The State Electricity Authority

SOME INFORMATION ABOUT ICELAND

ITS WATER RESOURCES AND ENERGY POTENTIAL

July 1965

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1. Statistical Data

1.1 Geographical Data

Latitude	63°24´ - 66°32´, N
Longitude (Greenwich)	13°30´ - 24°32´, W
Length, W-E (max)	490 km
Breadth, N-S (max)	312 km

	1000 km^2
Area, total	103
Cultivated land, estimated at	1
Other land with vegetation	24
Lakes	3
Glaciers	12
Lava	6
Sand	4
Other desert land	53

Population, Dec. 1, 1964	189.785* (1.8 per km^2)
(Reykjavik - - -	76.921*)

Net increase 1959-63, annual average ... 1.9%

Born alive 2.7%

Died 0.7%

Net migration .. – 0.1%

Average life (1951-60)

Men .... 70.7 years

Women ...... 75.0 -

Marriages (1959-63) 7.6°/oo

Separations ..... 2.5 -

Divorces .... 0.9 -

1.2 National Economy

Occupations

Farming	13.5%
Fisheries	10.0%
Fish processing	10.0%
Other manufacturing	13.0%
Construction	10.0%
Commerce, communications	21.5%
Other services	14.5%
Pensions, publ. relief etc.	7.5%
	100.0%

Farming (about 5.200 farms)

Cattle	56 000
Horses	30 000
Sheep	777 000
Poultry	107 000
Pigs	1 000

Number of dairies 15

Milk processed in dairies	100 000 000 1
Total milk production	120 000 000 1
Mutton production	12 000 000 kg

Fisheries (830 craft, totalling 75 000 G. R. T.)

1963	total catch	774 000 tons
	(of which herring	395 000 -)
1964	Herring	542 000 tons
	Cod, haddoch and flat fish	425 000 -
	Capelin	9 000 -
	Crustacea	3 000 -
	Total	979 000 tons

Exports, imports, balance of payments

Imports 1964	5650 mill. kr.	c.i.f.
Exports -	4776 - -	f.o.b.
Adverse balance	874 million kr.	

The net balance of payments for 1964 (including services) is not yet available. In 1963 it was 220 million kr. and will probably be similar in 1964.

Fish and fishery products	92% of exports
Agricultural products	6% - -

Principal trading partners 1964

	Exports	Imports
United Kingdom	17.5%	13.3%
United States	16.1%	11.9%
Soviet Union	9.1%	8.4%
Western Germany	8.6%	10.3%
Sweden	7.3%	5.4%
Denmark	3.6%	7.0%
Norway	6.3%	10.8%
Nigeria	4.8%	-

Principal exports

Frozen fish	24.0%
Herring meal	12.5%
Salted herring	11.0%
Salted fish	9.0%
Herring oil	9.0%
Iced fish (incl. herring)	7.0%
Dried fish	7.0%

Import of Fuels in 1964

	Metric tons
Coal	12 695
Coke	899
Heavy Fuel Oil	101 634
Gas Oil	250 090
Kerosine	7 621
Gasoline	42 831
Aviation Gasoline	15 231

Estimated Consumption of Energy in 1964

(expressed as useful energy, i.e. excluding transmission and conventional losses)

Total consumption		3000 GWh
Supplied by	hydro power	17%
	geothermal energy	18%
	imported fuels	65%

Shipping

End 1963 67 vessels, 67 000 G.R.T.

Aircraft (in overseas operation)

1965 (January) 11 aircraft (1026 seats)

Passenger transports (overseas), 1963

	Foreigners	Icelanders	Total
By sea	2 800	3 212	6 012
By air	14 775	9 912	24 687
	17 575	13 124	30 699

Living Standards

Calories per day 3240

Minimum hourly daytime wages, July 1964	Kr. 36.18
Average yearly income of married workers and seamen, 1963	Kr. 125 000

According to income tax returns 1963 75% of married male taxpayers, ages 25-66 years lived in own houses

Per 1000 inhabitants :

Passenger cars	125
Radio sets	460
Telephones	254

Energy consumption per head, coal equivalent metr. tons	4.4
Milk consumption per day per person	0.66 ltr

Production and Capital Formation

Gross National Product in 1964 at 1962 prices

Millions of I kr.	13 845
Per head, US $	1 710
Growth per annum	5,5%

Gross Fixed Capital Formation in 1964 at 1962 prices

Millions of I kr.	4 170
Percent of G.N.P.	30

Currency

Icel.kr.

