JACEK ZIMNY*

POTENTIAL OF GEOTHERMAL ENERGY IN POLAND AND GERMANY – STATE FOR THE YEAR 2005

The paper includes the results of estimation of accessible resources of geothermal heat in Poland and comparison of estimations of energy made after 1985 according to the methodology used in Poland, prepared by J. Sokołowska and J. Sokołowski, and ways of calculations approved in EU. All the data presented have been verified by the latest results issued by German government. After the analysis of resources and geoenergetic potential of Poland, which is based on many years' research and comparison with other countries in Europe, we can state that Poland has the biggest geothermal resources. A real technical energetic potential of geothermal waters to a depth of 3,000 m, which can be used in practice, is almost 200 times bigger than energy demand in Poland. According to the result of investigations and analysis it can be said that Poland can certainly be in a short time energy independent due to geothermal resources.

1. INTRODUCTION

Accessible resource base (ARB), as defined by the International Geothermal Association, refers to all of the heat energy stored in the earth's crust, measured from the annual local mean temperature [4]. The amounts of supplies are estimated at different depths, depending on the technical and economical potential of possible exploitation. Commonly in Europe and Poland the assumed depth is 3,000 m. Last calculations of heat energy resources and energy potential (in PJ = 10^{15} J) to a depth of 3,000 m for the whole area of Poland were prepared for state authorities in 2001 (J. Sokołowska, J. Sokołowski, J. Zimny), [6], [1], [2], [7], [10], [12].

Since in the past 5 years, the cost of energetic raw material and heat energy has increased by 100%, and raw material sources are observed to decrease as well, a need has arisen of extracting raw materials from deeper mining levels. Therefore it is a matter of urgency that calculations for a 3,000 m depth should be verified and geothermal sources for depths of 5,000 m and 7,000 m be estimated, which fact has been commonly ac-

_____

* Department of Power Installations, Faculty of Mechanical Engineering and Robotics, University of Science and Technology, al. Mickiewicza 30, 30-059 Kraków, Poland.

cepted worldwide and in the European Union.

2. GEOTHERMAL PROVINCES IN POLAND

In figure 1, there is a map of geothermal provinces and districts, according to J. Sokołowski [9], with data concerning estimated potential of geothermal water sources in mln m^3/km^2, t c.e./km^2 and energetic potential of heat energy in geothermal waters (mln t c.e.) [1], [8] collected in the table.

3. METHODOLOGY OF ESTIMATING RESOURCES; RESULTS

The paper includes the results of estimation (ARB) of accessible resources of geothermal heat in Poland and comparison of estimations of energy made after 1985 according to the methodology used in Poland, prepared by SOKOŁOWSKA [6] and SOKOŁOWSKI [6], [11], and ways of calculation approved in EU [4]. Enormously helpful in verification of calculations is the latest data provided by the German government.

Table 1

Accessible resources of geothermal energy (ARB) in separate geothermal regions of Poland
(hot water, hot rocks) [8]–[10]

District No.	Name of the region	ΔT[ºC]			GJ/m^2			Area $\times 10^9$[m^2]	Geothermal energy resources ARB$\times 10^{21}$[J]		
		3 km	5 km	7 km	3 km	5 km	7 km		3 km	5 km	7 km
1	Grudziądz–Warsaw	70	115	160	260	720	1400	70	18	50	98
2	Szczecin–Łodź	85	140	195	320	870	1700	67	21	58	110
3	Fore-Sudetic	90	150	210	340	940	1800	39	13	37	70
4	Pomorze	65	110	150	240	690	1300	12	3	8	16
5	Lublin	80	130	180	300	810	1600	12	4	10	19
6	Baltic	65	105	145	240	650	1300	15	4	10	20
7	Podlasie	65	105	145	240	650	1300	7	2	5	9
1–7	Central Europe							Total:			
	Province average:	77	128	176	290	800	1540	222	65	178	342
8	Fore-Carpathian	80	135	190	300	840	1700	16	5	13	27
9	Carpathian Province	70	115	160	260	720	1400	13	3	9	18
1–9	Average	77	128	176	290	800	1540	Total: 251	73	200	387

Accessible resources of geothermal energy (ARB) in Poland have been calculated for depths of 3,000 m, 5,000 m and 7,000 m, according to current standards [1], [3], [6], [8], [11]. In calculations, a constant amount of energy accumulated in the rocks (2.5 MJ/m^3) was taken into account [10]. For the rock mass volume of area 1 m^2 and depths of 3,000 m, 5,000 m and 7,000 m, the calculated energy accumulated in the rocks amounted to 7.5 GJ per calculated volume, 15.5 GJ per calculated volume, and 17.5 GJ per calculated volume, respectively [5], [6]. Then resources of heat energy for one square meter in spe-

cific geological structures as a function of depth have been calculated. Results of calculations of energetic potential of 9 geothermal districts (covering the area of 250,000 km^2), which makes up 80% of the whole country, are shown in table 1 [8]–[10].

