COUNTRY UPDATE REPORT FROM POLAND

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ABSTRACT

Geothermal waters have been known and utilized in Poland for balneological purposes since XI century. The interest in their utilization for heating purposes started in the eighties. Series of investigations have been carried out since that time. They allowed estimations the resources and reserves occuring in Tertiary, Cretaceous and Jurassic formations, The estimation of resources and reserves shows that Poland has one of the largest potentials for geothermal energy at the Central European countries.

It is estimated that the recoverable geothermal energy resources amount lo over $30x10^9$ t.o.e. and waters temperature is from 35 to 130°C at 1000-3000 m depth.

Geothermal energy resources occur also in older deposits but till now they havn't been topics of interest

An expenmental geothermal plant built in the Podhale Region in Bańska-Biały Dunajec and a geothermal plant in Pyrzyce - which is under construction - show the economic effectivity of geothermal energy utilization for heating purposes.

INTRODUCTION

In Poland, in the eighties, interest began in matters relating to geothermal water utilization for heating purposes. This interest resulted from the effects of researches conducted in other countries and from eceptionally unfavourable energetic balance, from the ecological point of view, in our country. The drilling of Bańska IG-1 well in Podhale Region, finished in 1981, proved the occurence of geothermal waters with a very low mineralization (3g/l), high temperature (82°C) and with artesian pressure of about 26 atm.

These results allowed conduct by Polish Academy of Sciences - Mineral and Energy Economy Research Centre (MEERC), Academy of Mining and Metallurgy and State Institute of Geology. some detailed investigations. These investigations focused on utilization of geothermal energy contained in waters for heating purposes and others The estimation of the potential and of the resources of geothermal energy, elaboration of the project and construction of expenmental geothermal plant, demonstrating large and various possibilities of utilization of the Earth's heat. was made by MEERC.

From 1987 - 1994 there has been carried out exploration drilling at Biały Dunajec, Poronin, Chochołów, Furmanowa, Nowy Targ, Bukowina, Skierniewice, Uniejów, Pyrzyce. Also an experimental geothermal plant in Podhale was constructed and construction of the heat-generating plant in Pyrzyce was started.

REGIONS OF INVESTIGATIONS

On the basis of data obtained during oil exploration (over 200,000 km of seismic profiles and over 7000 bore-holes), the following regions in Polish territory were distinguished (Fig. 1):

- Polish part of the Carpathian Province withan area of over 13,000 km^2,
- Polish part of the Fore-Carpathian Province withan area of 16,000 km^2,
- Polish part of the Central European Province withan area of 222,000 km^2,
- the Sudetic-Świętokrzyski Region withan area of 61,000 km^2

The Polish part of the Carpathian Province contains Tertiary and Cretaceous formations, folded and overlaped during Alpine Orogenesis, and is one of the youngest geostructural units in Poland. Geothermal water-bearing levels occur here in:

- Tertiary formations (nwnulitic limestones of Middle Eocene) and sandstones of the Podhalanian flysch,
- Tertiary flysch formations,
- Cretaceous flysch formations.

The Polish part of the Fore-Carpathian Province (the youngest) is built of Tertiary formations containing geothermal waters in sandstone and mudstone lavers Cretaceous. Jurassic. Triassic and Carbon-Devonian basins - which are the continuation of Central European basins - occur in the basement of these formations

In the Central European Province, occupying the area from the North Sea through Germany to Poland, exist the following geothermal and oil-gas-bearing basins Cretaceous, Jurassic. Triassic, Permian, Carbon-Devonian and Lower Paleozoic Generally, these basins are dislocated, especially different locations have Lower Paleozoic, Carbun-Devonian, Permian and Mesozoic basins (Fig 2)

The Sudetic - Świętokrzyski Region is the area of two mountain chains, with small, but economically important basins, Cretaceous and Paleozoic in the Sudetes Mts. and Paleozoic in the Świętokrzyskie Mts.

METHODOLOGYOFRESEARCHES

Various methodologies of research were used in all of the mentioned regions. They were adapted to the individual geological structure. The first research was carried out in the Carpathian Mts. but only in the eighties did they result in discovery and estimation of resources and reserves, mainly in the Inner Carpathians.

Exploratory work in the area of the Fore-Carpalhian Province, numerous data were obtained from oil drilling. lhis includedlogs of the main water-bearing levels.