100 kr.	16,08 D.Kr.
100 kr.	11.39 F.Fr.
100 kr.	9.27 D.Dm.
100 kr.	2.32 US $
100 kr.	0/16/7 UK £

1.3 Electric Power Industry

Installed Capacity and Generation of Electricity

Public Power Plants	Installed Capacity 31.12.64 MW	%	Generation in 1964 GWh	%	Average 5 year increase 1959-1964 %	Average 10 year increase 1954-1964 %
Hydro Power	123	82,2	653	98,1	6,8	7,1
Thermal Power	26	17,8	13	1,9	- 1,8	1,1
Total	149	100,0	666	100,0	6,6	7,1

Ownership	Installed Capacity 31.12.64 MW	%	Generation in 1964 GWh	%
State	22	14,5	52	7,8
State and Municipal	103	69,4	566	85,0
Municipal	24	16,1	48	7,2
Total	149	100,0	666	100,0

	Installed Capacity 31.12.1964		
Private Power Plants	Hydro MW	Thermal MW	Total MW
Farms	4	2	6
Industry, Schools, etc.	0	14	14
Total	4	16	20

Total Private Generation of electricity, estimated at 15 GWh

Gross Consumption of electricity in 1964, 3 640 kWh/capita

Consumption and Sale of Electricity in 1963

Consumption	Retail Sales GWh	%	Revenue M.kr.	%	Average Prices kr/kWh
Domestic Consumption	116,9	22,1	118,6	39,0	1,01
Space Heating	83,2	15,7	20,9	6,9	0,25
Commercial Lighting	29,3	5,5	48,8	16,0	1,67
Handicrafts	13,7	2,6	23,8	7,8	1,74
Large Power Industry	77,6	14,6	49,5	16,3	0,64
Public Lighting	8,8	1,7	9,0	3,0	1,02
Other Concumption	23,4	4,4	11,7	3,8	0,50
Total Ordinary Consumption	352,9	66,6	282,3	92,8	0,80
Fertilizer Plant	128,0	24,2	6,6	2,2	0,05
Cement Plant	12,0	2,3	3,0	1,0	0,25
Keflavik Airport (Nato-Base)	36,7	6,9	12,3	4,0	0,36
Total Special Consumption	176,7	33,4	21,9	7,2	0,12
Total Consumption	529,6	100,0	304,2	100,0	0,57
Transmission and distribution Losses, etc.	111,8				
Total Generation	641,4				

Degree of Electrification (31. 12. 1964)

Percentage of Population with access to electricity	97%

Rural Electrification (31. 12. 1964)

	No. of farms	%
Power from public networks	2 911	56. 0
- - own hydro plants	480	9. 2
- - - diesel -	574	11. 1
Total electrified	3 965	76. 3
Without electricity	1 235	23. 7
Total farms	5 200 *	100. 0
Total hydro generation in 1964 in percentage of the estimated technically available potential	1. 9	

1. 4 Utilization of Geothermal Energy

Total geothermal energy production 860 Tcal
(equivalent to about 120 000 tons of crude oil)

Population served by central heating systems utilizing natural hot water	60 000
Average temperature of the water in the houses, about	75 ° C
Area of greenhouses using natural heat (31. 12. 1964)	105 000 m^2

2. Notes on the Climate and Hydrology of Iceland

2.1 Climate

The climate of Iceland is of rather mild maritime type with relative mild but windy winter and rather cool summers.

For indication of temperature and precipitation some monthly and annual means are given for three meteorological stations: Reykjavík, Akureyri in the northern part of the country and Hólar in the southeasternmost part (see figure 1).

	Temperature C°				Precipitation mm			
	January	June	July	Year	May	June	Oct.	Year
Reykjavík	- 0.4	9.5	11.2	5.0	42	41	97	805
Akureyri	- 1.5	9.3	10.9	3.9	15	22	57	474
Hólar	0.3	9.3	10.9	4.9	90	83	170	1632

Average duration of bright sunshine in Reykjavík a year (1930-49) 1 236.0 hours
" " " " " " " in December 6.4 "
" " " " " " " " May 187.9 "

The mean daily range of temperature is negligible during winter but ca 2°C in summer. Maximum temperature on warmest days in summer may exceed 20°C and minimum on coldest days in winter is usually below - 20°C in the inland and on the northern coast.

Spring and early summer is the dryest part of the year with some 15-20 days pr. month without rain in the southern part of the country and up to 24 days on the northern side.

2.2 Hydrology

Runoff

The average runoff for the country as a whole is approx. 55 litres per second per square kilometre. The geographical distribution is shown in Fig. 1. The highest runoff occurs near the south and west coast, in mountaineous regions; the lowest in inland areas in the north and east.

