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GEOTHERMAL ENERGY COUNTRY UPDATE REPORT FROM POLAND

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ABSTRACT

Poland has large low-enthalpy resources connected with extensive sedimentary geothermal provinces covering ca. 80% of the whole area. The wider geothermal use was initiated in the 1980s. So far, it concentrates on space heating, balneology/bathing, while other uses are on semi-technical scale. In the end of 1999 three heating plants went on-line. In the Podhale Region, the plant supplies over 220 houses and cascaded uses'. The large-scale heating project has been developed there for several years. In Pyrzyce town, the heating plant opened in 1996 serves 12,000 customers. The third plant (Mszczonow town) was opened in the end of 1999. Generally, in 1999, the installed geothermal capacity totalled ca. 70.5 MW_t, (including ca. 26 MW_t from geothermal and ground heat pumps). The yearly geothermal heat production amounted ca. 280 TJ. During 1995-1999 further geothermal drillings and exploration works were carried out. Several utilisation projects have been prepared. Some of them are to be realized in the coming years. Basic researches and high education were gradually instituted.

1. INTRODUCTION

Poland possesses one of the largest low-enthalpy resources within the Central European countries. The wider interest in geothermal reserch and practical implementation dates back to the 1980s. The first Experimental Geothermal Plant in the Podhale Region was opened in 1992 (Sokolowski, 1995). It paved the way for further activities expressed particularly in the opening the second plant in Pyrzyce town in 1996. During 1995-1999 the Podhale geothermal heating project has been under constant development, accompanied by basic researches and work on cascaded uses. The third plant was opened in the end of 1999 in Mszczonow town. Further feasibility studies and utilisation projects were prepared.
Similar to other countries, geothermal is projected to have local share in the Polish energetics. The main benefits of its use are environmental by limiting the pollutants generated by the coal-based heating systems. Geothermal energy should be promoted in the view of admission to the European Community, as Poland must fulfil many preconditions, including the practical use of renewables.
The paper presents the geothermal state-of-art in Poland in 1995-1999. Previous periods were reported at the World Geothermal Congress 1995 by Sokolowski (1995).

2. GEOTHERMAL RESOURCES

As a whole, Poland is characterised by low-to-moderate geothermal parameters. The terrestrial heat flow values amount to 20-90 W/m^2, while geothermal gradients are in the range of 1-4°C/100 m (Sokolowski *ed.*, 1995).

Three main geothermal provinces built of sedimentary basins with numerous geothermal aquifers were described within the country (Fig. 1). They cover ca. 251,000 km^2, i.e. 80% of the Polish territory. Their brief characteristics are as follows (more details were given by Sokolowski, 1993, 1995):

- *The Polish Lowland Province.* It occupies the area of 222,000 km^2 and contains seven geothermal Regions (Palaeozoic-Cretaceous). The reservoir temperatures range from 30 to 130°C (1-3 km of depth). The TDS range from 1 to 300 g/l. Geothermal resources have been estimated for over 6,225 km^3 of water with thermal energy equal to 32,458 million toe.
- *The Fore-Carpathian Province.* It occupies the area of 17,000 km^2. Geothermal aquifers occur in Mesozoic-Tertiary rocks. The reservoir temperatures range from 25 to 50°C. The TDS is variable, from several to ca. 100 g/l. Geothermal water resources have been estimated for 361 km^3 with thermal energy equal to 1,555 million toe.
- *The Carpathian Province.* It occupies the area of 12,000 km^2. Geothermal aquifers occur in Mesozoic-Tertiary formations. The TDS range from 0.1 to ca. 100 g/l. Geothermal water resources have been estimated for 100 km^3 with thermal energy equal to 714 million toe.
- *The Sudetes-Holy Cross Region.* It is asssumed to have limited possibility of geothermal aquifers' occurence in fractured Precambrian and Palaeozoic crystallinic rocks.