The most extensive geothermal research, using geophysical and dnlling work by the oil industry and by the State Institute of Geology, were carried out in the Polish part of the Central European Province. Mesozoic and Permian formations were studied in this area. Partly studied were Carbon and Devonian formations in Lublin and Pomeranian regions, and also Cambrian and Ordovician formations within the Polish part of the Precambrian Platform.

Single wells were drilled were carried out and analysed in the Sudetes Mts. and Świętokrzyskie Mts.

RESOURCESANDRESERVES OF GEOTHERMAL ENERGY

Data analyses of several hundred wells, made in 1985, located in all geothermal basins, allow estimation of geothermal energy resources. The thickness of reservoir levels, depth of occurence, formation temperature and porosity were considered dunng analysis. Water and geothermal energy resources of each water-bearing basins were estimated on the basis of these data Ten geothermal regions on the Polish territory were distinguish.

I. Grudziądz - Warszawa region with area of about 70,000 km^2, thevolume of subartesian and artesian geothermal waters contained in Cretaceous and Jurassic reservoirs amounts to 2766 km^3, and recoverable thermal energy resources amount to 9835 mln t.o.e. On the average it amounts to 44 mln m^3 of geothermal water/km^2 of the surface, and 140,500 t.o.e./km^2.

2. Szczecin _Łódź region with area of about 67,000 km^2, the volume of subartesian and artesian geothermal waters contained in Cretaceous, Jurassic and Triassic reservoirs amounts to 2854 km', recoverable thermal energy resources amount to 18812 mln t.o e. On the average it amounts to 42 mln m^3 of water/km2 and 280,800 t.o.e./km^2.

3 Fore-Sudetic - Northern-Świętokrzyski region with area of about 39,000 km^2, the volume of subartesian and artesian geothermal waters contained in Jurassic, Triassic and Permian reservoirs is estimated on 155 km^3, recoverable thermal energy resources amount to 995 mln t.o.e. On the average it amounts to about 4 mln m^3 of water/km^2 and about 26,000 t.o.e./km^2 of the surface.

FIG I MAP OI IHI GLO IHI RMAI REGIONS AND SUB-BASINS OF POLAND (AFTER R NEYAND J SOKOŁOWSKI)

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Julian Sokołowski and others – GEOSYNOPTICAL ATLAS OF POLAND