Most drainage basins are relatively small; the largest is that of Jökulsá á Fjöllum in the north 7950 sq. kilometres; Thjórsá in the south 7530 sq. kilometres and Hvítá, also in the south, 6100 sq. kilometres. In spite of this modest size of the catchments, the relatively high runoff per unit area create rivers of appreciable mangitudes. Thus the mean discharge of the three rivers mentioned above is 190, 394 and 392 kilolitres per second, respectively.

Stream-types

Icelandic streams may be divided into two basic types, viz. (1) glacial streams and (2) clearwater or non-glacial streams, according to whether or not they receive a substantial part of their summer discharge from glacier meltwater. As a matter of fact, a pure glacial stream can only exist at the snout of a glacier, since after leaving the glacier it receives additional water as surface runoff from non-glaciated areas, and as groundwater. However, in common usage, these streams are called glacial streams throughout their whole length, mainly because of the characteristic milky to brownish colour of such streams which they retain all the way to mouth. The colour stems from fine particles of glacial flour - an erosion product from the bed of the glaciers - that are suspended in the water. About ten percent of Iceland is covered with glaciers and all the major streams in the country are glacier streams.

The clearwater streams may again be divided into two subgroups viz. (1) dragá or direct run-off streams and (2) lindá or ground-water fed streams, according to whether the river is fed predominantly by surface or subsurface run-off. That again depends primarily on the geology of the basin, especially its permeability. Dragá streams thus tend to be associated with impermeable basins; lindá streams with permeable ones. Naturally, since the permeability may vary between wide limits within even a small basin, most clearwater streams are more or less a mixture of the two types. However, the characteristics of each are very marked in the case of many Icelandic rivers, notably the lindá features of many streams in the volcanic regions of the country where large areas are covered with highly permeable materials like volcanic ash and lava, with practically no surface runoff. These lindá rivers may have a remarkably even flow throughout the year; a feature of great practical importance from a development standpoint.

Many of the largest rivers of Iceland are found in the volcanic areas.

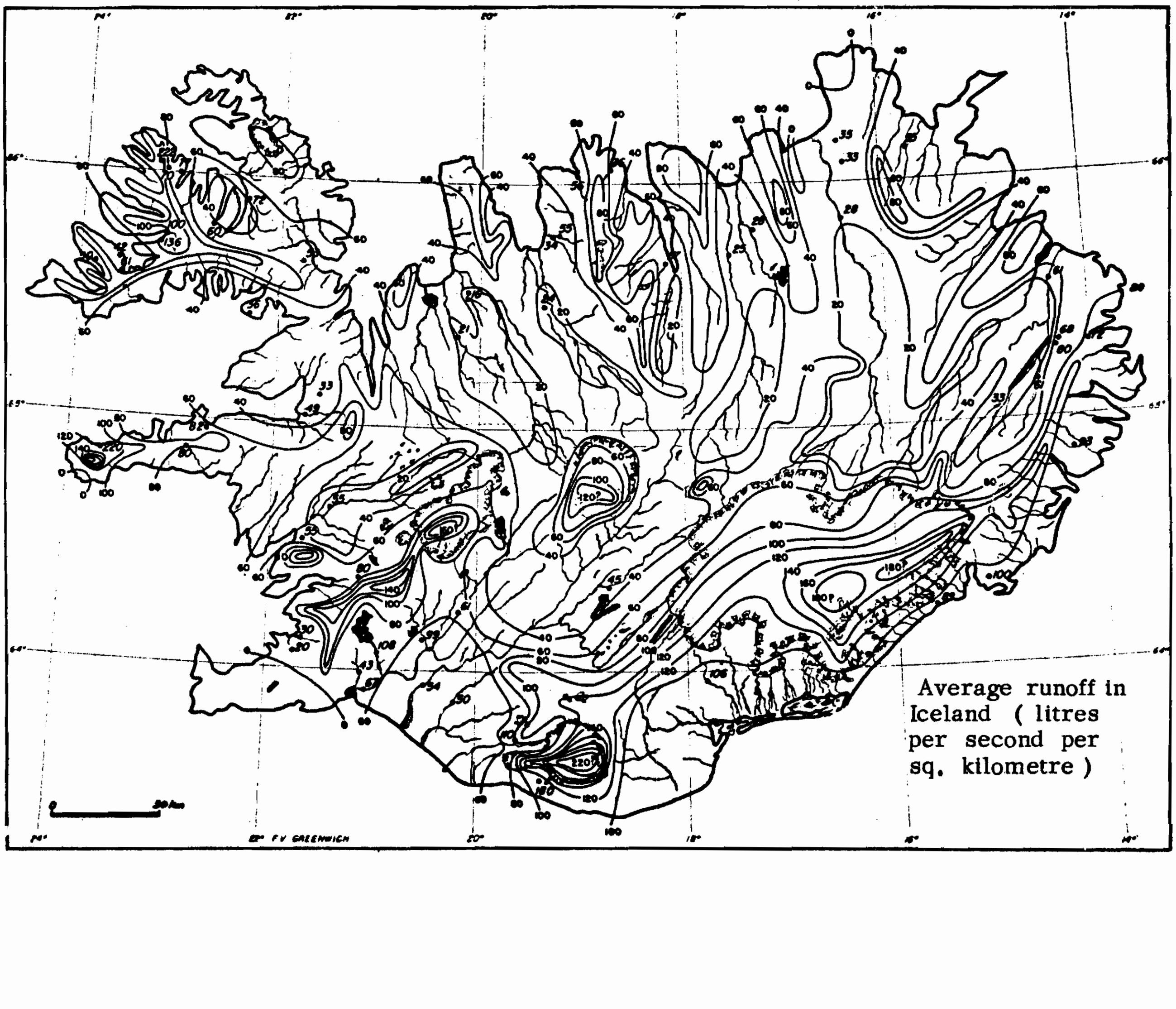
Each of the three stream types, glacial dragá and lindá rivers has its typical annual flow pattern. This is illustrated in Fig. 2. The ordinates are expressed as percentages of the mean in order to enlighten comparison. Actually, the mean discharge of all three examples is very nearly the same, 30 kl/s. Note particularly the extreme uniformity of the lindá river.

