The United Nations University
GEOTHERMAL TRAINING PROGRAMME

Kepinska, B.: Geothermal resources and utilization in Poland and Europe
Reports 2003
Number 2, 45-62

LECTURE 3

GEOTHERMAL ENERGY DEVELOPMENT IN POLAND

1. INTRODUCTION

Poland is a country situated in Central Europe. It occupies an area of 323,500 km^2. The population is about 38 million inhabitants. The capital city is Warsaw, with some 1.8 million residents. Poland is a lowland country. The mean altitude is 174 m a.s.l. The Rysy peak in the Tatra Mts. (2,499 m a.s.l) is the highest point. The country lies in the temperate climatic zone with the result that the heating season lasts between 5 and 8 months per year. Owing to diversified geological structure, the country has numerous mineral resources (hard and brown coal, natural gas, copper, zinc and lead ores, halite, sulphur, phosphate rocks, building materials). Among important natural resources are also low-enthalpy geothermal resources. The country has a diversified landscape (mountains, sea, lakes), which abounds with many areas of great natural and environmental values. Forests cover about 28% of the territory. Different categories of protected areas include over 20 national parks.

Since 1989, Poland has been on its way to democracy and to a market-driven economic system. These fundamental social, political, and economical changes were initiated by the Solidarity movement. In May 2004, the country will join the European Union. The energy sector of Poland is based on traditional fossil fuels such as coal, oil, and gas. The first of them remains the main resource as the country has large coal reserves, taking one of the top places in the world. The interest in using renewable energy sources started to grow in the 1980s to 1990s. It was also inspired by the developed countries, including the European Union members, as well as the growing consciousness that energy policy has to be changed. This should result in the reduction of energy consumption, employment of economical and rational energy use methods, diversification of energy sources, and ecological benefits.

The results of research and estimations have proven that geothermal energy has the greatest potential at 90% among all renewable sources accessible in the country. Moreover, Poland is regarded to have one of the largest low-enthalpy geothermal potentials in Europe. The development of activities aimed at practical implementation of geothermal energy for heating purposes was initiated in the mid 1980s. Currently (2003), five geothermal space-heating plants are operational, while some other investment projects are underway. R&D studies of numerous geothermal issues, often of pioneer character, started to develop, and geothermal specialists were trained. Despite various difficulties caused by the political and economic transition period, typical of a number of Central and Eastern European countries, geothermal energy use started to develop gradually. Poland is in the beginning stages of development of geothermal energy use, therefore cannot yet be compared with other more advanced countries. However, the author hopes that some Polish geothermal solutions and experiences will be interesting and useful also for specialists from other countries.

2. GEOLOGICAL SETTING

Poland is situated in a specific part of Europe, where three main geostructural units building this continent meet. They are (Stupnicka, 1989; Figure 3.1):

- Precambrian platform of Northwestern Europe (occupying over half the total area of the continent);

- Palaeozoic folded structures of Central and Western Europe (Caledonian and Variscian), partly covered by the Permian-Mesozoic and Cainozoic sediments;
- Alpine system, running through Southern Europe from the Iberian Peninsula to the Caucasus Mts. In Poland, it is represented by part of the Carpathian range.

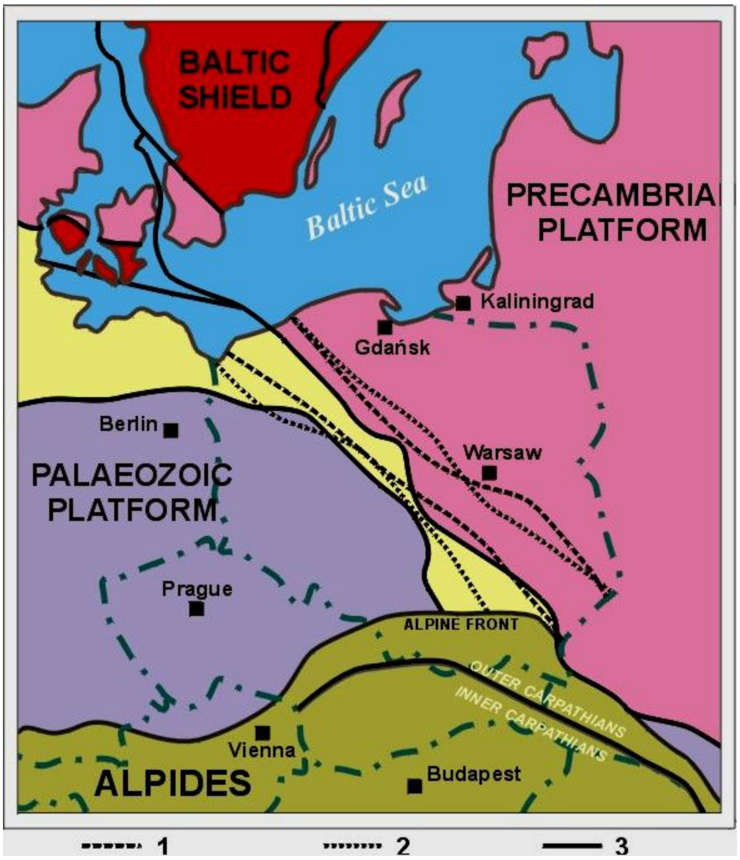

FIGURE 3.1: Geological setting of Poland within Europe
1. T-T zone; 2**.** Polish Trough; 3**.** Inter Cratonic Boundary

Poland is crossed by the Teisseyre-Tornquist tectonic zone (T-T zone). Being one of the most important and interesting geological structures in Europe, it separates two huge continental provinces: Precambrian platform of Northwestern Europe and Palaeozoic structures of Central and Western Europe.