To estimate the recoverable thermal energy from geothermal waters in formations to 3 km depth one assumes that the heat will be extracted to the temperature of 20°C and the waters will not be injected back (Sokolowski, 1995).
For the listed provinces, the proven geothermal reserves (evidenced on the basis of flow tests from numerous wells) amount from several l/s up to 55-150 l/s of geothermal water. Geothermal resources calculated using the methodology recommended by the Geothermal Atlas of Europe will be given in its new edition (under preparation).
Considering the present prices of traditional energy, feasible geothermal plants can be built in ca. 40% of Poland. The most favourable reservoir conditions are found in the Polish Lowland (Gorecki *ed.*, 1995; Ney, 1995), while in other provinces are scattered.

3. GEOTHERMAL DIRECT USE

3.1. Generals

In 1999, the installed geothermal capacity totalled ca. 44 MW_t and the energy use was ca. 171 TJ/yr (Table 1, Table 2). In 1995-1999, geothermal direct use was on very limited scale, as Poland is still a new-comer in this branch. The utilisation concentrated on space heating (ca. 23 MW_t and 122 TJ/yr), balneology and bathing, while other types (greenhousing, drying, fish farming) were conducted on experimental or semi-technical scale. Three heating plants were on-line: in the Podhale Region, in Pyrzyce town, and in Mszczonow town commissioned in the end of 1999 (Fig. 1).

3.2 Space heating

The Banska-Bialy Dunajec plant (the Podhale Region)

In that part of Poland, the construction of a large-scale geothermal heating network has been developed since the end of the 1980s (Sokolowski, 1993, 1995). It will benefit by the elimination of 300,000 t coal/yr and over 80% of the gas and dust emissions generated by coal burning.

The main geothermal artesian aquifer occurs in the Eocene and Mesozoic carbonates (depths of 1-3.5 km). The reservoir temperatures reach up to 80-100°C; flowrate from a single well 55-150 l/s; TDS of 0.1-3 g/l; wellhead static pressure 27 bar. In 1993 several houses started to be supplied with heat from the Experimental Geothermal Plant Banska-Bialy Dunajec. In 1994, the Geotermia Podhalanska Co. was established in order to further provide the heating service. In the end of 1999 it served over 220 houses (17 TJ/yr). So far, the network is based on a doublet of the production and injection wells. The flowrate amounts 8-16 l/s of 76-80°C water. The maximum power is ca. 9 MW_t geothermal (water cooled down to 20°C). Geothermal heat is transmitted to the district heating water via the heat exchangers.

In 1996-1999 the following main projects and works have been completed by the Geotermia Podhalanska Co.: two exploitation wells (2.5-3.2 km deep; 150 l/s artesian flow of 86°C water); 60 MW_t geothermal base load plant; central peak load plant in Zakopane (22 MW_t from gas, increased to 44 MW_t after geothermal heat will be provided); part of a main transmission pipeline (total lenght 14 km) linking these two plants. Heat supplies will be based on geothermal (gas boilers in peak periods). By the end of 1999 ca. 25% of all customers in Zakopane (30,000 population) were linked to new central peak heating plant. By the year 2001-2002 geothermal heat will be delivered to ca. 4,400 receivers.

The researches, R&D and semi-technical cascaded uses have been conducted by the PAS MEERI Geothermal Laboratory. The system consists of the heating network; space heating and domestic water service; wood drying; greenhouse; fish farming; and plants' growing in heated soil.

The Pyrzyce plant

The plant in Pyrzyce town (13,000 population) was commissioned in 1996. It eliminated ca. 20,000 tonnes of coal/yr used in traditional heating plants. The aquifer (Lower Jurassic sandstones at the depths of 1.5-1.6 km) is tapped by two production and two injection wells. The maximum flowrate is 103 kg/s of 61°C water. The TDS amounts to 120 g/l. The maximum installed power is 50 MW_t, including 13 MW_t geothermal, while the rest (37 MW_t) comes from absorption heat pumps and gas boilers. The plant supplies central heating (95/45°C) and domestic warm water to 12,000 customers (Sobanski, 1998). In 1999, the geothermal energy output amounted to 100 TJ/yr. Geothermal is also planned to be used for recreation and agriculture.