Many Icelandic streams, and especially the major ones are mixtures of all three stream types. This fact, especially the lindá component of the glacial rivers is of great practial importance, since it is primarily this component which determines the low flow doncitions of these rivers.

Water resources

Since Iceland has abundant precipitation, water supply for domestic and industrial purposes has never been a serious problem here except in a few special cases, and probably will not be for a long time to come. Hydro-electric power generation is by far the most important potential use of the water resources of the country. Almost negligible quantities are uses for irregation a few weeks of the year and there is no river navigation or floating of timber. Freshwater fisheries are already of some importance and have good development possibilities. They are probably the only economic activity that may offer any noteworthy competion with power generation for use of the water in the future. Flood damage is practically non-existent and flood control is therefore of very small economic importance. Water resources developments in Iceland, therefore, are essentially single purpose undertakings and will continue to be so for a long time. That purpose is power generation.

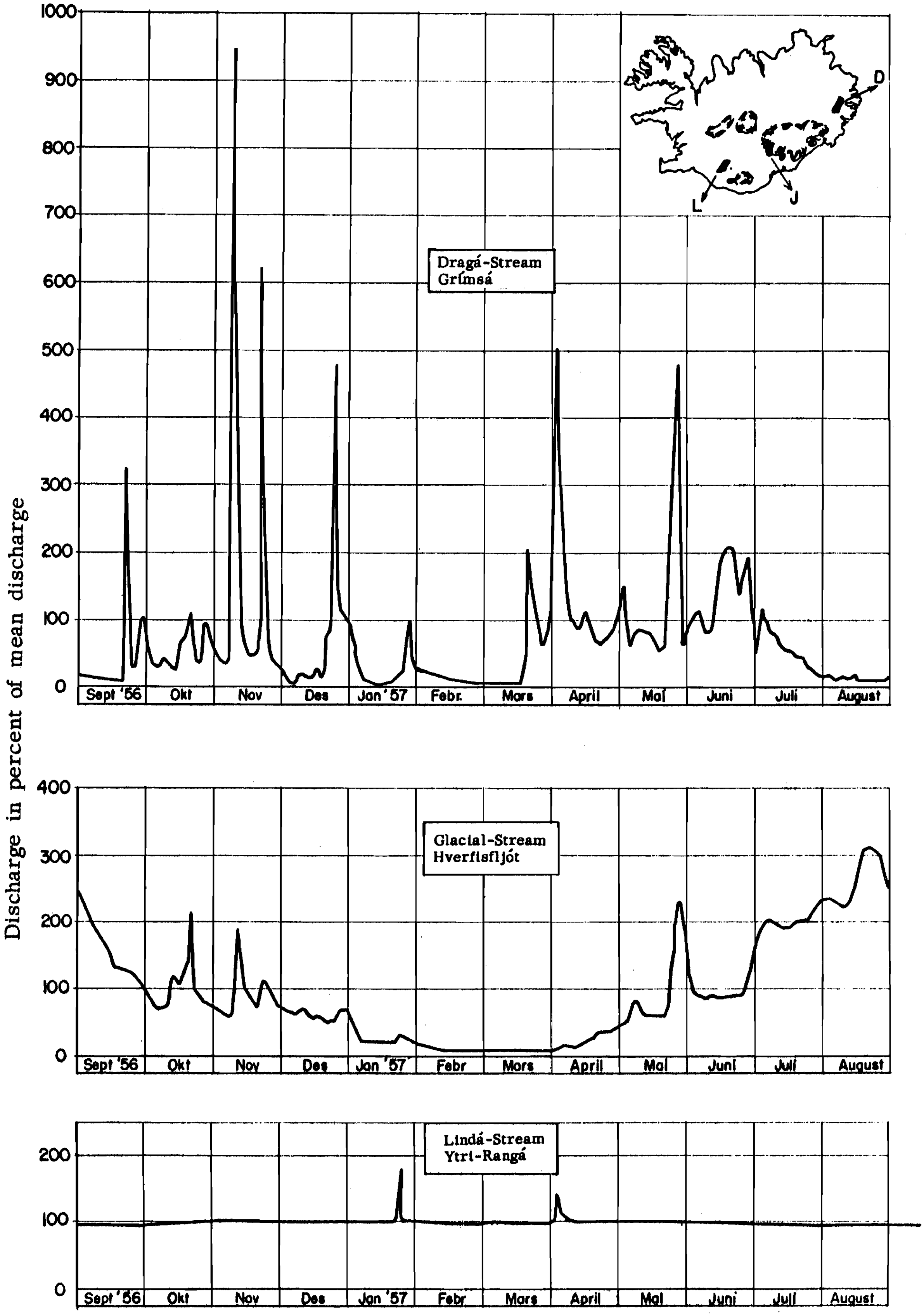
Fig. 1



Average runoff in Iceland (litres per second per sq. kilometre)

Fig. 2

Comparison of the annual flow pattern of dragá, glacial and lindá stream types. - All three rivers have a mean discharge of approx. 30 kl/s.



3. The Energy Resources of Iceland

3.1 The Hydro Power Potential

The total technically harnessable water power in Iceland is estimated at 35.000 GWh a year under normal and 31.000 GWh a year under adverse hydrological conditions.

Figure 3 shows the geographical distribution of the power potential. The river basins with the greatest potential are the Thjórsá Basin in the south, with around 30% ; Hvítá Basin, also in the south with 13% ; the Jökulsá á Fjöllum Basin in the north, with 12% and the Jökulsá á Brú Basin in the east, with 13% of the total resources.

The distribution of the power potential is favourable when compared to the population distribution since the greatest potential is found a short distance from the most densely populated regions.

Only about 2 percent of this power has been developed as yet. The water power resources are considered among the principal natural assets of the country, along with the fishing banks, the grasslands and the geothermal energy potential.

The above figures 35.000 and 31.000 GWh a year, represent the aggregate output of about 90 potential sites, the development of which is considered technically feasible. Many of these sites have only a small output. There are about 36 sites with an annual energy of 200 GWh or more each and their aggregate output is estimated at 30.000 GWh a year under normal hydraulicity conditions, or 86 percent of the total. The geographical distribution of these sites is shown by the circles in Fig. 4 where in a few cases adjacent sites have for reasons of clarity been reproduced by a single circle.

No attempt has as yet been made to assess the part of the technical potential that is economically harnessable, since in most cases the necessary site data are insufficient for cost estimation. It is expected that many of the smaller sites (below 200 GWh a year) will not prove economical but that most of the larger ones will be so.

