Geothermal Energy Country Update Report from Poland, 2000 - 2004

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ABSTRACT

The paper introduces the status of geothermal energy development in Poland during the period 2000 - 2004, since the presentation of update report at the World Geothermal Congress in 2000 (Kepinska et al., 2000).

The beginning of geothermal use for heating dates back to the last decade of the 20th century. The tradition of using warm waters for curing in several localities is much older as it originated in the 13th-14th centuries.

The country is characterised by significant low-enthalpy geothermal potential, connected mostly with the Mesozoic sediments. Space heating represents the most important type of direct uses, as it can play essential role in local energy markets and result in a considerable reduction in the consumption of fossil fuels.

Since 1992, five geothermal heating plants have been launched, including two of them put into operation in the period 2000 – 2004 reported in this paper. At the end of 2004, total installed geothermal capacity amounted to 170.8 MW_t, while heat sales was about 838.3 TJ comparing to 70 MW_t and 280 TJ in 1999, as presented at WGC 2000. The main contribution to these figures gave the Podhale plant (41.2 MW_t, and 187 TJ), and ground-source heat pumps (ca. 80 MW_t, and 500 TJ) the development of which has been recently observed in the country. The investments works were accompanied by basic research, feasibility studies and implementation projects. Among prospective geothermal options for the future are: the adaptation of abandoned wells; multipurpose, integrated systems; heat pumps; heat extraction from the underground mines.

1. INTRODUCTION

The paper introduces the status of geothermal energy development in Poland as of 2004, since the presentation of update report at WGC 2000 (Kepinska et al., 2000). In 2000 – 2004 some projects mentioned at this event were finished and some others were underway. There is also a constant increase of experience gained during the plants' operation as well as the number of new studies and projects.

Geothermal energy use for heating purposes in the country was initiated in the last decade of the 20th century. The experimental stage of the first geothermal plant was opened in the Podhale region in 1992 (Sokolowski et al., 1992). Since that time, four other plants have been launched, including two of them in the reported period of 2000 – 2004. Space heating is a key sector for geothermal development. Wide-ranging use adequate for the reservoir potential would permit to significantly limit reliance on fossil fuels and mitigate the negative effects of such fuels being burnt.

Over the last several years, the circumstances accompanying the development of renewables, geothermal including, remained more or less the same. Some general documents related to the long – term energy policy of the country were introduced. The most important of them is the Strategy for Renewable Energy Resources Development (2000). According to it, the share of all renewables, including geothermal, in primary energy production will oscillate around 7.5% in 2010 and 14% in 2020 (however, with little contribution of geothermal). These figures seem to be significant as compared to the current share of all RES in energy generation (2.5%) but inadequate for the country's potential. Among the main factors behind these forecasts are the competitive prices of traditional fuels, insufficient financing and weak law regulations. Relatively high investment costs (especially when deep geothermal wells are needed to be drilled) are indicated as the main reason for such a situation, while the other cheaper solutions, both working and planned are often neglected and not mentioned even by the opponents. As one of the main RES accessible in Poland, geothermal should also be promoted in view of the conditions the country has to meet after its accession to the European Union in May 2004. One such condition is the increase in the use of renewables.

Some progress in RES development is expected due to the amended Energy Law binding power companies to purchase green electricity and heat. It also makes local administrations responsible for managing the heating market, including the use of local energy sources.

Neverthless, the few legal acts introduced to date to facilitate the development of RES sector, specially geothermal, are insufficient. More favourable legal regulations as well as economic and fiscal incentives should be introduced. They would be a tool for the promotion of geothermal energy and, first of all, the creation of equal opportunities for geothermal and traditional fuels – a starting point for the rational energy policy. In this respect, long awaited but still not introduced new fundamental law on the renewables' management should create better conditions also for geothermal development.