The Mszczonow plant

The plant in Mszczonow town (6,000 population) was opened in the end of 1999 (Fig. 1). The geothermal aquifer is located in the Lower Cretaceous sandstones, TDS is below 1g/l. In 1996-1997, a 4.1 km well drilled in 1970s was adapted for exploitation purposes. The 2 MW_t pilot plant will use a 40°C water discharged by a single well both for heating purposes and drinking water production.

3.3 Geothermal heat pumps

During last several years, there has been increased interest in ground-coupled, groundwater and geothermal heat pumps. In Pyrzyce two such devices (20.4 MW_t) produced 40 TJ/yr of thermal energy. In 1997, was installed the first 0.06 MW_t heat pump based on 16-19°C ventilation air from the coal mine in the Upper Silesian Basin. In 1999 over 400 ground and groundwater heat pumps were on-line, with the capacity of 5.5 MW_t and heat production of 62 TJ/yr (Table 3).

3.4 Balneology, bathing, and other uses

In 1999, eight Polish spas used 20-62°C waters from springs or wells for balneology and bathing (Fig. 1; Table 1, Table 2). In Duszniki Resort (the Sudetes Mts.) there is on-line an installation for CO_2-extraction from 20°C water discharged by a shallow well. In Iwonicz Resort (the Carpathian Province), a 21°C brines produced by two wells are used for extraction of iodine-bromine medical and cosmetic salts. The country has a long tradition in geothermal bathing and balneology based on natural warm springs. The oldest spas using warm spring waters are Cieplice and Ladek Spas (the Sudetes Mts.) date back to the 12-13th centuries.

4. GEOTHERMAL EXPLORATION

The basic evaluation on geothermal resources in Poland was carried out in the 1980s. It was based on data from extensive drilling works, geological, hydrogeological and geophysical survey made during former decades for exploration, oil and gas purposes (Sokolowski, 1995). In 1995-1999 new data were obtained from drillings and other works. Detailed exploration focused on the most prospective areas of the Polish Lowland Province and on the Podhale Region. In 1997, successful geothermal drillings started in Cieplice Resort (the Sudetes Mts.; geothermal prospection was initiated there in 1970s; Dowgiallo, 1991).
As a whole, in 1995-1999 three deep (2.5-3.5 km) wells have been drilled and tested for geothermal purposes; two wells in the Podhale Region and one well in Skierniewice town (the Polish Lowland). One well drilled in 1970s was tested and adapted for geothermal exploitation purposes (Mszczonow town). One well was deepened from 660 m to 2002 m and tested (Cieplice Resort). One well drilled for oil&gas exploration revealed some geothermal prospects (Table 4).
Moreover, in 1995-1999 there have been prepared many estimations of thermal potential, R&D, and utilisation projects. They often make use of the abandoned wells that can be used for cascaded and integrated systems. One should

stress that the adaptation of previously drilled wells will result in saving considerable part of the investment costs.
There was also made first evaluation and attemps to extract heat stored in underground coal mines in the Upper Silesian Basin (Malolepszy and Ostaficzuk, 1999).
Table 5 depicts the main localities within the country where geothermal plants are on-line, about to start or, at least feasibility or prefeasibility studies have been prepared.

5. ALLOCATION OF PROFESSIONAL PERSONEL

During 1995-1999, the number of professional personnel working in the geothermal sector increased to over 100 Polish specialists, supported by some 50 foreign consultants. Detailed statistics is given in Table 6. Regular lectures on geothermics were introduced at some universities, as well as the courses organized by the Polish Geothermal Association.