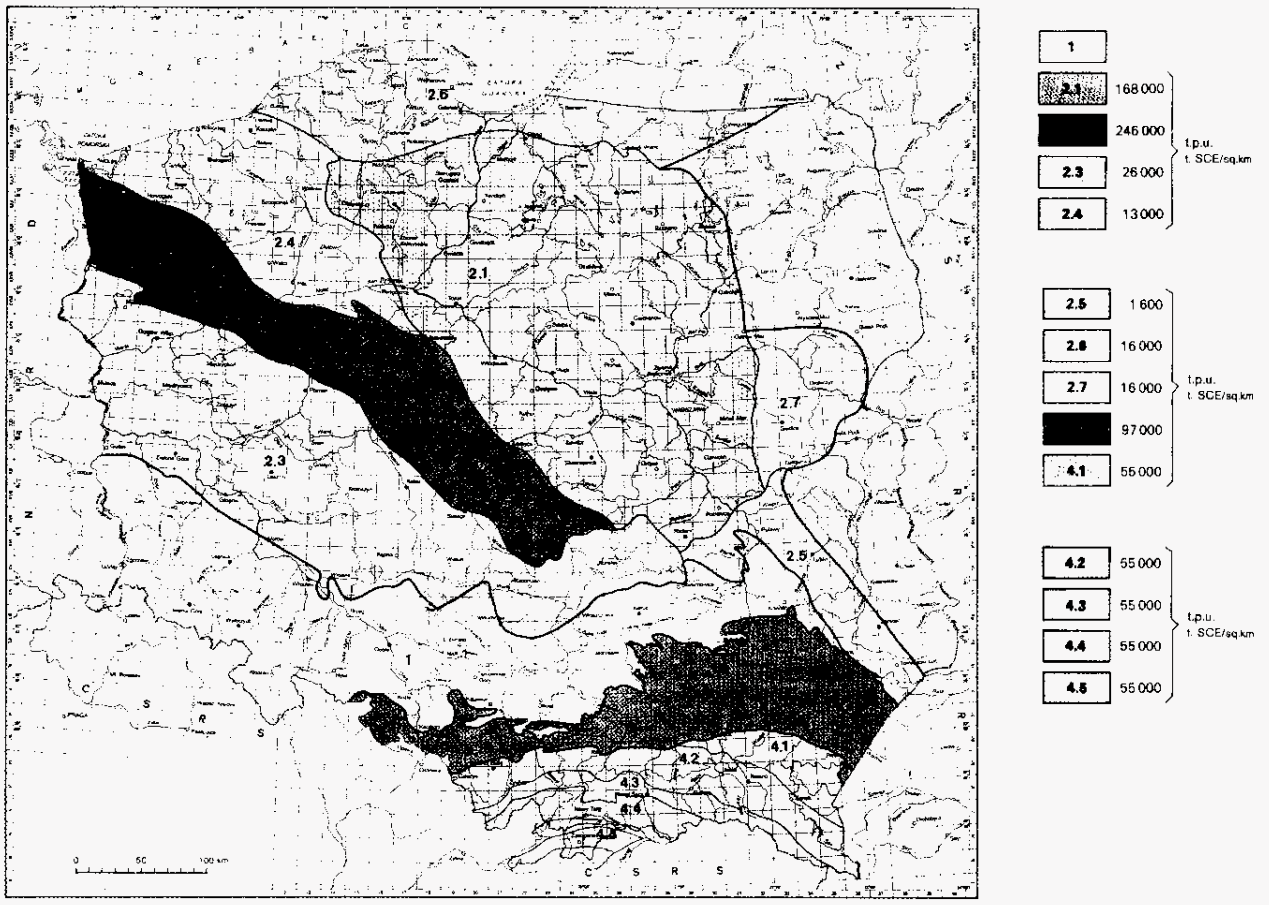


TABLE 1. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT.

(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, G-greenhouses)

Locality	Type	Maximum utilization					Annual utilization		
		Flow rate	Temperature (°C)		Enthalpy (kJ/kg)		Av. flow rate	Energy use	Load factor
		kg/s	Inlet	Outlet	Inlet	Outlet	kg/s	TJ/yr	
Podhale	A	2	70	40	370	168	2	12	0.86
	F	2	70	40	370	168	2	12	0.86
	B	2	70	40	370	168	2	12	0.86
	G	2	70	40	370	168	2	12	0.86
	C	5-20	70	40	370	168	70-200	50-120	0.86
Pyrzyce	C	100	60	25	251	104	90	410	0.82

4. Pomeranian region with area of about 12,000 km^2, the volume of subartesian and artesian geothermal waters contained in Jurassic, Triassic, Permian, Carbon and Dewonian reservoirs is estimated on about 21 km^3, thermal energy resources amount to about 162 mln t.o.e. On the average it amounts to 1.6 mln m^3 of water/km^2 and 13,000 t.o.e./km^2.

5. Lublin region with area of 12,000 km^2, the volume of geothermal waters contained in carboniferous and Dewonian reservoirs is estimated on 30 km^3, recoverable thermal energy resources on 193 mln t.o.e. On the average it amounts to 2.5 mln m^3 of waterh' and 16.000 t.o.e/km^2.

6. Peribaltic region with area of 15,000 km^2, the volume of geothermal waters existing in Permian and Cambrian reservoirs is estimated on 38 km^3, thermal energy resoources on 241 mln t.o.e. On the average it amounts to 2.5 mln m^3 of waterkm' and 16,000 t.o.e./km^2.

7 Podlasie region with area of 7000 km^2, the volume of geothermal waters existing in Permian, Carbon and Cambrian reservoirs is estimated on 17 km^3, recoverable thermal energy reserves on about 113 mln t.o.e. On the average it mounts to 2.5 mln m^3 of water/km^2 and 16.000 t.o.e./km^2.

8. Fore-Carpathian region with area of about 16,000 km^2, the volume of geothermal waters contained in Miocene, Cretaceous, Jurassic and Triassic reservoirs is estimated on about 362 km^3, recoverable thermal energy resources on about 1555 mln t.o.e. On the average it amount.; to 22.6 mln m3 of water/km^2 and 97,000 t.o.e./km^2.