2. GEOTHERMAL RESOURCES

Poland is situated in central Europe, where three main geostructural units bulding this continent meet: Precambrian platform of Northwestern Europe; Palaeozoic structures of Central and Western Europe (Caledonian and Variscian), partly covered by the Permian-Mesozoic and Cainozoic sediments; Alpine system (represented by part of the Carpathian range).

Crystalline rocks prevail within the Precambrian platform (NE-Poland) and within the Sudetes region (SW-Poland).

Sedimentary formations dominate the extensive area framed by these two units and stretch from the Baltic sea coast towards central and southern part of a country known as the Polish Lowland and the Carpathians. Significant thickness (up to 7-12 km) and share of sandstones and carbonates are characteristic of large areas built of sediments. These rock types often have good hydrogeological and reservoir parameters, creating conditions for the occurence of underground waters, including geothermal.

Main geostructural units that built the country's area served as a basis to distinquish three geothermal provinces (each of them being divided into several smaller units, called geothermal regions; Sokolowski 1993, Sokolowski [ed.]. 1995). They are formed mostly by extensive sedimentary formations and cover about 250 000 km^2, i.e. 80% of total area of a country and contain numerous geothermal aquifers (Fig. 1):

- The Polish Lowland Province. The most extensive one with the geothermal aquifers related to sandstones and carbonates (Triassic – Cretaceous);
- The Fore-Carpathians. The aquifers are connected with Mesozoic and Tertiary sediments;
- The Carpathians. The aquifers are connected with Mesozoic and Tertiary sedimentary formations.

Moreover, the Sudetes geothermal region was defined which contains the aquifers found in fractured parts of crystalline and metamorphic rocks (Dowgiallo, 2002).

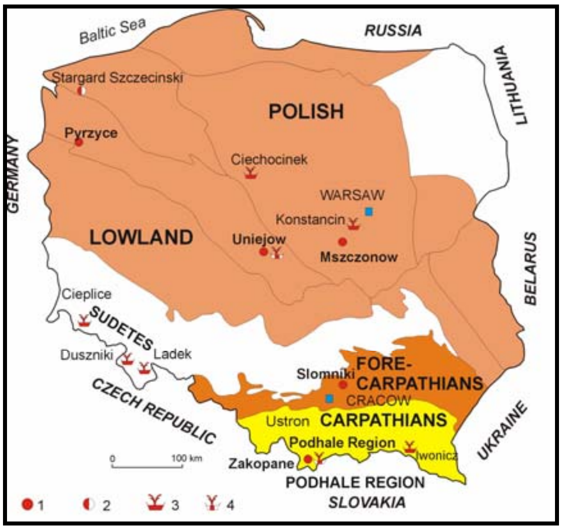

Figure 1. Poland, 2004: geothermal plants in operation (1), underway (2), spas using geothermal waters (3) and bathing facilities under construction (4) (division into geothermal provinces after Sokolowski, 1993).

The country is characterized by the heat flow values from 20 to 90 mW/m^2, while geothermal gradients vary from 1 to 4°C/100 m (Plewa, 1994). Thermal regime and geological conditions imply that the country possesses low-enthalpy resources (one of the richest in Europe). Generally, at the depths from 1 to 4 km reservoir temperatures vary from 30 to 130°C, while . the TDS values are from 0.1 to 300 g/dm^3. The proven geothermal water reserves, evidenced on the basis of well flow tests, amount from several l/s up to 150 l/s. The best geothermal conditions are found in the Polish Lowland and in the Inner Carpathians (Sokolowski [ed.], 1995; Gorecki [ed.], 1995). No traditional geothermal power generation is considered by 2010 and beyond. As in other countries, an interest arises in studies on binary plants which would be based on over 90°C water (expected to occur at the depths below 3-4 km).

