ORKUSTOFNUN

Iceland: Survey of low-temperature geothermal energy

Jón Steinar Guðmundsson

Greinargerð JSG-81-02

ORKUSTOFNUN
Geothermal Division
1981.03.13.

Note
JSG-81/02
óe

ICELAND: Survey of Low-Temperature Geothermal Energy

Geography

Area 102,828 km^2
Population 226,724 (1979)

Information

In the files of Orkustofnun there is information on most aspects of geothermal energy in Iceland. A recent compilation of data suitable for the survey was however not available. It was therefore decided to write an extensive note (Gudmundsson et al. 1980) on low-temperature geothermal energy in Iceland. An effort was made to update the available information and to bring forth any new aspects of geothermal energy in Iceland. The purpose of the extensive note was therefore twofold; to provide Icelanders working in the field of geothermal energy with new data and to supply information for the World Survey of Low-Temperature Geothermal Energy Utilization. The present note is an abbreviated version of the above mentioned note.

UTILIZATION

The main use of geothermal energy in Iceland is low-temperature energy for district heating. This type of utilization was initiated in 1930 in Reykjavík and today 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, Reykjahlíd and Vestmannaeyjar. Low-temperature geothermal energy is also used for heating greenhouses, swimming pools, industrial drying and fish culture.

Reykjavík District Heating Service

The RDHS is probably the world's largest district heating system using geothermal water. It serves the towns of Reykjavík, Kópavogur, Hafnarfjördur and Gardabaer and the rural townships of Mosfellshreppur and Bessastadahreppur, the last one having been connected to the system only

last year (1980). In the rural townships of Mosfellshreppur and Bessastadahreppur there are independent district heating services that buy their geothermal water from the RDHS. The total population of Mosfellshreppur and Bessastadahreppur was 2,724 and 422, respectively, in 1979. The total population of Iceland in that year was 226,724 people while the population of the towns (Reykjavík, Kópavogur, Hafnarfjördur and Gardabaer) served by the RDHS was 113,667 people. The 1979 annual report of the RDHS shows that the system served 98.4% of it's area, or 111,905 people, amounting to 49.4% of the total population of Iceland.

The Reykjavík District Heating Service provides geothermal water not only for homes but also for all commercial and inductrial 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 city of Reykjavík and one in Mosfellssveit at 15-20 km distance. 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. In addition, the RDHS has an oil-fired 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 total amount of geothermal water produced by the RDHS annually from 1944-1979 is shown in Figure 1. In 1979 the RDHS produced 45,091,000 m^3 of hot water from the pumping stations to the distribution network. However, due to shunting procedures the amount of hot water metered at the customers was only 40,450,000 m^3 and adding the 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 endpoints to maintain flow and temperature. About 10% of the hot water delivered to customers is used as tap water. The estimated load factor of the RDHS is about 50%.

District heating in general

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. Table 1 shows the 24 public district heating services in Iceland, not all of which are in low-temperature geothermal areas. The Sudurnes system is in the high-temperature field of Svartsengi and the Reykjahlíd system is in the Bjarnarflag field of the Námafjall area. The Hveragerdi system is in the Ölfusdalur field to the south of the Hengill high-temperature area. 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. Although the district heating systems in Sudurnes, Hveragerdi, Vestmannaeyjar and Reykjahlíd are thus not in low-temperature geothermal areas, they are shown in Table 1 for the sake of completeness. The 24 public district heating services provide 156,389 people or 69.0% of the population with geothermal heating. Table 2 shows the present and planned 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. It is expected that in 3-5 years about 185,000 people or 81.6% of the total population of Iceland will enjoy geothermal district heating.

Installed capacity of low-temperature geothermal fields

A compilation was made of the installed hot water production capacity of the 19 public district heating services (Mosfellshreppur is included in Reykjavík) that operate low-temperature geothermal fields. Table 3 shows this compilation. It should be noted that the 4 district heating system in high-temperature fields (Sudurnes, Hveragerdi, Vestmannaeyjar and Reykjahlíd) are excluded. Table 3 shows the installed production capacity in low-temperature fields as it was in late 1980. The low-temperature geothermal waters produced by the 19 district heating services in Table 3, are not only used for homes, but also for industrial, commercial, agricultural and recreational purposes in various amounts. Unfortunately, there is limited information available to show, in detail, to what purpose the hot water is used.

