B. Each Note has a section on: Geography ; Information ; Utilization ; Exploration and Assessment. A Bibliography is also included. The Notes are written in such a way as to be used individually if required. It is hoped that this will, for example, help in updating the information later.

In the present Survey an emphasis has been placed on estimating the installed capacity of geothermal installations. This is what was asked for in Recommendation B of the Technical Panel. It also happens to be the quantity which is probably the least difficult to measure or estimate for low-temperature geothermal fields.

Information on other countries than the six mentioned above, was written as individual Sheets. These are in Appendix C in alphabetical order. Most countries are compiled individually except for Africa, Central America, South America and West Indies. The sheets are written in the same manner as the Notes in Appendix B except not as detailed. Together the Notes and Sheets constitute the World Survey of Low-Temperature Geothermal Energy as compiled by Orkustofnun.

RESULTS OF SURVEY

It is probably true to say that geothermal energy is to be found in most countries of the world. With time it has become less of a novelty and now it is widely recognized as a viable resource. The Survey shows clearly that more countries than previously anticipated have geothermal potential both high- and low-temperature. This is particularily true for low-temperature areas since high-temperature ones are by nature more noticeable at the surface.

An overview of the results of the Survey are presented in Table 1. It shows in alphabetical order the countries to which a questionnaire was sent (48 in all) and also 10 other countries about which information was obtained. Table 1 indicates the countries that have low-temperature geothermal resources and gives information on Utilization, Exploration and Assessment within the following restrictions or definitions: Utilization is said to take place in a country if low-temperature geothermal waters are used for other purposes than simple bathing at natural hot springs. The use of hot springs for balneological purposes does therefore not constitute utilization in the restricted meaning of the present Survey. This restriction is necessary to bring out what countries have put effort into drilling and distribution systems to serve a thermal market. Table 1 shows that out of the 44 countries known to have low-temperature geothermal energy, only 11 are reported to utilize it ; Exploration is said to take place in a country if other measurements than heat flow are carried out in prospective geothermal fields. It is the contention here that only explicit geothermal prospecting or drilling constitutes exploration. Table 1 shows that 23 countries are involved in exploration work for low-temperature geothermal. It shows that about 1/2 the countries with known and reported low-temperature fields are involved in exploration of the resource ; Assessment is more difficult to define here than Utilization and Exploration. For the purpose of this Survey an assessment is said to have been carried out in a country if the hot water resource of a major geothermal area has been estimated. Table 1 shows that 9 countries have carried out assessment studies. These are basically the same countries that are involved in utilization. For more detailed information about exploration and assessment in the various countries a reference should be made to Appendices B and C.

Of great interest in this Survey must be the total installed capacity of the world. Based on the above definition of what constitutes utilization of low-temperature geothermal energy it was possible to compile Table 2. It shows the total installed capacity of the 11 countries listed in Table 1 that have other utilization than just hot springs for bathing etc. Japan is clearly the largest user of low-temperature geothermal waters with 4475 MW-thermal installed above 15°C. The thermal power for Italy above 15°C and 40°C was estimated from the above 0°C value by assuming 90°C as the initial temperature. Table 2 shows that Hungary is the second largest user of low-temperature geothermal with 1166 MW-thermal above 15°C. This Hungarian value is based on Note JSG-80/05 that illustrates the situation in 1976 as it was suggested to be the best available value because limited developments had taken place in recent years. Now, however, new information has been made available by Boldizsár (1980) in a Note to the U.N. Economic Commission for Europe. It shows that in 1979 the total installed capacity above 15°C amounted to 1540 MW-thermal or about 1/3 higher than shown in Table 2. This is indeed a significant increase from 1976. However, since this new information is limited to only one of many values representative of the extensive utilization of low-temperature geothermal in Hungary, it is not possible to incorporate it into the present Survey without further data. It should therefore be kept in mind that the present installed capacity in Hungary is probably greater than shown in Table 2.

It is perhaps opportune to mention why the temperature limits of 0°, 15° and 40°C are used in Table 2 and most other tables of the Survey. They were initially (when work on the Survey started) selected to represent the likely lower limit of 40°C to which geothermal waters tend to be cooled down to during utilization. As work on the Survey progressed, however, it became apparent that a temperature limit of 35°C would in most cases be more appropriate. As shown in the Note on Iceland in Appendix B, for example, the Reykjavík District Heating Service estimates 36°C as the average discharge temperature in district heating. It is therefore recommended here that in future surveys the temperature limit should be 35°C when considering the thermal power required by the user. When geothermal water cools down at ambient conditions it will gradually approach the temperature of its surroundings. It follows that the maximum amount of energy that can be extracted from geothermal water corresponds to cooling it to the average temperature at the location. The average temperature at the surface of the earth is reported to be close to 15°C. This temperature limit has therefore been used when considering geothermal energy on a world-wide basis. It is the view of the present authors that the annual average temperature in each country or area should be used when estimating the capacity of geothermal fields and installations. The average temperature of the Reykjavík area is close to 5°C and now this temperature limit is being introduced as the standard reference for installed geothermal power in Iceland.

The lowest temperature limit of 0°C in Table 2 and elsewhere can be considered as an extreme value applicable only in very harsh climate. It does not serve a useful purpose in this Survey but is included here for consistency with the various Notes and Sheets in Appendices B and C.

Table 2 shows the total installed low-temperature geothermal in the 11 countries that utilize it for other purposes than bathing in hot spring areas. An examination of the information in Appendices B and C shows that most of the geothermal waters used in Japan is for bathing and related purposes. Such an examination does also show that 38% of the installed thermal power above 15°C in Hungary is associated with baths corresponding to 48% of the energy used. This appears a surprisingly large percentage of the total. Table 3 was therefore compiled, showing the installed thermal capacity associated with other uses than bathing. Installed geothermal power not used but available has also been excluded from Table 3 to show the actual capacity utilized.

The world total above 15°C decreases from 8008 MW-thermal in Table 2 to 2644 MW-thermal in Table 3. In other words, about 2/3 of the total installed low-temperature geothermal power is associated with bathing, balneology and swimming. Table 3 shows that Iceland is the largest user of low-temperature geothermal energy in the world if bathing and such is excluded.

CONCLUDING REMARKS

This World Survey of Low-Temperature Geothermal Energy has shown that over 8000 MW-thermal above 15°C reference temperature are installed in the 11 main low-temperature geothermal countries. It should be noted that only those countries that use low-temperature geothermal for other purposes than bathing in hot spring areas are included in the above value. The most recent review of non-electrical applications that is available and includes both high- and low-temperature geothermal shows that 7300 MW-thermal above 35°C reference temperature as installed 1977. It has not been attempted here to investigate how much of this could have been attributed to low-temperature sources. It is of interest that the present Survey shows that about 2/3 of the total installed geothermal capacity of the world is associated with bathing and similar uses. Thermal waters not used but installed and available are also included in this value. The low-temperature geothermal fluids used for other purposes than bathing amount to 2644 MW-thermal over 15°C reference temperature.

While the present Survey does not show how the total installed thermal capacity of low-temperature geothermal has increased with time, except by simple comparison with results of other surveys, it does show new data on the type of use to which the resource is applied. Instead of 5000 MW-thermal for agricultural applications in the Soviet Union it reports on nearly 4400 MW-thermal associated with bathing applications in Japan. This is a major shift in emphasis although the total megawatts have not increased dramatically. This example does perhaps demonstrate that low-temperature geothermal may have other surprises yet to be made known. An important contribution of this Survey are the data from the People's Republic of China. It was found that over 150 MW-thermal are installed in several locations and are being used for most known uses of geothermal.

An examination of the various Notes and Sheets will show that a large number of countries have potential geothermal resources in sedimentary basins not considered of importance in past years. The examples of Hungary and France are now being followed world-wide in an effort to exploit geothermal in sedimentary basins.

BIBLIOGRAPHY

Waring, G.A., Blankenship, R.R. & Bentall, R., 1965: Thermal Springs of the United States and Other Countries of the World - A Summary. U.S. Geological Survey Professional Paper 492, 383 p.

Facca, G., 1970: The Status of World Geothermal Development. Pisa, 1, 8-23.

Einarsson, S.S., 1970: Utilization of Low Enthalpy Water for Space Heating, Industrial, Agricultural and Other Uses. Pisa, 1, 112-121.

Muffler, L.J.P., 1975: Present Status of Resource Development. San Francisco, xxxiii-xliv.

United Nations, Energy Section, Centre for Natural Resources, Energy & Transport, 1975: Present Status of World Geothermal Development. San Francisco, 3-9.

Howard, J.H., 1975a: Principal Conclusions of the Committee on the Challenges of Modern Society Non-electrical Applications Project. San Francisco, 2127-2139.

Howard, J.H. (editor), 1975b: Present Status and Future Prospects for Nonelectrical Uses of Geothermal Resources. Lawrence Livermore Laboratory, UCRL-51926 & NATO-CCMS Report No. 40, 162 p.

National Technical University of Athens, 1976: Proc. Int. Cong. Thermal Waters, Geothermal Energy Vulcanism Mediterranean Area. Athens.

Meidav, T., Sanyal, S. & Facca, G., 1977: An Update of World Geothermal Energy Development. Geothermal Energy Magazine, 5(5), 30-34.

Barbier, E. & Fanelli, M., 1977: Non-Electrical Uses of Geothermal Energy. Prog. Energy Combust. Sci., 3, 73-103.

Electric Power Research Institute, 1977: Geothermal Energy Prospects for the Next 50 Years. ER-611-SR.

Ellis, A.J. & Mahon, W.A.T., 1977: Chemistry and Geothermal Systems. Academic Press, 392 p.

Armstead, H.C.H., 1978: Geothermal Energy: Its past, present and future contribution to the energy needs of man. E. & F.N. Spon, London, 357 p.

DiPippo, R., 1980: Geothermal Energy as a Source of Electricity. U.S. Department of Energy, DOE/RA/28320-1, 370 p.

Fanelli, M. & Taffi, L., 1980: Status of Geothermal Research and Development in the World. 26th. Int. Geol. Cong. (Published in: Revue de l'Institut Francais du Pétrole, XXXV, 429-448).

Boldizsár, T., 1980: Low and Medium Temperature Geothermal Resources of the Pannonian Basins in Hungary and Adjoining Countries. U.N. Economic Commission for Europe Seminar on Technologies Related to New Energy Sources. 8-12 December 1980, Jülich.

TABLE 1

Countries included in the Survey and an overview of their activity regarding low-temperature geothermal energy. See text for definitions

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

\+ = Known
– = Unknown
... = No information

TABLE 2

Total installed low-temperature geothermal power in countries with other utilization than just hot springs. [x]

Country	Thermal power (MW)		
	>0°C	>15°C	>40°C
Japan	...	4475	...
Hungary	1523	1166	690
Iceland	1378	1141	757
U.S.S.R.	669	555	364
Italy	318	~265	~177
China	257	151	24
U.S.A.	...	~115	...
France	74	56	25
Czechoslovakia	59	43	21
Romania	47	36	22
Austria	7	5	4
Total	...	8008	...

[x] See text for details.

TABLE 3

Utilized low-temperature geothermal power excluding bathing. [x]

Country	Thermal power (MW)		
	>0°C	>15°C	>40°C
Iceland	1118	932	632
Hungary	808	619	366
U.S.S.R.	669	555	364
China	247	144	21
U.S.A.	...	~111	...
Japan	103	81	44
Italy	88	~73	~49
France	74	56	25
Romania	47	36	22
Czechoslovakia	49	35	21
Austria	3	2	1
Total	...	2644	...

[x] See text for details.

APPENDIX A

Material Relevant to Method of Survey

A1. Countries and individuals

A2. Covering letter

A3. The questionnaire

A4. Addresses

Countries and individuals contacted, dates and comment on reply

	Country	Name	Questionnaire	Reply	Comment
1	China	Xin, K.	80.01.17	80.03.05	Met by IBF
2	New Zealand	Bolton, R.S.	80.02.08	80.03.12	Satisfactory
3	Italy	Ceron, P.	80.02.11	80.03.20	Extensive
4	U.S.A.	Brownlee, R.R.	80.02.11	80.03.19	Not satisfactory
5	U.S.A.	Muffler, P.	...	80.06.12	Reed: Extensive
6	U.S.A.	Lienau, P.T.	80.06.05	80.06.30	Extensive
7	Algeria	Khelif, B.	80.02.11	80.03.23	Limited
8	Poland	Dowgiallo, J.	80.02.11	80.03.20	Good
9	Yugoslavia	Miosic, N.	80.02.08	-	-
10	Yugoslavia	Galovic, S.	80.09.17	80.10.14	More to come
11	Hungary	Balogh, J	80.02.11	80.03.30	Satisfactory
12	Hungary	Boltizsár, T.	80.02.12	80.03.05	Satisfactory
13	Kenya	Wairegi, W.J.	80.02.12	80.06.13	Kinyariro: Limited
14	Japan	Takashima, I.	80.02.12	80.03.21	Good
15	Mexico	Marcado, S.	80.02.12	80.03.15	Satisfactory
16	Indonesia	Akil, I.	80.02.12	80.02.26	Limited
17	Israel	Rappaport, A.	80.02.12	-	-
18	Czechoslovakia	Cermak, V.	80.02.12	80.04.29	Satisfactory
19	Austrália	Cull, J.P.	80.02.12	80.02.22	Good
20	Romania	Manilici, A.	80.02.12	-	-
21	Austria	Zötl, J.G.	80.02.12	80.03.28	Good
22	West Germany	Kappelmeyer, O.	80.02.19	-	-
23	France	Varet, J.	80.02.19	-	Met by JSG later
24	U.S.S.R.	Gutsalo, L.K.	80.02.18	80.03.18	No information
25	U.S.S.R.	Mislin, G.A.	80.02.18	-	-
26	U.S.S.R.	Gavlina, G.B.	80.02.18	-	-
27	U.S.S.R.	Kononov, V.I.	80.02.18	80.03.25	Good
28	U.S.S.R.	Kutateladze, S.S.	80.02.19	80.03.27	Limited
29	U.S.S.R.	Pampura, V.D.	80.02.19	-	-
30	Djibouti	Abdallah, A.	80.02.18	-	Met by AB
31	Fiji	Plummer, H.	80.02.19	80.03.18	Satisfactory
32	Canada	Jessop, A.M.	80.02.19	80.02.20	Good
33	Greece	Papastamataki,	80.02.20	80.04.25	Fytikas: Satisfactory
34	Argentina	Fernandez, A.	80.02.20	80.03.13	Limited
35	Philippines	Vasquez, N.C.	80.02.20	80.03.11	Limited
36	Turkey	Alpan, S.	80.02.20		
37	Denmark	Balling, N.	80.02.20	80.04.08	Saxov: Satisfactory
38	Sweden	Eriksson, K.G.	80.02.20	80.04.03	Satisfactory
39	Nigería	Nwachukwu, S.	80.02.20	-	-
40	England	Garnish, J.D.	80.02.20	80.04.24	Good
41	India	Sabnavis, M.	80.02.20	-	-
42	India	Sabramanian, S.A.	80.04.10	-	-
43	India	Raymahashay, B.C.	80.04.11	80.05.02	Satisfactory
44	India	Krishnaswamy, V.S.	80.04.10	-	Sent him telex 80.05.28
45	India	Gupta, M.L.	80.04.11	80.05.29	Satisfactory
46	Ecuador	Ortiz, E.A.	80.04.11		Terán: Limited
47	El Salvador	Cueller, G.	80.04.11	-	Should contact G.N. Iraheta
48	Haiti	Rigand, J.G.	80.04.11	-	-
49	Columbia	Echeverry, G.A.C.	80.04.11	80.06.10	Satisfactory
50	Jamaica	Hay, W.	80.04.11	-	-
51	Venuzuela	Lezama, C.J.	80.04.11	-	Should contact M. Mendez
52	Peru	Arnao, B.M.	80.04.11	-	-
53	East Germany	Hurtig, E.	80.04.16	80.05.15	Limited
54	Honduras	Flores, R.	-	-	Met by IBF & SSE
55	Panama	Pascal V, J.	-	-	"
56	Costa Rica	Corrales V, M.F.	-	80.03.23	" : Limited
57	Nicaragua	Martinez Tiffer, E.J.	-	-	"
58	Guatemala	Bethancourt, R.	-	-	"
59	Netherlands	Prins, S.	-	80.03.13	Met by JSG: Satisfactory
60	Switzerland	Rybach, L.	-	80.04.14	" : Good

ORKUSTOFNUN
NATIONAL ENERGY AUTHORITY

Our date | Our ref.
Your date | Your ref.

Dear colleague:

You may know that the United Nations have decided to convene an International Conference on New and Renewable Energy Sources to take place in 1981 in a developing country. In order to prepare this conference and to ensure the active participation of the international community the UN decided to form several panels of experts nominated by governments. These panels will address the principal renewable energy sources such as: solar geothermal and hydropower. One of the Technical Panels is on Geothermal Energy. As the representatives of Iceland on that panel we have been asked to compile a World Survey of Low Temperature Geothermal Fields as a contribution to the preparatory work for the second meeting of the panel scheduled later this year.

To compile this world survey we are writing to you for information about your country. Enclosed is the questionnaire of the survey. Your assistance in this matter will be highly appreciated. Unfortunately there is limited time and we must ask you to send the requested information no later than March 31, 1980 for it to be included in the survey. When the survey is completed all contributors will be sent a copy.

With kind regards.

Yours faithfully,

J.S.Gudmundsson

Dr. J.S.Gudmundsson
Geothermal Division

8

UNITED NATIONS CONFERENCE ON NEW AND RENEWABLE SOURCES OF ENERGY

World Survey of Low-Temperature Geothermal Energy

In this survey a low-temperature geothermal field is defined as having a base or subsurface temperature of less than 180°C. The information required for each geothermal field should include 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 to-day) 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 finance is available or being arranged) of present and future new 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/or local programmes and activities in the exploration of low-temperature fields which are still in the pre-drilling 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.

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APPENDIX B

Orkustofnun Notes

B1. Union of Soviet Socialist Republics

B2. Hungary

B3. People's Republic of China

B4. France

B5. Japan

B6. Iceland

ICELAND ENERGY AUTHORITY

Geothermal Division
1980-07-22

Note
JSG-80/04
gss

UNION OF SOVIET SOCIALIST REPUBLICS: Survey of Low-Temperature Geothermal Energy

Geography

Area 22,740,000 km^2

Population 260,000,000 (1977)

Information

The questionnaire was sent to six individuals in the USSR. Replies were received from three of these. Kutateladze replied in Russian and gave information on the 750 kW binary plant at Paratunski. Gutsalo said he worked in geochemistry and had no information on utilization. Kononov with I.M. Duvorov and V.I. Dvorov sent a good reply - it appears that the Scientific Council on Geothermal Studies of the Academy of Sciences of the USSR is the correct institution to contact for information on geothermal energy. Several papers were consulted for background information.

Utilization

Almost all published (Barbier & Fanelli 1977, Howard 1975) values on geothermal utilization in the USSR are based on papers by Soviet authors at the 1970 U.N. Symposium in Pisa. District heating being reported 114 MW thermal and greenhouses 5000 MW thermal. The latter value was derived indirectly from average energy requirements (0.2 kW/m^2) of greenhouses and reported area of "hotbeds and hothouses" (5000 x 5000 25,000,000 m^2) at Makhachkala. However, the stated area (or a small part of it) was heated only by one borehole discharging 1800 m^3 per 24 hours of 63°C geothermal water, corresponding to 48 MW if cooled down to 40°C. The estimated 5000 MW were therfore 100 times greater than was actually used. This "error" resulted in distorted values for geothermal energy use in agriculture in the world because 5000 MW represented 90% of the installed thermal capacity in 1975.

In the 1979 P.R. Pryde published a good overview of geothermal energy development in the USSR. According to a Soviet reference the total amount of geothermal fluids axtracted in 1976 was 26.4 x 10^6 m^3 with an average temperature of 70°C. About 62% went for space heating, spas and industrial applications, 25% went into agricultural applications (mostly hothouses) and 13% was used in the two geothermal electrical generating stations on the Kamchatka Peninsula. These values are therefore both low and high temperature waters. However, the low teperature waters account probably for at least 90% at the total. Tables 1 and 2 show the thermal energy used and the estimated thermalpower associated with that energy use, assuming 50% load factor. In practical situations in many countries the average energy use during one year corresponds roughly to 1/2 the innstalled capacity being used all year. The values in Table 2 are only estimates.

In Kutateladze's reply there was information about the experimental binary cycle plant at Paratunski. In the 1960's they investigated the hot spring at Paratunski and in 1965 a 0.75 MW electrical generator was constructed. The plant uses 200 m^3/h (56 l/s) of 80°C water that is cooled to 50°C. This corresponds to 7 MW thermal. At reference tempertures 0°C, 15°C and 40°C the thermal energy uses corresponds to 19 MW, 15 MW and 9 MW thermal, respectively. Hot water from the Paratunski geothermal area is also used for space heating (homes and greenhouses). Total flowrate of hot water from the area 167 l/s.

In the reply from Dvorov, Kononov & Dvorov, at the Scientific Council on Geothermal Studies, the use of low-temperature geothermal energy was given on 3 typed pages and listed under the heatings " Characteristic of the Present State and Perspectives of Utilization of Low-Temperature Underground Waters of the USSR" as: I-1 District heating, I-2 Utilization in agriculture, I-3 Fish-breeding, I-4 Utilization for industrial purposes, I-5 Utilization for medicinal-rehabilitation purposes. II Past and future utilization. III Exploration projects. IV Potential resources of low-temperature hydrothermal systems in USSR. Actual numbers/values to quatify geothermal energy use in the above categories were limited. Temperatures of waters were given and typical flowrates from boreholes, but not the number of boreholes nor total amount of fluids produced. The thermal energy and power associated with the various uses were therefore not given.

Dvorov, Kononov & Ďvorov stated that district heating was in three regions. The Caucasus, West Siberia and Kamchatka. For the first of these the number of inhabitants using thermal waters was given as 110,000 people. To estimate the associated thermal power here, some values from the two papers by P.R. Pryde (1979) will be used. He stated that in the town of Kizlyar (in the Daghestan Autonomous Republic in the Caucasus) in 1974 there were 5 boreholes yielding 17,340 m^3/day of 105°C water and 4 boreholes yielding 16,950 m^3/day of 60°C water. Dvorov, Kononov & Ďvorov stated that 90°C water was used for the heating in Kizlyar with a discharge temperature of 58°C. Assuming, however, that district heating scheme in Kizlyar uses 200 l/s (17,340 m^3/day) of 105°C water and 196 l/s (16,950 m^3/day) of 60°C water, the thermal energy was estimated. The number of inhabitants in Kizlyar using thermal water is 30,000 according to Dvorov, Kononov & Dvorov. With reference discharge temperature of 40°C the thermal power of the Kizlyar district heating systems becomes 82 MW or 2.7 MW per 1000 inhabitants. According to Einarsson (1975) the corresponding figures for Reykjavík (Iceland) are 4.4 MW per 1000 inhabitants and 4.9 MW per 1000 inhabitants when considering all the district heating systems in Iceland. However, on the assumption that the Kizlyar value above is representative for the other towns in the Caucasus with geothermal heating, the total thermal power was estimated and is shown in Table 3. Dvorov, Kononov & Dvorov did not provide any data on district heating in the regions of West Siberia and Kamchatka. Limited data was given on categories I-2 to I-5, execept "the total area of all greenhouses in the USSR heated by thermal waters is at present 420,000 m^2". Tikhonov & Dvorov (1970) in a paper presented in Pisa stated that 45-50 m^3/h of 60-65°C water was required to heat one hectar (10,000 m^2) of greenhouses in the USSR. Taking the average of these (47.5 m^3/h and 62.5°C) corresponds to 0.345 kW/m^2, 0.262 kW/m^2 and 0.124 kW/m^2 for 0°C, 15°C and 40°C reference temperature, respectively. For comparison it may be stated that in Iceland it is estimated tha 0.233-0.250 kW/m^2 (200- 250 kcal/h m^2) are required for typical greenhouses. Based on the USSR values given by Tikhonov & Dvorov it takes 52 MW, 110 MW and 145 MW thermal to heat 420,000 m^2 at 40°C, 15°C and 0°C reference temperature, respectively.