9. Carpathian region with area of about 13,000 km^2, the volume of geothermal waters contained in Tertiary and Cretaceous reservoirs (on Podhale also in Jurassic and Triassic) is estimated on about 100 km^3, recoverable thermal energy resources on about 714 mln t.o.e. (including over 60 mln t.o.e on Podhale). On the average it amounts to 7.7 mln m^3 of water/km^2 and 55,000 t.o.e/km^2.

10. Sudetic - Świętokrzyski region has considerable resources of geothermal energy (they haven't been estimated quantitatively) related to dislocation zones of the Sudeuc crystalline rocks with sedimentary and crystalline beds of Opole region

In the methodology used w estimate the thermal energy resources recoverable from geothermal waters, one accepted that from the volume of geothermal waters contained in the porous space of Tertiary, Mesozoic and Paleozoic rocks to 3000 m depth, the heat will be received only w the temperature of 20°C and that these waters will not be reinjected. Presently. it is known that methods of reinjection of waters have been mastered and, in relation with this. the presented estimations of resources of potential thermal energy recoverable from gmthermal waters in the future are lconsiderably low.

Reserves of geothermal waters and contained thermal energy were estimated *only* for some regions, in intervals depending on the method of exploitation.

Presently, geothermal water reserves were preliminarily estimated in the following regions (Ney, Sokołowski, 1987. Sokołowski, 1988):

- Podhalanian basin,
- Pyrzyce basin,
- Szczecin - Stargard basin,
- Skierniewice,
- Uniejów,
- Środa Śląska
- and approximately in Żyrardów and Warszawa.

The term reserves is based on the output of particular wells, during exploitation. The size of reserves depends on the methodology used and the length of time of exploitation. They are calculated. in most cases, in m^3/h. The total quantity of heat that may be received fromthem depends on the exploitation technology and reinjection process.

In the Polish part of the Podhalanian Basin, where geothermal waters are under artesian pressure, the output of particular wells, i.e. reserves, ranges from $25 m^3/h$ to $600 m^3/h$. This large spread of the output results from the methods used for heat receipt. Similar flow rates were obtained during the preliminary tests on Wiśniowa of oil well, situated near Krosno.

In Polish part of the Carpathian Foredeep, geothermal water reserves were identified in Tarnów region in Jurassic formations and in many other regions, in oil wells. Waters output ranges here from several to over 100 m^3/h and they are under artesian and subartesian pressure.

In Polish part of the Central European Province, geothermal water reserves (with subartesian pressure) rangc from several to about 400 m^3/h, depending on the thickness, porosity and permeability of reservoir levels and the method of their access.

Geothermal water reserves in Pyrzyce, where four geothermal wells were drilled, were estimated at 300 m^3/h

TABLE 2. GEOTHERMAL HEAT PUMPS

Locality	Heat source °C	COP - factor	Heat pump rating Mw_t (Output)	Thermal energy used in heating mode TJ/yr
Pyrzyce	25	1.4	18	198

Reserves in Stargard - Szczecin basin (Marianowo 1,2 and 3 wells) were estimated at 70 - 200 m^3/h