In addition to the public district heating services shown in Table 3, a compilation was made of the installed production capacity in other low-temperature fields around the country. This was done to estimate the total installed production capacity of all the low-temperature geothermal fields in operation in late 1980. For reference temperatures 0°C, 5°C, 15°C, 35°C and 40°C the total installed low-temperature geothermal power in Iceland was estimated as 1360.8 MW, 1282.4 MW, 1127.1 MW, 823.4 MW and 747.1 MW-thermal. The above thermal power values were arrived at by adding to Table 3 the following items: (1) private and public heating systems in the county of Árnessýsla not already included; (2) the almost 30 school centres in rural areas not already included; (3) all swimming pools in operation outside district or other heating systems already included; (4) the fish culture stations outside systems already included; (5) industrial utilization. It should be pointed out that all the greenhouses in low-temperature areas are within the above categories. In the survey the installed thermal capacity was derived from data on the flowrate and temperature of the geothermal water being produced in each field. It is the amount of water already available but not necessarily used. The details of the survey procedure are given by Gudmundsson et al. (1980).

Overview of utilization

The installed production capacity of all low-temperature geothermal fields was estimated in the previous section. It shows the amount of hot water available but not necessarily used. However, it is of great interest to estimate how much low-temperature geothermal energy is used, and for what purpose. In the following section the utilization in greenhouses, swimming pools, industry and fish culture will be estimated as well as the thermal power associated with the heating of residential, commercial and industrial buildings.

There are 79 swimming pools in Iceland that use low-temperature geothermal water. In addition there are 5 swimming pools served by the Sudurnes, Hveragerdi and Vestmannaeyjar systems. The total volume of the 79 pools is 20,267 m^3 of which 17,484 m^3 are outdoors and 2,783 m^3 indoors. It was estimated, based on the total amount of water metered to 7 swimming pools in Reykjavík during one year, that the average thermal power requirement of outdoor pools is 1 kW/m^3 and indoor pools 0.5 kW/m^3, if it

is assumed that the inlet temperature is 80°C and the outlet temperature 40°C. Applying this rough estimate to all the 79 swimming pools in low-temperature areas, this total average thermal power requirement becomes 37.8 MW, 35.4 MW, 30.8 MW, 21.3 MW, and 18.9 MW-thermal based on 0°C, 5°C, 15°C, 35°C and 40°C reference temperatures.

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. About 24.7% of the area under glass is in Hveragerdi and must therefore be excluded from the present survey. The heating requirements for greenhouses in Iceland are estimated 200-250 kcal/h m^2 (0.233-0.291 kW/m^2). By assuming geothermal water at 80°C and using 0.291 kW/m^2 as the specific thermal power requirements, the 109,185 m^2 (the 75.3% outside Hveragerdi) result in 63.5 MW, 59.6 MW, 51.6 MW, 35.6 MW and 32.2 MW-thermal above 0°C, 5°C, 15°C, 35°C and 40°C respectively.

Geothermal water is used in 9 fish culture stations in Iceland for rearing salmon and trout smolts. In total they have the capacity to raise 610,000 smolts per year. It is estimated that the installed thermal capacity of these stations is 9.6 MW, 6.9 MW, 3.2 MW, 2.1 MW and 1.9 MW-thermal for 0°C, 5°C, 15°C, 35°C and 40°C reference temperatures, respectively.

The main use of low-temperature geothermal energy for industrial processing is the seaweed drying plant at Reykhólar. At Reykhólar there is also a public district heating service (Table 3). The district heating system uses one borehole while the drying plant uses three boreholes. These three holes produce about 45 l/s in total of 112°C water corresponding to 21.1 MW, 20.2 MW, 18.3 MW, 14.5 MW and 13.6 MW-thermal above 0°C, 5°C, 15°C, 35°C and 40°C.

In 1979 the Reykjavík District Heating Service (RDHS) provided 114,158 people with geothermal water for space heating. This corresponds to 98.4% of the people in Reykjavík and neighbouring towns and 82.7% of the people living in Mosfellshreppur. Table 2 shows that in total 157,945 people enjoyed geothermal space heating in 1979. As already mentioned, this includes Sudurnes, Hveragerdi, Vestmannaeyjar and Reykjahlíd that