From the stage calculations and after summing up, all of the accessible resources of geothermal energy (ARB) in Poland, over approximately 250,000 km^2 in area, in particular geographical units (districts 1–9, table 1) are the following [7]–[12], [1], [3]:

1) to a depth of 3,000 m – energy potential: $73 \cdot 10^{21}$ [J] $\approx 75 \cdot 10^6$ [PJ],
2) to a depth of 5,000 m – energy potential: $200 \cdot 10^{21}$ [J] $\approx 200 \cdot 10^6$ [PJ],
3) to a depth of 7,000 m – energy potential: $387 \cdot 10^{21}$ [J] $\approx 390 \cdot 10^6$ [PJ].

Resources of heat energy connected with geothermal waters of Poland, estimated by the team of Prof. J. Sokołowski (table 1), have also been recalculated according to the methodology approved by EU for comparison purposes (J. Sokołowska, A. Tomaszewski, W. Górecki). The results of the evaluations are shown in table 2 [1], [6], [11].

T a b l e 2

Resources of H_0 and H_1 heat energy in geothermal waters of Poland,
according to SOKOŁOWSKI [8]–[10]

District No.	Name of the district	Average resources H_0 for 1m^2		Average resources H_1 for 1m^2	
		kg c.e.	GJ	kg c.e.	GJ
1	Grudziądz–Warsaw	550	16	140	4.1
2	Szczecin–Łódź	870	25	250	7.3
3	Fore-Sudetic	80	2.5	23	0.7
4	Pomorze	50	1.5	14	0.4
5	Lublin	60	1.5	16	0.5
6	Baltic	50	1.5	14	0.4
7	Podlasie	30	1.2	10	0.3
8	Fore-Carpathian	320	9	85	2.5
9	Carpathian	170	5	50	1.4
	Poland, average	450	13	120	3.5

Summing up, the resources of H_0 and H_1 estimated for geothermal area of Poland (250,000 km^2), as indicated in the map (figure 1) – with investigated water levels and hot rocks, to a depth of 3,000 m, are as follows [7]–[11]:

a) Heat potential of geothermal reservoirs in Poland:

$H_{0(3)} = 3200 \cdot 10^{18}$ [J] $= 110 \cdot 10^{12}$ kg c.e. $110 \cdot 10^9$ t c.e. ≈ 130 billion tons of coal.

b) Resources of geothermal energy in Poland (investigated)

$H_{1(3)} = 880 \cdot 10^{18}$ [J] $= 30 \cdot 10^{12}$ kg c.e. $= 30 \cdot 10^9$ t c.e. ≈ 36 billion tons of coal.

This constitutes 4.2% and 1.2% of accessible base resources (ARB) calculated to a depth of 3,000 m [7]–[10].

Analogical calculated estimates of energetic potential in Poland for deeper reservoirs of geothermal waters are [8]–[10]:

● for a depth of 5,000 m:

$H_{0(5)} = 5400 \cdot 10^{18} \,[\text{J}] = 190 \times 10^{12} \,\text{kg c.e.} = 190 \cdot 10^{9} \,\text{t c.e.} \approx 230$ billion tons of coal,

$H_{1(5)} = 1400 \cdot 10^{18} \,[\text{J}] = 50 \times 10^{12} \,\text{kg c.e.} = 50 \cdot 10^{9} \,\text{t c.e.} \approx 60$ billion tons of coal,

● for a depth of 7,000 m:

$H_{0(7)} = 7500 \cdot 10^{18} \,[\text{J}] = 260 \times 10^{12} \,\text{kg c.e.} = 260 \cdot 10^{9} \,\text{t c.e.} \approx 300$ billion tons of coal,

$H_{1(7)} = 2060 \cdot 10^{18} \,[\text{J}] = 70 \times 10^{12} \,\text{kg c.e.} = 70 \cdot 10^{9} \,\text{t c.e.} \approx 70$ billion tons of coal.