3. GEOTHERMAL DIRECT USES

3.1 Generals

During the period 2000 – 2004, geothermal energy has been used in several localities mainly for heating, balneotherapy and bathing (Fig. 1, Table 3a and Table 5). For other purposes it was used on a semi-industrial scale (this same cascaded system as reported before; Kepinska et al, 2000). As compared to the data presented at WGC 2000, the installed geothermal capacity and heat sales have increased significantly since the end of 2001, especially after the extension of the Podhale project and linking large number of clients in Zakopane, main town of the region (by 41 MW_t and 187 TJ in 2003) as well as significant heat pumps development observed in recent years (chapter 3.4).

Taking into account the data from particular geothermal heating plants, at the end of 2003 the installed geothermal capacity (heat pumps excluded) totalled 69.95.MW_t (including 59.2 MW_t for space heating) while geothermal heat sales was ca. 258.9 TJ/y (244 TJ for space heating; Table 3a). It should be noticed that Tables 3a shows that in the case of heating plants, there are the differences between the figures resulted from the equations and those reported by the plants, specially that some of them work in integration with heat pumps.

Following the equations recommended to prepare particular tables attached to this country report, at the end of 2003, geothermal capacity would total ca. 39.25 MW_t and the energy utilisation would be 477.5 TJ/y (heat pumps exluding). What concerns the respective figures for heat pumps, exact data are well known for the heating plants (absorption pumps), while for ground-source compressor pumps tentative data are available representing a fraction of all installations working throughout the country but giving a good insight on their constant development (Table 4).

3.2 Space heating

In 2004, five geothermal space heating plants were operational (Tables 3a and 5). Three plants opened before 2000, i.e. in the Podhale region (1992/1993), in Pyrzyce (1996) and in Mszczonow (1999) were joined by the Uniejow plant (in 2001) and a small one in Slomniki (in late 2002). As each of them uses waters of different parameters, they operate on the basis of different layouts and vary as far as geothermal capacity and heat production are considered. Among them are plants with some gas peaking (Podhale), integrated ones with big gas contribution (Pyrzyce, Mszczonow, Uniejow) and plant integrating groundwater heat pumps with gas and fuel oil boilers (Slomniki). Their brief characteristics follows.

Podhale region. In that region, the 1st geothermal heating project in the country was initiated. Its pilot stage was open in 1992 (Sokolowski et al., 1992). Since 1994 the biggest in the country geothermal heating system has been underway. Heat supply is based on geothermal, with gas peaking.

The main aquifer (artesian) – a subject of exploitation, is hosted by the Triassic and Eocene carbonates at the depths of 1 – 3.5 km. Reservoir temperatures reach up to 80 - 90°C. The maximum flowrates vary from 50 to 150 l/s of 82 - 86°C water. The TDS are at the level of 0.1 – 2.5 g/l (Kepinska, 2000).

By autumn 2001, the heating network was based on one doublet of wells and supplied heat to over 220 buildings and cascaded system (about 21 TJ/y; Kepinska et al., 2000). In late 2001 it was extended by two new wells, other surface facilities (including, among others, 14 km - long main transmission pipeline, geothermal base load plant and gas peak load plant, and distribution networks) and linking considerable part of receivers in Zakopane – the main city of the region (population 30,000, over 3 million tourists/y). As a result, the heat use has significantly increased: in 2003 the installed geothermal capacity was 41 MW_t (not fully used yet) and heat sales amounted to 187 TJ/y (peak gas including, it totalled 247 TJ). By the end of 2003, over 400 individual consumers, 120 large-scale receivers and 25 local coal-fired space heating plants that supplied over 100 blocks of flats were connected to geothermal network.

According to the initial project assumptions, geothermal was planned to supply prevailing number of buildings in the region by 2005. In 2003, the project's target capacity was reviewed and defined as ca. 80 MW_t, and heat production as ca. 600 TJ/y (Dlugosz, 2003). In 2004, further activities were undertaken to decide the ultimate geothermal capacity and heat sales possible to achieve under current economic and market circumstances. Along with the construction of a regional heating network, the R&D works on cascaded uses have been conducted (PAS MEERI). The system comprises the same installations as given in previous report (Kepinska et al., 2000), i.e. wood drying, greenhouse, fish farming and foil tunnels with a heated soil (Table 3a, Table 5).