Exploration

Two projects: a) Hydrogeological and geothermal studies in the region of the Baikal-Amur railway line for space heating and other purposes in next few years. b) Drilling of deep wells to investigate hot-dry-rock possibilities in the western regions of the European part of the USSR (Carpathians) and in the Caucasus (e.g. Daghestan) in the future.

Assessment

A heat flow map of the USSR in available. Main geothermal areas are on Kamchatka and in the Caucasus. Buachidse et. al. (1970) presented data on thermal waters in Georgia. Mentioned more than 50 groups of outlets of thermal waters with temperatures 35-105°C and total flowrate of more than 1000 l/s. Data shows 30 MW, 150 MW and 260 MW thermal flowing from these outlets at 40°C, 15°C and 0°C reference temperatures, respectively.

For the whole of the USSR Tikhonov & Dvorov (1970) stated that 7.9. x 10^6 m^3/day was the "thermal water reserve". Dvorov (1970) stated the average temperature of these waters as 65 to 70°C and gave the reserve as 7.90 x 10^6 m^3/day of waters with mineralization up to 10 g/l. Dvorov (1974) stated the reserve of thermal waters with mineralization up to 35 g/l as 19.75 x 10^6 m^3/day. Dvorov, Kononov & Dvorov (in reply to questionnaire) gave the "regional resource of thermal waters in the USSR" as 19.75 x 10^6 m^3/day with mineralization up to 35 g/l and stated that the temperature of the waters ranged from 50°C to 180°C. A table showed the reserve of 5 regions of the USSR. From the available data the thermal power of these reserves can be estimated indirectly. By using an average temperature of 65°C for all the thermal water reserves (see Dvorov 1974) and the table given by Dvorov, Kononov & Dvorov, Table 5 was constructed.

Bibliography

Tikhonov, A.N. & Dvorov, I.M., 9170: Development of Research and Utilization of Geothermal Resources in the USSR. Pisa, pp. 1072-1078.

Buachidse, I.M., Buachidse, G.I. & Shaorshadse, M.M., 1970: Thermal Waters in Georgia. Pisa, 1092-1101.

Dvorov, I.M., 1974: Study and Utilization of the Earth's Thermal Energy in the USSR. Proc. Int Conf. Geothermal Energy for Indusrial, Agricultural & Commercial - Residental Uses, Oregon Institute of Technology, pp. 60-78.

Einarsson, S.E., 1975: Geothermal Space Heating and Cooling. San Francisco, pp. 2117-2126.

Pryde, P.R., 1979: Geothermal Energy Developments in the Soviet Union. Soviet Geography: Review & Translation. Scripta Publishing Co., Washington, pp.69-81.

Pryde, P.R., 1979: Geothermal Energy Developments in the Soviet Union. Geo Heat Utilization Center Quarterly Bulletin, 4, pp. 8-14.

J.S. Gudmundsson

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TABLE 1

Geothermal energy use in 1976

Type of use		Thermal energy TJ		
		>0°C	>15°C	>40°C
Space heating	(62%)	4797	3769	2056
Agriculture	(25%)	1934	1520	829
Electricity	(13%)	1006	790	431
Total		7737	6079	3316

TABLE 2

Estimated thermal power in 1976

Type of use		Thermal power MW		
		>0°C	>15°C	>40°C
Space heating	(62%)	304	240	130
Agriculture	(25%)	122	96	52
Electricity	(13%)	64	50	28
Total		490	386	210

TABLE 3

District heating in the Caucasus

Type of use		Thermal power MW		
		>0°C	>15°C	>40°C
Kizlyar	(30,000)	137	117	82
Total	(110,000)	502	429	301

TABLE 4

Known use of low-temperature geothermal waters in the USSR

Type of use	Thermal power MW		
	>0°C	>15°C	>40°C
District heating	500	430	300
Greenhouses	150	110	55
Electricity	19	15	9
Total	669	555	364

TABLE 5

Regional resources of thermal waters in the USSR

Region	Discharge		Thermal power GW[x]		
	x 10^{-6} m^3/day	m^3/s	>0°C	>15°C	>40°C
European USSR	3.02	35	9.5	7.3	3.6
Middle Asia	1.43	17	4.6	3.5	1.8
Kazakstan	1.2	14	3.8	2.9	1.5
West Siberia	10.75	124	33.7	25.9	13.0
East Siberia & Far East	3.35	39	10.6	8.2	4.1
Total	19.75	229		47.8	24.0

x Assuming 65°C average temperature.

ICELAND ENERGY AUTHORITY

Geothermal Division
1980-07-24

Note
JSG-80/05
gss

HUNGARY: Survey of Low-Temperature Geothermal Energy

Geography

Area 93,030 km^2

Population 10,625,000 (1976)

Information

The questionnaire was sent to I.Boldizsár and J.Balogh. It was stated by Boldizsár that no central geothermal authority existed in Hungary but by the end of 1980 it will be established. He sent a reprint of a paper published in 1979 that gives data on geothermal energy production in 1976. Boldizsár stated that the situation had not change much since then and that the data could be used to-day with confidence. The paper gives estimates of geothermal resources in Hungary and indicates future plans. It is similar to a paper by Boldizsár in Geothermics in 1975, except in the 1979 paper there is information on geoheat utilization. Balogh sent a table showing the utilization of geothermal energy in Hungary to-day with information about the boreholes, type and size of users, and the amount of thermal waters available and utilized. Balogh enclosed several small maps that indicated the amount of "exploitable, opened up and used" geothermal waters in Hungary. Balogh sent also a copy of a lecture on "Discovery and Utilization of Geothermal Energy in Hungary".

Utilization

The information from Balogh shows that 33 x 10^6 m^3/year of thermal waters are used in Hungary. The thermal energy of this water above 50°C corresponds to about 1485 TJ/year. This water is used to heat 1.9 x 10^6 m^2 of agricultural area (0.7 x 10^6 m^2 greenhouses and 1.2 x 10^6 m^2 plastic covered), 3400 flats and 21 industrial facilities, 135 baths (for 224,000 people), 90 water supply installations and 41 animal (and similar) shelters. Balogh stated that the total quantity of thermal waters available to-day (opened up) amounts to 166×10^6 m^3/year such that 20% are used.

Boldizsár (1979) shows the utilization of geothermal energy in Hungary in two tables with different reference teperatures: Thermal wells that produce water above 60°C in one table and above 40°C in the other . In both tables the reference temperature is 15°C. Knowing the total flowrate of the 343 boreholes (343.3 m^3/min) producing waters above 40°C, and knowing the nominal thermal power (1166.34 MW) above 15°C, it is possible to estimate the average temperature of this flow - here calculated as 64°C. From this data it is possible to estimate the thermal power above other reference temperatures. Table 1 shows the installed thermal power in Hungary and the thermal energy used in 1976. It is not clear how Boldizsár obtained his values for thermal energy used ("yearly actual heat consumption"). However, it appears his values are based on 15°C reference temperature. If that is the case the load factors are 19.6%, 51.4%, 61.2% and 31.9% for agriculture, district heating, industry and baths, respectively. A load factor of 51.4% for district heating is what would be expected. The overall load factor for geothermal energy utilization in Hungary is 24.9%. It should be noted that Balogh states that 1485 TJ/year are used above 50°C, which is much less than given by Boldizsár.

At the end of 1975 there were 1.7×10^6 m^2 of greenhouses in Hungary, 8 district heating systems (3500 flats with 710,000 m^3 heated space), 134 baths and various other uses (Boldizsár 1979). About 40% of Hungarian territory is suitable for economic hot water production for space heating and other purposes. In the next few years there are plans to increase the use of geothermal energy in Hungary. However, the situation has not changed much in recent years as stated by Bolizsár. In the replies from Balogh and Boldizsár no special mention was made of exploration projects.

<u>Assessment</u>

Maps sent by Balogh showed that 6.05 km^3/year of thermal waters are "exploitable" in Hungary, of which 0.166 km^3/year have been "opend up" and 0.0336 km^3/year presently used. The corresponding thermal values were given as 47 x 10^{12} kcal/year (197,000 TJ/year), 15 x 10^{12} kcal/year (63,000 TJ/year) and 0.36 x 10^{12} kcal/year (1500 TJ/year). The table sent by Balogh, however, showed the "opened up" thermal energy as 1542 x 10^9 kcal/year (6456 TJ/year), which is an order of magnitude less than on the map. In the table the reference temperature was 50°C.

Boldizsár (1975,1979) has made an assessment of geothermal energy resources of Hungary. The geothermal waters are found in the Pannonian sedimentary basin. The heat stored in the sediments down to a depth of 3 km was estimated as 12,600 x 10^{18} cal (53 x 10^{21} J). The thermal waters produced to-day are taken from below 1000 m in the Upper-Pannonian with temperatures 50-100°C. This reservoir stores 768 x 10^{18} cal (3.2 x 10^{21} J) of heat of which 7.42 x 10^{18} cal (31 x 10^{18} J) are considered recoveable. The overall recoverable geothermal energy in Hungary is about 15 x 10^{18} cal (62 x 10^{18} J). Geothermal energy is available on 40,000 km^2 of the country or 43% of it´s area. The above values given by Boldizsár are based on reference temperature 15°C.

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Bibliography

Boldizsár, T., 1974: Geothermal Energy Use in Hungary. Proc. Int. Conf. Geothermal Energy for Industrial, Agricultural and Commercial-Residential Uses. Oregon Institute of Technology.

Balogh, J., 1975: Results Achieved in Hungary in the Utilization of Geothermal Energy. San Francisco, 29-31.

Boldizsár, T. & Korim, K., 1975: Hydrogeology of the Pannonian Geothermal Dasin. San Francisco, 297-303.

Boldizsár, T., 1975: Research and Development of Geothermal Energy Production in Hungary. Geothermics, 4, 44-56

Boldizsár, T., 1979: Non-Electric Use of Geothermal Energy in Hungary. Acta Geodaet., Geophys. et Montanist. Acad. Sci. Hung., 14, 289-297.

TABLE 1

Geothermal energy production and use in Hungary in 1976

Application	Number of wells	Flow-rate m^3/min	Installed thermal power MW			Thermal energy used[x]	
			>0°C	>15°C	>40°C	TJ	%
Agriculture	77	117.0	699.35	535.44	316.89	3311	36.2
District heating	8	11.7	76.25	58.39	34.56	946	10.3
Industry	13	14.0	32.00	24.50	14.50	473	5.2
Baths	194	165.3	574.00	439.47	260.09	4415	48.3
Not used	51	34.3	141.40	108.27	64.08	-	-
Total	343	342.3	1523.00	1166.34	690.12	9145	100.0

x Probably based on 15°C reference temperature.

PEOPLE'S REPUBLIC OF CHINA: Survey of Low Temperature Geothermal Energy.

Geography.

Area 9,560,985 km^2

Population 852,130,000 (1976)

Information.

The questionnaire was sent to K. Xin because he had visited Iceland in 1979 as a United Nations University (UNU) Special Fellow. A reply was received but Xin was not able to give much information relevant to the survey.

In January 1980 I.B.Fridleifsson visited the People's Republic of China (PRC) on UNU business and was able to gather valuable information for the survey by meeting people working on geothermal energy. Fridleifsson provided data on thermal water use in Tianjin, Beijing, Kunming, Xiang and Xiaotungsan. Several papers were consulted for further information.

Utilization.

Geoheat is used for various purposes in the PRC to-day. Among these are electricity generation (high and low-temperature fluids), space heating of residential and industrial buildings and greenhouses, health resorts, various industrial uses (textiles, printing and dyeing, cement production, boilers) and extraction of chemicals. Some use in agriculture has also been reported. For most of these limited information is available on actual energy use.

In the city of Tianjin some 40 x 10^6 m^3/year (1268 l/s) of 30-50°C thermal waters are produced from 190 boreholes for uses in the textile industry and for space heating, baths and other uses. In 150 wells the temperature is 30-40°C and in 40 wells about 50°C. The average depth of these wells is 860m. All the wells have a down-hole pump. In one borehole drilled 1972 to 786m (152mm diameter) the water level is now at 50m. In most of the 190 boreholes there is a 3-5m draw-down per year. In the one borehole mentioned above the down-hole pump is set at 75m. The pump is 4" with a 34 kW motor and pumps 60m^3/h (17 l/s) of 50°C water. There are 4 textile factories in Tianjin that use thermal water amounting to 6000 m^3/day (69 l/s) in total. The thermal water is used down to 20-30°C. The thermal power of the thermal waters used in Tianjin can be estimated by assuming that the average flowrate of the 40 boreholes producing 50°C water and 150 boreholes producing 30-40°C is the same. It has also to be assumed that the average temperature of the 150 boreholes is 35°C. It follews that 267 l/s of 50°C water and 1001 l/s of 35°C water amount to 11.2 MW, 112.9 MW and 202.6 MW for 40°C, 15°C and 0°C reference temperature respectively.

In the city of Beijing (population 8 millions) there have been drilled 20 wells of which 14 are used. The deepest well is 2600m, the average depth is 1000m. Most of these wells need pumping. Maximum water temperature 69°C lowest 45°C with 50°C as average. Water level at 40m. Extreme flowrate values are 700-1500 m^3/day with 1000 m^3/day (12 l/s) as average from the 14 producing boreholes. The thermal water in Beijing is used in the textile industry, for space heating and baths. In the future it is hoped that 10% of Beijing will be heated by geothermal water. Assuming 14 boreholes that produce 12 l/s each (168 kg/s in total) of 50°C water the thermal power becomes 7.0 MW, 24.6 MW and 35.2 MW at 40°C, 15°C and 0°C reference temperatures respectively.

In the city of Kunming there are 3 wells used for baths producing in total 1200 m^3/day (14 l/s) of 55°C water. This gives 3.2 MW, 2.3 MW and 0.9MW thermal at 0°C, 15°C and 40°C.

In the city of Xian there are used 400 m^3/day (4.6 l/s) of 42°C water for industrial purposes. This corresponds to 0.8 MW, 0.5 MW at 0°C and 15°C respectively.

There are about 80 health resorts (sanatorium) in the PRC that use geothermal water (Cai 1979). One of these is at Xiaotungsan about 40 km from Beijing. The thermal water there is used for both baths and space heating. There are two wells 76m and 120m producing 2600 m^3/day (30 l/s) of 54°C water by pumping. Artesian flow is only 1200 m^3/day. The heated area is 25,500 m^2. A 800m pipeline serves the sanatorium. The associated thermal power amounts to 6.8 MW, 4.9 MW and 1.8 MW for 0°C, 15°C and 40°C respectively.

It is reported (Cai 1979, An & Huang 1980) that low-temperature geothermal waters are used for industrial and space heating purposes in other cities, but no data is yet available on flowrates and temperatures to estimate the associated thermal power. The largest users of thermal waters are therefore probably Tianjin and Beijing.

Cai (1979) gives details about 7 experimental electric power generation stations in the PRC. While it is not clear if these are located in high or low-temperature fields, the stations use waters at low temperatures. Table 1 is reproduced from the paper by Cai (1979). Fan (1979) and An & Huang (1980) have given information about several geothermal fields in the PRC. For the present survey it is assumed that high-temperature areas (with measured temperature above 180°C) in the PRC are only to be found in the Xizang-Yunnan Geothermal Zone (and Taiwan Geothermal Zone). The Yangbajing geothermal field in Xizang is probably a high-temperature field and will therefore be excluded from this survey (the silica temperature has been reported 250°C). Table 1 shows that there is a 1 MW-electrical power station there using steam/water at 150°C. Apparently there are two 3 MW-electrical power stations under construction in the Yangbajing field and will probably be operational 1980 and 1981. The other stations (using waters at 67-92°C) have a total design capacity of 0.936 MW-electrical (about 1 MW-electrical). Cai (1979) gives details about the 50 kW-electrical experimental binary plant at Wentang (Yichun in Jiangxi). One artesian well produces 100 m^3/h of 67°C water. This fluid is used in the binary plant and then in local greenhouses, sanatorium, hospital and rice paddies to raise the soil temperature. This full use of the thermal water amounts to 7.9 MW, 6.1 MW and 3.2 MW at 0°C, 15°C and 40°C reference temperatures. Table 1 shows that of the 7 experimental power stations in the PRC there are 3 using flashed steam and 4 some binary fluid. Unfortunately there is no technical information available on the flowrates (and temperatures) to enable an estimation of the thermal opwer involved, except the 50 kW plant at Yichung. The 0.886 MW-electrical (0.936-0.050) capacity in the low-temperature fields will therefore have to be omitted for the time being.

Table 2 shows the known low-temperature geothermal energy utilization in the PRC. As already stated Table 2 does not show the thermal power associated with 886 kW-electrical generating capacity in the low-temperature fields because no information is available. While there are about 80 hot spring savatoriums in the PRC (Cai 1979) there are 8 main locations (Finn 1979) with active operations. Two of these are in Tianjin and Beijing, one at Xiaotungsan and one at Yichun. In view of the above and other factors it could be argued that Table 2 shows approximately 1/2 the low-temperature geothermal energy used in the PRC at present. However, until more data becomes available the values in Table 2 shows our best information.

An & Huang (1980) give details about the Dengwu field, Fengshun country, Guangdon province. Information supplied by I.B. Fridleifsson indicates that tens of boreholes have been drilled with maximum flowrate 3000 m^3/day but average flowrate 1000 m^3/day at temperatures 93°C. As shown by Cai (1979) some of this water is used for electric power production. Some of the thermal waters are reported being used in agriculture (fish hatching, farming). The information given to I.B. Fridleifsson indicates that the two experimental power stations use 300 m^3/day (3.5 l/s) of 93°C water, the discharge temperature being 60°C. The discharge temperature for the agricultural operations was reported as 30°C.

Exploration/Assessment.

During the period 1960-1970 the development of geothermal resources in the PRC was limited to hot springs for therapeutic purposes (Cai 1979). Since 1970 however the emphasis has shifted to the comprehensive use for industry and agriculture. To-day more than 2/3 of the provinces, municipalities and autonomous regions have started reconnaissance surveys and exploration work for utilizing geothermal resources. An & Huang (1980) stated that "since 1970 geothermal work has developed rapidly and at present geothermal resources have found their utilization in power generating, extraction of chemicals, textiles, printing and dyeing, space heating, greenhouses, medical treatment, etc."

Both Cai (1979) and An & Huang (1980) give information about the geothermal resources of the PRC. The An & Huang (1980) information will be used here for illustration. There are about 2500 geothermal water points in the PRC. In the north all water points above 20°C are included but 25°C is the temperature used in the south. There are 4 major geothermal zones in the country: Xizang-Yunnan Zone, Taiwan Zone, Eastern Coastal Zone and North-South Zone. The major features of these zones are explained. It appears that high-temperature fields (with measured temperature above 180°C) are to be found in the Xizang-Yunnan Zone and the Taiwan Zone. There are identified 3 types of resources in the PRC,

I) magmatic activity type;
II) uplift-fault type and
III) depressional basin type.

An & Huang (1980) demonstrate these 3 types by considering the Yangbajin, Dengwu and Beijing geothermal fields, respectively.
In the Xizang-Yunnan Zone there are more than 400 hot water points, 145°C maximum measured temperature. In the Taiwan Zone 103 hydrothermal areas, 294°C maximum temperature measured. In the Eastern Coastal Zone more than 550 known hot water points, 63°C maximum temperature. In the North-South Zone about 100 hot water points, 92°C maximum measured temperature. It is of interest to note that An & Huang (1980) classify geothermal energy as following: 25-40°C

low temperature, 40-60°C medium temperature, 60-100°C high temperature and above 100°C super-heated.

Bibliography.

Cai, Y.H., 1979: Present Status of the Development and Utilization of Geothermal Energy in the People's Republic of China. Energy Resources Laboratory, University of Tianjin.

Wei, T., 1979: A Brief Note on Geothermal Research in Xizang (Tibet). Geothermics, 8, 135-140.

Fan, P.F., 1979: Geothermal Fields and Hot Springs of Mainland China. Geothermal Resources Council Transactions, 3, 193-195.

Finn, D.F.X. 1979: Geothermal Developments in the People's Republic of China. Geothermal Resources Council Transactions, 3, 209-210.

An, K.S. & Huang, S.Y., 1980: Geothermal Resources in China. 26th International Geological Congress, Colloque C2, Energy Resources, Revue de l'Institut Francais du Petrole, 35, 449-460.

Fang, J. & Xia, D., 1980: Using Geothermal Resources in China. Geo-Heat Utilization Center Quarterly Bulletin, 5 (2), 14-18.

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TABLE 1

Experimental geothermal power stations in the PRC (Cai 1979)

Name of Experimental Geothermal Power Station	Location	Thermal Water Temperature (°C)	Design Capacity (kw)	System Type	Working Medium	Generating Date
Fengshun	Fengshun (Dengwu), Guangdong					
No. 1 Unit		91	86	Flashed-steam cycle	Water	1970. 10
NO. 2 Unit		91	200	Dual Fluid cycle (Binary cycle)	Isobutane	1971. 9
Wentang	Yichun (Wentang), Jiangxi	67	50	"	Chlorethane	1971. 9
Huailai	Huailai (Houduyao), Hebei	85	200	"	Chlorethane, Normal butane	1971. 9
Huitang	Ningxiang (Huitang), Hunan	92	300	Flashed-steam cycle	Water	1975. 10
Yingkou	Xiongyue Liaoning	75-84	100	Dual Fluid cycle (Binary cycle)	Normal butane Freon	1977. 4
Yangbajing	Yangbajing, Xizang	150	1000	Flashed-steam cycle	Water	1977. 9

TABLE 2

Known uses of low-temperature geothermal energy in the PRC

Location	Thermal power MW >0°C	Thermal power MW >15°C	Thermal power MW >40°C
Tianjin	202.6	112.9	11.2
Beijing	35.2	24.6	7.0
Yichun*	7.9	6.1	3.2
Xiaotungsan	6.8	4.9	1.8
Kunming	3.2	2.3	0.9
Xian	0.8	0.5	0.0
Total	256.8	151.3	24.1

* Includes 50 kW-electrical of a total of 936 kW-electrical generating capacity in low-temperature fields that are however excluded here because no further information is available.

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1980.08.22

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France: Survey of Low-Temperature Geothermal Energy

Geography

Area 52,9200,000 (1976)

Information

The questionnaire was sent to J. Varet. No reply was received but the BRGM was visited by the author and information obtained in discussions with J.M. Lejeune and O. Goyeneche. Papers by J. Varet (1978) and A. Ten-Dam (1978) were also consulted. A book by Cerisier (1978) gives information about thermal springs in France.

Utilization

The main use of geothermal in France is in space heating. There are 4 heating systems in the Paris Basin and two in the Aquitaine Basin. Table 1 shows all the particulars. There are presently at least 11,700 flats heated by geothermal. Varet (1978) stated that about 20,000 flats are heated. At Mont de Marsan the district heating systems serves a hospital and military barracks.