6. INVESTMENTS IN THE GEOTHERMAL SECTOR

The total investments in geothermal sector in Poland in 1995-1999 can be estimated as 54.5 million US$ (Table 7). They were financed from the Polish sources (National Fund for Environmental Protection and Water Management, Ecofund, Committee for Scientific Researches, counties, cities, geothermal companies) and from the foreign sources.

7. FUTURE ACTIVITIES

In the coming years, the major geothermal investments are expected to be as follows:

- The Podhale Region: continuation of the heating network project (the main stage to be finished by 2001-2002); construction of two recreation and balneological centres.
- Mszczonow town: construction of the recreation centre based on waste geothermal waters from the heating plant.
- Pyrzyce town: development of other uses along with the space heating system on-line.
- Uniejow town: construction of the balneological centre and the heating network.
- Slomniki town: construction of the recreation centre (supplied with geothermal water either from the adapted abandoned well or from the new-drilled one).

Several other space heating-oriented projects are most likely to start mostly within the Polish Lowland (Fig. 1). Among other activities to be undertaken there are drillings in the Sudetes Mts. (Cieplice, Ladek) followed by utilisation of high-quality warm waters for balneology; works on adaptation of the abandoned wells for geothermal purposes; progress in geothermal heat pumps' use; R&D works on the borehole heat exchangers; studies on utilisation of geothermal energy stored in the Upper Silesian Coal Basin.

8. GEOTHERMAL IN ENERGY POLICY

The Polish energetics is based on fossil fuels (70% of primary energy production). The share of all renewables including geothermal in energy production is officially projected to reach several percentages in the years 2015 - 2020 (as compared to the maximum 15 - 20% for European Community countries assumed by the ALTENER Programme). Such a situation has been predicted despite large geothermal resources of Poland.
Among the key reasons which influence the prognosis are low coal, oil and gas prices as well as still insufficient financial support from the budget and beyond-budget sources. In some places, however, the geothermal direct use can achieve considerable impact, being significant factor for environmental protection and local energy market.
Present and planned electricity production is based on fossil fuels and hydropower, as depicted in Table 8.
Geothermal progress is expected to be enhanced by the new Polish Energetics Law making the local administrations responsible for managing the space heating sector, also with the use of local energy sources. This type of energy should be preferred in Poland in the view of admission to the European Community as the country is obliged to use renewable energy and to reduce the present level of the dust and gas emissions.
Geothermal energy is supposed to be an important agent of the sustainable regional development strategies. It is perceived as an attractive factor for efficient environmental protection, stimulating new trends in horticulture, agrotourism, recreation,and the local employment market.
The prospects for geothermal use in Poland lie particularly in moderate-scale plants based on abandoned wells adapted for exploitation, working as cascaded and/or integrated systems.

9. CONCLUSIONS

1. In 1995-1999 further progress was made in Poland in geothermal exploration and utilisation, as compared with the previous reported period up to 1995. Although officially prognosed as a local energy source, geothermal appears to be of great importance for environmental protection mostly by providing considerable reduction of pollutants generated by coal-based heating systems.

2. In 1999, the installed geothermal capacity totalled ca. 44 MW_t and yearly heat production ca. 171 TJ. Direct use focused on space heating and balneology, while others were on semi-technical size. Two heating plants were on-line (the Podhale Region and Pyrzyce town) serving ca. 13,000 customers (122 TJ/yr). In the end of 1999, the third plant was put into operation in Mszczonow town. The implementation of heat pumps was small but has a constant development.

3. Three new deep stricte geothermal wells were drilled, two abandoned wells were adapted for exploitation purposes. Moreover, successfull deep drillings started in 1997 in the Sudetes Mts. There were initiated first attemps to extract heat stored in mines in the Upper Silesian Coal Basin.

4. Many feasibility studies, R&D and utilisation projects have been prepared. They often make use of the abandoned wells for cascaded and coupled systems.