In the case of Zakopane town, thanks to the introduction of geothermal heating, annual average concentrations of particulate matter PM_{10} and SO_2 have dropped by about 50% in comparison to the period before this heating type was put on-line. Moreover, during heating season of 2001/2002 the SO_2 concentration dropped by 67% as compared to the situation prior to geothermal heating initiation (Dlugosz, 2003). The ecological effect is expected to increase along with the growing geothermal heat sales as a result of connecting new consumers.

Pyrzyce. The heating plant has been in operation since 1996. The aquifer is situated within the Jurassic sandstones at the depths of 1.5 – 1.6 km. It is exploited by two production and two injection wells. The maximum flowrate is 100.1 l/s of 61°C water. The TDS are 120 g/l. The plant's maximum installed capacity is 48 MW_t including 14.8 MW_t geothermal and 20.4 MW_t from heat pumps and 12.8 MW_t from gas boilers. The plant supplies district heating and warm water to 12,000 users out of the town's total population of 13,000. The network water parameters are 95°C/40°C (winter) and 60°C/45°C (summer).

In 2003 geothermal heat sales was 72 TJ/y including ca. 42 TJ extracted directly by exchangers and 30 MWt from heat pumps (Tables 3, 3a, and 4) while the total heat sales was 146 TJ/y. Basically, the exploitation and technical parameters of the plant remain these same as during the past years.

However, both the thermal capacity and heating network were oversized while project planning in early 1990s. The current maximum thermal demand is equal to ca. 27 MW_t. So big decrease of thermal demand after the plant had been launched was caused by closing several factories (planned to be supplied with geothermal heat), thermal modernisation of buildings, bigger energy saving due to installation of thermostatic valves and water-meters by individual heat receivers and, last but not least, by higher outside temperatures in last several years Relatively high costs of produced heat and its price are the result of partial utilisation of installed capacity and large share of gas .Introducing geothermal energy for space heating purposes results\ed in limitation of CO_2 emission to the level of 4,500 tonnes/y as compared to 85,000 tonnes/y before geothermal plant was launched.

Mszczonów. The heating plant was launched in 1999. Maximum 12.5 l/s of 41°C water is produced from the Cretaceous sandstones through a single well drilled in the 1970s and reconstructed for geothermal production in 1996 – 1997. The adaptation of abandoned well (instead of drilling a new one) significantly reduced investment costs. The plant of a total installed capacity of 10.2 MW_t uses geothermal water both for heating and drinking. The heating part of the plant operates as an integrated system: the district heating water is heated to the required temperature by the heat extracted from geothermal water and gas boilers fitted with 2.7 MW_t absorption heat pump and 0.6 MW_t cooler. When cooled down, geothermal water is supplied to the water works and then to consumers as potable one (TDS 0.5 g/l). In the heating season, ca. 30 - 35% of a total heat sales comes from geothermal water (27 TJ in 2003; Table 4). The plant replaced three traditional, low-efficient heating plants based on coal dust-burning (ca. 4,500 tonnes/y). Other emissions were reduced by 75-100% (Bujakowski, 2003).

Assuming identical work conditions and overheads, the costs of producing 1 GJ of heat in the gas boiler plant and in the coal-based plant are similar (gas being slightly more expensive) while in the case of Mszczonow geothermal plant, the cost of producing of 1 GJ is lower by 25%.

Recently, the Municipality of Mszczonow has initiated activities aimed at construction of geothermal swimming and recreation facilities.