Regarding lithological features of the aforementioned units, crystalline rocks prevail within the Precambrian platform (NE-Poland) and within the Sudetes region (SW-Poland) – the latter being a part of the Bohemian massif occurring mostly on the territory of the Czech Republic. Sedimentary rock formations dominate within the area framed by these two units and stretch from the Baltic Sea coast towards the central and southern part of the country built of the Polish Lowland and the Carpathians. The maximum thickness of sedimentary formations amounts to 7-12 km.

Large thicknesses and significant contributions of sandstones, limestones, and dolomites are characteristic of extensive areas built of sedimentary formations. These lithological rock types often have good hydrogeological and reservoir parameters. Therefore, they create favourable conditions for the occurrence of underground waters, including geothermal ones. Figure 3.2 shows an exemplary geological cross-section through Poland. It illustrates the large amount of sedimentary formations (predominantly of Mesozoic age), sometimes containing proven and potential geothermal water resources.

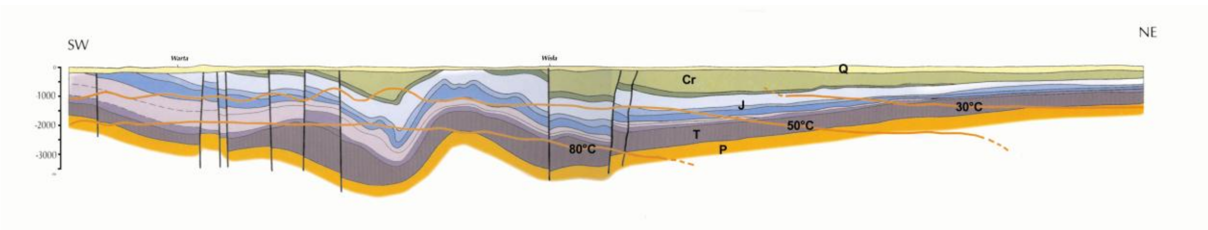

FIGURE 3.2: Geological cross-section through Poland showing a great share of Mesozoic sedimentary rock formations; some of them contain geothermal aquifers (Gorecki [ed.], 1995)

3. GEOTHERMAL CONDITIONS AND POTENTIAL

In general, Poland is characterized by low-to-moderate heat flow values. This parameter ranges from 20 to 90 mW/m2, while geothermal gradients vary from 1 to 4°C/100 m (Plewa, 1994). Thermal regime and geological conditions imply that Poland (similar to the prevailing part of continental Europe) mostly has low-enthalpy resources, predominantly connected with sedimentary formations.

A basic assessment of geothermal potential was conducted in the 1980s, when the interest in practical implementation of geothermal and other renewable energy sources started to grow. It was based on knowledge of geological structure of the country combined with comprehensive analyses and interpretation of data and results coming from several thousands of boreholes as well as geophysical, geological, and hydrogeological exploration and other works carried out for various purposes. These efforts resulted in evaluation of geothermal potential of Poland.

Three geothermal provinces have been distinquished in Poland (each of them being divided into several smaller units, called geothermal regions (Sokolowski 1993; Sokolowski [ed.]. 1995). They are built on extensive sedimentary formations (mentioned in the previous section) which cover about 250,000 km^2, i.e. 80% of the total area of the country and contain numerous geothermal aquifers (Figure 3.3):

- The Polish Lowland Province (ca. 222,000 km^2). The most extensive one with the geothermal aquifers related to sandstones and limestones (Triassic–Cretaceous);
- The Fore-Carpathians (ca. 17,000 km^2). The aquifers are connected with Mesozoic and Tertiary sedimentary formations;
- The Carpathians (ca.12,000 km^2). The aquifers are connected with Mesozoic and Tertiary sedimentary formations;
- The Sudetes region: geothermal aquifers are found in fractured sectors of crystalline and metamorphic formations (Dowgiallo,1976; Dowgiallo and Fistek, 2003).

FIGURE 3.3: Poland – division into geothermal provinces and regions (after Sokolowski, 1993); 1) Geothermal space-heating plants on-line; 2) Underway; 3) Spas using geothermal waters; and 4) Therapeutical facilities under construction in 2003.

Generally, at the depths from 1 to 4 km (technically and economically feasible at present), reservoir temperatures vary from 30 to 130°C. The TDS of waters change from 0.1 to 300 g/dm3. The proven geothermal water reserves, evidenced on the basis of flow tests from the wells, amount from several l/s up to 150 l/s. Static geothermal potentials of rock formations and waters were also assessed for particular provinces and regions (Sokolowski [ed.], 1995). The best conditions are found in the Polish Lowland Province and in the Podhale region (the Carpathians). Attention should be paid to numerous complexes of great regional range, and good hydraulic properties (potential and proven geothermal aquifers) in the Polish Lowland Province, owing to the lithology of the sandstones and carbonates making up the strata.