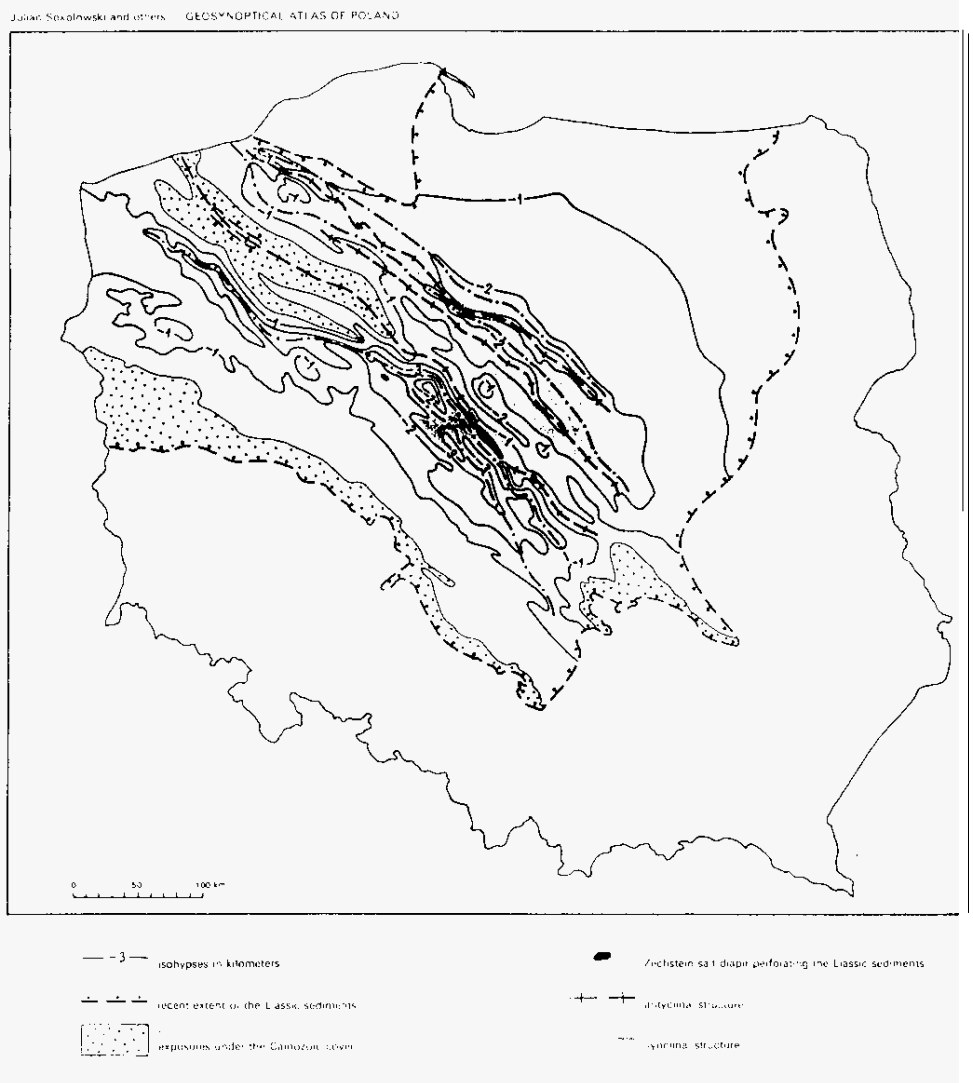
Reserves in Skierniewice were estimated at 70 - 150 m^3/h

In Żyrardów and Warszawa, in projects elaborated on the basis of old oil wells reserves are estimated at about 200 m^3/h

EXEMPLES OF PROJECTED GEOTHERMAL WATER UTILIZATION

A program of research and construction of geothermal plants

FIG. 2. GEOLOGICAL AND STRUCTURAL MAP OF POLISH LIASSIC (AFTER J. SOKOŁOWSKI)



was elaborated in 1985, on the basis of estimations of the geothermal water resources and thermal energy contained in them, which were made in the same year. In line with this program, an Experimantal Geothermal Plant in Bańska - Biały Dunajec was built and put into operation, and conceptions for construction of further geothermal plants in Stargard Szczeciński, Szczecin, Gniezno, Skierniewice, Żyrardów, Mszczonów and Tarnów were elaborated.

At present the Town Council Office m Pyrzyce is implementing construction of a large power plant utilizing geothermal energy and natural gas in order to heat the town, numbering about 14,000 residents (Table 1, 2, 3, 4)

TABLE 3. *SUMMARY* TABLE OF GEOTHERMAL DIRECT HEAT USES.

	Installed thermal power MW$_t$	Energy use TJ/yr
Space heating	0	0
Bathing and swimming	1	11.8
Agricultural drying	1	11.8
Greenhouses	1	11.8
Fish and other animals farming	1	11.8
Industrial process heat	0	0
Snow melting	0	0
Air conditioning	40	460-530
Other	0	0
Subtotal	44	507.2-577.2
Heat pumps	19	198.0
Total	63	705.2-775.2

TABLE 4. INFORMATION ABOUT GEOTHERMAL LOCALITIES.