Uniejow. The integrated space heating plant was opened in 2001. Geothermal aquifer is situated within the Cretaceous sandstones at the depth of 1.9 – 2km. The maximum production is 18.8 l/s of 68°C water, and the TDS are 5 g/l. Water is exploited in one doublet system. The installed capacity of the plant is 5.6 MW_t, including 3.2 MW_t from geothermal and 2.4 MW_t from peak oil boilers. In 2003 about 50% of heat consumers in the town were supplied by this plant, while the number of connected clients amounted ca. 60%. The total heat sales in 2003 was ca. 20 TJ, with ca. 15 TJ from geothermal (Table 3a). The works on connecting some new consumers are planned. Because of valuable curative features, geothermal water started to be used for recreation and balneotherapy and research of its healing features are in progress.

Słomniki. A small heating system was launched in late 2002. It works as integrated one: a 17°C water produced from the Cretaceous sandstones and sandy limestones by a shallow (314 m) well – heat pumps – gas and fuel oil boilers. The total installed capacity amounts 2.3 MWt, including 0.3 MW_t from geotermal water being a low source for heat pumps (Table 4), while the rest comes from gas and fuel oil boilers. The system supplies the school building and two blocks of flats. When the outside temperature is above -5°C, heat supply is based on geothermal heat pumps (0.25 TJ in 2003) and if it is lower than this value, the system is switched into gas and oil boilers. After cooling in heat pumps, water is sent to the water works as a drinking one (TDS 0.4 g/l). Several other public buildings and a residential housing estate will be connected to the system (Bujakowski, 2003).

3.3 Balneotherapy and other uses

Geothermal waters discharged by springs or wells, with temperatures from 20°C to 62°C, are used for medical treatments in seven spas. Some by-products, like iodine-bromine medical and cosmetic salts, and CO_2 are extracted from geothermal waters. In one locality, production of cosmetics based on geothermal water was initiated (Table 3a, 5). Moreover, the realization of two new projects was initiated in 2001 - 2002 in Uniejow and Zakopane (Fig. 1). In Duszniki Spa the amount of geothermal water available for healing treatments was increased after a new well was drilled. However, it is not in operation yet (chapter 7).

3.4 Geothermal heat pumps

The constant growth in using geothermal heat pumps is observed in the country. They have been working in three geothermal plants (Table 4). As given in chapter 3.2, in Pyrzyce two pumps of 20.4 MW_t total capacity produced about 42 TJ in 2003. In the case of two other plants geothermal heat production is entirely based on them: in Mszczonow, the installed capacity is 2.7 MWt and heat sales was 27 TJ in 2003, while in Slomniki the respective values were 0.35 MW_t and 0.25 TJ/. For these installations one can give the exact data regarding their parameters and heat production. In 2003, they reached 23.5 MW_t and 74.45 TJ (Table 4), contributing significantly to the total geothermal capacities and heat sales by all heating plants in 2003 (total of 62.2 MW_t and 301.25 TJ, respectively). The first heat pump based on ventilation air from a coal-mine in the Upper Silesia (reported at WGC2000; Kepinska et al., 2000) is not in operation after the mine was closed. Besides, ground source and groundwater heat pumps are installed for the individual consumers and office buildings. Its worth to note significant increase of such devices as compared with the previous reported period 1995-2000. According to the available data (Rubik, 2004, Rubik, *personal communication*) one can suppose a number of at least 8 000 ground-source pumps within the country. Their total installed capacity is at least 80 MW_t and heat production 500 TJ/yr (Table 4). The survey to estimate the exact number of units and capacities is a very difficult task, since no system exists allowing to collect all data. In recent years the interest in heat pumps increased especially when their purchasing and installation started to be supported by the national and regional funds of environmental protection or by profitable credits offered by the Bank of Environmental Protection. The observed growth is also connected with the fact that several domestic Polish companies entered the market offering heat pumps cheaper then those made by the foreign producers.

4. GEOTHERMAL DRILLING

In 2000 – 2003 three geothermal exploitation wells were drilled (Table 6): one production (2672 m) and one deviated injection well (2960 m) in Stargard Szczecinski (chapter 6), one well in Duszniki (1695 m) aimed at water production for healing treatment. These gave a total depth of 7327 m. Besides, one shallow (314 m) well was drilled in Slomniki producing 17°C water - a low heat source for heat pumps (chapter 3, 4).