There are plans to increase the use of geothermal in the next few years. Several wells have already been drilled. At Mellerary a 17,000 m^2 greenhouse will be connected and at Cergy, Coulommiers, Jonzac and Dax, district heating systems are being built. There are (were) hot springs at Dax used for baths.

Exploration

There are several exploration projects being carried out in France. However, there is already good information about the main sedimentary basins in France because of oil exploration.

Assessment

Lavigne (1978) has reported an assessment study of geothermal energy in France. The study was based on the method presented by Muffer & Cataldi (1978). The identified resources of France are 380 x 10^{18} cal (1.6 x 10^{21} J) of which 300 x 10^{18} cal (1.3 x 10^{21} J) are in the Aquitain Basin and 67 x 10^{18} cal (0.3 x 10^{21} J) in the Paris Basin. The reserve (réserves en place) are 10.8 x 10^{18} cal (4.5 x 10^{19} J) of which 7.2 x 10^{18} cal (3.0 x 10^{19} J) are in the Paris Basin. Based on experience in the Paris Basin Lavigne (1978) stated that 1.8 x 10^{18} cal (7.5 x 10^{18}J) of the geothermal reserve is recoverable (reserves récupérables).

Bibliography

Varet, J., 1978: Low Enthalpy Geothermal Fields, with Reference to Geothermal Energy in France. Journal Japan Geothermal Energy Association, 15, 3-16.

Ten-Dam, A., 1978: Geothermal Heating in France. Geothermal Energy Magazine, 6, 11-16.

Cerisier, M., 1978: La France Thermale. Marabout, pp. 278.

Lavigne, J., 1978: Les ressources géothermiques francaises - possibilités de mise en valeur. Annales des Mines.

Muffler, P. & Cataldi, R., 1978: Methods for Regional Assessment of Geothermal Resources. Geothermics, 7, 53-89.

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TABLE 1

Utilization of geothermal energy in France for district heating

Name	Year when operational	Heated apartments	Flowrate m^3/h	Flowrate l/s	Boreholes P	Boreholes R	Temp. °C P	Temp. °C R	Installed thermal power MW >0°C	Installed thermal power MW >15°C	Installed thermal power MW >40°C
Melun l'Almont	1970	3300	95	26.4	1	1	70	35	7.7	6.1	3.3
Villeneuve la Garenne	1976	1800	180	50.0	1	1	54	30-40	11.3	8.2	2.9
Creil	1977	3400	220	61.1	2	2	57	20	14.6	10.7	4.3
Melun le Mee Sur Sein	1978	1450	200	55.5	1	1	72	30-35	16.7	13.2	7.4
Blagnac	1976	1750	45	12.5	1	0	60	—	3.1	2.4	1.0
Mont de Marsan	1977	?	300	83.3	1	1	58	?	20.2	15.0	6.3
Total	—	(11,700)	1040	288.8	7	6	—	—	73.6	55.6	25.2

P: Production

R: Reinjection

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JSG-80/08
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JAPAN: Survey of Low-Temperature Geothermal Energy

Geography

Area 369,699 km^2

Population 113,086,000 (1976)

Information

The questionnaire was sent to I. Takashima who sent a comprehensive reply. Several papers were consulted for further information.

Utilization

There are both high and low-temperature fields in Japan and both electrical and direct uses. Presently there are six geothermal power stations with installed capacity of 168 MW-electrical. The direct uses are mainly in low-temperature areas, but also at high-temperature areas.

Takashima gave a summary of "present nonelectrical applications of geothermal energy in Japan". In the present survey direct uses in low-temperature areas are to be considered. Takashima showed direct uses at Otake, Matsukawa and Onuma (all high-temperature areas) seperately as 1.5 x 10^{12} J/day (reference temperature 15°C) in total. All other direct uses (preseumable all at low-temperature areas) were given as 3.866 x 10^{14} J/day (reference temperature 15°C) which corresponds to 4475 MW-thermal. Takashima stated that "almost all of hot water are directly used for baths and space heating" and also various use (mainly for mineral baths)". It must be assumed that these 4475 MW-thermal are all the thermal waters used in Japan. Takashima stated that 7 main localities use in total 158,176 l/min (2636 l/s) of thermal waters at 56-100 °C but the rest was used at various other localities at 1624 places. Details about direct uses in high-temperature areas (according to Takashima 1.5 x 10^{12} J/day or 17.4 MW-thermal above 15°C) are given by Minohara & Sekioka (1980).

It was reported by Mashiko & Hirano (1970) that in 1968 "there were 17,126 hot water wells in Japan, 3363 wells of which were no longer used and 1955 wells not yet utilized". They stated that: "At present, in the 11,608 wells that are in use, 60% of them have high enthalpy involving vapor and gas with high temperatures above boiling point, and 13% are cool mineral springs that are under 25 °C. There are 2235 wells that are between 25 and 42°C and 8350 wells are above 42°C and not aqueous vapor wells. The total quantity of hot water pumped up from these hot water wells has reached 1,207,194 liters per minute". This flowrate amounts to 20,120 l/s. According to the Japan Geothermal Energy Assocation (1974): "The total discharge of thermal water throughout Japan was about 730,000 l/min (12,167 l/s) in 1966. By 1969 this volume had doubled to 1,330,000 l/min (22,167 l/s). The number of hot springs and thermal water wells had increased to 14,000 by 1969. 70% of these springs and wells produced waters having temperatures above 42°C.... The geothermal energy being discharged as thermal water is approximately 1.5 x 10^{24} erg/year", (1.5 x 10^{17} J/year = 4756 MW). This value is close to the one given by Takashima above. Komagata et. al. (1970) report the status of geothermal utilization in Japan.

It was stated above (according to Takashima) that the total thermal power associated with the utilization of low-temperature geothermal energy in Japan amounts to 4475 MW-thermal above reference temperature 15°C. Most of this geothermal energy is used in baths. Takashima gave information on the use of thermal waters in agriculture. These include 4 locations (Ibusuki, Higashi-Izu, Mori-cho and Shikabe) with 43,000 m^2, 1056 m^2, 19,000 m^2 and 1880 m^2 of greenhouses, 64,936 m^2 in total. The flowrate and inlet temperature for 3 of these was given. To estimate the thermal energy associate with the 19,000 m^2 at Mori-cho, it was assumed to be the same as at Ibusuki (43,000 m^2) or 86 W/m^2, 147 W/m^2 and 184 W/m^2 for 40°C, 15°C and 0°C reference temperature respectively. The total thermal power associated with the 64,936 m^2 (65,000 m^2) was 10.3 MW, for 16.8 MW and 20.7 MW for 40°C, 15°C and 0°C respectively. Takashima reported that geothermal energy was used at Minami-Izu (300 l/min at 115°C) and Beppu-Ueda (small use) for animal husbandry. At Atagawa (2000 l/min at 105°C) thermal waters are used for breeding alligators and crocodiles and at Shikabe (70 l/min at 70°C) eel and carp breeding are carried out with the use of geothermal energy. The total thermal power associated with these animal husbandry operations amounts to 10.9 MW, 14.9 MW and 17.4 MW for 40°, 15°C and 0°C respectively. Takashima reported that 14,267 m^2 of roads etc. are heated with geothermal energy for snow-melting. This energy use was reported as part of energy used for space heating. Sekioka et.al. (1979) and Sato & Sekioka report on these snow melting operations in detail. Takashima reports <u>space heating</u> systems (space and water heating, mineral baths) at 9 locations using 12,386 l/min (206 l/s) of thermal water at 25-70°C. The space heating systems at Otake, Matsukawa adn Onuma are excluded here since they are in high-temperature fields. The air conditioning system at Beppu-Kankaiji is also omitted here for the same reason? The thermal power associated with the 9 space heating systems using low-temperature fluids (fields) as reported by Takashima amount to 23.0 MW, 49.1 MW and 65.0 MW for 40°C, 15°C and 0°C reference temperature. Table 1 shows the utilization of low-temperature geothermal energy in Japan for space heating greenhouses and animal husbandry. These uses represent less than 2% of the total utilization (4475 MW-thermal above 15°C).

<u>TABLE 1</u>

Utilization of low-temperature geothermal energy in Japan[x]

Use	Thermal power MW		
	>0°C	>15°C	>40°C
Space & water heating	65.0	49.1	23.0
Greenhouses	20.7	16.8	10.3
Animal husbandry	17.4	14.9	10.9
Total	103.1	80.8	44.2

x Not including bathing, since total utilization amounts to 4475 MW-thermal (>15°C).

Takashima gave information on "past and future utilization" as follows: "There are no big changes for the use of low-temperature geothermal energy related to volcanic activity from early 1970's to present and don't expected to have a big change in the future. However, Japanese government want to develop the non-volcanic geothermal resources of deep sedimentary basin and use them for space heating and binary systems etc. in the amount of 2.5 x 10^5 kl in 1985, 5.4 x 10^6 kl in 1990 and 2.1 x 10^7 kl in 1995 (oil equivalent) respectively". The unit kl is probably kilolitre (1000 litres).

Exploration

Takashima stated that most exploration projects of low-temperature resources are done by commercial companies on a very small scale. He also stated that only one large scale project was under way at present - in the deep sedimentary Wada Basin (Akita prefacture). However, it is evident from papers by Sumi (1978) and Nakamura et.al. (1978) that the Geological Survey of Japan does extensive geothermal exploration work - albeit mostly in high-temperature fields.

Assessment

Takashima sent a table showing: "Assessment of non-volcanic geothermal resources or deep sedimentary basin in Japan" and stated it was a "preliminary assessment". The table lists 30 localities. The total area of 25 of these is 39,372 km^2 and the "recoverable heat of... 22 localities (is) 2.0 x 10^{17} kcal" above 15°C reference temperature. The corresponding recoverable volume of geothermal fluid is 2610 x 10^9 m^3. (2 x 10^{17} kcal = 8,4 x 10^{20} J). It was also stated by Takashima that: "We don't have a national wide resource assessment of low-temperature geothermal resources related to volcanic activity(We already use fairly large amount of this kind of resource)". Sumi (1978) gives an excellent overview of the geothermal resources of Japan. Geothermal assessments have beeen carried out in 1957, 1970, 1974 and 1976. The main emphasis of all of these assessments has been on high-temperature fields for power generation. It is of interest that the natural heat discharge from 10,578 hot springs and fumaroles (presumably in both high and low-temperature fields) in Japan has been reported (Sumi 1978) as 16 x 10^{10} cal/min (11,200 MW-thermal). The reference temperature was not given. The above value was calculated (Sumi 1978) by simple preportional multiplication using the observed value in Hokkaido where 6.3 x 10^{10} cal/min is discharging from 411 hot springs.

Bibliography

Komagata, S., Iga , H., Nakamura, H. & Minohara Y., 1970: The Status of Geothermal Utilization in Japan. Pisa, 185-196.

Mashiko, Y. & Hirano, Y., 1970: New Supply Systems of Thermal Waters to a Wide Area in Japan. Pisa, 1592-1595.

Japan Geothermal Energy Association, 1974: Geothermal Energy Utilization in Japan. 45 p.

Hirakawa, S., 1978: Situation of Geothermal Resources in Japanese Primary Energy. Journal Japan Geothermal Energy Association, 15, 7-10.

Sumi, K., 1978: Geothermal Resources of Japan. Energy Developments in Japan, 1, 3-32.

Nakamura, H., Sumi, K. & Ozawa, T., 1978: Geological and Geochemical Characteristics of Geothermal Resources in Japan. Energy Developments in Japan, 1, 277-301.

Sato, M. & Sekioka, M., 1979: Geothermal Snow Melting at Sapporo, Japan. Geo-Heat Utilization Center Quarterly Bulletin, 4 (3), 16-18.

Sekioka, M., Sato, M. & Ishihara, M., 1979: Geothermal Snow Melting in Japan. Geothermal Resources Council Transactions, 3, 639-642.

Minohara, Y. & Sekioka, M., 1980: Non-Electric Utilization of Geothermal Water and Steam from Production Wells of Geothermal Power Stations in Japan. Geo-Heat Utilization Center Quarterly Bulletin, 5 (2), 10-41.

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LOW-TEMPERATURE GEOTHERMAL ENERGY IN ICELAND

Introduction

The present Note has been written as a part of a World Survey of Low-Temperature Geothermal Energy that Orkustofnun is compiling at the request of the Technical Panel on Geothermal Energy of the Preparatory Committee for the United Nations Conference on New and Renewable Sources of Energy. The Conference is due to take place in 1981 in a developing country. The representative of Iceland on the Panel is G. Pálmason.

A World Survey of High-Temperature Geothermal Energy is being prepared by New Zealand, also at the request of the Technical Panel on Geothermal Energy. It was decided convenient by the Panel, for the purpose of these two surveys, to use 180°C as the base or subsurface temperature dividing low- and high-temperature geothermal fields. This temperature does not necessarily define such fields, it only defines the tasks of New Zealand and Iceland in preparing the two respective Surveys.

This Note on Iceland describes mainly the utilization of low-temperature geothermal energy but also the exploration and assessment of the resource. It is by no means a complete treatise of the subject and should therefore be viewed as draft material for the World Survey. All staff and money required for compiling the survey has been provided by Orkustofnun.

Utilization

The main use of geothermal in Iceland is low-temperature energy for district heating. This type of utilization was initiated in 1930 in

Reykjavík and to-day about 70% of the population of Iceland enjoy geothermal district heating. Most of the district heating systems are in low-temperature areas, the exceptions being Sudurnes, Hveragerdi, Reykjahlid and Vestmannaeyjar. Low-temperature geothermal is also used for greenhouses, aquaculture, drying etc. A special Note (JSG-GVJ-HeT-80/02) has been written on "High-Temperature Geothermal Areas in Iceland".

The Reykjavík District Heating Service (RDHS) is probably the world largest heating system using geothermal waters. It serves the towns of Reykjavík, Kópavogur, Hafnarfjördur, Gardabaer and the rural townships of Mosfellshreppur and Bessastadahreppur, the last one having been connected only this year. To discuss in more detail the RDHS the statistics for 1979 will be used. The rural townships of Mosfellshreppur and Bessastadahreppur are both excluded from the statistics. In Mosfellshreppur there is an independent district heating service that buys hot water from the RDHS. The population of Mosfellshreppur is 2,724 but Orkustofnun files show that 2,253 people or 82.7% enjoy geothermal district heating. The water is not sold through flowmeters but "maximum flow restricters" and amounts to 3,106 litres/minute or 52 l/s in total. In Bessastadahreppur (population 422) there is also an independent district heating service but since it´s operation started only this year it is not in the 1979 statistics.
At 1979.12.01 the total population of Iceland was 226,724 while the population living in the towns served by the RDHS was 113,667 people. The 1979 annual report of the RDHS shows that the system served 98.4% of the people living in it´s area or 111,905 people amounting to 49.4% of the total population of Iceland. It should be stated that the RDHS provides hot water not only for homes but also for all commercial and industrial buildings in it´s area. In 1979 the total heated space was 22,388,000 m^3.

The RDHS produces hot water from 3 geothermal fields, two within the town of Reykjavík and one at 15-20 km distance in Mosfellssveit. During the winter months of 1979-1980 the greatest demand was in February 1980 at which time the production reached 6100 tonnes/hour of 87°C water in the Mosfellssveit field, 1100 tonnes/hour of 127°C water in the Laugarnes field and 540 tonnes/hour of 97°C water in the Ellidaár field. (Private communication from Á. Gunnarsson). Table 1 shows the corresponding thermal capacity with reference to 0°C, 5°C, 15°C, 35°C and 40°C. In addition the RDHS has an oil field station for peak demand with a 35 MW-thermal capacity. This station has played a minor role in the operation of the district heating system in Reykjavík and has not been used since 1978.

The above quantities of hot water are not delivered to the customers at the temperatures stated. The temperatures in Table 1 are average temperatures produced by each field. Individual boreholes produce waters in the range 60-130°C. All boreholes have down-hole pumps placed at 100-120 m.

In a report being prepared by the Iceland Research Council on all aspect of energy in Iceland there is information on the RDHS. On average the RDHS delivers hot geothermal water at 80°C to the distribution network. To achieve this there are closed systems in some parts of Reykjavík by which the used (and cooled) water is returned to the pumping station and blended to the much hotter fluids produced by the boreholes. A study by the RDHS has shown that on average the geothermal water is delivered at 75°C to the customers and leaves at 36°C. The customers use therefore on average the thermal energy associated with a temperature drop of 39°C. Based on Table 1 it follows that almost 475 MW-thermal were used for district heating in the Reykjavík area during maximum demand in February 1980.

On the amount of geothermal water produced annually, Table 2 shows the development from 1967-1976 (table provided by G. Kristinsson), while Figure 1 is taken from the RDHS 1979 report and shows the same except over a longer period 1944-1979. In 1979 the RDHS report shows that 45,091,000 m^3 of hot water was produced from the pumping stations to the distribution network. As already stated the temperature of this water is 80°C. However, due to shunting proceedures the amount of hot water metered at the customers was only 40,450,000 m^3 and adding 728,000 m^3 delivered to swimming pools the RDHS sold in total 41,178,000 m^3 or 91.3% of the production. The 8.7% not sold was wasted at end points to maintain flow and temperature. A study by the RDHS has shown that about 10% of the hot water delivered to customers is used as tap water. This fact does affect statistics on actual thermal use by customers but for the present purpose it is not necessary to deal with tap water seperately.

In calculating the load factor of the geothermal district heating system of Reykjavík and neighbouring towns it will be assumed here that Table 1 shows the maximum capacity while the total amount of hot water produced by the pumping stations represents the average capacity used. The maximum amount of water delivered to the Mosfellshreppur system (3,106 litres/minute = 52 l/s) should really be subtracted from the RDHS's installed capacity to arrive at a more correct value for the load factor but this was not considered necessary here. It should be noted that the former applies to February 1980 while the latter applies to the whole of 1979. However, by considering the thermal energy above 40°C the 45,091,000 m^3 of 80°C water from the pumping stations amounts to 239 MW-thermal. The estimated load factor is therefore 50%. Table 2 shows not only the annual production of hot water, but also the production each month of the year. For this 10 year period 1967-1976 the minimum monthly production is 29-43% of the maximum monthly production, the average being 38%. The demand for hot water in Reykjavík during each 24 hours is variable and experience shows that the maximum demand is approximately 30% higher than the average 24 hour demand (see Orkustofnun Note HThJ-80/01). However, there is evidence to suggest that in more recent years the load curve has flattened out such that the above percentage has become lower.

Other district heating services. In 1979 there were 24 district heating services in Iceland. All of these are public services owned by the local community. In addition there are at least 6 privately owned services and various other systems. Table 3 shows the 24 public district heating services in Iceland according to the files of Orkustofnun. As mentioned above, not all of these are in low-temperature geothermal fields. The Sudurnes system is in the high-temperature field of Svartsengi and the Reykjahlid system in the Bjarnarflag field of the Námafjall high-temperature area. The Hveragerdi system uses geothermal fluids both above and below 180°C such that it draws on both high- and low-temperature geothermal waters. The town of Hveragerdi is in the south of the Hengill high-temperature area where the Ölfusdalur field is located with lower temperature fluids at its edge. For further details Note JSG-GVJ-HeT-80/02 should be consulted. The district heating system in Vestmannaeyjar is unique in Iceland (and perhaps the world) because it's source of energy is a lava field that was formed in a volcanic eruption on the island of Heimaey in 1973. The lava field ran over a part of the town and is gradually cooling down due to rainfall and sea-water ingression. The heat of the lava field is harnessed by spraying fresh water on the surface within a defined area. The water percolates down into the lava and is heated and turned into steam at the interface with the still molten material. In some respects this is "hot-dry-rock" geothermal energy. The steam thus formed rises to the surface and is collected in large concrete channels (sewer pipes) and collected to a heat exchanger where the circulating water of the district heating system is heated by the low quality steam. At present there are two sites harnessed with a thermal capacity of 3 MW each and one more will soon be on stream (private communication M. Karlsson). Some of the older pilot heat exchangers are also still in operation. The Vestmannaeyjar system has an oil fired boiler for maximum demand. The district heating system is still under construction. Because of the inherent ambiguity in using 180°C as the criteria for high- and low-temperature geothermal fields, the Sudurnes, Reykjahlid, Hveragerdi and Vestmannaeyjar district heating systems are shown in Table 3 for the sake of completeness. The 24 public district heating services provide 156,389 people or 69.0% of the population with geothermal heating. It is estimated that these 24 operational district heating services will be extended to provide 174,000 people (including Bessastadahreppur mentioned above) with geothermal heating. Table 4 shows the present and future district heating systems in Iceland both public and private. It shows that in 1979 157,945 people enjoyed geothermal district heating or 69.7% of the total population of Iceland. The Reykjavík District Heating Service with it's installed capacity of 475 MW-thermal above 40°C served 49.4% of the total population such that 69.7% would correspond to at least 666 MW-thermal being installed. This value is only given here for illustration purposes since it is a great simplification and includes also the systems producing from high-temperature fields. Table 4 shows the towns of Akranes and Borgarnes with Hvanneyri (agricultural college) as district heating systems under construction. Borgarnes and Hvanneyri will be connected this year while Akranes the next. This will add 6,682 people to the ones enjoying geothermal space heating. In the next few years it is expected that 5 towns will have geothermal district heating, adding 2,718 people and rendering the total as 185,000 or 81,6% of the population. At a later date there are a few other towns and rural centres where it may prove economic to use geothermal for space heating but it is not known how many people this will involve. To summarize; at the end of 1979 about 157,945 people in Iceland enjoyed geothermal district heating and in a few years this number will probably increase to 185,000 people, representing 69.7% and 81.6% of the total population, respectively.

It is not straight foreward to estimate the total utilization of low-temperature geothermal energy in Iceland nor is it easy to arrive at a value for the total installed thermal capacity. The statistics for the Reykjavík District Heating Service are the most comprehensive available and span a period of about 50 years. The RDHS meters all the water produced and delivered to the customers who pay for each m^3 received. As a rule most other district heating systems sell the hot water through "maximum flow restricters" that deliver some maximum flowrate that is fixed and the customer pays for if he uses it or not. This equipment is much simpler than rotating flowmeters and it is thought that the load curve becomes more even with lower peak demand. Table 3 shows the maximum fixed flowrate (litres/minute) that the various district heating services sell. The advantages and disadvantages of the two methods of selling geothermal water are still being debated in Iceland, partly because limited flowrate data is available and partly because the various district heating services have different constraints on their operations.

Table 3 shows that 42,853 litres/minute are sold by public district heating services in Iceland by the maximum flow method or 714 l/s as compared to the installed flowrate capacity of the RDHS of 7740 tonnes/ hour or 2150 l/s. It follows that the specific installed flowrate requirements are 16 and 19 l/s per 1000 people, respectively. This simplification shows what is claimed for the maximum flowrate method, that it requires less installed flowrate capacity. These values are only rough estimates and must be used with caution.

Installed capacity of low-temperature geothermal fields. A compilation has been made of the installed production capacity of the low-temperature geothermal fields operated by public district heating services in Iceland. This compilation excludes therefore the Sudurnes, Reykjahlid and Vestmannaeyjar systems as well as sections of Hveragerdi. This exclusion is necessary because of the frame of reference of this Note being on low-temperature geothermal energy in Iceland. The Vestmannaeyjar system is excluded because the temperature of the still molten lava exceeds 1000°C. Table 5 shows this compilation. The information presented was obtained by contacting the district heating services and asking how much water all connected boreholes could produce and at what temperature. The table shows therefore the installed production capacity of the low-temperature geothermal fields used by the public district heating services in Iceland at present. Based on the total flowrate capacity of 3071 l/s and thermal capacity of 640.6 MW above 40°C the average temperature becomes 90.0°C. This temperature represents the average well-head temperature of low-temperature geothermal water produced by public district heating services.

