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STATE-OF-THE-ART OF GEOTHERMAL ENERGY USE IN SLOVENIA (Country Update)

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ABSTRACT

Information is provided on the status of geothermal direct heat utilization in Slovenia, with emphasis on developments from 1995 to 1999. The principal modern use of geothermal energy in Slovenia is for space heating and for bathing and swimming (including balneology), the latter started on a large scale over 40 years ago. Also other utilization schemes are summarized: greenhouses, industrial uses and geothermal heat pumps. The total direct use of geothermal energy amounted, in 1999, to about 685 TJ at 27 locations with installed capacity of about 41.1 MWt. Geothermal heat pumps (GHPs) at thermal spas are also included that are used to increase the geothermal water temperature. Thermal spas and recreation centres are the main consumers where thermal water is used for space heating and bathing with balneology. Thermal water is used less for the heating of greenhouses, and very little as industrial process heat. Probably at least 56 heat pump units extract an additional heat of about 19 TJ from shallow groundwater while the share of closed loop heat pump units is poorly known. During the last 5 years exploration and production have resulted in 18 wells with a total depth of almost 12 km.

1. INTRODUCTION

Slovenia is relatively rich in thermal water springs. Twenty one natural thermal springs are known with temperature close to or above 20 °C, however, there are several drilled localities where no surface thermal manifestations existed. Details about the geothermal field of Slovenia as well as geotectonic background can be found in Ravnik (1991), Ravnik *et al*. (1992) and Ravnik *et al*. (1995). Geothermal investigations and results of hydrogeological and geophysical research as well as the methods used for determination of geothermal resources are briefly described in Rajver *et al*. (1995) and Ravnik *et al*. (1995). Information about the present direct use of geothermal energy and some geothermal projects in northeastern Slovenia is given in Kralj (1996, 1998, 1999), Kralj *et al*. (1994) and Vorsic *et al*. (1995). Geothermal energy is estimated to currently supply approximately 703 TJ/yr of heat energy through direct heat applications in Slovenia. Table 5 summarizes the Slovenian geothermal direct heat uses.

The production of electricity and heating energy in Slovenia, with a population of 2 million, amounting to 13106 GWh/yr, is based, as of December 1997, on partly imported fossil fuels (38.7%), domestic hydro power (23.0%) and nuclear power (38.3%) (Table 1). Increasing attention is being given to alternative energy sources, such as solar, biomass and geothermal energy, which are ecologically preferable.

Thermal spas and recreation centres are the main consumers of geothermal energy, where it is used for direct heat. Therefore, the main type of use is for bathing and swimming (including balneology) and for space heating. In Figure 1 the energy used in 1999 (in TJ/yr) is shown. A certain percentage goes through geothermal heat pumps (GHPs) for space heating and heating of swimming pools.

2. SPACE HEATING

The most important type of direct use of geothermal energy in Slovenia is for space heating. The heating of sanitary hot water at thermal spas is also included. Space heating is mostly implemented at thermal spas, and at most of them directly. The users only have GHP units installed in the case when the temperature of the thermal water is too low. At Murska Sobota 300 dwellings are heated with geothermal energy through heat exchangers, especially from October to April. The total geothermal energy used for space heating in Slovenia is about 263 TJ per year in comparison with 205 TJ in 1994. This increase can be attributed mostly to some new localities and also improved heating schemes.

3. BATHING AND SWIMMING

The second most important type of direct use of geothermal energy in Slovenia is for bathing and swimming. There are 24 thermal spas and recreation centres where swimming pools with a surface area of about 29600 m^2 and volume of about 42700 m^3 are heated by geothermal water directly or indirectly through heat exchangers and GHPs. In Figure 2 all geothermal localities for direct heat use are presented; most of them are thermal spas and recreation localities. The outdoor swimming pools prevail (72 %). The largest pool complex is at Terme Catez with a surface area of 7000 m^2. Water temperatures range from 68 to 21.7 °C in Slovenian thermal spas. The total geothermal energy used for bathing and swimming is estimated to be 246 TJ per year in comparison with 383 TJ in 1994. New developments have been completed at Rogaska Slatina, Maribor and Dobova in eastern, at Snovik in central, and at Cerkno and Portoroz in western Slovenia, based on successful surface exploration and successful exploitation wells drilled at these localities during the last 8 years.