4. GEOENERGETIC SITUATION OF POLAND COMPARED TO EUROPE

After the analysis of the resources and geoenergetic potential of Poland which is based on many years' research and comparison with other countries in Europe (detailed geological maps of Europe – figure 2) – we can state that Poland has the biggest geothermal resources (area: 80% of Poland's territory, quantity: 3 times more than Germany has) [12], [13]. The main thermal axis of "geothermal trench" goes from
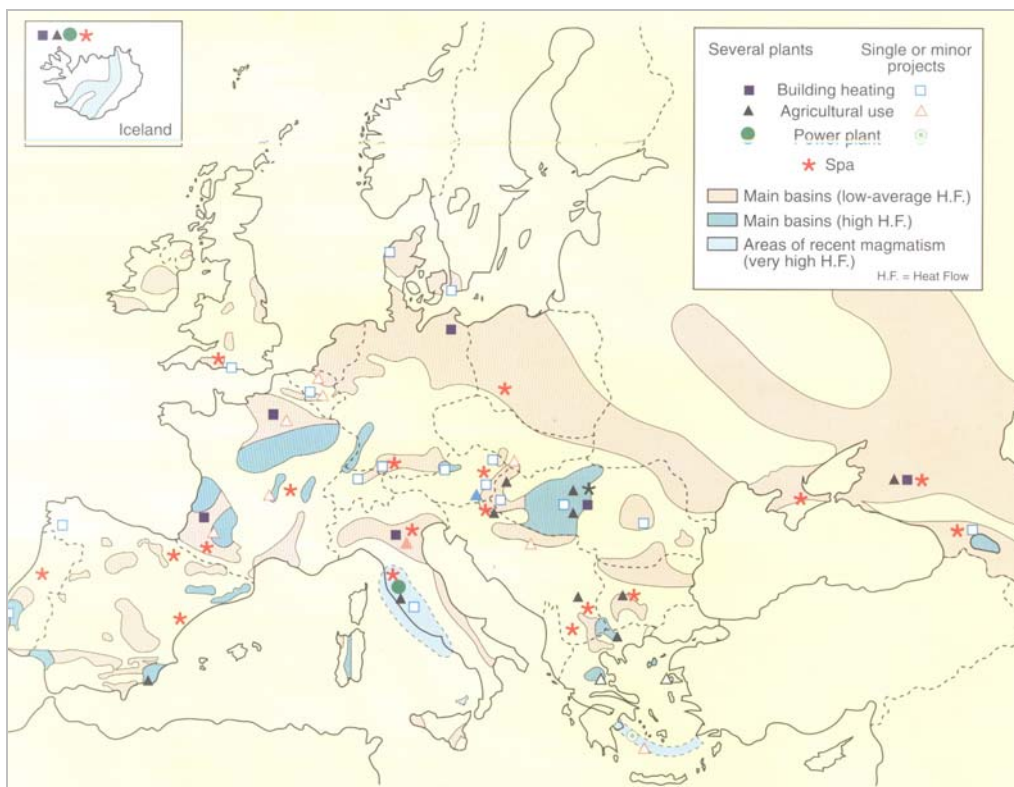

Fig. 2. Resources of geothermal energy in Europe [13]

Island through the Denmark, northeastern Germany, Poland, Ukraine, through the Black Sea to Turkey (axis: Reykjavik–Szczecin–Łódź–Rzeszów–Ankara) [12]. As regards eastern Europe such analogical data concerning the potential of geothermal resources were published only in Germany in 2004 [14]. An official document issued by German government in September 2004 presenting the program of geothermal energy development in Germany confirms the results of investigations and analysis carried out in Poland, which are presented in table 3 [1], [3], [8], [12].

5. SUMMARY

1. According to the investigations performed by Polish scientists and estimations of the Geology Department (Ministry of Environmental Protection and Natural Resources 1995), energetic potential of geothermal water resources to a depth of 3,000 m is estimated at over 100 billion t c.e.; over 80% of the area of Poland is covered with geothermal reservoirs [1], [6], [9].

2. Recent calculations of geothermal resources in Poland confirm this data. According to J. Sokołowski and J. Sokołowska (Polish Academy of Sciences, Department of Geosynpotics and Geothermal Energy, Kraków) the amount of heat for geothermal waters to a depth of 3,000 m is $110 \cdot 10^9$ t c.e., which corresponds to 130 billions of tons of coal (2001) [6]–[12]. This is a potential of approximately 75 millions of PJ. The potential of resources which can be technically used in Poland, taken on the level of 1% is 730 000 PJ. According to GUS (Central Statistical Office) data of 2003 the primary energy consumption throughout the whole year was about 4000 PJ.

3. Therefore, a real technical energetic potential of geothermal waters to a depth of 3,000 m, which can be used in practice (with existing frozen and possible boreholes of PGNiG – The Polish Oil and Gas Company) is almost 200 times bigger than energy demand in Poland [12] (table 3, col. 7).