It should be pointed out that Poland has one of the richest low-enthalpy geothermal resources in Europe. Different but positive opinions are expressed by the professionals regarding the possible scale of their use. Considering reservoir parameters, technical factors and current prices of traditional energy carriers, economically viable geothermal facilities could be built on an area equal to some 40% of Poland's territory (Ney, 1999). This area is believed to be even bigger if another approach was adopted (Sokolowski, 1988; Sokolowski, 1993).

4. ENERGY POLICY OF THE COUNTRY AND PROSPECTS FOR RENEWABLE ENERGY SOURCES

The energy sector in Poland is based on traditional fossil fuels such as coal, oil, and gas. Hard coal remains the main source as the country has large reserves of this mineral, taking one of the top places in the world. Before the 1990s, energy was cheap. Frequently, the prices were below production costs, therefore had to be subsidized. However, in the 1990s, they started to grow and be more real as a result of political changes and introduction of the principles of a market economy. This fact also raised the interest in the potential and use of renewables in Poland which started to grow during the 1980s and 1990s. This was also inspired by the western countries, including the European Union members, as well as the growing consciousness that power policy had to be changed. to achieve a reduction of energy consumption, employment of economical and rational energy use methods, diversification of energy sources, and ecological benefits. Among available renewable energy sources in Poland are hydropower, biomass, wind, and solar energy. Geothermal has undeniably the greatest potential at 90% of total potential of all renewables.

The energy sector in Poland is in the process of transformations. This is a very tedious and costly social, economic, and political operation, hindering the development of the renewables. However, in the last ten or fifteen years, renewable energy sources have been the subject of research and various projects. They have begun to function in society consciousness and have found practical usage in some installations and plants. The EU member countries – which Poland will join in 2004, as well as other industrialised states, develop renewable energy technologies mainly in view of ecological concerns, and in order to reduce their dependence on imports of fossil fuel sources (particularly oil).

In Poland, current consumption of energy is still dominated by hard coal (over 60%); contrary to the global situation where other fossil fuels such as oil and natural gas have similar contributions as coal, i.e. each of these sources reaches some 20 to 34%. Poland has low consumption of renewable energy. In 2001, the market share of all RES, inclusive of waste energy was 6.1% while it did not exceed a level of 3.6% with waste energy excluded (Ney, 2003). These figures are beyond the average global (Table 3.1) and EU-countries' values.

The main document related to the whole sector of renewables in Poland is the Strategy of renewable energy resources development (Ministry of Environment, 2000). According to this document, the share of all renewable energy sources (RES), including geothermal, in energy production will oscillate around 7.5% in 2010 and 14% in 2020. These figures seem to be significant as compared to the current share of all RES in energy generation (ca. 3%), but inadequate for the country's potential and situation in many other European states. Among the main factors behind these low forecasts are the competitive prices of traditional fuels, insufficient financing, and weak institutional and law regulations.

TABLE 3.1: The structure of energy consumption in Poland and worldwide, 2001 (Ney, 2003)

Energy source	Poland		World	
	A (%)	B (%)	A (%)	B (%)
Coal	62.3	65.62	22.0	24.7
Oil	19.6	20.7	34.3	38.5
Natural gas	12.0	12.6	21.2	23.7
Nuclear energy	-	-	5.9	6.6
Renewable energy	6.1[1)]	1.1	16.6	6.5
%	100	100	100	100
Energy consumption, million TOE	93.8	89.8	10225.9	9125.9

A – Including estimated consumption of energy from renewable sources;
B – Including grid system hydropower only;
1) – Excluding waste energy penetration of renewable energy is 3.1%.

Within the sector of renewables itself, geothermal is still unappreciated since other RES are much more strongly promoted. Relatively high investment costs (especially when deep geothermal wells are to be drilled) are indicated as the main reason for such a situation. Moreover, the other cheaper solutions, both working and planned are often neglected and not mentioned even by the opponents.

On the other hand, as one of the main RES accessible in Poland, geothermal should also be promoted in view of Poland's pre-conditions connected with joining the European Union, as the country will be obliged to increase the use of renewables and reduce gas and dust emissions. Considering that geothermal is used in many locations chiefly for heating, it could contribute to a significant reduction of emissions caused by the burning of fossil fuels.

In the case of RES, there still exists no leading institution whose fundamental aim would be to support and coordinate all the activities. This is also one of the important obstacles to increase the share of renewables in the production of primary energy in Poland. On the contrary, there is a strong subsidiary system supporting development of the traditional power industry.

Progress in the development of geothermal as well as other renewables is anticipated due to the amended Energy Law binding power companies to purchase electricity and thermal energy obtained from renewable sources. This law also makes local administrations responsible for managing the heating market, including the use of local energy sources. In Poland, it is geothermal which can fulfil these conditions offering in many cases good reservoir conditions as well as several technical solutions, reliable supplies, and multiple options.

Nevertheless, the few legal acts introduced to date to facilitate the development of the RES sector, especially geothermal, are too general and insufficient. The appropriate economical and supporting instruments are still missing. It is expected that the new fundamental law concerning the renewables' management and development to be introduced soon will create more conducive conditions to wider geothermal development in the country.