5. PROFESSIONAL PERSONEL ALLOCATION

The country has sufficient professional manpower to run geothermal research, R&D works and projects. Theoretical studies have been conducted by several agencies (as already written, practical works are limited). The leading one is the PAS MEERI involved also in projects running and maintenance of geothermal plants. Proper background exists concerning domestic companies providing geothermal drilling, logging and servicing. At same universities, lectures on geothermal energy were introduced. In 1991-2003, the country was significantly supported by training fourteen persons at the UNU Geothermal Training Programme, Iceland (Kepinska, 2003). In 2000 – 2004, the number of professional personnel working at different fields of geothermal activities and on different scale can be summarized as about 90 person-years of effort, supported by several foreign consultants (Table 7).

6. INVESTMENTS IN GEOTHERMAL SECTOR

The investments in geothermal sector in 2000 – 2004 estimated for 49.57 million USD (Table 8) refer to the field development (drilling, surface equipment) and utilization according to the information provided by space heating plants in operation and underway, additionally they cover also the drilling of one deep well. These figures do not include the funds spent for R&D and many different types of studies and projects by several agencies and paid from several sources (public and governmental mostly). Predominant share in investments (similar to the period of 1995 – 1999) was connected with the Podhale geothermal project.

7. PROJECTS UNDERWAY AND PLANNED

Different stages of four geothermal investment projects were underway in 2004 (Fig. 1):

- The Podhale region: the regional heating project is to be finished in 2005 (basic stage). Since 2001, a large recreation centre has been in construction;
- Stargard Szczecinski: construction of a geothermal heating plant in the town of 75,000 of population. In 2001-2003, a deep production (2672 m) and deviated injection well (2960 m) were drilled. The aquifer is situated within the Jurassic sandstones. During the tests, the well discharged 200 – 300 m^3/h of 87°C water. The plant is expected to start in July 2004.
- Geothermal heat will be extracted by heat exchangers (total capacity 14 MW_t) and it will be sold to the existing coal-fired municipal district heating plant (total capacity 116 MW_t) serving about 75% of local population. This plant will distribute ca. 300 TJ/y of geothermal heat to the consumers via the existing municipal network. It will fully cover the heat demand for warm tap water in summer while during the heating season it will be supported by existing coal-fired plant. Geothermal heat production will reduce the coal consumption by 33%/y (15,194 tonnes/y);
- Uniejów: works on linking next heat consumers. The increase of flowrate is planned by enlarging the production well diameter and other works. The second injection well is to be put into exploitation The R&D on curative features of geothermal water are being conducted, which will be followed by the construction of balneotherapeutical centre;
- Mszczonów: the activities aimed at construction of swimming and recreation facilities; .

- Duszniki: ca. 30°C water tapped by newly drilled well (1695 m) is envisaged to be used for healing treatments and pool, thus increasing the scope of curative services offered in this spa (based so far on 19°C water discharged by one spring and cold mineral water). This will be preceded by well tests and economic feasibility studies.

Apart from the investments underway and expected, many geothermal assessments and projects have been prepared over the reported period. They focussed on heating sector and included different solutions, i.e.: adaptation of abandoned wells; heat pumps; integrated and distributed systems. The area which should form a subject of interest is balneotherapy and recreation. The listed solutions could provide a chance for development by reducing investment costs, increasing the effectiveness of investments and expanding the market. Another interesting idea awaiting practical realization is the use of heat from the underground mines. Some research and project studies are continued on this subject. Recently, the possibility of binary power generation has been considered (theoretical studies and first concepts). It is based on over 80 – 90°C waters which were tapped in some deep wells or are expected to occur at the greater depths.