4. GREENHOUSES

Heating of greenhouses with geothermal water is performed only at Catez by the Agraria-Flowers Co., which began in 1962. The total area under glass has decreased a little over the last 5 years from 5.5 ha to 4.5 ha, but the production of flowers mainly for the domestic market remained unchanged. The total geothermal energy used in the greenhouse sector in Slovenia is estimated to be 137 TJ/yr in comparison with 72

TJ in 1994. It is interesting to note that at closely spaced localities at Catez (Terme and Agraria) flow rate at maximum utilization amounts to 80 kg/s for each. They do not interfere much with each other, because the active period of Terme Catez is during warmer part of the year, while that of Agraria during colder months.

5. INDUSTRIAL PROCESS HEAT

Industrial use of geothermal energy in Slovenia is almost negligible since energy is used at only two locations in amounts of 11.3 TJ/yr in comparison with 12.9 TJ/yr in 1994. At Vrhnika thermal water of 21.5 °C is heated to about 55 or 60 °C and used for the leather industry, while at Trbovlje thermal water of 25 °C is used for cooling at the cement works in addition to heating of the swimming pool.

6. GEOTHERMAL HEAT PUMPS

At seven thermal spas and/or recreation centres the GHPs are used in an open loop system, mainly for raising the thermal water temperature for further utilization in swimming pools for bathing and balneology and for space heating. The geothermal energy used for GHPs amounts to about 27 TJ/yr in comparison with almost 64 TJ in 1994. Such a decrease is mostly due to economic reasons. At some important thermal spas, such as Terme Catez, Topolsica and Zrece, the GHPs are out of use because additional heating of thermal water appears to be cheaper with gas and oil fuel during the last decade or so.

There are at least 56 GHP units of water-water type that extract at least about 19 TJ from shallow groundwater. The number of closed loop (ground coupled) geothermal or ground-source heat pumps in Slovenia is poorly known and is probably less than ten units. The reasons for such a low interest in GHPs, both open loop of water-water type and closed loop, are high initial costs and high price of electricity and low prices of gas and oil in comparison with the situation before 1990 when GHPs were more popular.

7. GEOTHERMAL ELECTRIC POWER GENERATION

The first project for the geothermal electricity generation including direct uses was elaborated in 1994 for the town of Ljutomer, but has not been realized yet. It is anticipated that at Lendava the construction of a geothermal power plant (probably binary) will begin in the year 2000, and the beginning of electricity production at the end of 2002. The whole project comprises: geothermal power plant with installed capacity of 10 MWe (80 GWh/yr), district heating with 6 MWt (9 GWh/yr), cooling with 3 MWt (2.5 GWh/yr), aquaculture (1 ha – area, 200 t/yr of fish), agriculture (2 ha of greenhouses), tourism (2 MWt, up to 16 GWh/yr). The project is registered at the European Commission Research Directorates.

8. DRILLING ACTIVITIES

Drilling activity has been slower in Slovenia for the past 5 years compared with earlier periods. Nevertheless, 18 wells have been drilled with a total depth of almost 12 km. From this number four wells have been dedicated to direct use exploration only, while the purpose of eight production wells with a total depth of 5.4 km has been mainly for new projects at Cerkno, Snovik and Dobova. At Agraria-Catez and Lasko, production wells have been drilled for flow rate and temperature improvements. The purpose of the other six wells, mostly shallower than 400 m, has been temperature gradient measurements. The locality of Cerkno holds the title of the deepest exploration well and low temperature production well, of 2450 and 1948 m, respectively.

9. CONCLUSIONS

The northeastern part of Slovenia is affected by the large positive geothermal anomaly of the Pannonian basin. All known geothermal resources are of the low enthalpy type with the exception of the high temperature geothermal system Termal II (preTertiary basement aquifers) in northeastern Slovenia. Newly discovered resources are of low enthalpy type as well.

Most significant developments have been completed at Cerkno in western part of the country and at Rogaska Slatina and Dobova (near Catez) in the east. At all of the above mentioned localities fractured aquifers are tapped. In Maribor and Portoroz and at Snovik, where exploration and production wells had been drilled before 1995, the annual energy use is small, however, new recreational facilities have been built there.

High enthalpy resources are still not in use. Doublet schemes are not yet in use but should be introduced as soon as possible, due to overexploitation. The most vulnerable locations are in northeastern Slovenia where thermal water is extracted from the Upper Miocene and/or Lower Pliocene aquifer Termal I composed of sand and sandstone layers. Since 1994, the maximum flow rate has decreased in most of the exploitation wells of this area.

The promotion of shallow geothermics is somehow in a steady state, because of the high price of electricity for driving the heat pump units, and on the other hand the lower prices of oil and gas prevent greater interest in this type of geothermal direct use.