As already mentioned, Poland is now beginning a greater use of geothermal. Despite all difficulties, geothermal energy develops gradually. Many solutions and the experience thus far are a good foundation for further development. In view of the accession to the EU, Poland will have better access to the international co-operation, EU funds for energy projects, and will be granted a greater share in RES. Among the most recent international initiatives is GEOFUND – a World Bank fund for minimization of geological risk connected with drilling first wells to be used for geothermal exploitation. Poland is one of the countries which should benefit from this fund.

5. MAIN DOMAINS AND METHODS OF GEOTHERMAL DIRECT USE

Reservoir conditions, ecological reasons, economic factors, and market demand determine current and future main types of geothermal applications in Poland:

- Space-heating;
- Agriculture (greenhouses, heated soil cultures);
- Drying (agricultural, industrial, wood products);
- Aquacultures (fish farming);
- Balneotherapy and recreation.

A key sector for developing geothermal energy use in Poland is space-heating. Wide-ranging application that would be adequate for the reservoir potential, market demand, and social interest would permit limiting reliance on traditional fuels, and eliminate the negative effects of such fuels being burnt. A huge potential lies in cascaded, multi-purpose and integrated types of uses that can be adapted to match a wide range of temperatures and purposes, making geothermal energy more effective, attractive and marketable. The temperatures of waters accessible for practical implementation cover a wide range, from several degrees to over 90ºC.

Several methods can already be applied for exploiting and extracting geothermal energy. This can be realized in the following forms:

- "Deep geothermics": water (or heat) production from deep wells (up to 3-3.5 km);
- "Shallow geothermics": water of low temperatures or heat produced from shallow wells extracted through heat pumps or borehole heat exchangers;
- Natural geothermal springs: 20-45°C water is used by seven spas for healing purposes.

Considerable prospects and expectations are linked with the adaptation of abandoned wells for the purposes of geothermal energy exploitation; several thousands of wells have been drilled within the country so far and some of them may serve for such aims. Such an approach may result in saving a considerable part of total investment costs. Another interesting option is recovery geothermal energy from underground mines in the Upper Silesia Coal Basin (Malolepszy, 1998; Malolepszy, 2000) or in other regions of the country. Another option offers geothermal energy extraction from salt dome structures.

The experience gained so far shows that the particular prospects for geothermal development in Poland greatly depend on the construction not only of large heating systems, but also of smaller installations that will work as multi-purpose, cascaded, distributed, or even integrated systems (i.e. combined both with traditional ones and other renewables as well).

6. GEOTHERMAL DIRECT USES – STATISTICS, 2003

Possessing a long tradition in geothermal bathing and balneotherapy dating back to the 13-14th centuries (Sokolowski et al., 1999; Lecture 1), Poland may still be regarded as a newcomer in the geothermal heating sector. The latter started to be developed in the last decade of the 20th century, and so far five geothermal space-heating plants have been launched.

As compared to the countries leading geothermal applications in Europe, this type of energy has been used on a limited scale mainly for heating, balneotherapy and bathing in Poland. In the middle of 2003 the total installed geothermal capacity amounted to 108.2 MW_t while the heat production was about 455.5 TJ/a (Kepinska, 2003) (Table 3.2). The greatest contributors were five space-heating plants, in particular the plant in the Podhale region; 38 MW_t and 150 TJ/a in 2002.

TABLE 3.2: Poland – geothermal direct uses 2003 (Kepinska, 2003)

Type of use	Installed thermal power (MW_t)	Energy use (TJ/a)
Space-heating and warm water supply	78.2	336.0
Balneotherapy and bathing	18.7	34.5
Greenhouses, fish farming, drying	1.0	4.0
Other – extraction of CO_2, salts	0.3	1.0
SUBTOTAL	98.2	425.5
Heat pumps (estimated)	10.0	80.0
TOTAL	108.2	455.5

Geothermal waters produced by natural springs or boreholes, with temperatures ranging from 20 to 62°C, are used for medical treatments in seven spas (Figure 3.3). The scope of geothermal bathing and balneotherapy is expected to be slightly increased, as some new projects were initiated in 2001-2002 (Section 7). This line of geothermal implementation and some historical highlights are more broadly discussed in Lecture 1.

7. GEOTHERMAL SPACE-HEATING PLANTS – AN OVERVIEW

7.1 General

As already mentioned, the space-heating sector represents the most important and prospective type of geothermal applications in Poland. Since 1992/93, five geothermal space-heating plants have been put into operation in various regions and localities in Poland (see Figure 3.3):

- The Podhale region (since 1992);
- Pyrzyce (since 1996);
- Mszczonow (since 1999);
- Uniejow (since 2001);
- Slomniki (since 2002).

One of the plants is situated within the Carpathian Province (the Podhale region), three are located within the Polish Lowland Province (Pyrzyce, Mszczonow, Uniejow) and one operates within the Fore-Carpathian Province (Slomniki).