8. DISSCUSSION AND CLOSING REMARKS

During the reported period of 2000 – 2004, some progress in geothermal direct applications in Poland has been made despite numerous difficulties. Two geothermal heating plants were opened which joined three other launched in 1992 – 1999. The construction of the sixth plant was underway. It is also worth noticing that one of the basic objectives of the Podhale regional project was achieved by linking the town of Zakopane to geothermal grid in 2001. The HPs' development has been recorded expressed by at least 8 000 ground-source instalments (about 80 MW_t and 500 TJ). These facts resulted in reaching the total level of ca. 170.8 MW_t of installed geothermal capacity and 838.3 TJ/y of heat use for the whole country at the end of 2003 as compared to the level of 70 MW_t and 280 TJ in 1999 (Kepinska et al., 2000).

For further progress in geothermal implementation, it is necessary to limit investment costs so as to make geothermal more competitive and marketable than the heat obtained from other sources both fossil and other renewables. With this in mind, emphasis is placed on the design and construction not only of large facilities based on deep wells, but also of smaller installations based on the existing wells, shallow resources and working as cascaded and/or integrated systems.

It is hoped that geothermal facilities in use or under construction will provide further arguments for the feasibility and profitability of geothermal energy, thus helping to elevate it to the more important role in the renewable energy sector and in Poland's sustainable development, which it undoubtedly deserves.

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TABLE 3a. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2004 (other than heat pumps) – showing the installed geothermal capacities and heat sales according to data provided by space heating plants (Podhale, Pyrzyce, Uniejow)

1) I = Industrial process heat; H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling); D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables); B = Bathing and swimming (including balneology)
F = Fish farming; G = Greenhouse and soil heating
K = Animal farming; O = Other (please specify by footnote)
S = Snow melting

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

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
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.

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization					Capa-city[3)]	Installed capacity	Annual Utilization			
		Flow Rate	Temperature (°C)		Enthalpy[2)] (kJ/kg)				Ave. Flow	Energy[4)]	Capacity Factor[5)]	Energy sales (in heating plants)
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(MWt)	(kg/s)	(TJ/yr)		(TJ/yr)
Podhale	D (+G+F+A)[a]	100	87	50	-	-	15.5	41.2	61	241.4	0.49	187
Pyrzyce*	D	100.1	61	28	-	-	13.8	14.8	44.2	174.9	0.40	42
Uniejow	D + B	18.8	68	42	-	-	2.1	3.2	10.0	34.3	0.51	15.0
Cieplice	B	7.5	36-39[b]	26	-	-	0.3	0.3	6.0	10.0	0.8	10.0
Ladek	B	13.8	20-44	30-34	-	-	0.7	0.7	9.8	12	0.5	12.0
Duszniki	B +O[c]	5.5	19-21	20	-	-	0.05	0.05	5.5	0.7	0.5	0.7
Ciechocinek	B	56.8	27-29	20	-	-	1.9	1.9	4.2	2.8	0.1	2.8
Konstancin	B	2.5	29	12	-	-	1.8	1.8	0.1	0.2	<0.1	0.2
Ustron	B	0.9	28	11	-	-	0.6	0.6	0.4	0.6	0.5	0.6
Iwonicz	B+ O[d]	3.0	21	10	-	-	1.4	1.4	0.4	0.6	<0.1	0.6
TOTAL		308.9				-	39.25	65.95	141.6	477.5		258.9

[a]) G+F+A works in a cascaded layout and is supplied with geothermal heat from the main space heating pipeline (ca.1 MW_t and 4 TJ/y); [b]) mixture of 20-62°C water from springs and wells; [c]) extraction of CO_2 from geothermal water; [d]) production of iodine-bromine and cosmetic salts, production of cosmetics

* - Pyrzyce: plant works in integration with heat pumps and gas boilers; Table 3a lists only a part of produced geothermal heat (which totaled 72 TJ in 2003) while the rest produced by heat pumps is given in Table 4