It should be stressed that Table 5 shows the present installed capacity of low-temperature geothermal fields serving district heating services that are public. Table 3, however, shows data for all the 24 public district heating services in Iceland at the end of 1979. It should also be stressed that the district heating services provide hot water not only for homes but also for industrial, commercial, agricultural and recreational purposes in various amounts. Unfortunately there are no statistics that show in detail to what purpose the hot water is used. What is however known is that most of the water is used for home heating. In Table 4 there are listed 5 private district heating services with 559 inhabitants and it is estimated that all other private systems provide 1000 people with district heating. Many of these systems are in rural areas with educational, agricultural (greenhouses) and commercial buildings. The number of inhabitants does therefore not necessarily reflect the amount of installed geothermal. It was estimated above that the total installed capacity of all district heating systems in Iceland serving 157,945 people would be 666 MW-thermal (above 40°C) by simple proportion with the RDHS. If the same would be done for the private systems that serve 1,556 people the installed capacity would be 6.6 MW-thermal which is probably far too low. In what follows an attempt will be made to estimate the installed production capacity of geothermal fields in rural areas.

A compilation was made of all the district heating systems (public and private) in the county of Árnessýsla in the south of Iceland. The information was obtained by asking the operators of the systems. Table 6 shows only the rural district heating systems, the towns of Selfoss, Hveragerdi and Thorlákshöfn are excluded. A comparison with Table 5 shows that the rural towns of Flúdir, Laugarás and Brautarholt are included in both tables such that Table 6 has to be lowered by 21.3 MW-thermal, for 40°C reference temperature, if it is to be added to Table 5, the result being 683.3 MW-thermal. The values in Table 6 show that the average temperature of the geothermal water is 90°C as it was in Table 5.

Many rural educational, commercial, industrial and agricultural centres in Iceland have been built at locations where hot geothermal waters are to be found. The majority of these are in low-temperature geothermal fields. Such a rural geothermal centre would typically have one or more boarding schools (from primary to upper secondary) with all the associated buildings for teachers and other staff. There are swimming pools at most of these centres. In more recent years as commercial, industrial and greenhouse activities have increased, then these have tended to be built at established eduational centres. While Table 5 shows the installed production capacity in low-temperature geothermal fields serving public district heating systems and Table 6 shows both public and private systems in the county of Árnessýsla, there are numerous centres in other parts of Iceland that must be included in the present survey. A compilation was made of the installed production capacity at the almost 30 geothermal rural school centres in Iceland. Table 7 shows the information as obtained from the operators of the systems or the files of Orkustofnun. As in Table 6 the flowrate stated represents the amount of geothermal water that is presently harnessed in each field, although it may not all be used. It is the amount of water that is presently available and connected to the distribution system but not what could be available if all hot-springs and boreholes in the field were connected. Nor does it say anything about the ultimate potential of each low-temperature geothermal field. Unfortunately there is limited if any statistics about the maximum amount of water required by each centre. To arrive at some guess'timate would e.g. require a knowledge of the heated m^3 at each centre etc. ; information which is not available. Table 7 shows the rural school centres in each county, including Árnessýsla already shown in Table 6. To arrive at the total installed capacity then the 14.5 MW-thermal (reference temperature 40°C) must be subtracted from Table 7 if it is to be added to Table 6. Therefore, Tables 5, 6 and 7 add up to 734.7 MW-thermal above 40°C. The values in parenthesis after each location name show the number of students attending the schools, adding up to more than 2225. Most of the schools are boarding schools. The number of students is based on 1979 figures while the stated capacity figures apply to late 1980. The total values in Table 7 were used to estimate the average temperature of the geothermal waters as 80°C. There are probably very few if any rural geothermal centres that do not have a school that is listed in Table 7. It follows that Table 7 shows probably all the important rural geothermal centres in Iceland. In Table 4 it is estimated that about 1000 people in rural areas enjoyed geothermal district heating in 1979. This figure includes both people living in rural centres and individual farms. An examination of Table 7 shows that the counties of Borgarfjardarsýsla and Árnessýsla account for more than 1/2 the total installed capacity. It is well known that these are the two counties where alot of low-temperature geothermal energy is available. It is therefore likely that a large proportion of the above estimated 1000 people in rural areas live in these two counties. If that is the case then Tables 6 and 7 must represent a fair number of these people. For this reason and also because the installed geothermal power associated with home heating for the remaining people must be limited, probably less than 1/2% of the total for Iceland, it will not be considered further in the present Note.

Swimming pools. There are 84 swimming pools in Iceland using geothermal water directly and/or indirectly. The total volume of these pools is 22,427 m^3 according to Orkustofnun files, with 18,789 m^2 or 83.8% outside and 3,638 m^2 or 16.2% inside. At least 4 of these being in the Sudurnes region (2 inside 305 m^3 and 1 outside 105 m^3) and Vestmannaeyjar (1 inside 550 m^3) should be excluded from the present Note because they are in non-low-temperature areas. However, it is of some interest to estimate the total use of geothermal (high- and low-temperature). A rough estimate was made of the average water requirements of outside and inside swimming pools in the Reykjavík area. Based on the yearly amount of geothermal water metered to 4 outside and 3 inside pools, it was estimated that the former used on average 1 kW/m^3 and the latter 0.5 kW/m^3 based on 80°C inlet and 40°C outlet temperatures. These values are only first estimates and need to be looked at more carefully. The above estimates are based on annual usage - the swimming pools served by the RDHS are used all year round as are most pools in other towns and main rural centres. Table 8 shows the average and specific thermal power requirements of out- and inside pools and Table 9 shows the total geothermal power needed to supply the 84 swimming pools in Iceland. There is no information on the likely load factors of swimming pools. If they have the same load factor as typical district heating systems, which is 50% for the RDHS, the values in Table 9 have to be doubled to show the installed thermal capacity required for the 84 geothermal pools. It should be kept in mind that 26°C is considered ideal for normal swimming while 19°C is more appropriate for competitions. For small children and schools the temperature could be as high as 30°C. It may therefore be difficult to evaluate the amount of thermal energy actually used in swimming pools. About 45% (38 pools) of the 84 swimming pools using geothermal are served by the public district heating services listed in Table 3. The volume of these pools is 12,452 m^3 or 56% of the total. Table 10 shows the number and size of these pools at the end of 1979. Four of the private systems listed in Table 4 have swimming pools (3 inside 324 m^3 and 1 outside 890 m^3). Of the remaining 42 pools there are at least 11 (6 outside 1292 m^3 and 5 inside 884 m^3) at locations listed in Table 7. This leaves 31 pools not in areas already listed or 6,585 m^3 (29.4% of total) of which most are probably outside pools. The associated average thermal power of these 31 pools becomes 13.2 , 12.4 , 10.7 , 7.4 and 6.6 MW-thermal for 0° , 5° , 15° , 35° and 40°C , respectively, if they are all assumed outside type and using Table 8. In other words, these values have to be added to the installed geothermal production capacities listed in Tables 5, 6 and 7 to arrive at an estimate for the whole of Iceland. This addition amounts to 741.3 MW-thermal above 40°C reference temperature.

Greenhouses. It is estimated (Ó.V. Hansson) that at the turn of 1979/1980 the total area of commercial greenhouses in Iceland was 145,000 m^2. In addition there are small greenhouses used for home growing. The majority of these houses are in the south of Iceland as shown in Table 11 indicating the situation late 1978. About 70% of the greenhouses are used for growing vegetables, mostly tomatoes and cucumbers, and about 30% for flowers such as roses, carnations, chrysanthemums and various potted plants. The heating requirements for greenhouses in the south of Iceland are estimated 200-250 kcal/h m^2 at maximum (Ó.V. Hansson). Assuming geothermal water at 80°C and taking 250 kcal/h m^2 (= 0.291 kW/m^2) as the specific thermal power requirements, the 145,000 m^2 result in 84.4 , 79.1 , 68.6 , 47.5 and 42.2 MW-thermal for 0° , 5° , 15° , 35° and 40°C , respectively. The load factor of greenhouses is not known, but it is recognized that it is lower than for home heating. There is some growing of vegetables in Iceland in naturally and artifically heated ground. The total area of soil heating is probably 15,000 m^2 most of which is natural. Recent studies show that for successful growing in heated soil the heat flux has to be about 1/4 that of greenhouses or 50 kW/m^2. An examination of Table 11, although from late 1978, and a comparison with Tables 5, 6 and 7 will show that most if not all the indicated greenhouse areas (locations) are within already listed public and private district heating services or main rural centres.

Aquaculture. Geothermal water is used in several fish culture stations in Iceland for rearing salmon and trout smolts. This has been done for a number of years and now there is a great interest in salmon farming yet to be realized on a commercial scale. The prerequisite for all fish culture operations in Iceland is a plentiful supply of geothermal energy and fresh water except possibly when rearing salmon from smolt to adult size in seawater. Table 12 shows details about the 9 fish culture stations in Iceland using geothermal water. In total they have the capacity to raise 610,000 smolts per year. Table 13 shows the estimated thermal requirements as 1.9 MW above 40°C. It should be noted that the Ellidaár and Saudárkrókur stations obtain thermal water from public district heating services. The installed geothermal production capacity not listed in any other tables amounts therefore to 1.6 MW-thermal above 40°C.

Industrial. The main use of low-temperature geothermal for industrial processing is the seaweed (mainly) drying plant at Reykhólar in West-Central Iceland. At Reykhólar there is also a public district heating service as shown in Table 5. The district heating system uses one bore-hole while the drying plant uses three boreholes. These three boreholes produce about 45 l/s in total of 112°C water. The installed thermal capacity of these two boreholes (field) corresponds therefore to 21.1, 20.2, 18.3, 14.5 and 13.6 MW-thermal above 0°, 5°, 15°, 35° and 40°C reference temperature, respectively. The seaweeds produced at Reykhólar are used in the alginate industry. The dryer has a capacity of 8-10 tonnes/hour of dried seaweeds. The dryer is sometimes used to dry fish e.g. capelin.

Overview of utilization. There are basically two methods by which the installed geothermal power in Iceland has been estimated. The first method assumes that the Reykjavík District Heating Service is typical and that the total for Iceland is proportional to the population enjoying geothermal district heating. With minor adjustment this method has traditionally been used. The second method is based on a survey (compilation) of all boreholes connected to district heating services and other users. In the present Note an attempt has been made to use the second method. The survey is however not as detailed as it needs to be and should therefore be improved. It is perhaps reasonable to ask how the two methods compare. Based on the information compiled for the present Note it has been shown above ("survey method") that for reference temperature 40°C the installed low-temperature geothermal power amounts to 756.5 MW-thermal. Using the same procedure for other reference temperatures (0°, 5°, 15° and 35°C) the corresponding values are 1377.8, 1298.4, 1141.2 and 833.8 MW-thermal. This is the total installed low-temperature geothermal power in Iceland.

In applying method one it should be noted that the RDHS sold 40,450,000 m^3 of hot water for space heating and 726,000 m^3 (1.8%) for swimming pools in 1979. It should also be noted in Table 11 that 3.9% of greenhouses are in Reykjavík and 7.2% in the Mosfellshreppur and Kjalarnes. If it is assumed that the RDHS serves 10% of greenhouses in Iceland, then 8.4 , 7.9 , 6.9 , 4.8 and 4.2 MW-thermal must be subtracted in order to show the use of geothermal by type of utilization. Using the RDHS values in Table 5, being 831.7 , 787.1 , 697.9 , 519.9 and 475.4 MW-thermal for the standard reference temperatures, then 1.8% or 15.0 , 14.2 , 12.6 , 9.4 and 8.6 MW-thermal should also be subtracted. The use of geothermal for residential, commercial and industrial heating becomes therefore 808.3 , 765.0 , 678.4 , 502.5 and 462.6 MW-thermal, respectively, serving 114,158 people (111,905 + 2,253). For the 157,945 people enjoying district heating the proportional values are 1118.3 , 1058.4 , 938.6 , 695.2 and 640.0 MW-thermal. The installed geothermal capacity associated with all swimming pools and greenhouses and industrial uses have already been estimated above. Regarding fish culture as shown in Table 13 the Ellidaár and Saudárkrókur values should be subtracted from the total district heating values above, resulting in 1117.7 , 1057.9 , 938.3 , 694.9 and 639.7 MW-thermal. Because this Note deals only with low-temperature geothermal energy the estimated installed capacity of the Sudurnes, Vestmannaeyjar and Hveragerdi systems should be given special attention as these are not low-temperature. For simplification (because swimming pools in these 3 locations are included in the total and because there are some greenhouses in the Sudurnes region) the preportional (based on population) capacity of the Sudurnes region and the town of Vestmannaeyjar was estimated from the RDHS values in Table 5, resulting in 85.5 , 80.9 , 71.7 , 53.4 and 49.0 for Sudurnes and 12.3 , 11.6 , 10.3 , 7.7 and 7.0 MW-thermal for Vestmannaeyjar. In Hveragerdi the situation is complicated because it uses both high- and low-temperature geothermal energy. An approximation is to assume that each type of field provides 1/2 the total requirement and that greenhouses are 1/2 the total. The estimated total installed geothermal for greenhouses in Iceland should therefore be lowered by 1/2 the values shown for Hveragerdi in Table 5, and the total residential, commercial and industrial space heating estimated above should be lowered by the same value. Table 14 shows the total utilization of low-temperature geothermal energy in Iceland by type of use as estimated by the "proportional method".

A comparison of Table 14 with the results of the "survey method" of estimating the installed capacity shows that the latter gives 16-19% higher values. See Table 15. It is recognized that while the "survey method" represents all the hot water that is available and connected to a distribution system, the "proportional method" represents only the hot water required by a distribution system as demanded by the users. The excess water is therefore available but not used although installed. The installed capacity in high-temperature geothermal fields in Iceland is about 100 MW-thermal above 0°C reference temperature (Note JSG-GVJ-HeT-80/02).

Exploration

There is considerable exploration work for geothermal energy carried out in Iceland as would be expected in view of the great importance the resource plays in the national economy. This year (1980) the Geothermal Division of Orkustofnun is conducting exploration work for about 10 operational district heating services to enable them to meet expected increases in demand for hot water and also to better secure their present production capacity. Exploration is also being carried out for at least 5 towns and regions that hope to find enough geothermal water to start up new district heating systems in the next few years. More than 10 exploration studies are being performed this year for rural centres and groups of farms. At the same time several regional geothermal studies are on the agenda to provide a better understanding of the processes that give rise to usable geothermal energy.

The Geothermal Division has a staff of about 50 people of which 40 are geoscientists and engineers. All services (library, drawing office etc.) are provided by other staff at Orkustofnun.

Drilling for geothermal energy in Iceland is done with 5 main rigs. They have the following depth capabilities: Jötunn 3600 m , Dofri 1900-2200 m , Narfi 1500-1800 m , Glaumur 800-1200 m and Ýmir 400-600 m. The first two are used to drill in high-temperature areas while the 3 others in low-temperature areas. The second largest, Dofri, does also alot of drilling in low-temperature areas, particularily for the RDHS which owns it 50%. The state owns all the drilling rigs and they are operated by the Drilling Division at Orkustofnun. All the exploration and production drilling for geothermal in Iceland is done by the above 5 rigs, except for gradient holes, which are drilled by smaller rigs.

Assessment

Information on the natural flow and temperature of hot springs in Iceland has been updated for the purpose of the present survey. For a number of years it has been thought that the natural flow of all hot springs in Iceland amounted to 1500 l/s of 75°C water. This flow has been attributed to about 600 hot springs in 250 locations. In the files of Orkustofnun there is information about these hot springs to which more accurate measurements have been added in recent years. This updated information was used to estimate the total flowrate of hot water in low-temperature fields as well as the associated thermal power. Also, the information has been used to estimate the present flowrate and temperature in the same fields with the advent of drilling. Table 16 shows the result of this survey. The flowrate before drilling is the natural water discharge, while the after drilling values show both the remaining natural flow and borehole discharge. The estimated natural flow is now considered 1825 l/s or 325 l/s (22%) higher than previously thought. The weighted average temperature of this flow is 67°C. All drilling that has been carried out in locations of natural hot springs has increased the flow of geothermal water to 4657 l/s or by 155%. The average temperature of this increased flow is estimated as 80°C. The thermal power above 40°C has increased from 227 MW-thermal to 785 MW-thermal or by 246%. The greatest increases in flowrate have been achieved in the low-temperature fields producing hot water for the Reykjavík District Heating Service: In the county of Gullbringu- & Kjósarsýsla the flowrate has been increased about 10 times while the thermal power has increased by about 15 times.

The Geothermal Division of Orkustofnun has carried out a geothermal assessment study for Iceland. It is similar to studies that have been carried out in the United States of America, Italy and elsewhere. A few modifications of the methodalogy have been made to make the assessment more appropriate for Iceland. For example the continuous heat flux associated with the active volcanic zone in Iceland has been included. The assessment study is still to be published and since it is difficult to separate the results into above and below 180°C it was decided not to include them in the present Note. More details are however given in the Orkustofnun Note (JSG-GVJ-HeT-80/02) on high-temperature geothermal fields since they are better defined than low-temperature fields. What can be done here is to summarize the assessment results for all geothermal energy in Iceland above 5°C (average ambient temperature) in the terminology of geothermal assessment: Resource Base 0-10 km 1.2×10^{24} J , Inaccessible 1.1×10^{24} J , Accessible 0.1×10^{24} J , Residual 96.5×10^{21} J and Useful 3.5×10^{21} J. The Useful part of the Geothermal Resource Base has not been divided into Economic and Subeconomic as it is related to various time dependent assumptions.

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Bibliography

Bödvarsson, G., 1975: Estimates of the Geothermal Resources of Iceland. Proc. Second U.N. Symp. Development Use Geothermal Resources, 1, 33-35. San Francisco, May 20-29.

Pálmason, G., Ragnars, K. & Zoëga, J., 1975: Geothermal Energy Developments in Iceland 1970-1974. Proc. Second U.N. Symp. Development Use Geothermal Resources, 1, 213-217. San Francisco, May 20-29.

Einarsson, S.S., 1975: Geothermal Space Heating and Cooling. Proc. Second U.N. Symp. Development Use Geothermal Resources, 3, 2117-2126. San Francisco, May 20-29.

Gudmundsson, J.S., 1976: Utilization of Geothermal Energy in Iceland. Applied Energy, 2, 128-140.

Jónsson, V.K., 1976: Geothermal Power Utilization, Present and Future. In: Hartnett, J.P. Alternative Energy Sources. Academic Press, New York, 279-325.

Ragnars, K., 1978: Methods of Exploration and Exploitation of Low-Temperature Geothermal Fields in Iceland. Orkustofnun, OS-JHD-7833, 10 p.

Fridleifsson, I.B., 1978/79: Applied Volcanology in Geothermal Exploration in Iceland. Pure and Applied Geophysics, 117, 242-252.

Thórhallsson, S., 1979: Combined Generation of Heat and Electricity from a Geothermal Brine at Svartsengi in S.W. Iceland. Geothermal Resources Council Transactions, 3 , 733-736.

Fridleifsson, I.B., 1979: Geothermal Activity in Iceland. Jökull, 29, 47-56.

Ragnars, K., 1980: Icelandic Experience with Direct Use of Geothermal Energy. Orkustofnun, Note KR-80/02 , 9 p.

Björnsson, J., 1980: Conservation of Oil in the Space Heating Sector in Iceland through Substitution by Indigenous Energy Sources. 11th World Energy Conf., 1B, 400-409, 8-12 Sept., Munich.

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Annual hot water production of the Reykjavík District Heating Service 1944-1979

80-10-23	
J.S.G./Sy.J.	
Vinnslut. Reykjav.	
F 20126	

Fig. I

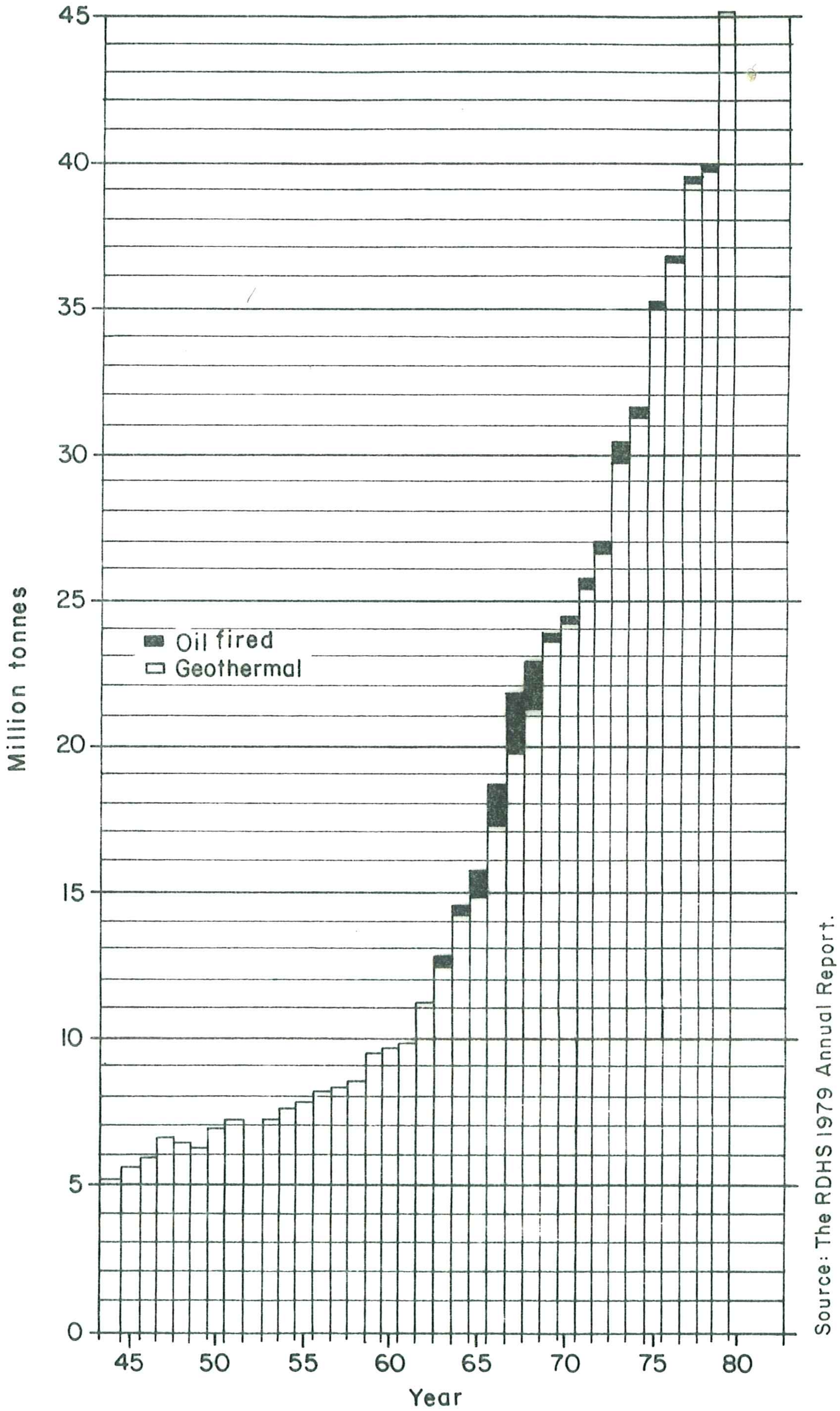

TABLE 1

Total installed thermal capacity of the low-temperature fields of the Reykjavík District Heating Service in February 1980. (Information Á. Gunnarsson).