As each of these plants is based on geothermal waters of different exploitation parameters, and serves different numbers of consumers, they operate on the basis of different schemes and vary considerably as far as thermal capacity and heat production are considered. Among them are plants with slight gas peaking only (Podhale); integrated plants with considerable gas contribution (Pyrzyce, Mszczonow, Uniejow); and plant integrating geothermal heat pumps with gas and fuel oil boilers (Slomniki). Three plants are based on well doublets and spent geothermal water is injected back to the aquifers while two of them are based on a single well and cooled geothermal water are used for drinking purposes (Table 3.3). Some other space-heating plants under realisation (2003) are described in Section 7.

TABLE 3.3: Poland - main data on geothermal space-heating plants, 2003

Plant	Year of opening	Reservoir $T_{wellhead}$, TDS	Installed power (MW_t)		Working scheme	Remarks
			Geothermal	Total		
Podhale	1992/93	Carbonates, Triassic / Eocene 82-86ºC, TDS<3 g/l	38	42	Geothermal, gas peaking	Under extension – target 80 MW_t, 600 TJ, 2 production +2 injection wells
Pyrzyce	1996	Sandstones, Jurassic 61ºC, TDS 120 g/l	13	48	Integrated, geothermal + heat pumps + gas boilers	Completed - 2 production + 2 injection wells
Mszczonow	1999	Sandstones, Cretaceous 40ºC, TDS 0.5 g/l	3.8	10.2	Integrated, geothermal + heat pumps + gas boilers	Abandoned well adapted for geothermal use; Cooled water for drinking 1- well system, no injection
Uniejow	2001	Sandstones, Cretaceous 60ºC, TDS 8 g/l	3.2	5.6	Integrated, geothermal + gas boilers	Under extension; 1 well doublet
Slomniki	2002	Sandstones, Cretaceous 17ºC, TDS 0.4 g/l	0.3	2.3	Integrated, heat pumps + peak gas boilers	Shallow aquifer, low investment costs; Cooled water for drinking, 1-well system, no injection

7.2 The Podhale region

The plant in the Podhale region (the Carpathians) was the first geothermal space-heating facility in the country. Its experimental stage was designed, constructed, and launched in 1987-1993 (Sokolowski et al., 1992). Since 1994, a large geothermal heating project has been under realisation (target capacity ca. 80 MW_t, heat production ca. 600 TJ/a (Dlugosz, 2003; Kepinska, 2000). By autumn 2001, the network supplied geothermal heat to over 220 buildings. In late 2001, a considerable part of receivers in Zakopane – the main city of the region (population 30,000, over 4 million tourists/year) were connected to the network. By 2005, geothermal will be delivered to the prevailing number of buildings in this city and the whole region. Heat supply will be based on geothermal, with gas being used at peak load. In 2002, the installed geothermal capacity was 38 MW_t and heat production ca. 150 TJ (total ca. 190 TJ). The project forms a study case presented in Lecture 4 in this volume.

7.2 Pyrzyce

The space-heating plant in Pyrzyce (the Polish Lowland Province) was designed and realised in 1991-1996. It has been owned and operated by the limited-liability company "Geotermia Pyrzyce" established by the National Fund for Environmental Protection and Water Management, Pyrzyce County, Voiewodeship Fund for Environmental Protection and Water Management in Szczecin, and the State Treasury. The investment was financed by Polish and some foreign sources (own capital, loans, credits, grants).

The geothermal aquifer is situated within the Jurassic sandstones at depths of 1.4 to 1.6 km. The total thickness of reservoir formation is about 150 m, while the reservoir temperature is 64°C. Static water level stabilises 34 m below ground level. Water is produced with the use of submersible pumps. The maximum flowrate is 103 l/s of 61°C water. The TDS are 120 g/l. The aquifer is exploited by two production and two injection wells. The distance between them is 1.5 km.

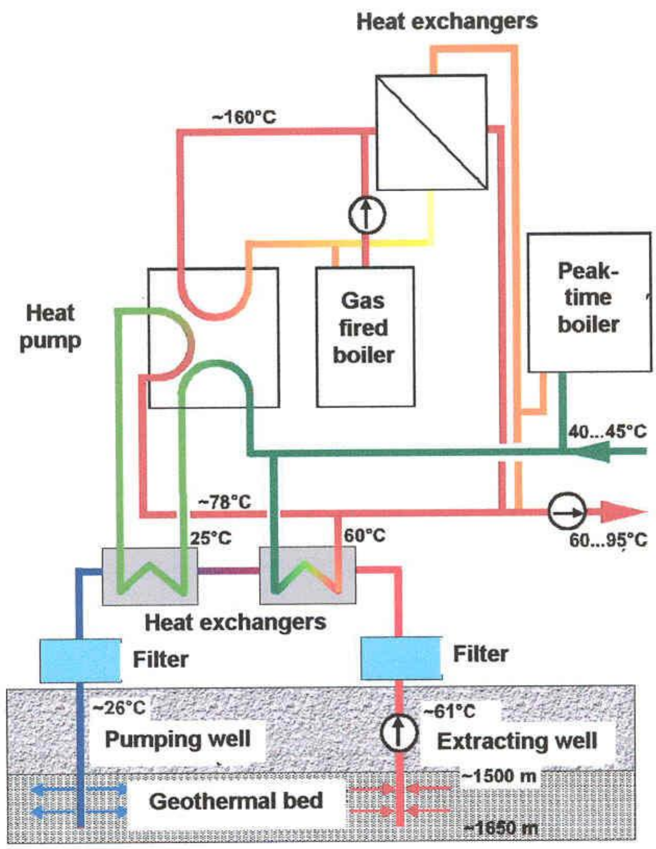

FIGURE 3.4: Pyrzyce – a sketch of a geothermal heating plant (according to Sobanski et al., 2000)