The total number of professional personnel in geothermal activities was, in the period 1995 – 1999, allocated as follows (in person-years): 12 – Public Utilities, 5 – University and 26 – Private Industry. Total investment in geothermal differs quite a lot from the numbers given for the 1994 update due to a misunderstanding of the people responsible at thermal localities. The investment given in Table 8 reflects the increase of private sector, from 18% in 1985 – 1989 to 99% in 1995 – 1999 in the context of economical and political changes in Central and Eastern Europe.

More attention needs to be paid to hydrogeothermal and geophysical investigations in general, especially in some areas where an interest for development of new recreational centres exists in western and central Slovenia, and above all to the more rational use of the presently available geothermal resources. The latter is notably the case in the NE Slovenia where meteoric precipitation is smaller than elsewhere, consequently, the doublet systems should be introduced at some locations. The cascade system of utilization of thermal

water in Slovenia is not in use enough. It is anticipated that in future such a system will be increasingly considered, so that for the same pumped water quantity energy utilization will be greater and therefore geothermal energy cheaper.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in January 2000			1117	5067	768	3019	632	5019			2517	13106
Under construction in January 2000			228									
Funds committed, but not yet under construction in January 2000												
Total projected use by 2005	10	80	1345		883	3522					2870	

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 1999

1) I = Industrial process heat; H = Space heating & district heating (other than heat pumps); C = Air conditioning (cooling); B = Bathing and swimming (including balneology); A = Agricultural drying (grain, fruit, vegetables); G = Greenhouse and soil heating; F = Fish and animal farming; O = Other (please specify by footnote)

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s) [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184 (MW = 10^{6} W)

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319 (TJ = 10^{12} J)

5) Capacity factor = [Annual energy use (TJ/yr) x 0.03171]/Capacity (MWt)

Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate	Temperature (^{o}C)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MW_t)	(kg/s)	(TJ/yr)	Factor[5]
Moravci	H,B	52.1	65.1	37.1			6.10	32	113.9	0.59
Murska Sobota	H,B	25	50	33			1.78	11	24.7	0.44
Terme Lendava	H,B	9	53	28			0.94	6.5	21.4	0.72
Lendava Ing-Gra	H	14	64	44			1.17	3	7.9	0.21
Ptuj	B	5.5	39	29			0.23	5.5	7.3	1
Moravci-Buckovci	B	7	43	28			0.44	0.23	0.5	0.04
Banovci	H,B	4.2	68	25			0.76	2.8	15.9	0.66
Zrece	H,B	22	29.9	24			0.54	15	11.7	0.68
Podcetrtek	H,B	50	35.4	30			1.09	28	20.1	0.58
Rogaska Slatina	B	6	55.2	30			0.63	2.5	8.2	0.41
Snovik	B	15	30.4	28			0.15	5	1.6	0.33
Dobrna	B	8.1	36	32			0.14	6.5	3.4	0.8
Topolsica	B	30	32	20			1.51	22	34.8	0.73
Medija	H,B	35	24	21.1			0.42	14	5.8	0.44
Smarjeske Toplice	H,B	40	32	17			2.51	30	59.4	0.75
Lasko	B	40	34	33			0.17	20	2.6	0.5
Rimske Toplice	H,B	7.3	38	32			0.18	5.2	4.1	0.71
Dolenjske Toplice	B	19.6	34.2	32			0.18	9	2.4	0.43
Terme Catez	H,B	80	60	30			10.04	40	158.3	0.5
Agraria Catez	G	80	54	28			8.70	40	137.2	0.5
Bled	B	10	21.7	20			0.07	10	2.2	1
Vrhnika	I	20	21.5	15			0.54	12	10.3	0.6
Trbovlje	I,B	10	25	23			0.08	4	1.1	0.4
Cerkno	H,B	40	30	28			0.34	10	2.6	0.25
Dobova	H,B	15	63	38			1.57	7	23.1	0.47
Portoroz	B	0.8	23	16			0.02	0.6	0.5	0.67
Maribor	H,B	10	40	21			0.80	1.5	3.8	0.15
TOTAL		656					41.10	343.3	685	0.53

Note: please report all numbers to three significant figures.

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF DECEMBER 1999

This table should report thermal energy used (i.e. energy removed from the ground or water) and not the heat rejected to the ground or water in the cooling mode.