Name of Field	Flowrate (tonnes/hour)	Temperature (°C)	Thermal capacity (MW)				
			>0°C	>5°C	>15°C	>35°C	>40°C
Mosfellssveit	6100	87	610.4	575.3	505.1	364.8	329.7
Laugarnes	1100	127	161.0	154.6	141.9	116.6	110.3
Ellidaár	540	97	60.3	57.2	50.9	38.5	35.4
Total	7740	.	831.7	787.1	697.9	519.9	475.4

TABLE 2

Geothermal water production x10^{-3} m^3 of the Reykjavik District Heating Service 1967-1976. (Information G. Kristinsson).

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
January	2,216	2,712	2,813	22,689	3,131	2,807	2,909	3,544	4,352	4,608
February	2,017	2,443	2,619	2,581	2,600	2,666	3,212	3,383	3,218	3,897
March	2,452	2,492	2,462	2,675	2,621	2,756	3,101	2,922	3,588	3,958
April	2,017	2,040	2,093	2,008	2,281	2,346	2,715	2,448	3,149	3,339
May	1,424	1,586	1,468	1,706	1,742	1,886	2.293	2.084	2,432	2,492
June	1,239	1,364	1,276	1,410	1,189	1,402	1,779	1,662	2,074	1,787
July	972	1,140	1,261	1,032	1,194	1,325	1,497	1,175	1,702	1,620
August	1,104	1,165	1,068	1,119	1,212	1,466	1,468	1,640	1,796	2,009
September	1,434	1,435	1,672	1,552	1,499	1,803	1,795	2,492	2.414	2,145
October	2,071	2,106	2,065	2,157	2,322	2,481	2,529	2,902	2,774	3.019
November	2,310	2,044	2,595	2,689	2,761	2,983	3,432	3,207	3,599	3,582
December	2,628	2,440	2,590	2,712	3,062	3,046	3,917	4,113	4,008	4,341
Total	21,884	22,967	23,982	24,330	25,614	26,967	30,557	31,572	35,106	36,797

TABLE 3

All public geothermal district heating services in Iceland 1979.

Town/Region	Year	Population 1979.12.01	Temperature (°C) Delivered	Returned	Quantity Water Sold $x10^{-3}$ (m^3)	(l/min.)	Heated Space ($x10^{-3}$ m^3) Total	Homes	Other	Revenue* $x10^{-3}$IKR
Reykjavík	1930	111,905	80	40	41,178	-	22,388	...	...	4,865,220
Seltjarnarnes	1972	2,981	80-85	40	-	2,289	520	...	...	72,915
Mosfellshreppur	1943	2,253	80	40	-	3,106	...	...	...	68,405
Sudurnes	1975	11,500	80-88	35-40	-	9,200	1,762	1,391	371	645,820
Thorlákshöfn	1979	500	80	40	-	350	...	...	...	1,952
Selfoss	1948	3,157	78	...	934	1,166	...	...	...	161,432
Hveragerdi	...	1,180	80-85	...	-	2,500	...	...	...	74,257
Laugarás	...	91	90	...	-	216	12	10	2	13,859
Flúdir	1967	162	80	40	-	1,403	60	15	45	15,974
Brautarholt	1979	50	73	...	-	300	...	...	...	1,548
Vestmannaeyjar	1975	1,650	75	35	273	-	211	165	46	74,372
Reykhólar	1974	90	100	...	-	173	...	...	...	977
Sudureyri	1977	512	60	...	-	658	...	...	...	48,700
Hvammstangi	1973	564	78-80	40	19	847	122	...	...	56,488
Blönduós	1978	1,012	60	30-40	-	1,435	176	108	68	93,402
Saudárkrókur	1953	2,113	66-68	30-45	-	3,520	408	259	149	99,125
Siglufjördur	1975	1,700	80	...	255	1,259	...	...	...	137,233
Ólafsfjördur	1944	1,100	57	25-30	-	2,113	158	116	42	45,031
Dalvík	1969	1,253	60	34-38	-	2,158	223	137	86	64,158
Hrísey	1973	295	56	...	-	455	...	...	...	13,700
Akureyri	1977	9,000	82-90	...	-	6,000	...	...	...	481,288
Húsavík	1970	2,587	80	40	17	3,110	...	...	...	121,312
Reykjahlíd	1969	284	80	40	-	-	39	29	10	7,923
Egilsstadir	1979	450	60-65	30-40	-	700	93	59	34	-
Total	.	156,389	.	.	42,676	42,858	...	...	...	7,165,091

*Average 1979 rate of exchange US$ = 353 IKR.

TABLE 4

Geothermal district heating in Iceland, 1979 and future

Town/Region	Population[1)] Present	Future
Public:		
24 systems	156,389*	174,000*
Private:	1,556*	1,600*
Laugarvatn	159	-
Kleppsjárnreykir	48	-
Reykholt	68	-
Laugarbakki	90	-
Varmahlíd	89	-
Laugar, Reykjadal	102	-
Rural etc.	1,000	-
Total:	157,945*	175,600*
Under construction:		6,682*
Akranes	-	5,017
Borgarnes	-	1,557
Hvanneyri	-	108
Under consideration:	-	2,718*
Eyrarbakki	-	538
Stokkseyri	-	476
Hella	-	520
Hvolsvöllur	-	524
Raudalækur	-	42
Rural etc.	-	618
Total:	-	9,400*
Grand Total	157,945 (70%)	185,000 (82%)

1) Census 1979.12.01 population 226,724

TABLE 5

Installed production capacity of low-temperature geothermal fields operated by public district heating services in Iceland 1980.

Town	Capacity (l/s)	Temperature[4] (°C)	Installed thermal capacity (MW) >0°C	>5°C	>15°C	>35°C	>40°C
Reykjavík[1]	1694	87	610.4	575.3	505.1	364.8	329.7
Reykjavík	306	127	161.0	154.6	141.9	116.6	110.3
Reykjavík	150	97	60.3	57.2	50.9	38.5	35.4
Seltjarnarnes	48	106	21.1	20.1	18.1	14.1	13.1
Thorlákshöfn	40	100	16.1	15.8	14.1	10.8	9.9
Selfoss	120	83	41.3	38.8	33.8	23.9	21.4
Hveragerdi[2]	45	90	17.0	16.0	14.1	10.4	9.4
Laugarás	45	100	18.6	17.7	15.8	12.1	11.2
Flúdir	38	96	15.1	14.3	12.8	9.6	8.8
Brautarholt	5	74	1.6	1.5	1.3	0.8	0.7
Reykhólar[3]	17	93	6.6	6.2	5.5	4.1	3.7
Sudureyri	22	61	5.6	5.1	4.2	2.4	1.9
Hvammstangi	19	94	7.4	7.0	6.2	4.6	4.3
Blönduós	45	70	13.1	12.1	10.3	6.5	5.6
Saudárkrókur	86	70	24.9	23.2	19.6	12.5	10.7
Siglufjördur	27	68	7.6	7.0	5.9	3.7	3.1
Ólafsfjördur	42	57	9.9	9.1	7.3	3.8	3.0
Dalvík	69	64	18.3	16.9	14.0	8.3	6.9
Hrísey	7	64	1.8	1.7	1.4	0.8	0.7
Akureyri	130	95	51.2	48.5	43.1	32.3	29.6
Akureyri	60	78	19.4	18.1	15.7	10.7	9.4
Húsavík	42	100	17.4	16.5	14.8	11.3	10.4
Egilsstadir	14	64	3.7	3.4	2.8	1.7	1.4
Total	3071	-	1149.9	1086.1	958.7	704.3	640.6

1) Includes Mosfellshreppur, cf. Tables 1 and 3.
2) Low-temperature field within town.
3) One borehole serving district heating only.
4) Temperature at well-head.

TABLE 6

Installed production capacity of low-temperature geothermal fields operated by public and private district heating services in the county of Árnessýsla 1980, excluding Selfoss, Hveragerdi and Thorlákshöfn.

District: Location	Capacity (l/s)	Temperature (°C)	Installed thermal capacity (MW) > 0°	> 5°	> 15°	> 35°	> 40°
Ölfushreppur:	9.4*	-	3.8	3.6	3.2	2.5	2.3*
Árbaer	4.4	93	1.7	1.6	1.4	1.1	1.0
Hlídardalur 2)	5	100	2.1	2.0	1.8	1.4	1.3
Grímsneshreppur:	22*	-	7.6	7.2	6.3	4.5	4.0*
Reykjanes	10	80	3.3	3.1	2.7	1.9	1.7
Sólheimar 2)	12	87	4.3	4.1	3.6	2.6	2.3
Hraungerdishreppur:	2*	-	0.5	0.5	0.4	0.3	0.2*
Sölvholt	2	65	0.5	0.5	0.4	0.3	0.2
Skeidahreppur	9.0*	-	2.6	2.4	2.0	1.2	1.0*
Brautarholt 1)	4.6	72	1.4	1.3	1.1	0.7	0.6
Hlemmiskeid	0.4	63	0.1	0.1	0.1	0.1	0.0
Húsatóftir	1	70	0.3	0.3	0.2	0.1	0.1
Ósabakki	2.	58	0.5	0.4	0.4	0.2	0.2
Reykir	1	69	0.3	0.3	0.2	0.1	0.1
Hrunamannahreppur:	79*	-	30.0	28.4	25.0	18.6	17.0*
Flúdir 1)	38	100	15.8	15.0	13.3	10.3	9.5
Midfellshverfi	10	65	2.7	2.5	2.1	1.2	1.0
Reykjaból	20	100	8.3	7.9	7.0	5.4	5.0
Sydra Langholt	5	67	1.4	1.3	1.1	0.7	0.6
Birtingaholt	4	62	1.0	0.9	0.8	0.5	0.4
Laugar	2	100	0.8	0.8	0.7	0.5	0.5
Biskupstungnahreppur:	118.4*	-	47.0	44.5	39.7	29.8	27.5*
Audsholt	4	92	1.5	1.4	1.3	0.9	0.9
Efri Reykir	0.4	92	0.2	0.1	0.1	0.1	0.1
Laugarás 1)	45	100	18.6	17.7	15.8	12.1	11.2
Reykholt (Aratunga) 2)	14	98	5.7	5.4	4.8	3.7	3.4
Sydri Reykir	40	95	15.7	14.9	13.3	9.9	9.1
Skálholt 2)	7	97	2.8	2.7	2.4	1.8	1.7
Spóastadir	8	74	2.5	2.3	2.0	1.3	1.1
Laugardalshreppur:	62*	-	22.4	21.1	18.5	13.4	12.0*
Bödmódsstadir	5	100	2.1	2.0	1.8	1.4	1.2
Útey	22	95	8.7	8.2	7.3	5.5	5.0
Laugarvatn 2)	35	80	11.6	10.9	9.4	6.5	5.8
Total	301.8	-	113.9	107.7	95.1	70.3	64.0

1) Public systems included in Table 5
2) Rural schools included in Table 7

TABLE 7

Installed production capacity of low-temperature geothermal fields operated by district heating systems at main rural (school) centers in Iceland 1980.

County: Location	Capacity (l/s)	Temperature (°C)	Installed thermal capacity (MW) > 0°C	> 5°C	> 15°C	> 35°C	> 40°C
Borgarfjardarsýsla:	96*	-	39.7	37.7	33.7	25.7	23.7*
Leirá (85)	5	80	1.7	1.6	1.4	0.9	0.8
Kleppjárnsreykir (117) 4)	71	101	29.7	28.2	25.3	19.4	17.9
Reykholt (?) 4)	20	100	8.3	7.9	7.0	5.4	5.0
Mýrasýsla:							
Varmaland: (149 + ?)	9*	97	3.6	3.4	3.1	2.3	2.1*
Snæfells- & Hnappadalssýsla:							
Laugagerdi (124)	2*	66	0.6	0.5	0.4	0.3	0.2*
Dalasýsla:							
Laugar, Sælingsdal (144)	14*	64	3.7	3.4	2.8	1.7	1.4*
Bardastrandasýslur:							
Krossholt (38)	20*	44	3.6	3.2	2.4	0.8	0.3*
Ísafjardarsýslur:							
Reykjanes (20 + ?)	20*	85	7.0	6.6	5.8	4.1	3.7*
Strandasýsla:							
Klúka (13)	14*	43	2.5	2.2	1.6	0.5	0.2*
Húnavatnssýslur:							
Reykir, Hrútafirdi (100 + ?)	12*	98	4.9	4.6	4.1	3.1	2.9*
Laugabakki (110) 4)	1)	-	-	-	-	-	-
Húnavellir (165)	2)	-	-	-	-	-	-
Skagafjardarsýsla:	31.5*	-	9.6	9.0	7.7	5.2	4.4*
Varmahlíd (135) 4)	16.5	86	5.9	5.5	4.9	3.5	3.1
Steinsstadir (54)	13	60	3.2	3.0	2.4	1.4	1.1
Haganes (25)	2	65	0.5	0.5	0.4	0.3	0.2
Eyjafjardarsýsla:	13*	-	4.5	4.2	3.6	2.6	2.3*
Thelamörk (126)	10	90	3.8	3.6	3.1	2.3	2.1
Hrafnagil (147)	3	57	0.7	0.6	0.5	0.3	0.2
Thingeyjarsýslur:	97*	-	26.0	24.0	20.0	12.0	10.0*
Stóru Tjarnir (134)	5	63	1.3	1.2	1.0	0.6	0.5
Laugar, Reykjadal (110 + ?) 4)	85	64	22.5	20.8	17.3	10.2	8.5
Hafralaekur (118)	7	75	2.2	2.0	1.7	1.2	1.0
Rangárvallasýsla:							
Laugaland, Holtum (110)	4*	50	0.8	0.8	0.6	0.3	0.2*
Árnessýsla: 3)	68*	-	26.5	25.1	22.0	16.0	14.5*
Reykholt (107)	14	98	5.7	5.4	4.8	3.7	3.4
Skálholt (?)	7	97	2.8	2.7	2.4	1.8	1.7
Laugarvatn (94 + ?) 4)	35	80	11.6	10.9	9.4	6.5	5.8
Sólheimar (?)	12	87	4.3	4.1	3.6	2.6	2.3
Hlídardalur (?)	5	100	2.1	2.0	1.8	1.4	1.3
Total (> 2225 students)	400.5	-	133.0	124.7	107.8	74.6	65.9

1) Included in Hvammstangi in Table 5
2) Included in Blönduós in Table 5
3) Included in Table 6
4) Included in Table 4

TABLE 8

Average (annual basis) specific thermal power requirements of swimming pools in Iceland*

Type	Specific thermal power (kW/m^3)				
	> 0°C	> 5°C	> 15°C	> 35°C	> 40°C
Outside	2.00	1.88	1.63	1.13	1.00
Inside	1.00	0.94	0.82	0.57	0.50

*Rough estimate based on experience in Reykjavík.

TABLE 9

Average (annual basis) total thermal power requirements of swimming pools in Iceland using geothermal*

Type	Volume (m^3)	No.	Average thermal power (MW)				
			> 0°C	> 5°C	> 15°C	> 35°C	> 40°C
Outside	18,789	64	37.6	35.3	30.6	21.2	18.8
Inside	3,638	20	3.6	3.4	3.0	2.1	1.8
Total	22,427	84	41.2	38.7	33.6	23.3	20.6

*Estimate based on Table 8 and the known volume of swimming pools.

TABLE 10

Swimming pools served by district heating services

Town/Region	Number	Volume (m^3)
Reykjavík[1)]	12	5,367
Sudurnes[2)]	3	410
Mosfellshreppur	4	615
Reykhólar	1	360
Sudureyri	1	90
Blönduós	1	100
Saudárkrókur	1	360
Siglufjördur	1	500
Ólafsfjördur	1	360
Dalvík	1	100
Hrísey	1	120
Akureyri[3)]	3	1,110
Húsavík	1	170
Egilsstadir	1	90
Vestmannaeyjar	1	550
Brautarholt	1	170
Flúdir	1	360
Selfoss	2	420
Hveragerdi	1	1,200
Total	38	12,452

1) Reykjavík, Gardabær, Kópavogur & Hafnarfjördur

2) Njardvík, Keflavík & Grindavík

3) Akureyri & Sydri-Laugaland

TABLE 11

Main greenhouse areas in Iceland in October 1978 with about 140 producers. (Information A.V. Magnússon).

Region: District	Area (m^2)	%
South-West:	16,100*	12.3*
Reykjavík	5,000	3.9
Reykjanes	1,600	1.2
Mosfellshreppur & Kjalarnes	9,500	7.2
West-Central:	13,600*	10.4*
Lundareykjadalshreppur	500	0.4
Reykholtsdalur	6,100	4.6
Stafholtstungnahreppur	5,700	4.3
Andakílshreppur	1,300	1.1
West-Fjords:	800*	0.6*
Nauteyrarhreppur	800	0.6
North-West	1,800*	1.4*
Ytri-Torfustadahreppur	200	0.2
Lýtingstadahreppur	1,600	1.2
North-East:	6,200*	4.7*
Hrafnagilshreppur	1,150	0.9
Öngulstadahreppur	1,100	0.8
Reykjahreppur	3,800	2.9
Skútustadahreppur	150	0.1
South:	92,700*	70.6*
Hveragerdishreppur	32,400	24.7
Ölfushreppur	12,600	9.6
Grímsneshreppur	700	0.5
Laugadalshreppur	1,900	1.4
Biskupstungnahreppur	32,100	24.5
Hrunamannahreppur	13,000	9.9
Total	131,200	100.0

TABLE 12

Icelandic fish culture rearing stations with capacities exceeding 10,000 smolts per year. (Information Á. Ísaksson).

Station	Geothermal water		Rearing water		Energy use	Capacity	Water
	(l/s)	(°C)	(l/s)	(°C)	(kcal/s)	(smolts)	Constraint
Kollafjördur	6	70	150	4	300	100,000	Geothermal
Laxalón	15	12	50	4	-	100,000	Geothermal
Keldur	9	9.5	0	0	-	30,000	Rearing
Ellidaár[1)]	-	80	-	4	-	10,000	Rearing
Saudárkrókur[1)]	-	75	6	4	-	20,000	Rearing
Laxamýri	-	80	50	4	300	100,000	Rearing
Tunga	-	-	-	4	-	-	Geothermal
Öxnalækur	80-90	11-14	-	-	-	250,000	Rearing
Húsatóftir	-	-	-	8-10	-	-	-

1) Geothermal water from public district heating services.

TABLE 13

Estimated thermal requirements of Icelandic fish culture rearing stations 1980

Station	Geothermal water		Capacity	Installed thermal capacity (MW)				
	(l/s)	(°C)	(smolts)	> 0°C	> 5°C	> 15°C	> 35°C	> 40°C
Kollafjördur	6	70	100,000	1.7	1.6	1.4	0.9	0.8
Laxalón	15	12	100,000	0.8	0.4	-	-	-
Keldur	9	9.5	30,000	0.4	0.2	-	-	-
Ellidaár[1) 2)]	-	80	10,000	0.2	0.2	0.1	0.1	0.1
Saudárkrókur[1) 2)]	-	75	20,000	0.4	0.3	0.3	0.2	0.2
Laxamýri[1)]	-	80	100,000	1.7	1.6	1.4	0.9	0.8
Tunga	-	-	-	-	-	-	-	-
Öxnalækur	80-90	11-14	250,000	4.4	2.6	-	-	-
Húsatóftir	-	-	-	-	-	-	-	-
Total	-	-	610,000	9.6	6.9	3.2	2.1	1.9

1) Installed thermal capacity estimated on requirements at Kollafjördur.

2) Geothermal water from public distric heating services

TABLE 14

Total installed capacity of low-temperature geothermal energy in Iceland as estimated by "proportional method"

Type of use	(%)**	Installed thermal power (MW)				
		> 0°C	> 5°C	> 15°C	> 35°C	> 40°C
Space heating*	87.9	1011.4	957.4	849.3	628.6	579.0
Greenhouses	6.4	75.9	71.1	61.6	42.3	37.5
Swimming pools	3.5	41.2	38.7	33.6	23.3	20.6
Industrial	1.9	21.1	20.2	18.3	14.5	13.6
Fish culture	0.3	9.6	6.9	3.2	2.1	1.9
Total	100.0	1159.2	1094.3	966.0	710.8	652.6

* Residential, commercial and industrial buildings.

** Calculation based on > 15°C values.

TABLE 15

Comparison of estimated installed capacity of low-temperature geothermal energy by type of method.

	Installed thermal capacity (MW)				
Method	> 0°C	> 5°C	> 15°C	> 35°C	> 40°C
Proportional	1159.2	1094.3	966.0	710.8	652.6
Survey	1377.8	1298.4	1141.2	833.8	756.5
Excess (not used)	281.6	203.7	175.2	123.0	103.9

TABLE 16

Survey of low-temperature geothermal energy in Iceland before and after drilling

Name of county	Number of hot-springs		Temp. (°C)		Flowrate (l/s)		Thermal power BEFORE drilling (MW)					Thermal power AFTER drilling (MW)				
	Total	Measured	(B)	A	Before	After	> 0°C	> 5°C	> 15°C	> 35°C	> 40°C	> 0°C	> 5°C	> 15°C	> 35°C	> 40°C
Gullbringu & Kjósarsýsla	17	16	(73)	93	208.5	2114.5	62.92	58.61	49.97	33.26	29.30	815.18	771.44	683.75	508.91	465.39
Borgarfjardarsýsla	49	40	(86)	91	446.2	555.4	158.21	149.03	130.64	94.48	85.57	209.94	198.08	174.38	127.64	116.07
Mýrasýsla	18	13	(65)	65	57.5	57.5	15.44	14.25	11.89	7.41	6.32	15.44	14.25	11.89	7.41	6.32
Snaefells- & Hnappadalssýsla	8	7	(49)	50	7.4	10.9	1.50	1.34	1.06	0.45	0.31	2.24	2.02	1.58	0.69	0.46
Dalasýsla	6	3	(52)	63	2.5	14.8	0.54	0.49	0.39	0.17	0.13	3.86	3.55	2.94	1.71	1.41
Bardastrandasýslur	93	65	(31)	33	153.8	264.0	19.95	16.97	11.01	4.04	3.22	36.57	31.15	20.49	6.52	4.25
Ísafjardarsýslur	35	34	(50)	50	161.0	188.5	33.10	29.74	22.91	10.86	8.14	39.25	35.31	27.34	13.03	9.96
Strandasýsla	22	20	(45)	45	102.8	103.2	18.96	16.84	15.59	4.43	2.91	19.07	16.95	15.68	4.48	2.94
Húnavatnssýslur	11	7	(87)	87	60.4	60.4	21.89	20.65	18.13	13.19	11.95	21.68	20.43	17.92	12.97	11.74
Skagafjardarsýsla	50	42	(52)	58	87.3	169.6	18.83	17.01	13.39	6.49	5.01	40.96	37.44	30.41	16.70	13.49
Eyjafjardarsýsla	43	36	(47)	47	46.0	230.9	8.90	7.90	5.59	2.47	1.84	44.98	40.68	32.46	15.68	12.48
S-Thingeyjarsýsla	35	24	(75)	74	99.0	253.6	30.57	28.53	24.40	16.84	15.11	77.87	72.63	62.09	42.36	37.69
N-Thingeyjarsýsla	2	2	(30)	30	3.0	3.0	0.37	0.31	0.18	0.00	0.00	0.37	0.31	0.18	0.00	0.00
N-Múlasýsla	2	2	(45)	64	1.5	2.5	0.28	0.25	0.19	0.06	0.03	6.65	6.13	5.10	3.02	2.51
E-Skaftafellssýsla	5	5	(47)	47	8.0	8.0	1.56	1.40	1.06	0.41	0.24	1.56	1.40	1.06	0.41	0.24
W-Skaftafellssýsla	11	7	(51)	51	11.9	11.9	2.52	2.25	1.83	1.06	0.89	2.52	2.25	1.83	1.06	0.89
Rangárvallasýsla	21	13	(40)	40	28.5	28.5	4.76	4.16	2.97	1.07	0.76	4.76	4.16	2.97	1.07	0.76
Árnessýsla	94	60	(78)	80	339.3	579.7	109.11	102.76	88.77	61.51	55.01	191.18	179.51	157.34	110.14	98.70
Total	522	396	(67)	80	1824.6	4656.9	509.41	472.49	399.97	258.20	226.74	1534.08	1437.69	1249.41	873.80	785.30

APPENDIX C

Individual Sheets

C1. Africa
C2. Central America
C3. South America
C4. West Indies
C5. Australia
C6. Austria
C7. Canada
C8. Czechoslovakia
C9. Democratic Peoples Rebublic of Korea
C10. Denmark
C11. Eire
C12. Federal Republic of Germany
C13. Fiji
C14. German Democratic Republic
C15. Greece
C16. India
C17. Indonesia
C18. Israel
C19. Italy
C20. Mexico
C21. Netherlands
C22. New Zealand
C23. Philippines
C24. Poland
C25. Republic of Korea
C26. Romania
C27. Solomon Islands
C28. Sweden
C29. Switzerland
C30. Thailand
C31. Turkey
C32. United Kingdom
C33. United States of America
C34. Yugoslavia

AFRICA

Information

The questionnaire was sent to W.J. Wairegi in Kenya and a reply was received from J.K. Kinyariro at the same institution. It was also sent to B. Khelif in Algeria who sent a reply. No reply has yet been received from S. Nwachukwu in Nigeria. The questionnaire was also sent to A. Abdallah in Djibouti but no reply has yet arrived. Papers presented in Pisa and San Francisco were e.g. consulted for information.