Fig. 3

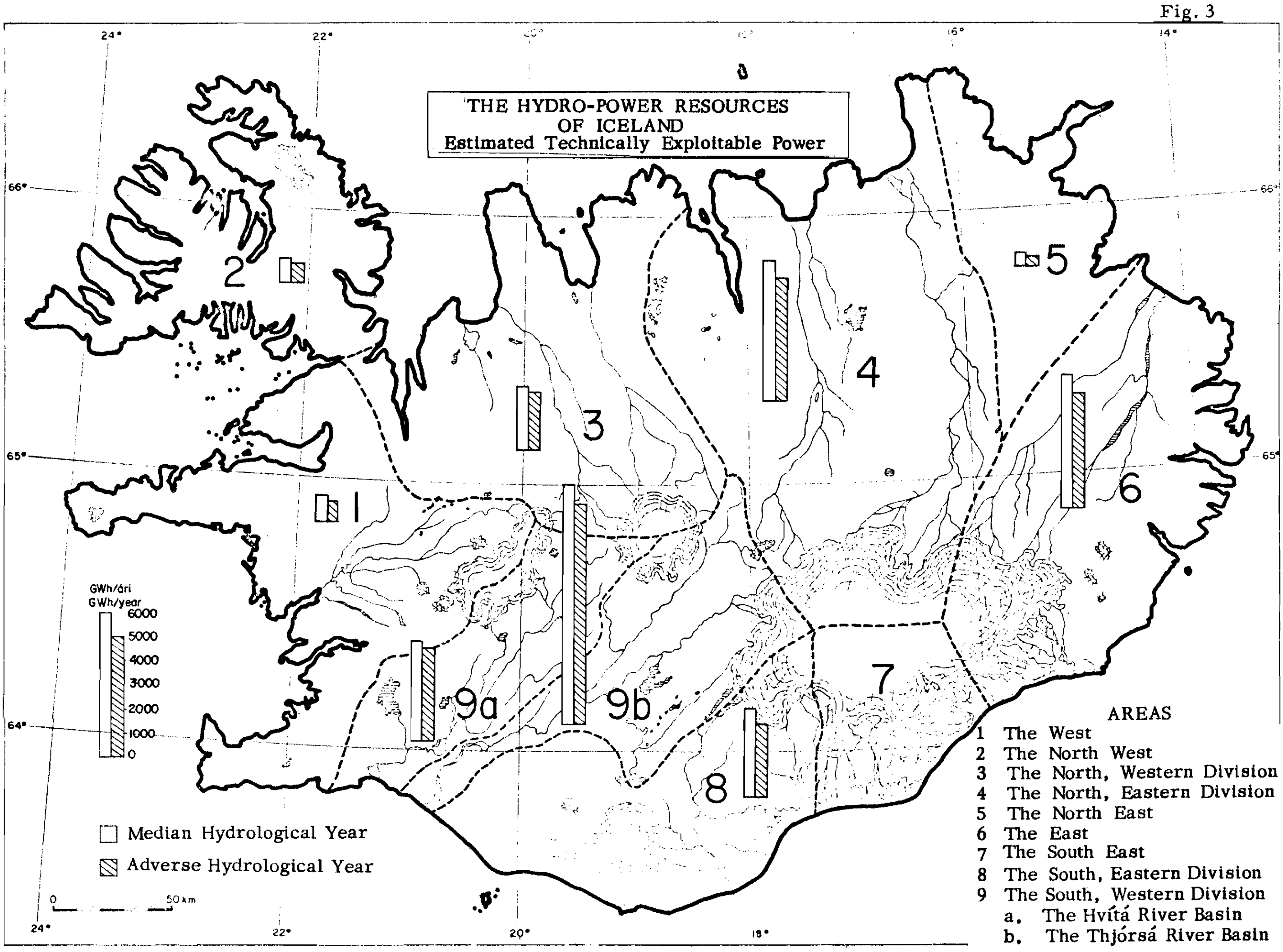