are in high-temperature areas, but their total population (enjoying geothermal space heating) in 1979 was 14,614 people (see Table 1). In 1979 there were therefore 143,311 people enjoying space heating in low-temperature areas in the whole of Iceland; this is 25.6% more people than served by the RDHS. Therefore, by adding 25.6% to the values shown for Reykjavík in Table 3, it is possible to arrive at an estimate for the whole country, assuming that the specific hot water usage (i.e. per person) is the same. However, before this is done, the amount of hot water used for greenhouses and swimming pools in Reykjavík must be subtracted. In 1979 about 1.8% of the hot water sold by the RDHS was delivered to swimming pools. An approximation of the installed production capacity associated with the swimming pools is therefore 15.0 MW, 14.2 MW, 12.6 MW, 9.4 MW and 8.6 MW-thermal for 0°C, 5°C, 15°C, 35°C and 40°C reference temperatures, respectively. About 11.1% of greenhouses in Iceland are in Reykjavík and Mosfellshreppur. Based on the thermal power requirements of greenhouses presented above it was estimated that 9.4 MW, 8.8 MW, 7.6 MW, 5.2 MW and 4.8 MW-thermal must be subtracted for reference temperatures 0°C, 5°C, 15°C, 35°C and 40°C. The resulting amount of low-temperature geothermal water used for space heating in Iceland in late 1980 becomes therefore 1012.8 MW, 959,3 MW, 850.1 MW, 634.4 MW and 580.0 MW-thermal for the standard reference temperatures. It should be noted that although the 1979 statistics for population are used, the installed capacity of the low-temperature fields refers to late 1980. The production capacity of the RDHS did not increase in 1980.

Table 4 shows the low-temperature geothermal energy used in Iceland in late 1980. It shows the thermal power associated with each type of use for the reference temperatures 0°C, 5°C, 15°C, 35°C and 40°C. It should once again be noted that all applications of geothermal energy in high-temperature fields are excluded from Table 4.

In Table 5 the installed thermal power (available) and the thermal power used (utilized) are compared at the standard reference temperatures showing that the installed thermal power is 16-19% higher than the thermal power used. It should be borne in mind that the available thermal power was derived from data on the flowrate and temperature of low-temperature waters in the various fields, while the utilized thermal power was estimated from information about the Reykjavík District Heating Service and an approximation of the thermal requirements of greenhouses and swimming pools.

EXPLORATION

In Iceland there is considerable exploration work carried out for geothermal energy. This would be expected in view of the great importance this resource plays in the national economy. Last year (1980) the Geothermal Division of Orkustofnun conducted exploration work for about 10 operational district heating services to enable them to meet expected increase in demand for hot water and also to secure better their present production capacity. Exploration was also 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 projects were carried out last year for rural centres and groups of farms. At the same time several regional geothermal studies were on the agenda to provide a better understanding of the processes that create usable geothermal energy.

Drilling for geothermal energy in Iceland is done with five 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 state owns all but one of the drilling rigs; Dofri is owned 50/50 by the state and the Reykjavík District Heating Service. All the rigs are however operated by the Drilling Division of Orkustofnun. All exploration and production drilling for geothermal energy in Iceland is done by the above five rigs, except thermal gradient holes, which are drilled with 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 the natural flow of all hot springs in Iceland has been estimated to amount 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. The information has also been used to estimate the present flowrate and temperature in the same fields with the advent of drilling. The estimated natural

flow is now considered 1825 l/s. 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 greatest increase in flowrate has been achieved in the low-temperature fields producing hot water for the Reykjavík District Heating Service where the flowrate has been increased about 10 times and 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 methodology have been adopted 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. 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 Sub-economic as it is related to various time dependent assumptions.

J. S. Gudmundsson
Geothermal Division

SELECTED BIBLIOGRAPHY

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.

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.

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.

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

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

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

Gudmundsson, J.S., Gunnarsdóttir, M.J., Halldórsson, R., Saemundsson, K. and Jakobsson, H. Th., 1980: Low-Temperature Geothermal Energy in Iceland. Orkustofnun, Note JSG-MJG-RH-KS-HThJ-80/10., 38 p.

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

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.

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

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

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.

Zoëga, J., 1980: The Reykjavík District Heating Service - Annual Report 1979, 12 p. (In Icelandic).