General

There is both high and low-temperature geothermal energy in Africa. The main high-temperature geothermal regions are associated with the Rift Valley of eastern Africa from the Red Sea to the north and continuing southward through the length of Ethiopia, Kenya and Tanzania. No reports are available of high-temperature geothermal in other parts of Africa except on the island of Réunion (French) in the Indian Ocean and the Canari Islands (Spanish) in the Atlantic Ocean. Low-temperature geothermal energy is found in many African countries. Many of these are listed in U.S. Geological Survey Professional Paper 492 from 1965 "Thermal Springs of the United States and Other Countries of the World - A Summary". In African countries that have done work on geothermal resources in recent years the main emphasis has been on high-temperature fields for electricity production. Data on low-temperature fields is therefore non-existent.

Kenya

The reply from Kinyariro indicated that there was no utilization of low-temperature geothermal in Kenya nor was there any mention of exploration and assessment. Two papers on "Olkaria Geothermal Field and its Potential Contribution to Power Requirements in Kenya" and "Geothermal Exploration in Kenya" were enclosed. It was mentioned that several non-electrical projects will be investigated in connection with the development of high-temperature resources. It was in 1970 that a joint United Nations/Kenya Government exploration project was started. The main high-temperature fields of interest are Olkaria, Eburru and Bogoria.

Algeria

Khelif stated that the main low-temperature fields are in the north of Algeria. In the west 4 hot springs 43-80°C ; in the centre 2 hot springs 40-54°C and in the east 2 hot springs 65-70°C. These and other hot springs in Algeria are used for bathing purposes. In 1978-79 there was some exploration for geothermal in Algeria. The most promising areas are in the east. Information from BRGM in France indicates that an experimental binary cycle plant is being set up at one hot spring location.

Egypt

Papers by Morgan & Swanberg (1978/79) and Morgan et al. (1976) discuss heat flow in Egypt and its geothermal potential. The heat flow "data indicate potential for development of geothermal resources along the Red Sea and Gulf of Suez coasts. Water geochemistry data confirm the high heat flow but do not indicate any deep hot aquifers". Also: "The hottest springs in Egypt are located in the Gulf of Suez area". The hottest spring in Egypt is 75°C.

Uganda

Dixon & Morton (1970) give information about hot springs in Uganda although limited temperature measurements were reported. Three geothermal drillholes (1954) were mentioned giving 52°,58° and 72°C. They listed 19 thermal springs of which 12 are 20-45°C, 3 are 45-75°C and 4 are 75-100°C. Some of these are used for bathing. No mention was made of high-temperature fields. Maasha (1975) gives some information on hot springs in Uganda: ".... at least 20 geothermal areas with numerous hot springs discharging water at 30 to 100°C occur ....." . Electrical resistivity measurements indicate 160°C in one location.

Tanzania

Nzaro (1970) listed 32 hot springs in Tanzania with temperatures 28-76°C. The amount of silica in the listed springs indicates low-temperature geothermal.

Since early 1976 there has been carried out geothermal exploration (reconnaissance) in Tanzania by foreign consultants (SWECO in Sweden and VIRKIR in Iceland). Several reports (1976, 1978 and 1979) have been prepared. In the 1978 report it is concluded that: On the basis of geology and geothermal fluid chemistry the thermal activity in Tanzania can be divided into four main regional systems: the Mbeya Region, the Ngorongoro Region including the Musoma Area, the Dotoma-Singita-Konda Area, and the Kisaki-Rufiji River Area". Also: "The chemical geothermometers indicate that high-temperature geothermal activity may exist in the Mbeya Region but not in the other regions".

Other countries

Exploration work in Madagascar is being carried out by consultants (VIRKIR in Iceland) indicating low-temperature activity. In Djibonti the thermal activity is mainly high-temperature. The same applies to Réunion, but French institutions are doing work in both. It has been reported that geothermal is to be found in Malawi, Burundi, Zaire, Chad and Morocco (Fanelli & Taffi 1980). Private communication from the B.R.G.M. in France indicates some geothermal interests in Tunisia and Rwanda.

Bibliography

Noble, J.W. & Ojiambo, S.B., 1975: Geothermal Exploration in Kenya. San Francisco, 189-204.

Nwachukwu, S.O.O., 1975: Geothermal Regime of Southern Nigeria. San Francisco, 205-212.

Morgan, P. & Swanberg, C.A., 1978/79: Heat Flow and the Geothermal Potential of Egypt. Pageoph , 117, 213-226.

Morgan, P., Blackwell, D.D. & Farris, J.C., 1976: Preliminary Geothermal Gradient and Heat Flow Values for Northern Egypt and the Gulf of Suez from Oil Well Data. Athens, 1, 424-438.

Dixon, C.G. & Morton, W.H., 1970: Thermal and Mineral Springs in Uganda. Pisa, 1035-1038.

Maasha, N., 1975: Electrical Resistivity and Microearthquake Surveys of the Sempaya, Lake Kitagata, and Kitagata Geothermal Anomalies, Northern Uganda. San Francisco, 1103-1112.

Nzaro, M.A., 1970: Geothermal Resources in Tanzania. Pisa, 1039-1043.

Fanelli, M. & Taffi, L., 1980: Status of Geothermal Research and Development in the World. 26th Int. Geol. Cong. , C2 , Paris.

CENTRAL AMERICA

Information

The questionnaire was sent to G. Cuéllar in El Salvador but Guatemala, Honduras, Nicaragua, Costa Rica and Panama were visited by I.B. Fridleifsson of Orkustofnun (as the resident co-ordinator of the United Nations University geothermal training programme in Iceland) and S.S. Einarsson of U.N.D.P. The institution in each of these countries responsible for (geothermal) energy was given the questionnaire. Only one reply has yet been received from M.F. Corrales V. in Costa Rica. His letter stated: "In regard to your request on world survey of low temperature geothermal fields I want to inform you that we are not considering or studying this kind of geothermal energy source".

General

It is evident that low temperature geothermal has not received any attention in Central America. The various reviews and papers show however that considerable interest is in high-temperature fields. El Salvador has a well advanced programme and is already generating 95 MW-electrical at Ahuachapan (DiPippo, 1978). Nicaragua is interested in exploration projects of several fields (Teilman, 1979) and drillings at Momotombo. A geothermal resources inventory of 235 localities (43 springs and 192 wells) covering an area of 20,000 km^2 identified 8 areas that showed geothermal anomalies. In 4 of these geothermometers indicate temperature in the range 150-200°C. In Guatemala and Costa Rica there are active geothermal exploration programmes. Honduras has recently embarked upon an exploration programme. Panama has carried out some geothermal exploration.

Bibliography

DiPippo, P., 1978: The Geothermal Power Station at Ahuachapan, El Salvador, Geothermal Energy Magazine, 6 (10), 11-22.

Einarsson, S.S., 1978: Opportunities for Direct Use of Geoheat in Central America and Other Tropical Countries. Geothermics 6, 209-219.

Teilman, M.A., 1979: A Geochemical Reconnaissance of Thermal and Non-thermal Waters in Nicaragua. Geothermal Resources Council Transactions, 3, 717-720.

Zuniga, A. & Lopez, C., 1977: Development of Geothermal Resources of Nicaragua. Geothermal Energy Magazine., 5 (7), 8-12.

SOUTH AMERICA

Information

The questionnaire was sent to A.C. Echeverry G. at CHEC in Colombia. A reply was received with useful information and 3 maps. To Ecuador the questionnaire was sent E.A. Ortíz who forewarded it to C.Q. Terán at INE who sent a reply with a table and a map. The questionnaire was sent to B.M. Arnao at INGEMMT in Peru who sent a reply. The questionnaire was also sent to C.J. Lezama in Venezuela but no reply was received. In Argentina the questionnaire went to A. Fernandez who sent some material and an address for further information.

Chile

In South America most of the geothermal mentioned is along the Andes or at its boundaries. Very limited published material is available except on the El Tatio high-temperature field in Chile that was explored and drilled in the early 70's. Nothing very much appears to have happened at the field in recent years. There are other areas in Chile with similar high-temperature potential as El Tatio.

Colombia

The information sent by Echeverry on geothermal in Colombia is most interesting. Geothermal investigations are just starting and are initially centred on the department of Caldas and will later be extended to other parts of Colombia. The region being studied is the Volcanic Massif of Ruiz (15,000 km^2) but specifically a 300 km^2 part of it Area del Ruiz. Both geological and geochemical studies are used. There are hot springs named Thermal Springs of Ruiz that are used for unique agricultural purposes. In translation: "From this spring, part of the fluid is carried through pipes to a plant of water treatment for aquaduct, and using the high contents of $Al_2(SO_4)_3$, $F_2(SO_4)$ and $FeSO_4$ in the fluid like coagulent for treatment of hard water with excellent resuts". It was mentioned by Echeverry that at one other hot spring site the water is "carried through pipes for space heating of a tourist centre". It is not clear if these above areas are high-or low-temperature fields. Echeverry then mentions that hot springs in Area del Ruiz measure 92°C and states that geothermometers indicate higher temperatures than 180°C. The hot springs in question are therefore probably in high-temperature fields.

Ecuador

In his reply Terán stated that: "The information in this report belongs to the first phase of the inventory of geothermical resources of low enthalpy determined in the 13 areas of interest in the Andes region and one in the coastal part of the country". The table enclosed showed 30 hot springs in 13 areas. The temperatures were in the range 20-50°C and the pH was low 5.5-7.5 . Flowrates 0.5-15 l/s. Some of the hot springs are apparently used for bathing purposes.

Peru

In 1979 INGEMMET started a reconnaissance study of an area of 100,000 km^2 in cooperation with OLADE in the south of Peru, according to Arnao. OLADE has given a contract to the Italian company Aquater to work with INGEMMET. Numerous hot springs and fumaroles are known to exist in Peru.

Argentina

Starting 1980 extensive geothermal investigations are to be carried out until 1984 costing 12.5 million U.S. dollars. There are 7 identified geothermal regions in the east Andes that constitute 15 areas in total 2,000 km^2. Some of the work is to be carried out by Latinoconsult S.A. with the assistance of Electroconsult S.A. In a book by Maraggi (1970) there is information about hot springs and boreholes discharging very large quantities of water or 1000 m^3/h at 63°C and 15 atm. This well is at Bahía Blanca.

Brazil

Geothermal exploration has been started in Brazil and there are at least 23 known hot springs, primarily in the state of Goias. A paper by Hamaza et al. (1978/79) describes heat flow studies and the Parana Basin which "is found to offer at present the best site for extraction of geothermal energy in Brazil. Preliminary examination of the temperature distributions in the major aquifer .... suggest that it contains substantial quantities of warm waters in the temperature range 40 to 90°C". It is concluded by the authors that this water does not constitute an economic resource.

Bolivia

According to Carrasco (1975) "there exist numerous geothermal manifestations in the western or Andean region of Bolivia, such as hot springs, fumaroles, and solfataras". Data from about 30 thermal springs indicate temperatures from 37 to 77°C with one exception 80°C. Many of the hot springs are being utilized for bathing purposes. The rates of discharge are estimated to range from 1-40 l/s.

Bibliography

Maraggi, E.S., 1970: Energia Geotérmica. Ediciones Pannedille, Buenos Aires, 100 p.

Carrasco, R., 1975: Preliminary Report on Bolivia's Geothermal Resources. San Francisco, 45-46.

Parodi, A., 1975: Feasibility of the Development of the Geothermal Energy in Peru. San Francisco, 227-231.

Hamza, V.M., Eston, S.M. & Aranjo, R.L.C., 1978/79: Geothermal Energy Prospects in Brazil: A Preliminary Analysis. Pageoph , 117, 180-195.

WEST INDIES

Information

The questionnaire was sent to J.G. Rigaud in Haiti and to W. Hay in Jamaica. No reply has yet been received. It is known that in Guadeloupe there is high-temperature geothermal.

AUSTRALIA

Geography

Area 7,686,884 km^2

Population 13,915,500 (1976)

Information

The questionnaire was sent to J.P. Cull who replied quickly and enclosed several papers.

Utilization

Although steam fields are unknown in Australia, large volumes of hot water are continuously extracted from sedimentary basins throughout the continent for domestic and stock use and these low-enthalpy resources have already been exploited for industrial purposes. About 17 hot spring areas have been developed for tourism and at 3 locations hot water bores produce for domestic and industrial uses. Water at 68 °C for use in paper manufacturing has been obtained from a depth of 600 m near Traralgon in the Gippsland Basin. In addition there are towns which rely exclusively on distribution of boiling artesian water e.g. at Quilpie in Queensland all hot water requirements are supplied directly from the town bore and drinking water is air cooled in individual tanks. A geothermal space heating system is at a motel in Innot in Queensland. Proposals have also been made to extract geothermal energy for space heating at the Portland hospital in Victoria but because of excessive pumping costs it has not been acted on. At Portland water at 52°C is continuously extracted (80 l/s) from aquifers at depths near 1400 m. This water is cooled and aerated to remove odour and iron deposits before it is distributed. There is limited information available of the flowrate and temperature of hot springs and boreholes producing thermal water. In the Great Artesian Basin (alone) there are more than 1000 indexed water bores deeper than 300 m, of these, 226 penetrate to depths greater than 1000 m. Fifty-eight (58) bores are classified as hot (water temperature greater than 65°C), with flow rates generally in excess of 10 l/s. The above mentioned borehole in Potland is in the Otway Basin. It is of interest to note that 58 boreholes at 10 l/s and 65°C correspond to 158 MW, 122 MW and 61 MW-thermal above 0°, 15° and 40°C reference temperatures, respectively. Only a small fraction of this water is used for thermal purposes.

Exploration

Heat flow measurements have been done in Australia to compile a heat flow map. More detailed measurements have been done in the Otway Basin for geothermal purposes. No standard geothermal exploration work (geochemistry, electrical resistivity etc.) has been done nor has any drilling for hot waters been carried out. It appears clear that geothermal in Australia is low-temperature associated with sedimentary basins. There are extensive sedimentary basins in Australia - they occupy more than 60% of land surface area.

Assessment

Sedimentary basins containing high-yield aquifers are found in all states (the Great Artesian Basin alone cowers 22% of the total land area of the continent). The energy contained in these basins exceeds 10^{21} J down to 10 km.

Bibliography

Cull, J.P., 1977: Geothermal Energy Prospects in Australia. Search, 8, 117-121.

Cull, J.P., 1979: Heat flow and Geothermal Energy Prospects in the Otway Basin, SW Australia. Search, 10, 429-433.

Cull, J.P., 1978/79: Geothermal Resources in Australia. Draft for publication in Geothermal Energy World Directory, 459-507.

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AUSTRIA

Geography

Area 83,849 km^2

Population 7,513,000 (1976)

Information

The questionnnaire was sent to J. Zötl who sent a reply with satisfactory information.

Utilization

In Waltersdorf in the Syrian Basin one borehole 10 l/s of 61°C produces from an aquifer at 1100-1200 m with 37 m drawdown the water being used to heat schools and a greenhouse. Thermal power therefore being 2.6, 1.9 and 0.9 MW-thermal for 0°, 15° and 40°C reference temperatures. In Geinberg in the Molasse Zone there is a well with 10 l/s artesian flow of 95°C. Utilization planned for heating and agricultural industry. Thermal power therefore 4.0, 3.4 and 2.3 MW-thermal.

Exploration

There are 5 main areas in Austria with low-temperature fields: Syrian Basin, Northen Burgenland, Vienna Basin, Molasse Zone and the Rhyne Valley. The first of these belongs to the western part of the Pannonian Basin. Some drilling for one in the Syrian Basin have been done but at present without success. This basin does have some remarkable local anomalies of the geothermal gradient. In the Northern Burgenland area the situation is similar. In the Vienna Basin there is a fault-zone at the SW boundary with thermal springs and well known health resorts. In the Molasse Zone some thermal water aquifers exist in the strata at the base of the molasse. The same applies to the Rhyne Valley area. Present exploration projects include geothermal mapping etc. (pre-drilling stage) for obtaining water for two towns in the Molasse Zone.

CANADA

Geography

Area 9,876,185 km^2

Population 23,300,000 (1976)

Information

The questionnaire was sent to A.M. Jessop who sent a reply, enclosing one report on sedimentary basins and a list of references, Canadian and foreign. Jessop stated:"We have been working mainly in two areas in Canada, the volcanic zones of British Columbia, with concentration on Meager Mountain, and in the sedimentary basin of the Prairies. At Meager Mountain we have now encountered a temperature of 202 °C at 365 m depth, and so this area is no longer relevant to your survey. However, there may be reservoirs of water below 180°C that are now unknown. In the Prairies we know there is very great amount of hot water in the porous formations, but we have not examined the detailed distribution of resources".

Utilization

There are 9 spas and swimming pools in British Columbia and 1 in Yukon Territory that use geothermal water. In the towns of Whitehorse and Mayo in Yukon Territory 150 l/s at 7°C and 15 l/s at 15°C, respectively, are used to prevent freezing in municipal water supply pipes in winter. In future it is planned to heat a 20,000 m^2 sports buildings at University of Regina in Regina, Saskatchewan. Estimated flowrate 50-75 m^3/h of 60°C water. Reinjection 20-30°C. Production well completed, reinjection to be drilled 1980, building expected 1981-1983.

Exploration

Sedimentary basins: 1) Research into thermal patterns beneath the Prairies, 2) Research into temperature in potential hot-dry-rock and low-temperature water areas in British Columbia.

Assessment

Total heat in hot water in sedimentary rocks beneath Prairies estimated at 4.8 x 10^{22} J (total heat above 0°C in water that is at least 50°C). In other areas there is insufficient data.

Bibliography

Jessop, A.M., 1976: Geothermal Energy from Sedimentary Basins. Energy, Mines & Resources Canada, Earth Physics Branch. Geothermal Series Number 8, Ottawa, 10 p.

Lewis, T.J., Judge, A.S. & Souther, J.G., 1978/79: Possible Geothermal Resources in the Coast Plutonic Complex of Southern British Columbia. Pageoph, 117, 172-179.

CZECHOSLOVAKIA

Geography

Area 127,871 km^2

Population 14,976,000 (1976)

Information

Questionnaire sent to V. Cermák that forewarded it to O. Franko regarding Slovak Socialist Republic (SSR). In Cermák's reply there was information from J. Jetel (assessment) and T. Paces (exploration) regarding Czech Socialist Republic (CSR). Cermák identified institutions and individuals in Czechoslovakia responsible for geothermal matters. Papers by Franko & Racický, Franko & Mucha and Paces & Cermák at San Francisco 1975 consulted.

Utilization

Present utilization of geothermal energy in Czechoslovakia is limited to the SSR in the east (West Carpathian) but not the CSR in the west (Bohemian Massif). Franko stated flowrates and temperatures of geothermal waters used in the SSR to heat greenhouses and plastic greenhouses, swimming and recreation pools and space heating. Individual flowrates are 3-53 l/s and temperatures 40-92°C.

TABLE 1:
Geothermal energy use in Czechoslovakia

	Thermal power MW		
	> 0°C	>15°C	> 40°C
Present (1973-1980)	49	35	21
Future (1981-1985)	10	8	—

The future utilization value above shows the geothermal waters already available (2-15 l/s at 48-62°C) that will be used in the next few years.

Exploration

In the CSR the possible use of hot-dry-rock is being investigated. Preliminary work should be finised by 1983 when a 1000 m borehole will be drilled. In the SSR about 24 prospective geothermal areas are to be investigated before 2000. In the most promising of these (central depression of the Danube basin) an exploration programm will be completed by 1982. Most of the Vienna basin exploration boreholes will be drilled 1982, 1983 and 1984 to a depth of 2500 m expecting 80°C reservoir temperature.

Assessment

In 1975 Franko & Racický stated that in the Bohemian Massif region (CSR) there are about 10 geothermal areas (localities). The total flowrate of the thermal springs was estimated 150 l/s and the maximium temperature 70°C. The thermal power of all the spring was estimated 23 MW (20 x 10^6 kcal/h). The reference temperature was not given. Franko & Racicíký also stated that in the West Carpathian region (SSR) there are about 60 geothermal areas (localities) yielding in total flowrate 700 l/s and maximum temperature 70°C. The thermal power was estimated 70 MW (60 x 10^6 kcal/h) the reference temperature not given. At the same time it was reported that about 30 MW thermal (reference 0°C) could be extracted from research boreholes that had been drilled in the SSR or West Carpathian region. These boreholes produced about 222 l/s of thermal waters at temperature 22-92°C.

In the hot-dry-rock work in the CSR it has been estimanted (J.Jaťed) that 28 x 10^{21} J of geothermal energy constitues the "accessible resource base" in the most favourable part of the region. This is in an area with 130°C at a depth less than 6 km.

In the SSR Franko & Mucha in 1975 estimated that 710 l/s of 100°C water could be exploited in a 3770 km^2 area of the Danube basin, amounting to 256 MW. Franko (in his reply to the questionnaire) stated that in the centeral depression of the Danube basin the thermal water "reserves" amounted to 120 MW with reference temperature 20°C. For the whole of the West Carpathians the "dynamic reserves of thermal energy" was given as fellows: Heat power of estimated prospective reserves of thermal waters 890 MW or 2773 MW in total.

Reference

Franko, O. & Racický, M., 1975: Present Status of Development of Geothermal Resources in Czechoslovakia. U.N. Symposium, San Francisco.

Franko, O. & Mucha, I., 1975: Geothermal Resources of the Central Depression of the Danubian Dasin in Slovakia. U.N. Symposium, San Francisco.