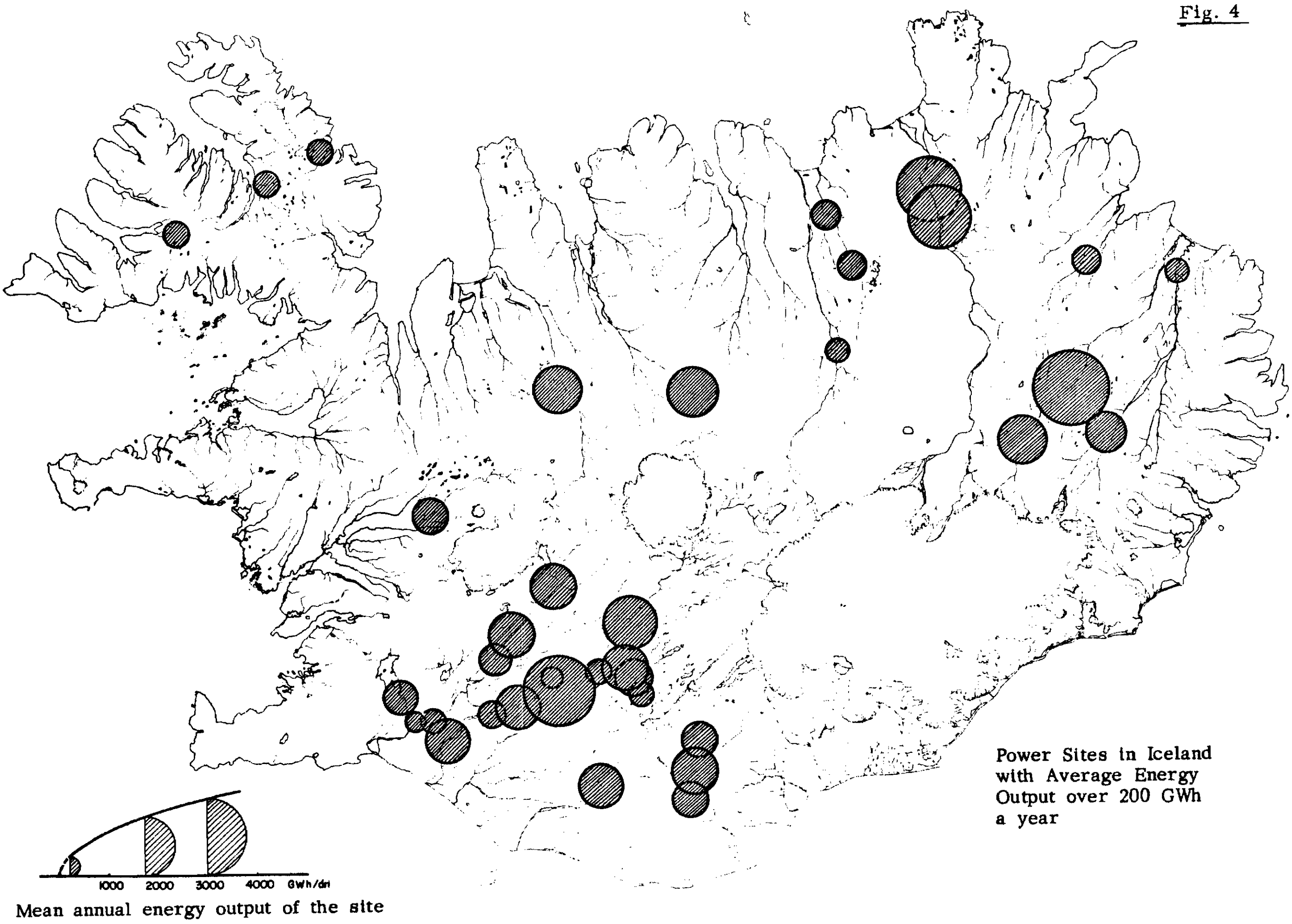