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2004

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

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 (TJ = 10^{12} J)
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. (°C) - outlet temp. (°C)] x 0.1319

or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or water temp. (°C)[1)]	Typical Heat Pump Rating or Capacity (kW)		Number of Units	Type[2)]	COP[3)]	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Ladek	32	60	60	1	W	3	5000	5.2	-
Pyrzyce*	40	10400	20400	2	W	3.5	5400	42.0	-
Mszczonow	41	2700	2700	1	W	1.7	5110	27.0	-
Slomniki*	17	11, 22, 320	353	3	W	3.5	3600	0.25	-
Groundwater and ground source heat pumps**	(- 7) – 20	10 - 200	>80 000	> 8000	V, H	2-6	3800	~ 500	ca. 20% devices used for cooling; exact data not known
TOTAL			>103 563	> 8 000				>574.45	

* - heat pumps in the Pyrzyce geothermal space heating plant are working as parts of integrated layout (see Table 3a and chapters 3 and 4)

** - tentative data (see chapter 4); water source pumps not considered

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2004

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

or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

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

or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

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

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1)] (MWt)*		Annual Energy Use[2)] (TJ/yr = 10^{12} J/yr)**		Capacity Factor[3)]
	Data provided by plants' operators	Acc. to equation	Real heat sales	Acc. to equation	
Individual Space Heating[4)]	-		-	-	
District Heating [4)]	59.2	*31.4*	232.0	*440.6*	
Air Conditioning (Cooling)	-		-	-	
Greenhouse Heating + Fish farming + Wood drying	1.0	*1.0*	4.0	*4.0*	
Fish Farming	-		-		
Animal Farming	-		-		
Agricultural Drying[5)]	-		-		
Industrial Process Heat[6)]	-		-		
Snow Melting	-		-		
Bathing and Swimming[7)]	6.75	*6.75*	26.9	*26.9*	
Other Uses – extraction of CO_2 and salts	0.3	*0.3*	1.0	*1.0*	
Subtotal	**67.25**	*40.15*	**263.90**	*472.50*	
Geothermal Heat Pumps					
a. Absorption (geothermal plants)	23.56	23.56	74.45	74.45	
b. Ground-source	~ 80	~ 80	> 500.00	> 500.00	
TOTAL	**~ 170.81**	~ 143.71	**~ 838.35**	~1046.35	

4) Other than heat pumps

5) Includes drying or dehydration of grains, fruits and vegetables

6) Excludes agricultural drying and dehydration

7) Includes balneology

* Installed capacities are given as follows: left part of the cell – installed capacities (data provided by the heating plants), right part of the cell – according to the equation 1). ** Annual Energy Use is given as follows: left part of the cell – real values (heat sales - data provided by the heating plants), right part of the cell – according to the equation 2).

Note*: In author's opinion more representative for the real situation are data given in left parts of the respective cells (bolded) specially as far as Annual energy use in concerned*

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2000 TO DECEMBER 31, 2004 (excluding heat pump wells)

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 (specify)	
Exploration[1)]	(all)	-	-	-	-	-
Production	>150° C	-	-	-	-	-
	150-100° C	-	-	-	-	-
	<100° C	-	2	-	-	4.367
Injection	(all)	-	1	-	-	2.960
Total		-	3	-	-	7.327

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

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000						
2001						
2002						
2003						
2004	10	50	15	-	10	15
Total	10	50	15	-	10	15

* - The figures refer strictly to professional person-years of effort thus are slightly lower as compared to the analogous numbers reported at WGC2000 showing the number of persons(Kepinska et al., 2000)

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) 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$	%	%
1990-1994				-		
1995-1999**	5.6	8.1	40.8	-	5	95
2000-2004	0.3	11.36	37.91	-	5	95

* - The figures according to the information provided by five space heating plants in operation and one underway.
They also include the drilling of one deep well.
** - The percentage of funding type in 1995 – 1999 was corrected as compared to the figures given in previous report (Kepinska et al., 2000)