Paces, T. & Cermák, V., 1975: Subsurface Temperatures in the Bohemian Massif: Geophysical Measurements and Geochennical Estimates. U.N. Symposium, San Francisco.

DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA

Geography

Area 121,248 km^2

Population 16,250,000 (1976)

Information

In 1978 G. Pálmason went on a U.N. mission to North Korea to advice on geothermal exploration. There are numerous hot springs in the People's Republic and 23 low-temperature areas have been identified. A 1200 m deep geothermal borehole was drilled in 1978 (10 km east of Kilju and 15 km north of Hwadae) yielding 70 l/s of 96°C water. There is now an exploration programme for geothermal. There is no information available on utilization. It is likely that most of the geothermal in North Korea is low-temperature as it is in South Korea.

DENMARK

Geography

Area 43,030 km^2.

Population 5,065,313 (1976).

Information

The questionnaire was sent to N. Balling and a reply was received from S. Saxov. There is no utilization of geothermal in Denmark and there are no plans for its use in future. The Ministry of Energy is however working on an updated Energy Plan in which geothermal is included. Denmark takes part in the European Communities geothermal programme, e.g. heat flow and thermal conductivity of rocks. A report is being prepared on a "proposal for prospective areas".

Bibliography

Balling, N. & Saxov, S., 1978/79: Low Enthalphy Energy Resources in Denmark. Pageoph, 117, 203-212.

EIRE

Geography

Area 70,282 km^2

Population 3,160,000 (1976)

Information

A paper by Aldwell & Burdon (1980) shows that 17 known warm springs are in Eire (Republic of Ireland). These are now being investigated as a part of the European Communities geothermal programme.

Bibliography

Aldwell, C.R. & Burdon, D.J. 1980: Hydrogeothermal Conditions in Eire. 26th. Int. Geol. Cong., Paris. (Section 14.2 Ref. No. 14.0068).

FEDERAL REPUBLIC OF GERMANY

Geography

Area 248,529 km^2

Population 61,531,000 (1976)

Information

The questionnaire was sent to O. Kappelmeyer but no reply has yet been received. It is however known that there is some geothermal work carried out in West Germany e.g. as a part of the geothermal programme of the Commission of the European Communities (CEC). At a seminar organized by the CEC in Strasbourg 4-6 March 1980 (Second International Seminar on the Results of the EC Geothermal Energy Research: "Advances in European Geothermal Research") there are details about some geothermal projects in West Germany. It appears that the Upper Rhine Graben is being investigated in a French/German programme and then there is a hot-dry-rock project near Falkenberg in NE Bavaria.

Bibliography

Delisle, G., Kappelmeyer, O. & Haenel, R., 1975: Prospects for Geothermal Energy for Space Heating in Low-Enthalpy Areas. San Francisco, 2283-2289.

FIJI

Geography

Area 18,272 km^2

Population 580,000 (1976)

Information

The questionnaire was sent to H.G. Plummer who replied and enclosed a Cabinet Memorandum from March 1979 on Geothermal Resources in Fiji by himself, an abstract of a paper by M.E. Cox (1979) on "Geothermal Occurrences in the Southwest Pacific" and a section entitled "Geothermal Energy in the Solomon Islands" from "Energy Resources in the Solomon Islands" by F.I. Coulson (1979). After meeting M.E. Cox in the U.S. he sent further information, including his 1979 paper mentioned above, a paper in the 1978 G.R.C. Transactions, a preprint on stable isotope work in Fiji and a section of a report by K.H. Williamson (1980).

General

Plummer stated that during 1980 some slim line holes to about 300 m are being drilled to make heat gradient measurements in 4 areas on the island of Viti Levu. The only use so far of Fiji occurrences is the cooking of native food in a small way at a few localities.

In Cox's (1979) paper on "Geothermal Occurences in the Southwest Pacific", there is information on geothermal energy in Fiji: In the Fiji islands, more than 60 localities with thermal springs are widely distributed over the two main islands of Viti Levu and Vanua Levu and also on the smaller islands of Katavu, Ono, Gau, Vanua Balavu and Rabi. The majority of occurrences are on the island of Vanua Levu. Most thermal discharges occur as springs with temperatures of 40 to 60°C and low flowrates (<3 l/s). Estimates of subsurface temperatures by geothermometers indicate 90 to 115°C for most spring groups. In two areas on Vanu Levu (Labasa and Savusavu) there are groups of boiling springs with estimated reservoir temperatures of 120°C (Labasa) and 150 to 160°C (Savusavu). These two areas appear to present the most potential of all the known geothermal occurrences on Fiji.

Bibliography

Cox, M.E., 1978: The Lambasa Area Geothermal Investigation, Fiji. Geothermal Resources Council Transactions, 2, 121-123.

Cox, M.E., 1979: Geothermal Occurrences in the Southwest Pacific. CCOP/SOPAC & UNDP Symp. Petroleum Potential Island Areas, Small Ocean Basins, Submerged Margins, Related Areas. 18-21 Sept., Suva, Fiji. (Preprint).

Williamson, K.H., 1980: An Appraisal of the Geothermal Prospects of Fiji. IGS Report No. WD/VS/80/10 , London. (Pages 29-33 only).

Cox, M.E. & Hulston, J.R., 1980: Stable Isotope Study of Thermal and Other Waters in Fiji. (Accepted for publication in N.Z. Journal of Science).

Cox, M.E., 1980: Chemical Description of Thermal Waters in the Fiji Islands. Geothermal Resources Council Transactions, 4, 153-156.

GERMAN DEMOCRATIC REPUBLIC

Geography

Area 107,861 km^2

Population 16,790,000 (1976)

Information

Questionnaire sent to E. Hurtig who sent a reply and stated: "At present in the GDR no geothermal energy is used and no exploration projects are in the stage of planning".

GREECE

Geography

Area 131,990 km^2

Population 9,170,000 (1976)

Information

The questionnair was sent to A. Papastamatoki at the Institute of Geology and Mineral Exploration (IGME). A reply was received from M. Fytikas at the same Institute - he is the head of the Geothermal Section of the IGME. The reply contained a large map of Greece showing the geothermal areas of the country The reply also contained a "Brief Note on Geothermal Resources in Greece" (one page) with information relevant to the survey.

Available information on geothermal energy in Greece is not extensive. One paper (Dominco & Papastamatoki) was presented in San Francisco on the chemistry of Greek geothermal waters. No paper was presented in Pisa. Several papers on geothermal in Greece were presented at an international conference in Athens 1976. These papers are of limited use in the present survey but do provide some background information.

Utilization

Fytikas stated that "up to date there is no use of low-temperature geothermal energy except in the case of natural thermal springs used for theraputical purposes".

Exploration

In the last 10 years the Greeks have mainly been interested in high-temperature areas. They have carried out geochemical and other studies and drilled in the most favourable sites. Exploration for low-temperature areas has not been extensive so far although some work has been carried out. Fytikas stated that "there is an extensive local reconaissance project to a relatively shallow depth (up to 200 m) in the area of Polichnitos (Lesbos island) starting this year and studying the possibility of heating application". Dominco & Papastamatoki (1975) stated that Polichnitos was one of three geothermal areas on the island of Lesbos. About 20 thermal springs are reported in the Polichnitos area with a flowrate of 53 m^3/h (15 l/s) of waters at 50-87.5°C. The reservoir temperature has been estimated 100-150°C. The two other areas on Lesbos are not as well documented. Fytikas stated that the IGME is also undertaking projects at pre-drilling stage at several other sites.

Assessment

A preliminary geothermal map of Greece has been prepared, showing low and high temperature fields. About 40 areas are under exploration. Several papers on thermal springs in Greece were presented at the "International Congress on Thermal Waters, Geothermal Energy and Vulcanism of the Mediterranean Area" in Athens, October 1976.

Bibliography

Dominco, E. & Papastamatoki A., 1975: Characteristics of Greek Geothermal Waters. San Francisco, 109-121.

Aesopos, G., 1976: Hot Springs of Greece. Athens, 2, 619-641. (In French and Greek).

INDIA

Geography

Area 3,287,606 km^2

Population 610,080,000 (1976)

Information

The questionnaire was sent to several individuals in India. These are: M.L. Gupta at the National Geophysical Research Institute, V.S. Krishnaswamy at the Geological Survey of India, B.C. Raymahashay at the India Institute of Technology, M. Sabnavis at Osmania University and S.A. Subramanian at the Central Electricity Authority. It was later discovered that Krihnaswamy had become Director General of the Geological Survey and moved to a new address. The questionnaire was therfore sent to him again in a telegram. Replies were received from M.L. Gupta and B.C. Raymahashay but not the others. Papers from the San Francisco symposium were consulted for background information.

Utilization

It was indicated by both Gupta and Raymahashay that there is no utilization of geothermal energy in India except for bathing purposes. They reported present and past experimental utilization projects - all of which are probably in high-temperature areas.

Exploration/Assessment

Raymahashay reported that: "There are four major belts where utilization of geothermal waters are promising. These are (i) The Puga-Chumathany Field in NW Himalayas where silica base temperature is 160 to 180°C, (ii) The Maikaran-Kasol Field also in NW Himalayas where silica base temperature is 110 to 130°C, (iii) The Vajreswari Group on the west coast with silica base temperature around 120°C and (iv) The Bihar-Bengal Group in Eastern India where silica base temperature is 100 to 120°C". He also mentioned two more areas viz. the Sohna Field near Delhi and the Sarguja Springs in central India...." both of which are presently under investigation.

Gupta reported that: "Over 250 hot spring sites are known presently in India. It has been inferred that 76 out of these have a total stored heat potential of 25.4 x 10^8 cal (1.1 x 10^{10}J).... Out of these over 30 are high temperature systems (150°C) and the others are intermediate systems (90-140°C). Except two, all the other high-temperature systems are located in the NW Himalayas". Gupta reported several geothermal exploration projects in India by various organizations: (i) The Geological Survey of India, (ii) The Central Energy Authority, (iii) The National Geophysical Research Institute and (iv) The United Nations Develoment Program. These were also mentioned by Raymahashay.

Bibliography

Iyengar, B., R., R., 1970: Geothermal Resources of India. Pisa, 1044-1049.

Gupta, M.L. & Sukhija, B.S., 1974: Preliminary Studies of Some Geothermal Areas in India. Geothermics, 3, 105-112.

Krishnaswamy, V.S., 1975: A Review of Indian Geothermal Provinces and Their Potential for Energy Utilization. San Francisco, 143-156.

Subramanian, S.A., 1975: Present Status of Geothermal Resources Development in India. San Francisco, 269-271.

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INDONESIA

Area 1,919,270 km^2

Population 139,620,000 (1976)

Information

The questionnaire was sent to I. Akil who sent a short reply regarding utilization which is none. Geothermal has not been of interest in Indonesia for long according to Akil although the country has a great resource potential. Indonesia is a part of an active island arc system and its geothermal fields are mostly high-temperature. No large scale geothermal power generation has yet been initiated in Indonesia although it is understood that a 250 kW station has or will shortly begin operation. Akil stated that some consideration has been given to non-electric uses in Indonesia and he mentioned several drying processes.

Bibliography

Akil, I., 1975: Development of Geothermal Resources in Indonesia. San Francisco, 11-15.

Radja, V. 1975: Overview of Geothermal Energy Studies in Indonesia. San Francisco, 233-240.

Radja, V., 1976: Investigations of Geothermal Energy Resources in the Minahasa Area, North Sulawesi, Indonesia. Proc. Int. Congress Thermal Waters Geothermal Energy Vulcanism Mediterranean Area, 1, 467-481.

ISRAEL

Geography

Area 20,702 km^2

Population 3,460,000 (1976)

Information

The questionnaire was sent to A. Rappoport but later it was returned (Inconnu Retour) un-opened. A paper by Eisenstat (1978) was then consulted.

General

There are several hot springs in Israel with temperatures up to 72°C. There are hot springs in the Red Sea area. Utilization experiments with soil heating and fish farming have been carried out.

Bibliography

Meidav, T., Sanyal, S. & Facca, G., 1977: An Update of World Geothermal Energy Development. Geothermal Energy Magazine, 5 (5), 30-34.

Eisenstat, S.M., 1978: Geothermal Resource Development in Israel. Geothermal Energy Magazine, 6 (1), 8-18.

ITALY

Geography

Area 301,191 km^2

Population 56,323,000 (1976)

Information

The questionnaire was sent to P. Ceron. A comprehensive reply was received, including reprints from Geothermis and a computer print-out showing the utilization of low-enthalpy fluids in Italy. A note on "Assessment of Geothermal Potential of Central Part of Italy" (by Ceron) was also received. In a later communication Ceron sent a note on "Geothermal Activity in Italy and Prospects for Increasing Production " that was prepared by ENEL and AGIP (ENI).

Utilization

The main use of geothermal in Italy is of course electricity production, with 430 MW installed at all high-temperature fields.

Ceron gave information on non-electrical uses of geoheat in Italy at temperatures blow 180°C. However, not all of these are in low-temperature fields. In the present survey district heating, greenhouses and industrial uses at Larderello will therefore be omitted, being 25 MW, 3 MW and 23 MW respectively.

In the computer print-out sent by Ceron it is not clear what reference temperature the stated MW-values are based on. An examination of the values seems to indicate 0°C as reference temperature.

Agriculture: At Galzignano there are 20,000 m^2 of greenhouses heated with 10 l/s of 60-65°C water. Heating capacity 3.5 MW thermal. In future a 3.5 MW greenhouses is planned at Mantova.

Balneotherapy: At Abano there are more than 130 "hotel spas" with 1100 l/s at 64-87°C amounting to 230 MW thermal. There are several other spas in Italy.

District heating: At Abano Terme 74 hotels and private dwellings heated with 450 l/s (maximum 600 l/s) at 65-87°C. Thermal capacity 84 MW. In future at San Donato a pilot scheme will be built using 100 m^3/h of 65°C water with thermal capacity 12 MW.

TABLE 1:

Use of low-temperature fields

Type	Installed capacity MW-thermal[x]	%
Greenhouses (20,000 m^2) at Galzignano	3.5	1.1
Bahts at Abano	230	72.4
District heating at Abano	84	26.5
Total	317.5	100.0

x Probably based on 0°C reference temperature

It is of interest to note that the present uses of geoheat given by Ceron are almost the same as given by Howard (1975) five years ago.

Exploration

With regard to low-temperature fields in Italy AGIP and ENEL have a programme to explore several "exclusively low-temperature areas" in the next 5 years. As a part of the EEC (European Economic Community) geothermal programme the Po Basin is being explored, e.g. for district heating at San Donato.

Assessment

Comprehensive assessment of geothermal energy in Italy has been carried out. Ceron presented the main results in a note that is based on several published papers. The "reserves" down to 3 km depth have been estimated as 12,000 GW-years-thermal (3.8×10^{20} J). It was assumed that 1/3 could be extracted above 130°C and 2/3 at temperatures 60-130°C. The reference temperature was 15°C. Therefore, the low-temperature (60-130°C) geothermal reserves of Italy have been estimated 8,000 GW-years-thermal or 2.5×10^{20} J above 15°C.

Bibliography

Muffler, P.& Catalti, R., 1978: Method for Regional Assessment of Geothermal Resources. Geothermics, 7, 53-89.

Cataldi, R., Lazzarotto, A., Muffer, P., Squarci, P. & Stefani, G., 1978: Assessment of Geothermal Potential of Central and Southern Tuscany. Geothermics, 7, 91-131.

Ceron, P. & Sommaruga, C., 1979: Economic Aspects of Utilizing Geothermal Energy. (Translation of "Aspetti economici connessi con l'impiego dell'energia geothermica" presented at "2a Mostra Convegno sull " Energia Solare", Bari, Italy.

Sommaruga, C., Guglielminetti, M., 1978: Usi dell'energia geothermica a bassa entalpia: realizzioni e prospettive italiane. ITLA Simposio Sobre Fuentes Energetucas Renovables, Ciudad de Panamá.

Sommaruga, C., 1980: High and Low Enthalpy Geothermal Resources Exploration: Models, Strategies and Reality 26th. International Geological Congress. Paris.

MEXICO

Geography

Area 1,972,363 km^2

Population 62,330,000 (1976)

Information

The questionnaire was sent to S. Mercado who indicated in his reply that Mexico was for the time being only interested in exploiting high-temperature fields. Paper by Alonso (1975) was consulted for background information.

Utilization

The main use of geothermal in Mexico is for electricity production, 150 MW-electrical being installed at Cerro Prieto. (Fanelli & Taffi 1980). Mercado sent a map of Mexico showing "several points of geothermal interest". He stated that many of these "have low-temperature reservoir but for now CFE have this under classification and evaluation. Mercado also indcluded some data (and a map of the area) on the province of Chapala showing utilization of low-temperature fluids. Table 1 shows the relevant data and the associated thermal power. The thermal waters range in temperature 33-68°C and are 1160 l/s in total flowrate. It should be noted that the thermal waters are used for irrigation drinking, washing and bathing. Utilizaiton in other provinces of Mexico was not reported by Mercado.

Exploration/Assessment

Alonso (1975) reported the status (exploration and development) at 6 geothermal fields in Mexico - most of these are probably high temperature. Alonso stated that some exploration (mainly geochemical) has been carried out at 15-20 other areas. He also stated that: "In Mexico, 130 hydrothermal areas have been located, varying from small seeps to large water and steam flows". A table presented by Alonso (1975) showed how many are in each of the Mexico states (provinces?). A "mean temperature" was also reported for the "principal hydrothermal zones" in each state. For the 130 areas the "mean temperature" was in the range 40-90°C. No assessment study has been reported for low-temperature fields in Mexico.

Bibligraphy

Alonso, H., 1975: Geothermal Potential of Mexico. San Francisco, 21-24.

Fanelli, M. & Taffi, L., 1980: Status of Geothermal Research and Development in the World. 26th. Int. Geol. Congress, Paris. Colloque C2, Energy Reources. Revue de l´Institut Francais du Pétrole, 35, 429-448.

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TABLE 1

Uses of low-temperature fields in the province of Chapala in Mexico

Name	Flow (l/s)	Surface temp. °C	Uses	Estimated Reservoir Temperature °C	Thermal power MW >0°C	>15°C	>40°C
Acatlán	140	36	I,D,S	166	20.9	12.8	0.0
Los Pozos	300	35	I,D	170	43.5	24.9	0.0
Mazatepec	20	68	S	159	5.6	4.4	2.3
San Isidro	150	35	I,D,W,S	171	21.7	12.4	0.0
Chapala	100	40	I,D,W,S	149	16.6	10.4	0.0
Colomilla	160	48	I,S	174	31.8	21.9	5.3
Verdía	200	33	I,D,W	100	27.3	14.9	0.0
Oblato	110	34	I,D,S	130	15.5	8.7	0.0
Total	1160	—	—	—	182.9	110.4	7.6

I:Irrigation W:Washing

D:Drinking S:Baths

NETHERLANDS

Geography

Area 36,175 km^2

Population 13,733,578 (1976)

Information

The questionnaire was given to S. Prins who sent a short letter in reply. A news brief has appeared in Nature on geothermal in Holland.

Utilization

At present there is no utilization of geothermal in the Netherlands. This year a demonstration project (just south of Rotterdam) is expected to start and will consist of a production and reinjection doublet. The expected production is about 150 m^3/h at a temperature of about 100°C. The intention is to heat 50 houses to be connected in 1982.

Exploration

The Netherlands is taking part in a Belgium seismic exploration project aimed at finding karstified areas in the carboniferous limestones at depths between 1000-3000 m.

Assessment

In the next two years the intention is to make an assessment of the low-temperature potential of the country on the basis of existing data mainly from the oil industry. It has been estimated that the geothermal resource in the Netherlands is equivalent to 12-25% of their natural gas reserves. The most favourable areas are in the south of the country. The Netherlands take part in the EEC geothermal programme.

Bibliography

Schurring, C., 1980: First geothermal plant in Holland. Nature, 283, 709.

NEW ZEALAND

Geography

Area 268,676 km^2

Population 3,129,383 (1976)

Information

The questionnaire was sent to R. Bolton who sent a map showing the location of main low-temperature geothermal areas and a table listing the temperature and flowrate of these.

Utilization

Bolton stated that: "In New Zealand there are a large number of low temperature hot spring areas. However, none is exploited on a large scale and there are no foreseeable plans for such exploitation. ...small scale utilization in the form of private or public bathing is the predominant use. Data on such utilization is non-extent".

Bolton gave information on flowrate and temperature of 11 thermal areas. One of these is in the Hauraki Geothermal Region, the others in the Rotorua-Taupo Geothermal Region. In total these uses amount to 3.0 MW, 2.6 MW and 2.0 MW-thermal for 0°C, 15°C and 40°C reference temperatures. Most of these are for bathing.

Although low-temperature geothermal energy is not used in New Zealand, there is considerable direct use in high-temperature fields. These are at Kawerau (186 tonne/hr of steam, 1590 TJ), Broadlands (9.4 tonne/hr of 184°C steam), Rotorua (industrial/commercial usage 720 TJ/yr and domestic 40 TJ/yr), and Taupo (not known). The installed electrical generating capacity was 202 MW-electrical in 1979, at Wairakei 192 MW-eletrical and at Kawerau 10 MW-electrical.

Exploration/Assessment

There are identified 3 geothermal region in New Zealand with low-temperature fields/areas. In the Northland Geothermal Region there are 10 areas, in the Hauraki Geothermal Region 9 areas and in the Rotorua-Taupo Geothermal Region 15 areas.

There is probably no exploration carried out in low-temperature geothermal fields and no assessment study has been reported.

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PHILIPPINES

Geography

Area 299,767 km^2

Population 43,750,000 (1976)

Information

The questionnaire was sent to N.C. Vasquez and a reply was received. There is stated: "We are very sorry to say that at this point we can not provide any meaningful information regarding this type of geothermal fields. Our government has placed the highest priority on electric power generation and for this our thrusts have been the exploration and development of hotter fields". Vasquez did enclose up-to-data information on the status of projects in the 7 high-temperature fields being explored and exploited at present. The geothermal developments in the Philippines are on a relatively large scale and have progressed rapidly in only a few years.

POLAND

Geography

Area 311,701 km^2

Population 34,528,000 (1976)

Information

Questionnaire sent to J. Dowgiallo. Reply 1 1/2 typed pages. Paper by same at San Francisco 1975 consulted.

Utilization

Water at 20-63°C used in baths and swimming pools 235 l/s. Water at 32-67°C available but not used 55 l/s. No new uses introduced recently nor planned in next few years.

Table 1

Geothermal waters in Poland

	Thermal power MW		
	>0°C	>15°C	>40°C
Used	35	20	1
Not used	12	9	3
Total	47	29	4

Exploration

The Sudets: Exploration drilling planned in West and Central Sudetes near Cieplice and Ladek, respectively.

The Mogilin-Lódz basin: Presently 5 boreholes being drilled temperatures reaching 80° expeted. High salinity may complicate utilization.

Assessment

Comprehensive report being prepared.

REPUBLIC OF KOREA

Geography

Area 99,591 km^2

Population 36,400,000 (1977)

Information

A preprint of a report by N.G. Banks at the Hawaiian Volcano Observatory was received from M. Cox at the Hawaii Institue of Geophysics (see Fiji).