Fig. 4

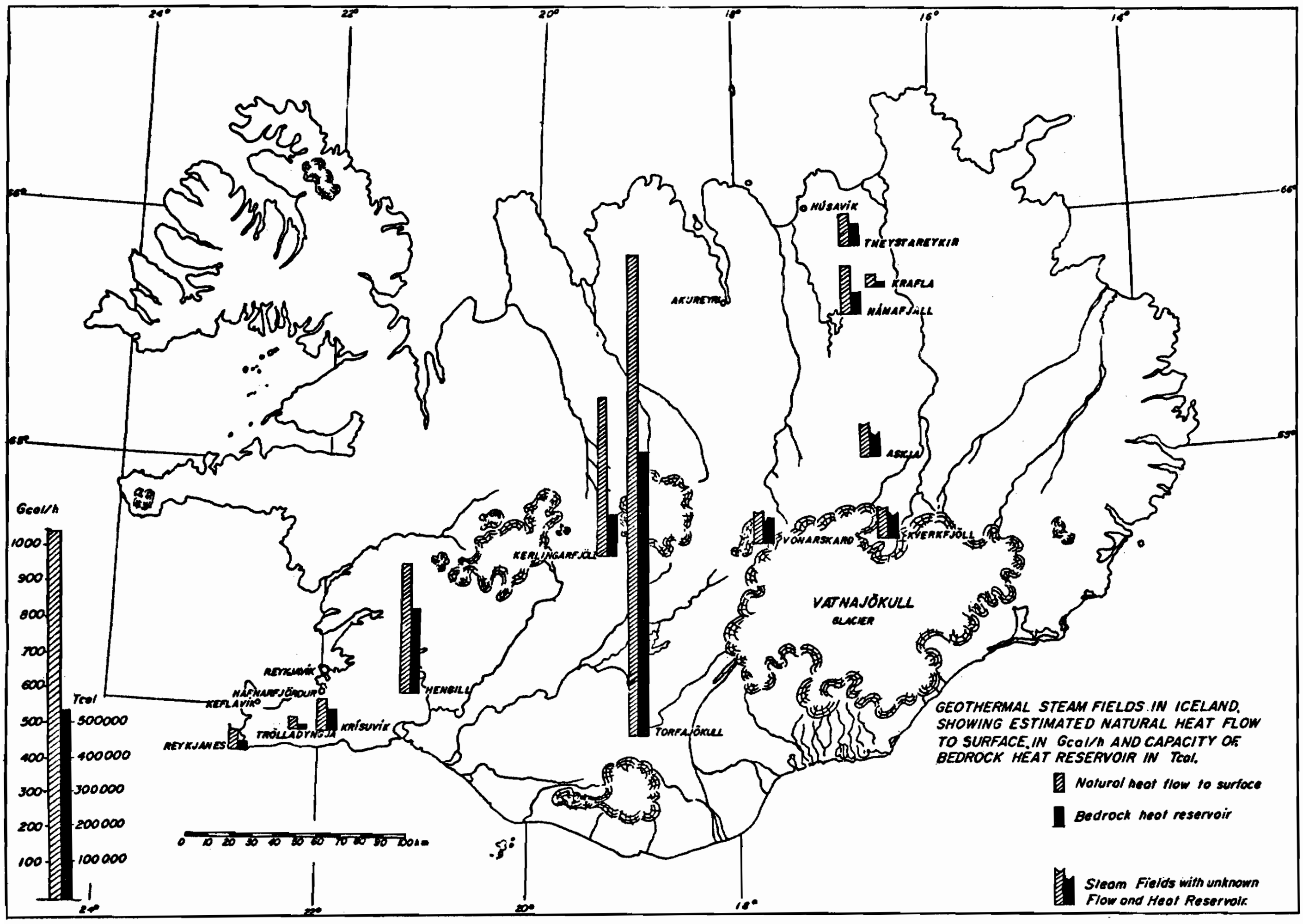


Power Sites in Iceland with Average Energy Output over 200 GWh a year

3.2 Geothermal Energy Potential

Geothermal heat is another important source of energy in Iceland. It occurs in about 250 so-called low-temperature thermal areas (characterized by water with a temperature of up to 100 degrees centigrade) and 14 high temperature areas (characterized by natural steam). Two basically different forms of geothermal heat occurrence should be distinguished : (1) recurrent form, which is comparable to hydro resources, consisting of the natural dissipation of heat to the surface in the thermal areas; and (2) non-recurrent form, analogous to fuel deposits, consisting of the heat content of the hot bedrock of these areas. The natural heat dissipation of all thermal areas has been very roughly estimated at one million kilocalories per second and the bedrock heat reservoir at between 10^7 and 10^8 Tcal (10^9 kilocalories) of which between one and ten percent is revocerable, depending on bedrock permeability, method of exploitation, and other factors. From the utilization standpoint the non-recurrent heat content of the bedrock is by far the most important form of geothermal energy so that the geothermal resources may roughly be characterized as exhaustible heat mines with a recoverable heat equivalent to several hundred million tons of oil. The production of geothermal heat in the country in 1964 was equivalent to approximately 120 000 tons of oil. Geothermal heat has in recent years been used for space heating as well as for heating of greenhouses and swimming pools, and the use is increasing.