The plant's maximum installed capacity is 48 MW_t including 13 MW_t from geothermal water and 37 MW_t from heat pumps and gas boilers. A simplified sketch of a plant is given on Figure 3.4. The plant supplies district heating and warm water to about 12,000 users out of the town's total population of 13,000, which is about 80% of the buildings in Pyrzyce. Along with construction of a new space-heating plant, a 15 km long new distribution heating network was built within the town. The network water parameters are 95/40°C (winter) and 60/45°C (summer) (Kulik and Grabiec, 2003).

In 2002, geothermal heat production was 95 TJ (Kepinska, 2003). The share of geothermal in total heat generation is about 60%, while the rest comes from gas boilers. The plant replaced 68 low-efficient, coal-based heating plants combusting about 30,000 tonnes of coal annually, and generating considerable amounts of emissions. Table 3.4 shows ecological effects achieved thanks to introduction of a geothermal-gas heating system in Pyrzyce.

TABLE 3.4: Pyrzyce – ecological effect achieved thanks to introduction of geothermal space-heating system (Kulik and Grabiec, 2003)

Type of emission	**Emission (tonnes/year)**	
	Before geothermal system introduction	**After geothermal system introduction**
Dust	240	0
SO_2	660	0
NO_x	38	0.5
CO	100	0.5
CO_2	85,000	4,500

The main ecological and economical advantages of introducing geothermal energy for space- heating purposes in Pyrzyce can be briefly summarised as follows (Kulik and Grabiec, 2003):

- High efficiency of the heating system;
- Heat losses minimization;
- Quick reaction to the needs of the customers;
- Little staff;
- Adjustable production to the changing demand.

However, both the thermal capacity and heating network were oversized while project planning at the beginning of the 1990s. The current maximum capacity reaches approx. 27 MW_t. So a big decrease of thermal demand after the plant had been launched was caused by closing of several industrial factories, thermo-modernisation of buildings, installation of thermostatic valves and water-meters by individual heat receivers and, last but not least, by higher outside temperatures in the last several years. Relatively high costs of produced heat and its price are the result of partial utilisation of installed capacity and a large share of gas. On the other hand, owing to the lower heat consumption in Pyrzyce, the heating cost of 1 m^2 of a house is the same or slightly lower than the average cost of heating with the use of traditional boiler rooms in other localities across Poland.

In Pyrzyce, geothermal water is connected with sandstone formations. These types of rocks are characterised by the presence of clay minerals in a matrix. During water exploitation, these minerals cause some colmatation and plugging of well casings, filters, and reservoir formation. Also some grains of sandstones can be removed, washed out and transported by geothermal water, causing mechanical damages (cavitation). This phenomenon can be stopped by filters installed both in the production casing and in the surface instalment. Geothermal water itself has relatively high TDS, 120 g/dm^3, and in contact with the oxygen it forms a corrosive medium. Therefore, geothermal well casings are made of anti-corrosion substances guaranteeing 30 years of operation. Heat exchanger plates are made of titanium, whereas the geothermal transportation pipelines are of low sulphur or low-phosphorous carbon steel (less than 0.02%). During breaks in deep pump operations, nitrogen is pumped into the geothermal system to create the so-called nitrogen pillow, protecting against the access of corrosive oxygen into the system.

Geothermal water exploited in Pyrzyce contains several chemical components such as chloride, sodium, bromide, iodine, iron and manganese. It has healing properties and can be used for some treatments or bathing. Balneotherapeutic applications are planned as another prospective use, if financial sources to develop this line of activities are available (Kulik and Grabiec, 2003).

It should be noted that the Pyrzyce geothermal project assumed multi-purpose uses, i.e. agriculture, and bathing and balneotherapy. Unfortunately, only the heating part has been realized so far.

7.4 Mszczonów

Mszczonów is a town (population around 6,000) situated within Central Poland, some 40 km west of the capital city Warsaw. This is a very active town, attracting investors with its free economic zone. It takes care of the infrastructure and the use of pure geothermal energy in the municipal district heating system. In the future, the town and the whole county (similar to Uniejów, to be described later in the text) see their prospective economic success in the development of services, e.g. tourism for the inhabitants of the nearby big agglomerations, i.e. Warsaw and Lodz, and the use of geothermal waters for heating, recreation, and balneotherapy.