[1] Main type of rock, [2] N-identified only, R-regional assessment, P-pre-feasability studies, F-feasability studies, U-comercial utilization)

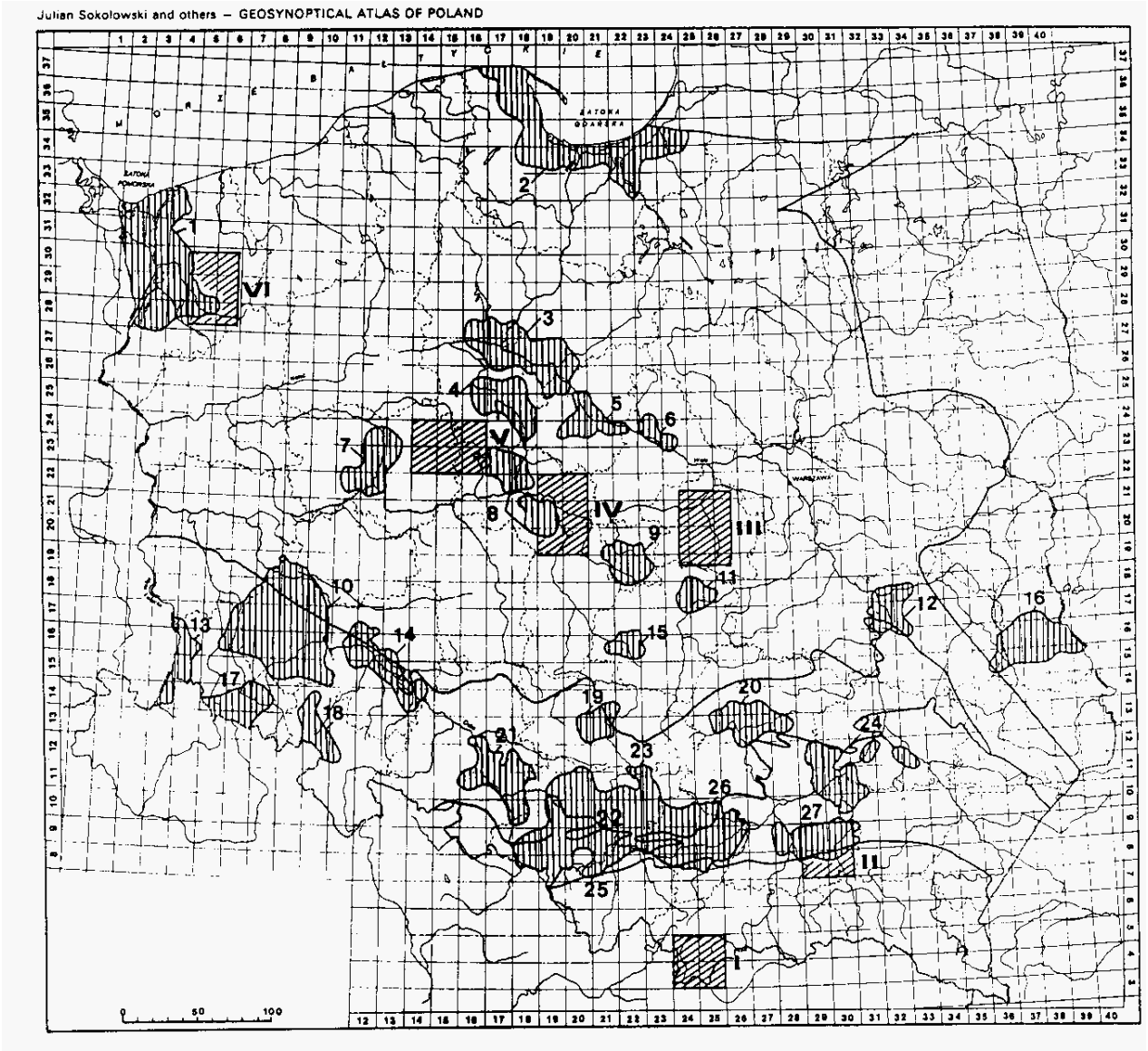
Locality	Location		Status"	Measured reservoir temp. (°C)
	Latitude	Longitude		
Podhale	49	20	U	a2
Pyrzyce	53	15	U	10
Uniejów	52	19	P	10
Żyrardów	52	20.5	P	60
Warszawa	52	21	P	*60*
Tarnów	50	21	N	*60*
Koło	52	19	N	65
Skierniewice	52	20	N	10
Szczecin	53	15	N	75

The geothermal water found at Cieplice (West Sudetes), Lądek and Duszniki (Middle Sudetes) are utilized for balneological purposes. The artesian water flowing at Cieplice From a depth of 150 m has a temperalure of 63 °C (Sokołowski, 1989). Total productivity of each reservoirs *mounts* to 10 m^3/h.