The largest undertaking of this kind is the Reykjavík District Heating System, which now supplies hot water for space heating and domestic hot water use to about 60 % of the city's population. It is planned to extend the system to the whole city in the next few years. Several other towns and villages are being heated in the same way. Prospecting work and studies of geothermal space heating systems for other towns which do not have one now are steadily going on. Furthermore, studies of the possibilities of using geothermal energy for industrial purposes have also been undertaken in recent years. Last, but not least, serious considerations are being given to the use of this energy for the production of electric power, and a 16 MW geothermal power plant has reached the final design stage, but has not been constructed as yet. There appears to be no special technical obstacles to the utilization of geothermal energy for power production, and the studies undertaken to date indicate that the cost of power from geothermal plants may, at least in some instances, be approximately the same as from hydro plants. Conversion to electric energy may turn out to be the only practical way of utilizing those geothermal areas that are situated far from the populated parts of the country.


GEOTHERMAL STEAM FIELDS IN ICELAND,
SHOWING ESTIMATED NATURAL HEAT FLOW
TO SURFACE, IN Gcal/h AND CAPACITY OF
BEDROCK HEAT RESERVOIR IN Tcal.
Natural heat flow to surface
Bedrock heat reservoir
Steam Fields with unknown
Flow and Heat Reservoir.
HÚSAVÍK
THEYSTAREYKIR
KRAFLA
NÁMAFJALL
AKUREYRI
ASKJA
VONARSKARD
KVERKFJÖLL
VATNAJÖKULL
GLACIER
KERLINGARFJÖLL
HENGILL
TORFAJÖKULL
REYKJAVÍK
HAFNARFJÖRDUR
KEFLAVÍK
TRÖLLADYNGJA
KRÍSUVÍK
REYKJANES
Gcal/h
Tcal
1000
900
800
700
600
500
400
300
200
100
500000
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0 10 20 30 40 50 60 70 80 90 100 km
24°
22°
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65°