5. Future geothermal activities comprise continuation of the investments on-line, realisation of several new space heating-oriented projects along with the progress in basic research, exploration, R&D works, education and promotion.

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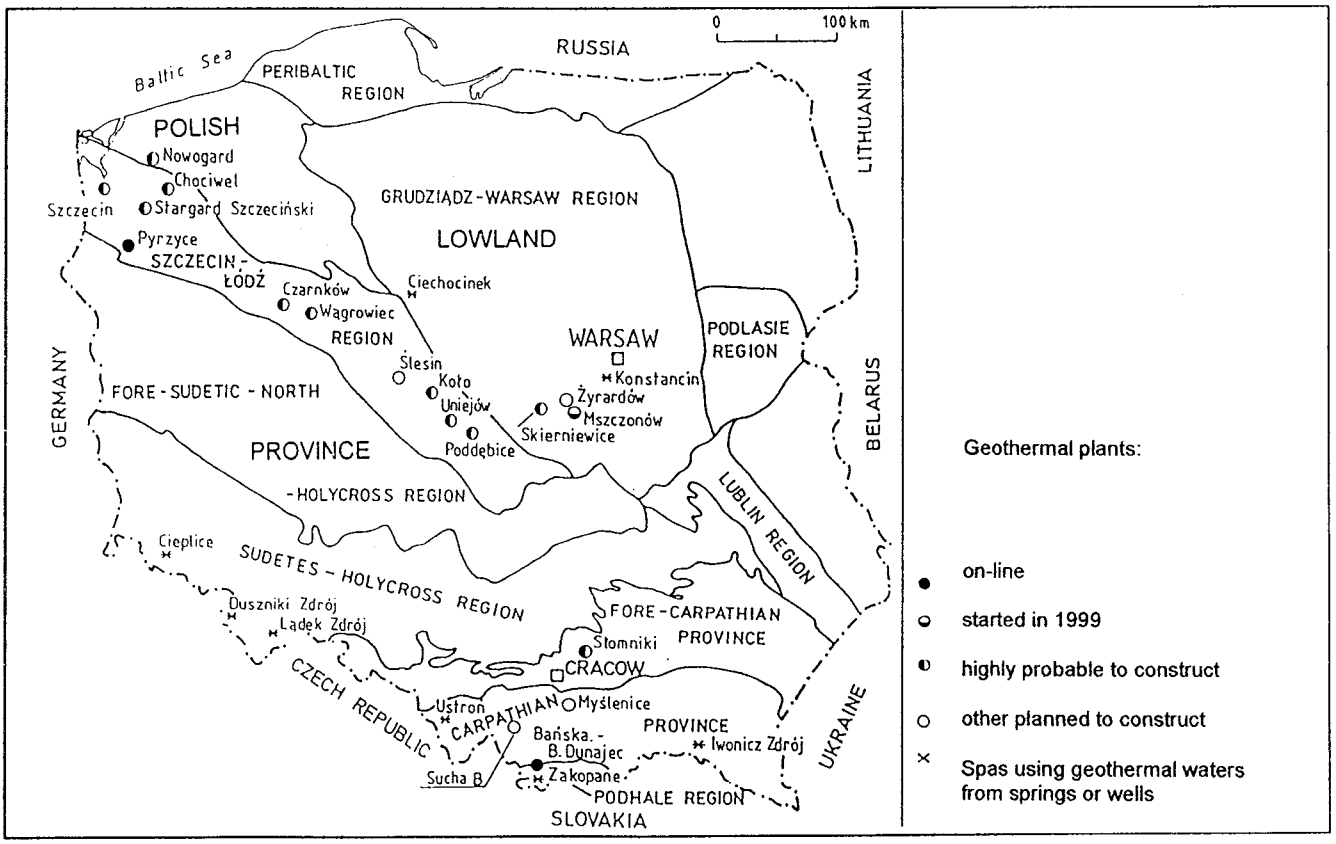