[1] Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

[2] Report type of installation as follows: V = vertical ground coupled
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

[3] Report the COP = (output thermal energy/input energy of compressor) for your climate

[4] Report the equivalent full load operating hours per year, or = capacity factor x 8760

[5] Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Locality	Ground or water temp. (^{o}C)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]	Equivalent Full Load Hr/Year[4]	Thermal Energy Used (TJ/yr = 10^{12}J/yr)[5]
open loop:							
water-water	11 - 15	10,6/unit= 212	min. 20	W	2.4-3.4	900-2520	8.86
water-water	11	18/unit= 540	min. 30	W	ca 3.0	1400-2300	8.24
water-water	11	25/unit= 50	2	W	ca 3.0	2200	1.44
water-water	12	59.5	4	W	3.8	2520	0.40
closed loop:							
ground coupled	2 - 6	51.8	ca 7	H,V	2.9-3.8		0.96
TOTAL		913.3	min. 63				19.90

Note: please report all numbers to three significant figures

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 1999

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319 (TJ = 10^{12} J)

[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^{6} W)

Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Space Heating[4]	17.3	263.3	0.48
Greenhouse Heating	8.7	137.2	0.50
Industrial Process Heat[6]	0.62	11.3	0.58
Bathing and Swimming[7]	12.75	246.0	0.61
Subtotal	39.36	657.8	0.53
Geothermal Heat Pumps	2.64	46.8	0.67
TOTAL	42.0	705.0	0.53

[4] Includes district heating (if individual space heating is significant, please report separately)

[6] Excludes agricultural drying and dehydration

[7] Includes balneology

Note: please report all numbers to three significant figures.

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1995 TO DECEMBER 31, 1999

[1] Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (gradient)	
Exploration[1]	(all)		4		6	6.583
Production	<100^{o} C		8			5.391
Injection	(all)					
Total			12		6	11.974

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with a University degree)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributied Through Foreign Aid Progra
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995		2	1			5
1996		2	1			5
1997		2	1			5
1998		3	1			6
1999		3	1			5
Total		12	5			26

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (1999) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1985-1989	2	5.79	5.68		18	82
1990-1994	1.6	2.32	15.46		75	25
1995-1999	1.94	3.16	10.98		99	1

Fig. 1. Direct heat utilization in Slovenia for 1994 and 1999.

Fig. 2. Geothermal localities for direct heat utilization in Slovenia with isotherms at a depth of 1000 m.