The heating plant in Mszczonów (the Polish Lowland Province) was launched in autumn 1999. Geothermal aquifers occur within the Cretaceous sandstones and sands at depths of 1602-1714 m. Maximum flowrate amounts to 60 m^3/h of 40°C water. The TDS is low; 0.5 g/dm^3. Water is of high quality and fulfils the requirements of potable water. This feature enables the plant to operate one single production well only, without reinjection (Bujakowski, 2003). The well was drilled in the 1970s. In 1996-1997, it was reconstructed for geothermal water production, according to the R&D project co-financed by the Polish Committee for Scientific Research and the Mszczonów Municipality. The scientific supervision of the project has been conducted by the PAS MEERI Geothermal Laboratory. It was the first time in the country when an abandoned well was reconstructed and adapted for geothermal purposes. It is also worth noticing that the adaptation of an already existing well (instead of drilling a new one) significantly reduced investment costs.

The plant, with a total capacity of 10.2 MW_t, uses geothermal water both for heating and drinking. The heating part of the plant operates on the basis of an integrated system: the district heating water is heated to the required temperature by the heat extracted from geothermal water through a 2.7 MW_t absorption heat pump fitted with gas boilers and a 0.6 MW_t cooler. In the heating season, ca. 35% of a total heat supply comes from geothermal water. When cooled down in the heat pump, geothermal water can be used for drinking (TDS 0.5 g/l) and is supplied to the waterworks (Bujakowski, 2000a). A scheme of the geothermal plant in Mszczonów is given in Figure 3.5.

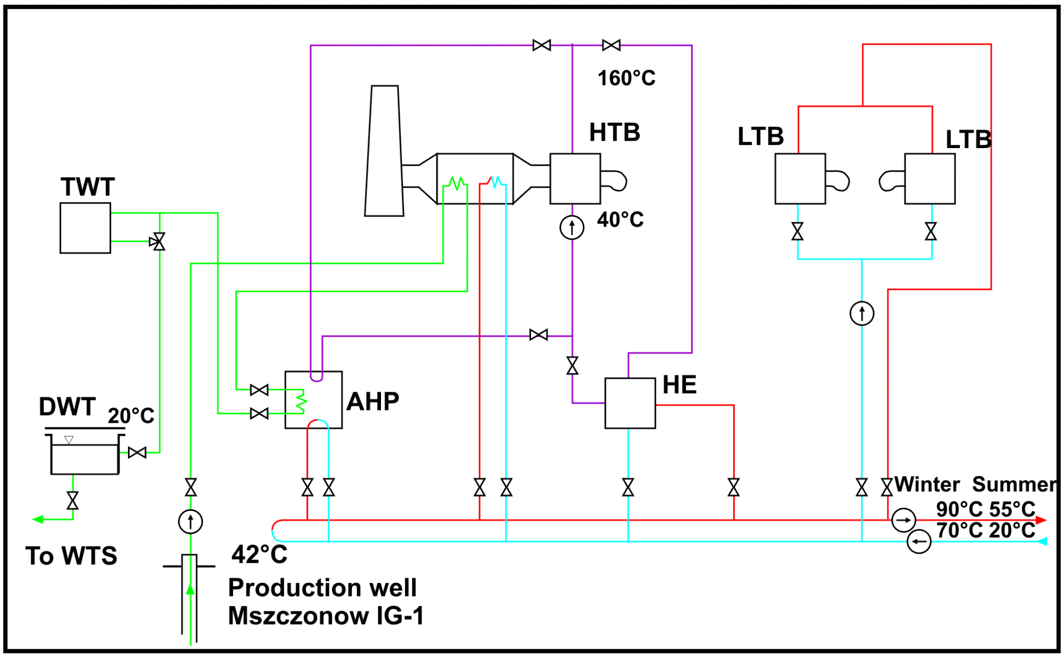

FIGURE 3.5: A scheme of the geothermal plant in Mszczonów;
APH – absorption heat pump; HE – heat exchangers; LTB – low-temperature gas boiler;
HTB – high-temperature gas boiler; DWT – cooled geothermal drinking water tank;
WTS – drinking water treatment station (according to Balcer, 2001)

The geothermal plant in Mszczonów replaced three traditional, low-efficiency space-heating plants. They had been based on coal-dust burning thus generating considerable amounts of emissions. The launch of the geothermal plant resulted in elimination of about 4,500 tonnes of coal annually. Harmful atmospheric emissions were reduced as follows: SO_2 by 100%, NO_x by 82%, CO by 98%, CO_2 by 75%, soot and dust by 100% (Bujakowski, 2003).

According to the analysis conducted by 'Geotermia Mazowiecka' company (the owner and operator of the plant in Mszczonów), 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 the geothermal plant, the cost of producing 1 GJ was lower by 25% (Bujakowski, 2003). Recently, the Municipality of Mszczonów has initiated activities aimed at construction of swimming and recreational facilities based on geothermal water.

The geothermal plant in Mszczonów is one of the most original geothermal heating plants in Poland. This project has been conducted since 1996 in the following aspects (Bujakowski, 2003):

- Reconstruction of Mszczonów IG-1 well which had been drilled in the 1970s and closed in 1976; providing such a technical condition of the well which could ensure its long-term use;
- Accessing geothermal horizon; activation of water production and stabilisation of chemical parameters of produced water;
- Creation of a modern thermal energy source based on an absorption heat pump (using 40°C geothermal water as a low heat source);
- Optimal two-way use of geothermal water for heating and for drinking.

