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Low-temperature geothermal energy in Iceland

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

80-10-23
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Fig. 1

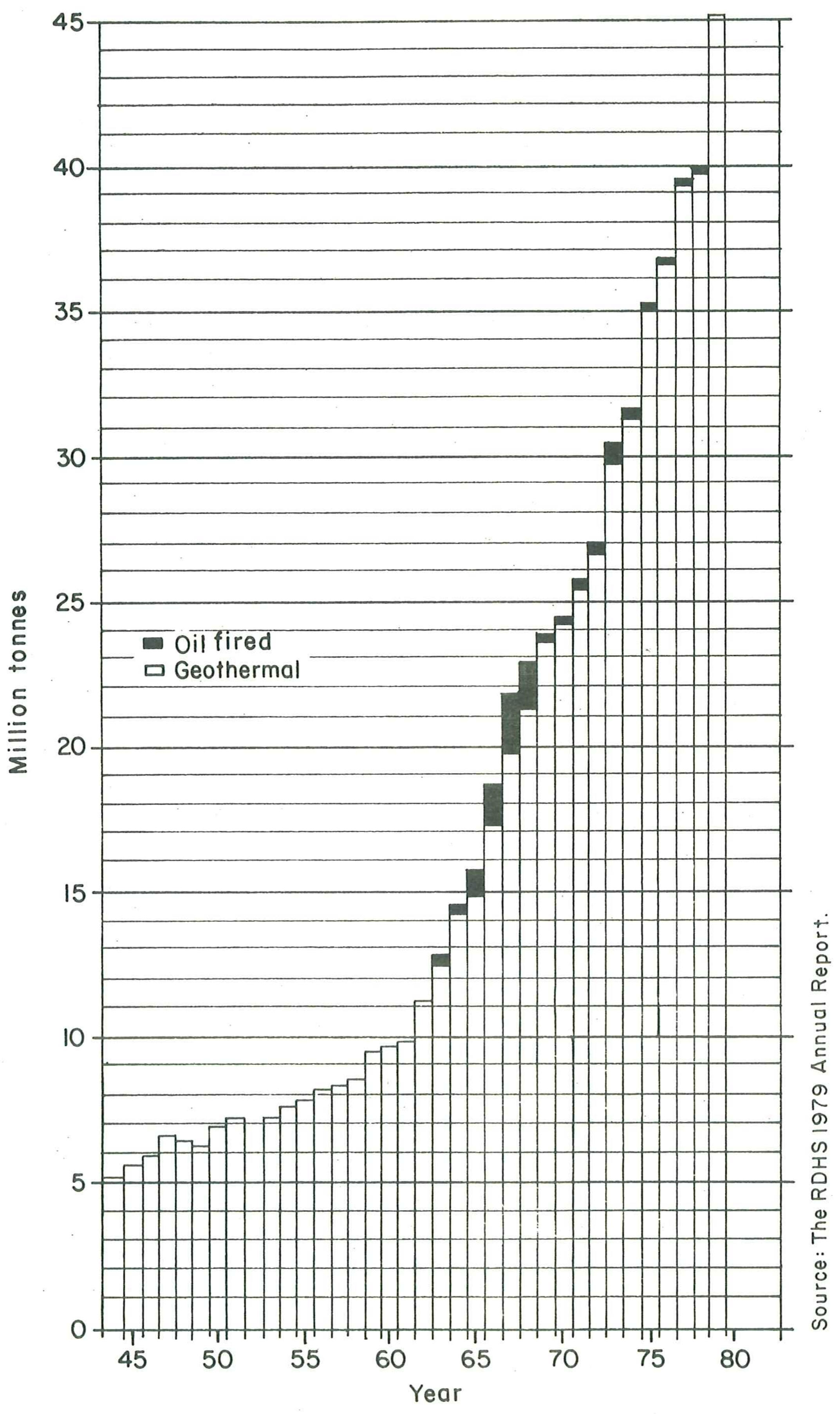

TABLE 1

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)		Quantity Water Sold		Heated Space ($x10^{-3}$ m^3)			Revenue* $x10^{-3}$IKR
			Delivered	Returned	$x10^{-3}$ (m^3)	(l/min.)	Total	Homes	Other	
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