ORKUSTOFNUN

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.1

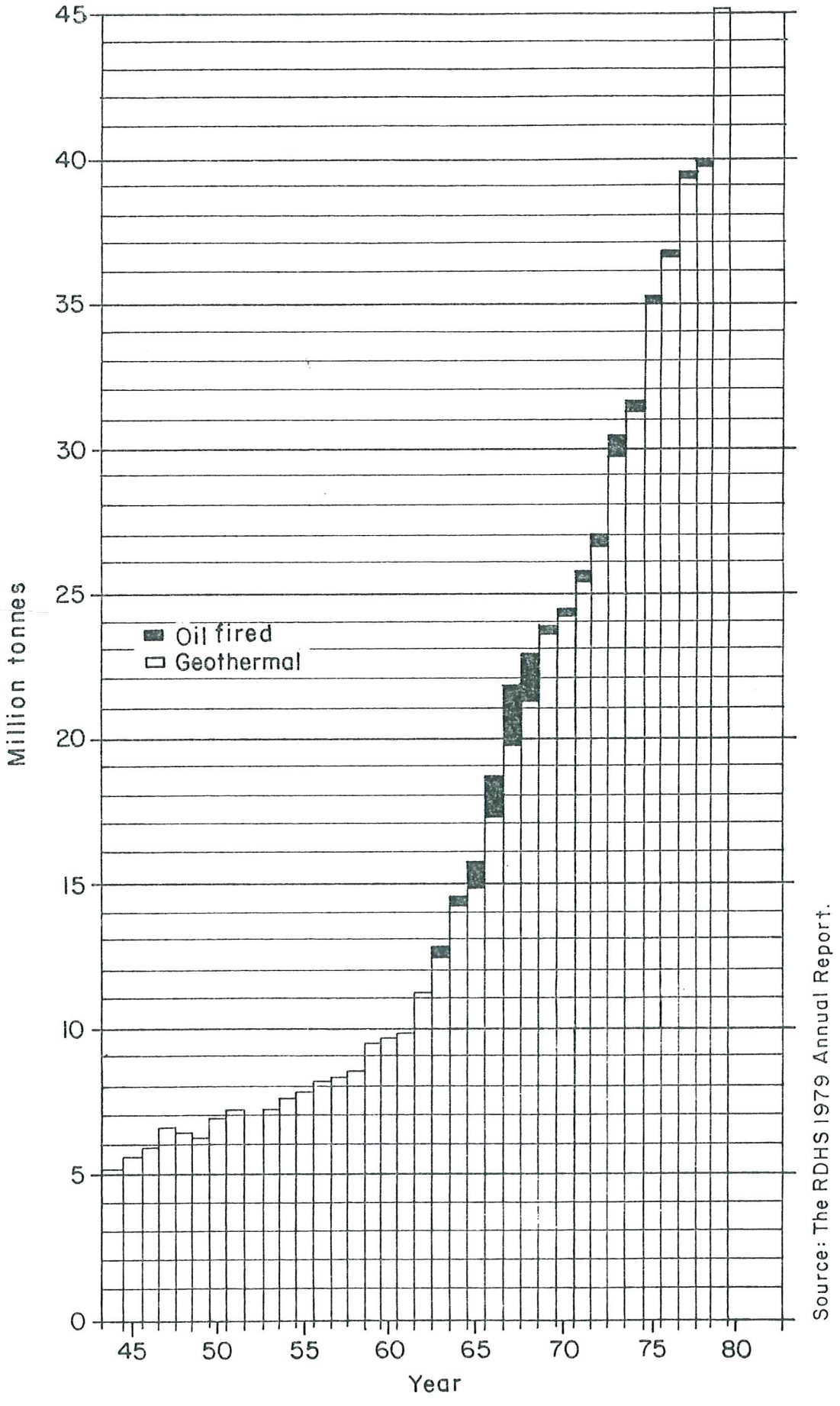

TABLE 1

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 xx	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 xx	...	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 xx	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 xx	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.

xx In high-temperature geothermal areas.

TABLE 2

Geothermal district heating services in Iceland, 1979 and planned

Town/Region	Population [1]	
	Present	Planned
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 3

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

Town	Capacity	Temperature [3]	Installed thermal capacity (MW)				
	(l/s)	(°C)	> 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
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 [2]	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:	3026	-	1132.9	1070.1	944.6	693.9	631.2

1) Includes Mosfellshreppur, cf. Table 1.
2) One borehole serving district heating only.
3) Temperature at well-head.

TABLE 4

Low-temperature geothermal energy used in Iceland in late 1980

Type of use	(%) **	Thermal power (MW)				
		>0°C	>5°C	>15°C	>35°C	>40°C
Space heating *	89.2	1012.8	959.3	850.1	634.4	580.0
Greenhouses	5.4	63.5	59.6	51.6	35.6	32.3
Swimming pools	3.2	37.8	35.4	30.8	21.3	18.9
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	1148.8	1081.4	954.0	707.9	646.7

* Residential, commercial and industrial buildings
** Calculation based on >15°C values.

TABLE 5

Comparison of utilized and available (installed) low-temperature geothermal energy.

Geothermal	Thermal power (MW)				
	>0°C	>5°C	>15°C	>35°C	>40°C
Utilized	1148.8	1081.4	954.0	707.0	646.7
Available	1360.8	1282.4	1127.1	823.4	747.1
Excess (not used):	212.0	201.0	173.1	115.5	100.4