General

The report by Banks is the result of a joint U.S. and Republic of Korea(ROK) assessment study. It reviews the literature and reports on his visits to The main geothermal sites and the chemical analysis of the water samples collected. The main results of the report are the following: Available geological, geochemical geophysical, and hydrological data do not favor presence of high temperature (>150°C) geothermal resources on the mainland of the ROK. There is however some potential for high (>150°C) or intermediate (90-150°C) enthalpy geothermal systems on the volcanic islands of Cheju-do and Ulleung-do. On the mainland there is also some potential for geothermal resourcs of intermediate temperatures. Measured temperatures and geothermal indicators at 7 of the mainland thermal springs suggest that reservoir temperatures approach or slightly exceed 90-100°C. Low temperature geothermal systems have been proven at twenty localities around the ROK and one other has been reported. The warm fluids issue or are pumped from restricted structural equifers and apparently result from deep circulation of groundwater in regions of normal heat flow and geothermal gredient. The water is potable at all localities, has neutral to high pH and low amounts of dissolved solids. The wells are normally 150-300 m deep, the depest is 1150 m but presently not being used. Currently, a total of about 3 x 10^4 m^3/day (350 l/s) are produced at the 20 known localities and undoubtedly production could be enhanced. Most of the thermal springs issue on or near valley floors. The thermal water have been used mainly for bathing and medical purposes,although small amounts are used for heating of dwellings and fish ponds. The use of the thermal springs for medical and bathing uses dates beck at least 10 centuries. The waters are alkaline and measured temperatures in springs and shallow wells range from about 20-99°C. Typically, they are less than 50°C. Geothermometers indicate 130°C as maximun reservoir temperature.

Bibliography

Banks, N.G., 1980: Assessment of Geothermal Resources in the Republic of Korea. U.S. Geological Survey, Hawaiian Volcano Observatory. (A Report for the Joint United States-Republic of Korea Energy Assessment).

ROMANIA

Geography

Area 237,500 km^2
Population 21,559,416 (1977)

Information

The questionnaire was sent to A. Manilici. No reply was received. Paper by Barbier & Fanelli was consulted for information. Also, a short note by C. Opran in Geothermics. Fragmented information available from discussions with a Romanian delegation to Iceland in 1978.

Utilization

There are probably a lot of spas in Romania as in Hungary and other neighbouring countries. Most of the spas are probably in the region or county of Bihor. Oradea is the largest town in Bihor.

Barbier & Fanelli (1977) state that there is district heating in 1600 apartments in Oradea using water at 65°C. They also state that in Oradea and surroundings there are 30,000 m^3 of greenhouses using geothermal energy, with 6 MW-thermal associated power. The power associated with the district heating was not given.

To estimate the associated thermal power, a simple comparison with Hungary can be made. In Hungary there are 1.7 x 10^6 m^2 greenhouses with 316.89 MW-thermal above reference temperature 40°C (Note JSG-80/05). Assuming the same energy requirements of greenhouses in Romania and Hungary, the thermal power associated with 30,000 m^2 becomes 5.6 MW-thermal, compared to 6 MW-thermal as given by Barbier & Fanelli (1977). For reference temperatures 15°C and 0°C the estimated associated thermal power becomes 9.4 MW and 12.3 MW respectively. The same can be done for the district heating. In Hungary with 34.56 MW-thermal above 40°C (Note JSG-

80/05). In Romania with 1600 apartments using 65°C water the estimated associated thermal power becomes 15.8 MW, 26.7 MW and 34.9 MW for 40°C, 15°C and 0°C reference temperature. These estimated values are shown in the following.

TABLE 1:

Estimated installed geothermal power in Romania

Use	Installed thermal power MW		
	>0°C	>15°C	>40°C
Baths	?	?	?
Greenhouses 30,000 m^2	12	9	6
District heating 1600 apartments	35	27	16
Total	47	36	22

Exploration

In 1970 a nationl geothermal programme was initiated. In 1978 about 60 geothermal boreholes had been drilled.Usual temperature 50-95°C with 140°C maximum in one well.

Assessment

Geological evidence suggests that the geothermal region of Hungary extends to Czechoslovakia and Romania....(EPRI - Roberts 1978). The geothermal formation (of Hungary) extends outside the boundaries of Hungary into Czechoslovakia, Romania, Yugoslavia and Austria. Outside Hungary no systematic geothermal exploations have been made, but from petroleum exploration data it has been estimated that the geothermal potential around Hungary, within the Carpathian basin, about 60% of the Hungarian value (Boldizsár 1979).

According to Opran (1974) the "evaluation of the thermal water resource in Bihor region only exceeds 76 x 10^6 m^3/year (2410 kg/s), that is 5.3 x 10^6 Gcal/year (743 MW-thermal)".

Bibliography

Opran, C., 1974: Geothermal Energy in Rumania. Geothermics, 3, 82.

Barbier, E. & Fanelli, M., 1977: Non-Electrical Uses of Geothermal Energy. Prog. Energy Combust. Sci., 3, 73-103.

Boldizsár, T., 1979: Non-Electric Use of Geothermal Energy in Hungary. Acta Geodaet. Geophys. et Montanist. Acad. Sci. Hung., 14, 289-279.

Airinei, St., Pricajan, A, & Bandrabur, T., 1976: The Significance of the Neogene Vulcanism in Romania in Thermal Water Springs. Proc. Int. Congress on Thermal Waters, Geothermal Energy and Vulcanism of the Mediterranean Area, 1, 1-16, Athens. (In French).

Cracium. P. & Bandrabur, T., 1976: Some Geothermal Aspects of the Deep-Seated Aquifer Systems of the Getic Depression (Romania). Proc. Int. Congress on Thermal Waters, Geothermal Energy and Vulcanism of the Mediterranean Area, 1, 169-183, Athens. (In French).

SOLOMON ISLANDS

Geography

Area 29,785 km^2
Population 200,000 (1976)

Information

In the reply of H.C. Plummer regarding Fiji there was included information on the Solomon Islands by F.I. Coulson. A preprint of a paper by M.E. Cox (1979) on "Geothermal Occurrences in Southwest Pacific" (see Fiji) gives information on the Solomon Islands.

General

Most of the geothermal activity on the Solomon Islands appears to be high-temperature. The main field of interest being at Paraso (Vella Lavella) in the New Georgia group of islands. In the northwest of Guadalcanal (Cox, 1979) there are 24 saline thermal springs with temperatures of 20-58°C. Likely subsurface temperatures there are 140-180°C.

Unfortunately there is not a big market for energy on the Solomon Island. However, if high-temperature fields are developed there is the possibility of processing local reserves of 60 million tonnes of bauxite or for use in forest and paper industry.

Bibliography

Cox, M.E., 1979: Geothermal Occurrences in the Southwest Pacific. CCOP/SOPAC & UNDP Symp. Petroleum Potential Island Arcs, Amall Ocean Basins, Submerged Margins, Related Areas. 18-21 Sept., Suva, Fiji.

SWEDEN

Geography

Area 449,792 km^2

Population 8,236,179 (1976)

Information

The questionnaire was sent to K.G. Eiriksson who sent a reply.

Utilization

At present there is no utilization of low-temperature geothermal energy in Sweden. It is however planned to use geothermal for house heating at two sites. Both are situated in the SW part of Sweden, in Skåne, in paleozoic and mesozoic sedimentary rocks. At Vellinge there is produced 25 l/s at 62°C which will be used in conjunction with a heat pump to heat the town hall and about 250 apartments. The above 25 l/s correspond to 6.5 , 4.9 and 2.3 MW-thermal above 0° , 15° and 40°C. At Landskrona there is 50 l/s produced at 25°C , i.e. 5.2 , 2.1 and 0.0 MW-thermal above 0°, 15° and 40°C. This water will be used in a heat pump system to heat about 300 small houses.

Exploration

There are no further geothermal exploration programmes "available" in Sweden according to Eriksson. There has been some interest in hot-dry-rock in Sweden.

Assessment

It was stated by Eriksson that "an assessment has been made only for the southwesternmost part of Skåne, which is supposed to have a total potential of low-temperature energy of about 6000 TW".

Bibliography

Eriksson, K.G., Ahlbom, K., Landström, O., Larson, S.Å., Lind, G. & Malmqvist, D., 1978/79: Investigation for Geothermal Energy in Sweden. Pageoph , 117, 196-204.

SWITZERLAND

Geography

Area 41,287 km^2

Population 6,350,000 (1976)

Information

No questionnaire was sent but after a meeting with L. Ryback two papers were received with up-to-date information.

Utilization

There is no utilization of geothermal in Switzerland except for spas and then on a small scale. Several studies have been made of district heating schemes, some of wich include heat pumps.

Exploration / Assessment

There are 14 distinct thermal spring zones in Switzerland with 5 more zones in neighbouring regions. Their discharge temperature at the surface vary from 25°C to a maximum of 62°C. Their flowrates are 1.1-190 l/min. Chemical geothermometers indicate temperatures of 80-120°C. The most promising geotheat is in the Molasse Basin. Switzeland takes part in a hot-dry-rock project of the International Energy Agency. From 1979-1981 a NEFF (Nationaler Energie Forschungs Fonds) project will comprise a preliminary investigation of a particular area of geothermal promise (nonthern flank of Jura range). Some drilling is foreseen in selected targets.

Bibliography

Ryback, L & Jaffé, F.C.,1975: Geothermal Potential in Switzerland. San Francisco, 241-244.

Ryback, L., Hänny, J & Werner, W., 1979: Utilization of Geothermal Energy in Switzerland - Possibilities and Limitations. Sulzer Technical Review, 61, 141-150.

Jaffé, F, Ryback, L & Vuataz, F. D. 1979: Exploration for Low Enthalpy Geothermal Energy in Switzerland. Proc. UNITAR Conf. Long. Term Energy Resources. Montreal, 15 p.

THAILAND

Geography

Area 513,579 km^2

Population 43,213,711

Information

In the geothermal literature there is limited information about Indo-China. However, recently a paper was published on geothermal energy in Thailand (Barr et.al. 1979). The questionnaire was not sent to Thailand, nor any other country in Indo-China.

General

The paper by Barr et.al. (1979) describes geothermal exploration work carried out (mainly by staff at Chiang Mai University) in northern Thailand. It reports the surface feature and geological selting of several hot springs and deals wiht their geochemistry. Measurements of thermal gradient are also reported.

There are numerous hot springs scattered throughout northern Thailand. Barr et.al. (1979) show 33 hot spring localities and state that undoubtedly more hot springs occur in isolated areas. Present uses of the hot springs is limited to bathing, and boiling eggs and bamboo shoots. This is partly because many hot springs are in remote areas, accessible only on foot, but also because no studies have been done to assess the possibility of alternative uses.

Geochemical studies of six hot springs show their silica temperature to be 142-194°C. In a different (and independent) study of 12 hot springs (also in northern Thailand) the silica temperatures were estimate 115-179 °C. The geothermal fields in Thailand are associated with margins of Cenozoic Basins, with magins of granitic intrusions, and/or with major fault zones.

Bibliography

Barr, S.M., Ratanasathien, B., Breen, D., Ramingwong, T. & Sertsrivanit, S., 1979: Hot Springs and Geothermal Gradients in Northern Thailand. Geothermics, 8, 85-95.

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TURKEY

Geography

Area 780,579 km^2

Population 40,900,000 (1975)

Information

The questionnaire was first sent to S.Alpan but later it was discovered that he is now working in New York. The second questionnaire was sent by telegram to O.Özkocak at the MTA Institute. A reply was received from S. Talu & M.F. Akkus. The MTA Institute is responsible for geothermal exploration work in Turkey. Papers by S. Alpan and F. Kurtman & E. Samilgil at the 1975 San Francisco symposium were consulted for background information.

Utilization

Talu & Akkus stated that "utilization of the geothermal energy in Turkey is very limited yet and only a few of them have installations. There is no record of the flow rates and temperatures (entering and leaving installation)....". From the geothermal literature it appears that only experimentel utilization facilities have been set up in Turkey. These are a 0.5 MW electrical turbine and a 1000 m^2 greenhouse at Kizildere a geothermal field with measured temperature above 200°C.

Talu & Akkus enclosed a comprehensive list of thermal water springs in Turkey. The list gives the province, name of hot-water spring, temperature °C, out flow lt/sn and type of installation. The installations were classified as: hotel, primitive and none. A map location of these springs was also enclosed. About 200 thermal springs are mentioned of which 50 are used at hotels, 90 are put to some (bathing?) primitive use and 60 not used.

Exploration

Extensive geothermal exploration has been carried out in Turkey by the MTA Institute as reported by Alpan (1975) and Kurtman & Samigil (1975). Most of the geothermal activity appears associated with grabens and faults. Geochemical and other studies show that reservoir temperatures (silica geothermometer) in the explored areas are 70-205°C. The known thermal areas in Turkey are therefore both high and low-temperature fields.

Talu & Akkus stated that exploration and drilling have been carried out in 6 low-temperature geothermal fields. At Kizildere-Denizli 16 boreholes have been drilled, in the other fields 1-4 boreholes. In total 26 boreholes in the six fields. These goethermal fields are probably the same as reported by Alpan (1975). Talu & Akkus stated also that exploration activities are in progress in 15 low-temperature fields that are in the pre-drilling stage.

Assessment

It was stated by Talu & Akkus that "the total potential of low-temperature geothermal fields is not known at present". No assessment has been given in the geothermal literature. It may, however, be
to look at the naturally
interesting/occuring thermal springs of Turkey. Talu & Akkus listed 200 springs with temperatures 25-100°C. The total flowrate of the springs is about 2000 kg/s. The thermal power of the individual springs was added up and shown to be 402.5 MW, 273.9 MW and 68.7 MW with reference temperature 0°C, 15°C and 40°C.

Bibliography

Alpan, S., 1975: Geothermal Energy Exploration in Turkey. San Francisco, pp. 25-28.

Kurtman, F. & Samilgil, E., 1975: Geothermal Energy Possibilities, Their Exploration and Evaluation in Turkey. San Francisco, pp. 447-457.

Bibliography

Alpan, S., 1975: Geothermal Energy Exploration in Turkey. San Francisco, pp. 25-28.

Kurtman, F. & Samilgil, E., 1975: Geothermal Energy Possibilities, Their Exploration and Evaluation in Turkey. San Francisco, pp. 447 -457.

UNITED KINGDOM

Geography

Area 244,755 km^2

Population 55,886,000 (1976)

Information

The questionnaire was sent to J. D. Garnish at the Energy Technology Support Unit at Harwell. A good reply was received with a paper on assessment enclosed.

Utilization

The only existing use of geothermal waters is at Bath the total flow from the spring complex being almost 16 l/s at 46.5°C. This corresponds to 3.1, 2.1 and 0.4 MW-thermal alove 0°,15° and 40°C reference temperature respectively. It is unlikely that the reservoir and Bath will be exploited in the near future.

A geothermal borehole has now been drilled in the Wessex basin near Marchwood Power Station not far from Southampton. If the well produces hot water in sufficient quantity it will either be used to heat the feed-water to Marchwood or for space heating in a proposed Civic Complex in Southampton.

Exploration

The U.K. exploration programme over the last 3 years has been concentrated on the Mesozoic basins.Only the Wessex and Northern Ireland basins have been tested by drilling.

Work is being carried out into hot-dry-rock by the Camborne School of Mines in Cornwall. The main topic of interst is permeability enhancement of rock in experimental boreholes.

Assessment

It was stated by Garnish that it is not possible to make any serious regional geothermal assessment yet. The report by Burley et.al. (1980) is a preliminary assessment. It can be added that the U.K. takes part in the geothermal programme of the European Economic Community.

Bibliography

Garnish, J.D. 1976: Geothermal Energy: The Case for Research in the United Kingdom. Energy Technology Suppont Unit, Department of Energy, Energy Paper Number 9, 66 p.

Burley,A.J. Smith, I.F, Lee, M.K. Burgess, W.G. Edmunds W. M. Arthur, M.J. Bennett J.R.P., Carruthers R.M. Downing, R.A. & Houghton, M.T. 1980: Preliminary Assessment of the Geothermal Potential of the United Kingdom. Presented at Commission of European Communities Second International Seminar "Advances in European Geothermal Research. Strasborug, 4-6 March 10 p.

UNITED STATES OF AMERICA

Geography

Area 9,363,168 km^2

Population 217,329,000 (1977)

Information

The questionnaire was sent to R.R. Brownlee. A reply was received but without much information. Brownlee enclosed a brochure "The State Coupled Program: Low- and Moderate- Temperature Resources" from the U.S. Department of Energy, and a report "Geothermal Reservoir Site Evaluation in Arizona" by W.R. Hahman (1979). When these had been received the questionnaire was sent to L.J.P. Muffler at the U.S. Geological Survey and P.J. Lienau at the Geo-Heat Utilization Center at the Oregon Institute of Technology. Comprehensive information was received from both of these institutions - from M. Reed at the Survey and G. Culver at the Center, in addition to P.J. Lienau.

Utilization

Information on geothermal energy utilization in the U.S.A. is compiled in the " Geothermal Progress Monitor" published by the U.S Department of Energy. Report no.1 was published in December 1979 and report no. 2 in Jan./Feb. 1980. The "Geothermal Progress Monitor" has sections on: Electrical Uses; Direct-Heat Uses; Drilling Activities; Leases; Geothermal Loan Guarantee Program; General Activities and; Legal, Institutional and Regulatory Activities.

At the end of 1979 the installed geothermal generating capacity in the U.S.A. was 663 MW-electrical, all at The Geysers. It is planned that by 1985 this will have increased to over 2000 MW-electrical at all geothermal areas. Direct uses of geothermal at the end of 1979 are listed in the "Geothermal Progress Monitor". The most rapid-growing application of geothermal energy is in the use of geothermal heat as the direct source of heat for a large variety of purposes. Individually, projects utilizing direct geothermal heat use relatively small amounts of energy in comparison to an electric power plant. However, the aggregate of such projects constitutes a significant amount of energy displaced from conventional energy sources.

Current direct-heat applications comprise 180 activities in 16 states, whith an estimated energy use of approximately 1400 billion BTU/yr (1500 TJ/year). There are 57 planned projects. Tabulations of balneology applications (hot water spas and pools) are maintained separately, as the energy benefit from these projects is ambiguous. Table 1 shows the totals for the "standard" applications, the balneology applications and the Enhanced Oil Resovery (EOR) project.

The EOR project consists of injecting water into depleted oil formations to recover more oil. This is currently being done at the Salt Creek Oil Field in Northeast Wyoming. The water is acquired from artesian flow (15,000 gal/min = 946 l/s) at 200°F (93°C). The 10,000 billion BTU/year listed for this project is a very crude estimate, and is given to show the magnitude of heat that might be utilized by this application. The producers are currently asserting that their application does not use the heat, just the water. Studies are planned, but not yet in progress, to address this issue.

TABLE 1

Summary of yearly direct heat uses[x]

Use	No. of users	Thermal energy $\times 10^{-9}$ Btu	TJ
Current on-line	180	1,386.2	1462
Baths and pools	90	51.8	55
Enhanced oil recovery	1	10,000.0	10,550
Total	273	11,438.0	12,067

x Reference temperature assumed 15°C.

Table 1 shows the amount of geothermal energy used per year in direct use application is the U.S.A. The "current on-line" uses are all the typical direct uses of low-enthalpy fluids (district heating, greenhouses, aquaculture etc). For the purpose of the present survey it is assumed that these direct uses are in low-temperature geothermal fields. It is not clear what reference temperature the thermal energy use is based on. In the "Geothermal Progress Monitor" no specific reference temperature is given. For the present survey, however, the reference temperature will be assumed 15°C because it is used in the U.S. assessment work.

In a table received from the Geo-Heat Utilization Center, showing areas with geothermal direct heat on line, there is information on the "peak" and "yearly use" of geothermal energy in the states of California, Washington, Alaska, Hawaii and Oregon. The largest users of these are California (77 x 10^{10} Btu/hr as peak load and 27.7 x 10^{10} Btu/yr as yearly use) and Oregon (33.1 x 10^{6} Btu/hr as peak load and 11.1 x 10^{10} Btu/yr as yearly use). Therefore, the load factor for California and Oregon are 41.1% and 38.3% respectively. Boldizsár (1979) has shown that a load factor of 50% is common for district heating systems and 20% for greenhouses in Hungary. With this in mind and knowing the overall load factor for a "mix" of applications in California (41.1%) and Oregon (38.3%) it would seem reasonable that a overall load factor of 40% would apply in the U.S.A.Based on this assumption the "peak" or installed geothermal power in the U.S.A. becomes 115 MW-thermal for "current on-line" in Table 1 and 4 MW-thermal for "baths and pools". Since no thermal energy is used in the "enhanced oil recovery" project (and no information is available on the load factor) it will be omitted from the present survey. The total installed geothermal power in the U.S.A. is therefore estimated as 119 MW-thermal with reference temperature 15°C.

Exploration

In the reply from Reed at the U.S. Geological Survey it was stated that: "The U.S. Department of Energy, Division of Geothermal Energy, is funding a national exploration program for low-temperature resources. Funding is \$13 x 10^{6} for this year, and contract work is performed mostly by the State geological surveys and universities. This year (1980) 22 sites should be drilled under a \$10 x 10^{6} programme to determine the potential and demonstrate its use".

Assessment

Several geothermal assessment studies have been carried out in the U.S.A. Reed at the U.S. Geological Survey sent the 1978 "Assessment of Geothermal Resources of the United Stated "(Circular 790) and stated that: "The U.S. Geological Survey is conducting an assessment of resources in the range 20° to 100°C.... to augment the assessment....conducted in 1978". The 1978 assessment considers hydrothermal convection systems with reservoir temperatures above 90°C. The systems considered are then divided into high-temperature (above 150°C) systems and intermediate (90-150°C) systems. The assessnent deals with hydrothermal systems with mean reservoir temperatures greater than or equal to 90°C at depths less than 3 km.

A good knowledge of the terminology and definitions of geothermal assessment is a prerequisite to an understanding of it's results. In the 1978 assessment several sets of values are reported with various assumptions. For the purpose of the present survey only a few values will be reported, based on Table 11 of the Circular.

Indentified (exaluding National Parks) geothermal energy in intermediate (90-150°C) hydrothermal systems is reported as follows: Accessible resource base 700±110 x 10^{18}J; Resource 176 ±55 x 10^{18}J and; Beneficial heat 42 ± 13 x 10^{18}J. The last of these (beneficial heat) is that amount of the resource that is assumed to be directly applicable to non-electrical uses. In the Circular the beneficial heat is taken as 24% of the resource.

Undiscovered geothermal energy in intermediate hydrothermal systems is reported as follows: Assessible resource base 5200-3100 x 10^{18}J; Resource 1300-770 x 10^{18}J and; Beneficial heat 184-310 x 10^{18}J.

Bibliography

Muffler, L.P.J. & Christiansen, R.L., 1978/79: Geothermal Resource Assessment of the United States. Pageoph, 177, 160-171.

Muffler, L.P.J. (editor), 1979: Assessment og Geothermal Resource in the United States - 1978. U.S. Geological Survey Circulae 790.

U.S. Department of Energy, 1979: Geothermal Progress Monitor 1, DOE/RA/0043-D.

Hahman, W.R., 1979: Geothermal Reservoir Site Evaliation in Arizona. Bureau of Geology and Mineral Technology, Geological Survey Branch, University of Arizona, ID-12009-1, 172 p.

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YUGOSLAVIA

Geography

Area 255,804 km^2

Population 21,560,000 (1976)

Information

The questionnaire was sent to N. Miosic but no reply has yet been received. Later a letter and a questionnaire was sent to S. Galovic after a meeting in the U.S.A. A reply is now in preparation by various institutions in Yugoslavia e.g. the Geological Inctitute in Zagreb. Although it is known that there is considerable geothermal potential in Yugoslavia and hot waters have for a long time been used for therapeutic purposes, there is limited information available. It appears there are e.g. possibilities for district heating near Zagreb and some boreholes have been drilled for geothermal purposes.