4. The latest investigations in Poland (J. Sokołowski, J. Sokołowska, A. Tomaszewski, J. Zimny), which describe energetic potential of geothermal resources according to Polish and EU standards (including hot rocks) to depths of 5,000 m and 7,000 m, show the data to increase 2–4 times (table 3, col. 7).

5. According to the above investigations and analysis it can be said that Poland can certainly be in a short time energy independent due to geothermal resources; the potential of primeval energetic sources, which technically is possible to use, is over 400–600 times bigger than annual demand for energy in Poland.

REFERENCES

[1] GÓRECKI W., *Atlas zasobów energii geotermalnej na niżu Polskim*, GEOS AGH, Kraków, 1995.
[2] GÓRECKI W., *Metodyka oceny zasobów energii i wód geotermalnych*, GEOS, Kraków, 1993.

[3] MAŁOLEPSZY Z. (ed.), *Energia geotermalna w kopalniach podziemnych*, Prace Wydziału Nauk o Ziemi, Uniwersytet Śląski, No. 17, 2002.

[4] MUFFLER L.J., CATTALDI R., *Methodology for regional assessment of geothermal resources*, Geothermics, 1977, Vol. 7, No. 2/4, Pisa, Italy.

[5] PLEWA S., *Termiczne własności skał*, PIG, Warszawa, 1972.

[6] SOKOŁOWSKA J., *Metodyka poszukiwania złóż kopalin płynnych*, Studia i rozprawy PAN, CPPGSMIE, Kraków, 1991, No. 10.

[7] SOKOŁOWSKA J., *Ocena zasobów geotermalnych*, Materiały Polskiej Szkoły Geotermalnej, III Kurs, Kraków–Straszęcin, 1997.

[8] SOKOŁOWSKI J., *Geotermalny potencjał Polski*, CPPGSMIE PAN, Kraków, 1995 (courtesy of J. Sokołowski).

[9] SOKOŁOWSKI J., *Prowincje, baseny i zbiorniki geostrukturalne, geotermalne i ropogazonośne Polski*, CPPGSMIE PAN, Kraków, 1985 (courtesy of J. Sokołowski).

[10] SOKOŁOWSKI J. (ed.), *Metody oceny zasobów i zasady projektowania zakładów geotermalnych*, CPPGSMIE PAN, Kraków, 1996.

[11] SOKOŁOWSKI J., TOMASZEWSKI A., *Ocena potencjalnych zasobów energii cieplnej wód geotermalnych w utworach kredy i jury niżu polskiego*, CPPGSMIE PAN, Kraków–Warszawa, 1995, (courtesy of J. Sokołowski and A. Tomaszewski, unpublished).

[12] SOKOŁOWSKI J., ZIMNY J., KOZŁOWSKI R., *Polska XXI wieku – nowa wizja i strategia rozwoju*, Wydawnictwo Uniwersytetu Kardynała Stefana Wyszyńskiego, Warszawa, 2005.

[13] Commission of the European Communities. Directorate General XVII for Energy, *The several uses of low temperature geothermal energy for heating*, Brusseles, 1992.

[14] Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Umweltpolitik, *Geothermie – Energie für die Zukunft*, Berlin, 2004.

[15] International Energy Agency, *Germany's Total Primary Energy Production* (*TPEP*) *and Total Primary Energy Consumption* (*TPEC*), 2005.

POTENCJAŁ ENERGII GEOTERMALNEJ POLSKI I NIEMIEC – STAN NA 2005 ROK

Artykuł zawiera wyniki oszacowania ARB, tj. dostępnych zasobów ciepła geotermalnego w Polsce, oraz porównanie ocen zasobów tej energii przeprowadzonych po roku 1985 według metodologii stosowanej w Polsce, a opracowanej przez J. Sokołowską i J. Sokołowskiego, oraz sposobu obliczeń przyjętego w Unii Europejskiej – zweryfikowane na podstawie najnowszych danych rządu Niemiec. Porównując zasoby i potencjał geoenergetyczny Polski, otrzymane w wyniku wieloletnich badań, z danymi z innych krajów Europy, można stwierdzić, że Polska ma największe w Europie zasoby geotermalne. Rzeczywisty techniczny potencjał energetyczny wód geotermalnych do głębokości 3000 m jest blisko 200 razy większy niż roczne potrzeby energetyczne Polski. W świetle przedstawionych badań i analiz porównawczych można jednoznacznie stwierdzić, iż Polska może być w krótkim czasie samowystarczalna energetycznie dzięki wykorzystaniu zasobów energii geotermalnej.