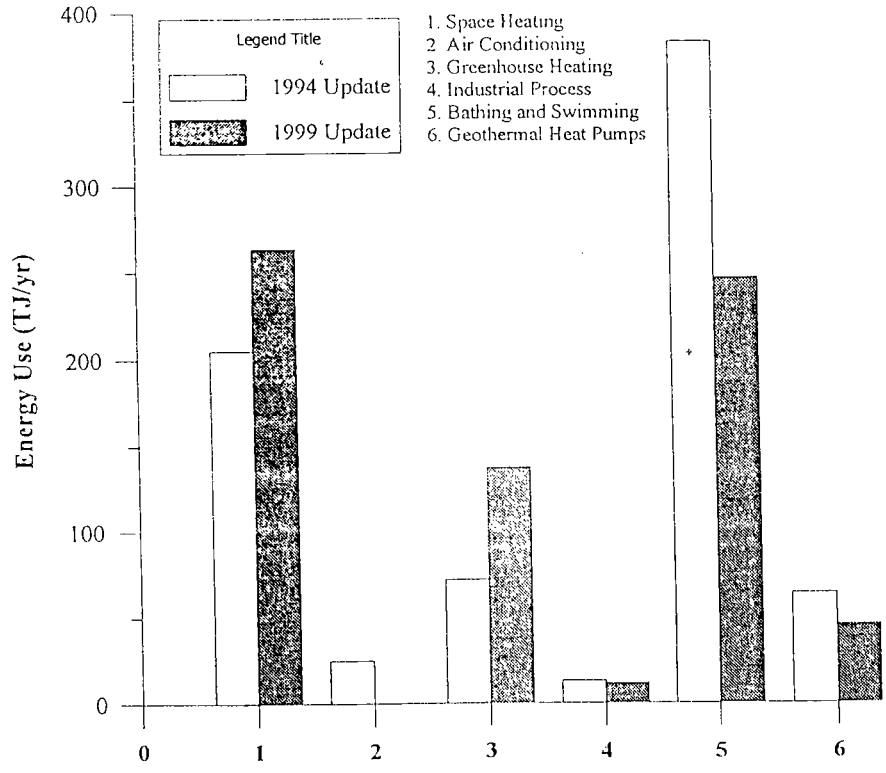
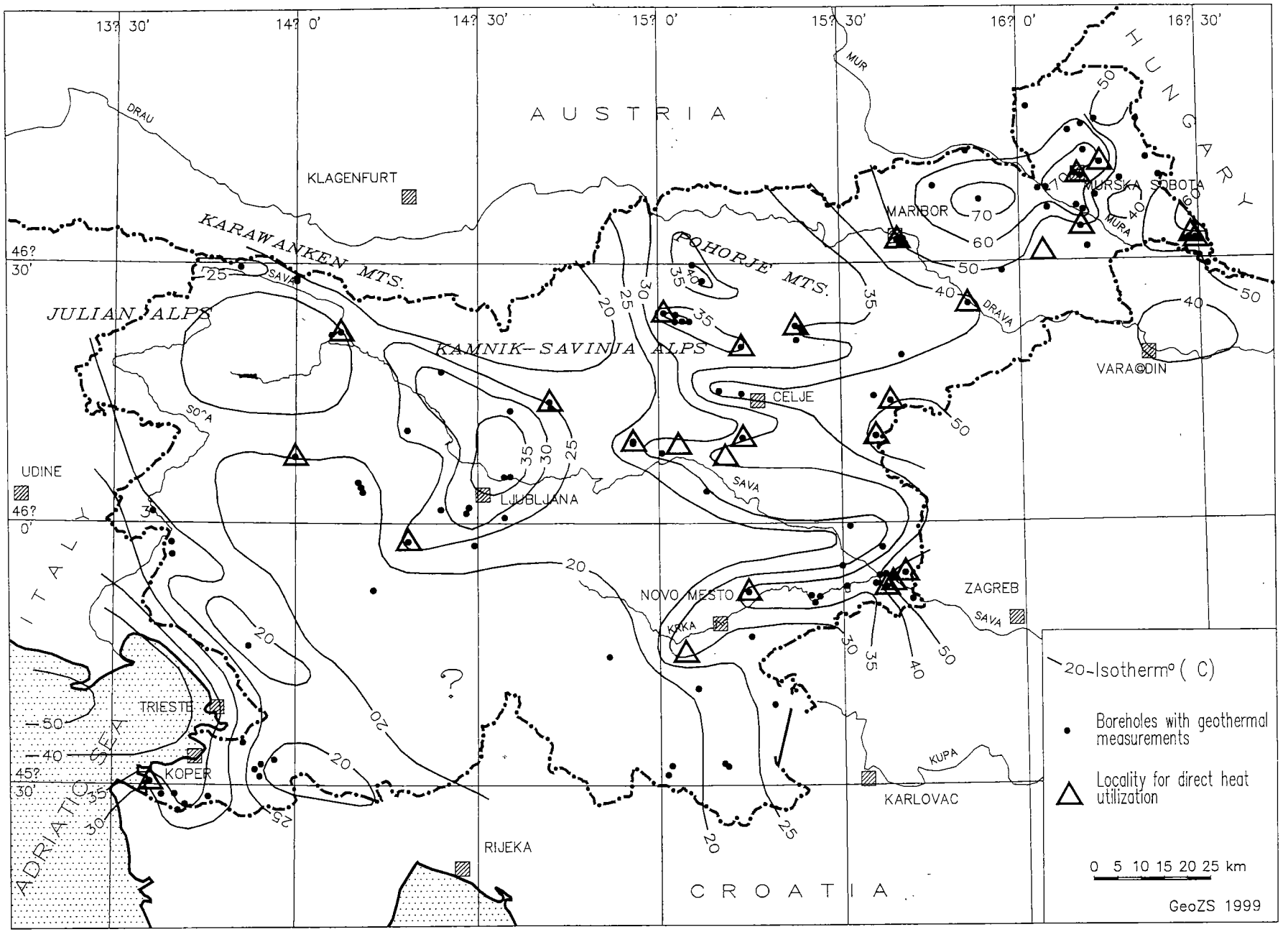


Fig. 1. Direct heat utilization in Slovenia for 1994 and 1999.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MARIBOR
MURSKA SOBOTA
VARAŽDIN
CELJE
LJUBLJANA
UDINE
TRIESTE
KOPER
NOVO MESTO
ZAGREB
KARLOVAC
RIJEKA
KARAWANKEN MTS.
JULIAN ALPS
KAMNIK-SAVINJA ALPS
POHORJE MTS.
ADRIATIC SEA
46? 30'
46? 0'
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20-Isotherm° (C)
Boreholes with geothermal measurements
Locality for direct heat utilization
0 5 10 15 20 25 km
GeoZS 1999