Figure 1. Geothermal resources, operating and planned geothermal plants in Poland (geothermal division after Sokolowski, 1995)

Table 1. Utilisation of Geothermal Energy for Direct Heat as of 31 December 1999

[1] I - industrial process heat, C-air conditioning, A-agricultural drying, F-fish and other animal farming, S-snow melting, D-space heating, B-bathing and swimming, balneology, G-greenhouses, O-other ; [2] Enthalpy information is given only if there is steam or two-phase flow;
[3] Energy use (TJ/yr) = Annual average water flowrate (kg/s) x [Inlet temp.(°C) - Outlet temp.(°C)] x 0.1319

Locality	Type[1]	Maximum utilisation					Annual utilisation		
		Flowrate kg/s	Temperature °C		Enthalpy[2] kJ/kg		Average flowrate kg/s	Energy use[3] TJ/yr	Load factor
			Inlet	Outlet	Inlet	Outlet			
Banska-B.Dunajec	D+G+F+A[a]	16	82	58	-	-	11	21.0	0.4
Zakopane	B	36	26-36	25	-	-	18	14	0.6
Pyrzyce	D	103	61	25	-	-	51	100	0.3
Cieplice Resort[b]	B	7.5	36-39[b]	26	-	-	6.0	10	0.8
Ladek Resort	B	11	20-28 s 44w	20	-	-	10.8	16.8	0.8
Duszniki	O[c]	5.5	19-21	19-21	-	-	5.5	0.3	0.5
Ciechocinek	B	56.8	27-29	20	-	-	4.2	2.8	0.1
Konstancin	B	2.5	29	12	-	-	0.1	0.2	0.1
Ustron	B	0.9	28	11	-	-	0.4	0.58	0.3
Iwonicz	O[d]	3	21	10	-	-	0.4	0.58	0.2
Mszczonow	D[e]	11	40	15	-	-	11	5.0	

[a] The Banska-Bialy Dunajec plant works as cascaded system: space heating (D) uses heat extracted directly from geothermal water (17 TJ/yr), while others (A, F, G) base mostly on the return water from space heating (4 TJ/yr); [b] mixture of 20-62°C waters from springs and wells (20-62°C); [c] extraction of CO_2 from warm brine; [d] production of iodine-bromine and cosmetic salts; [e] - plant in starting stage (tentative data from Nov.-Dec. 1999); s - springs, w-well

Table 2. Summary Table of Geothermal Direct Uses as of December 1999

[1] Installed thermal power (MW_t) = Max. water flowrate (kg/s) x [Inlet temp.(°C)- Outlet temp.(°C)] x 0.004184
[2] Energy use (TJ/yr) = Annual average water flowrate (kg/s) x [Inlet temp.(°C)- Outlet temp.(°C)] x 0.1319

Type of use	Installed thermal power[1] MW_t	Energy use[2] TJ/yr
Space heating	23.0	122.0
Bathing/swimming	20.0	44.4
A+G+F (cascaded)	1.0	4.0
Industrial process heat	-	-
Snow melting	-	-
Air conditioning	-	-
Other[a]	0.3	1.0
SUBTOTAL	44.3	171.4
Heat pumps	26.2	108.3
TOTAL	70.5	279.7

[a] - extraction of CO_2 and salts from geothermal brines

Table 3. Geothermal Heat Pumps as of December 1999

Locality	Heat source °C	COP factor	Heat pump rating (output) MW_t	Thermal energy used in heating mode TJ/yr
Pyrzyce[a]	40	3.5	20.4	40
Podhale[a]	~20	3.5	0.01	0.1
Ladek Resort	32	3	0.2	5.2
Piekary Slaskie[b]	16-19	4.0	0.06	0.96
Groundwater and ground heat pumps[c]	(-7)-10	3-4	5.5	62

[a] - heat pumps in geothermal heating plants
[b] - ventilation air from the coal mine as a low heat source
[c] - total figures for groundwater and ground heat pumps