TECHNOLOGY AND COSTS OF GEOTHERMAL ENERGY EXPLOITATION IN POLAND

The technology used during geothermal energy exploitation for heating, drying, market gardening and recreation purposes is based on the flow of geothermal water, from exploitation to reinjection wells, with total fluid insulation from inflow of atmos-

FIG 3 *MAP* OF AREAS OF ECOLOGICAL SENSITMTY (afler S Kozłowski, H Leszczyszyn, E A Kossakowska) (J Sokołowski and other, 1992)



Areas of ecological sensitivity:

1. Szczecin
2. Gdahsk
3. Bydgoszcz – Toruń
4. Inowroclaw
5. Wloclawek
6. Plock
7. Poznah
8. Konin
9. Łódź
10. Legnica – Głogów
11. Tomaszów
12. Puławy
13. Turoszów
14. Wroclaw
15. Bełchatów
16. Chelrn
17. Jelenia Góra
18. Walbrzych
19. Częstochowa
20. Kielce
21. Opole
22. Upper Silesian
23. Myszków – Zawiercie
24. Tarnobrzeg
25. Rybnik
26. Kraków
27. Tarnów

Geothermal provinces:

Carpathian Province
Fore-Carpathian Province
Sudetes-Holy-Cross Region
Lowland Province

Areas of study:

I Podhale
II Tarnów
III Skierniewice
IV Kolo
V Gniezno
VI Stargard Szczecihski

POLLUTION [t]	PYRZYCE PLANT			PODHALE PLANT		
	Present	Project	Reduction	Present	Project	Reduction
CO_2	86,000	17,000	80%	463.W	27.W	94%
NO_x	263	21	93%	270	19	93%
SO_2	1,158	0	100%	2,100	0	100%
DUST	241	0	100%	1,200	0	100%

pheric oxygen, so are to provide minimalization of corosion, incrustation and high economic effectivity.

The cost of exploitation and supply of energy to users ranges from 3.5 to 10 USD/1GJ, and in most cases it is l o w than the costs of energy exploitation from traditional energy sources. Therefore, geothermal energy is competitive with respect to ecology and economy among other sources ofthermal energy.

Total investments in geothermal projects in Poland in years 84-94 are summarised in table 7.

ECOLOGICAL ASPECTS OF GEOTHERMAL WATERS UTILIZATION

The ecological of benefits substituting geothermal energy for traditional coal heating systems for the two main geothermal proj. ects in Poland are summarized in table 5. The map of the areas of ecological sensivity in Poland, on a background of geothemal provinces with location of further geothermal plants, is presented on the fig.3 (Sokołowski, 1992, 1993).

TABLE 6. ALLOCATION OF PROFESSIONAL PERSONNEL

Year	Professional Man Years to Effort					
	Govement	Public utilities	Universitie s	Paid For- eign Con- sultants	Contr. Through For- eign Aid Pro- grams	Private Industry
1993	5	3	30	9	10	-
1994	5	3	30	9	10	10

TABLE 7. TOTAL INVESTMENTS IN GEOTHERMAL IN US$.

Period Period	Research& Development Inc. Surf. Exp.	Field Devel- opment Incl. Prod.	Utilization		Funding Type	
	Milion US$	Milion US$	Direct Milion US$	Electrical Milion US$		
85/94 85194	20	20	20		2	2

CONCLUSIONS

structures and considerable papulation (over 38 mln), is a country with large chances for geoenergetics development. The reasons for fast geoenergetic development are as follow:

1. partial elimination of the large pollution of atmosphere and superficial waters caused by the products of coal burning in individual, municipal and industrial heat engineering.

2. favourable conditions of geothermal wafer occuring ones an area of 250,000 km^2, with large numbers of heat users in this area (over 30 mln residents),

plate heat exchangers.

4. the proven economic profitability of geothermal beat supply to industrial, municipal and individual users on the basis of the Podhale, Pyrzyce and Zyrardów plants.

5. possibilities for complex utilization of geothermal energy in beat engineering, drying, refrigeration, market gardening, balneology and recreation

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