Table 5. Information about Geothermal Localities

[1]N - identified only, R - regional assessement, P - pre-feasibility studies, F - feasibility studies (Reservoir evaluation and Engineering studies), U - commercial utilisation

Locality	Location		Status [1]	Measured reservoir temperature (°C)
	Latitude	Longitude		
Podhale R.	49.17-49.25	19.47-20.19	U	20-95
Pyrzyce	53.09	14.54	U	70
Cieplice	50.50	15.41	U/F	98
Ladek	50.21	16.53	U	50[a)]
Ciechocinek	52.53	18.50	U	45[a)]
Konstancin	52.05	21.08	U	45[a)]
Ustron	49.43	18.50	U	58
Iwonicz	49.34	21.47	U	40[a)]
Duszniki	50.25	16.14	U	25
Mszczonow	51.56	20.28	U	42
Uniejow	51.58	18.49	F	70
Zyrardow	52.03	20.27	F	70
Skierniewice	51.58	20.11	F	70
Kolo	52.02	18.56	P	85
Czarnkow	52.55	16.33	P	95
Poddebice	51.54	18.55	P	65
Slesin	52.22	18.18	P	75
Szczecin	53.28	14.40	F	90
Stargard Sz.	53.21	15.05	F	90
Chociwel	53.26	15.25	F	90
Nowogard	53.40	15.08	F	90[a)]
Wagrowiec	52.48	17.23	P	65
Krakow R.	49.40-50.25	19.35-20.30	R	20-70
Myslenice	49.52	19.55	P	80[a)]
Sucha B.	49.50	19.35	P	70-80[a)]

[a)] - reservoir temperature estimated

Note: there are given data from operating plants and localities where geothermal plants are highly probable to be constructed in the close future; data on the regional assessment and identified resources are available all over Poland

Table 6. Allocation of Professional Personnel to Geothermal Activities (restricted to personnel with an University degree)

Year	Professional Man Year of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1995-1999	30	35	30	25	24	22

(1) - Governmental
(2) - Public utilities
(3) - Universities
(4) - Paid foreign consultants
(5) - Contributed through foreign aid programmes
(6) - Private industry

Table 7. Total Investments in Geothermal in million US$ (estimated)

Period	(1)	(2)	(3)		(4)	
			a	b	a	b
1995-1999	5.6	8.1	40.8	-	50	50

(1) - Research & Development Including Surface Exploration & Exploration Drillings
(2) - Field Development Incl. Production Drilling & Surface Equipment
(3) - Utilisation: a. Direct, b. Electrical
(4) - Funding Type (%): a. Private, b. Public

Table 4. 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 less than 100 m deep

Purpose	Wellhead Temperature	Number of wells drilled				Total depth (km)
		Electric Power	Direct use	Combined	Other (specify)	
Exploration [1]	(all)	-	-	-	1[a)]	4.1
Production	>150°C	-	-	-	-	-
	150-100°	-	-	-	-	-
	<100°C	-	2[b)] 1[c)]	-	1[d)]	10.2 2.0
Injection	(all)	-	1[b)]	-		2.3
Total		-	4	-	1	18.6

Wells: a - drilled mostly for oil &gas exploration purposes with geothermal prospects, b - new drilled, c - deepened, d - abandoned, adapted for geothermal exploitation purposes and coupled with heat pump

Table 8. Present and Planned Production of Electricity

	Geothermal		Fossil fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity Mwe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in January 2000	-	-	30162	138547	2046	4203	-	-	12 [a)]	10 [a)]	32220	142760
Under construction in January 2000	-	-	-	-	-	-	-	-	-	-	-	-
Funds committed, but not yet under construction in January 2000	-	-	-	-	-	-	-	-	-	-	-	-
Total projected use by 2005	-	-	33640	162000	2174	4440	-	-	15 [a)]	30 [a)]	35829	166470

[a)] - tentative total data for biogas, biomass and wind power plants