The underground part of the geothermal plant includes:

- Cretaceous sandstones hosting a geothermal aquifer;
- The Mszczonów IG-1 production well;
- Equipment installed in the well and its production facilities (wellhead, downhole pump, probes for measuring water level, temperature, pressure, flowrate, automatic system of data acquisition and processing).

The surface part of the plant includes:

- The wellhead equipment;
- The geothermal pipeline with a signalling and control system connecting the Mszczonów IG-1 well with the geothermal plant;
- A heating unit of peak demand low-temperature oil-gas-fired boilers (2x2.3 MW_t);
- A heating unit consisting of an absorption heat pump (2.7 MW_t) coupled with a high-efficiency oil-gas boiler;
- A DN 50-250 heat distribution network, with a total length of 3.7 km;
- An installation to utilise geothermal water in the existing municipal water-supply network.

Since the geothermal plant in Mszczonów is based on an over 20-year-old well reconstructed and adapted for the requirements of long-term warm water production, it is necessary to systematically monitor the well casing and other facilities – both old and added or installed during reconstruction works. Another specific problem is the sanding-up of the geothermal horizon. This process was first observed upon completion of the reservoir and its testing. Thus further systematic monitoring and measurements, as well as mineralogical and petrographical examination of the rock particles removed from the aquifer and carried out by water to the surface are being conducted. What also requires controlling and examination, is an analysis of the chemical composition of geothermal water, especially the content of chlorine ions. Increased concentration of this element may affect its usability for drinking purposes.

The mentioned issues are only a few of several problems of the Mszczonów geothermal system, production well and plant, and require constant control, further development of a specific methodology of testing, and monitoring. Such activities are being conducted by the PAS MEERI Geothermal Laboratory.

7.5 Uniejów

Uniejów (the Polish Lowland Province) is a small town (3,200 of population) situated in Central Poland. Thanks to natural conditions and landscape, the town and its vicinity are very attractive for the development of countryside tourism, especially for nearby agglomerations of Warsaw and Lodz – two of the largest ones in the country. An integrated geothermal-oil space-heating plant was put into operation in 2001.

This geothermal aquifer is situated within the Cretaceous sandstones at depths of 1900-2070 m. It belongs to the same regional formation which is being exploited in Mszczonów. The reservoir temperature is about 70°C. The maximum flowrate is 90 m^3/h of 68°C water in terms of self-outflow (4 atm static). The TDS are relatively low, at the level of 8 g/dm^3 (Kurpik and Cebulski, 2003).

Water is exploited in one doublet of the well system. The total 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. The system is divided into two segments. One is a geothermal block consisting of a well doublet and heat exchangers, filters and the pumping system between the wells. The second one is the oil block comprising two low-temperature boilers using light furnace oil. The latter block heats the network water up to the required temperatures in the peak demand periods (Bujakowski, 2003) when the outside temperature is lower than -2°C. The heat distribution system includes a pipeline network made of pre-insulated pipes (total length of 10 km), with individual meters and valves.

In 2002, about 40% of heat consumers in the town were already supplied with space-heating and domestic warm water by this plant, while the number of connected clients amounted to 60%. The total heat production was ca. 20 TJ, including 15 TJ from geothermal water. So far, the system replaced 10 local coal-based boiler houses and 160 boiler units in single-family houses. The main pollutants generated previously by coal-burning for heating purposes were eliminated as follows: SO_2 – 31 tonnes/year; CO – 99 tonnes/year; NO_2 – 3 tonnes/year; dust – 33 tonnes/year. It resulted in improvement of air-quality in the town and its vicinity, as well as in considerable limitation of heavy metals contained in by-products generated by coal-burning and introduced to the environment. Works on connecting new consumers to the geothermal network are underway (Kurpik and Cebulski, 2003).

Owing to its valuable curative properties, geothermal water will also be used for balneotherapy and recreation. Medical investigations on healing features of warm water are currently underway. A geothermal swimming pool is going to be opened in Uniejow soon. The combination of geothermal balneotherapy and recreation as well as natural values and many historical monuments of this region of Poland, are anticipated to create very attractive weekend and holidays tourist offers. It should give new possibilities for local economical development, and new places of employment.

7.6 Slomniki

Slomniki (the Fore-Carpathians Province) is a small town (5,000 population) situated in southern Poland. In late 2002, a moderate–scale heating system based on heat pumps was launched. It was an outcome of a project prepared, conducted, and supervised by the PAS MEERI Geothermal Laboratory in cooperation with the local municipality. Currently (2003), the plant is in the initial phase of operation.

Geothermal water is connected with shallow (ca. 305–309 m) Upper Cretaceous (Cenomanian) sandstones and sandy limestones (Figure 3.6). This formation has relatively high water flowrates, in the same cases self-outflows are recorded. On the other hand, in Slomniki and adjacent areas, due to shallow location at depths not exceeding several hundred meters (up to 200-800 m), the reservoir temperatures are low (up to 40°C, sometimes even less than 20-25°C). However, owing to other reservoir properties, this formation has been a subject of R&D works as a potential base for moderate-scale space-heating systems using heat pumps (Barbacki and Uliasz-Misiak, 2003). The project which has been underway in Slomniki is intended to test and implement such a scheme, much cheaper and easier to run than the so-called "deep geothermics".

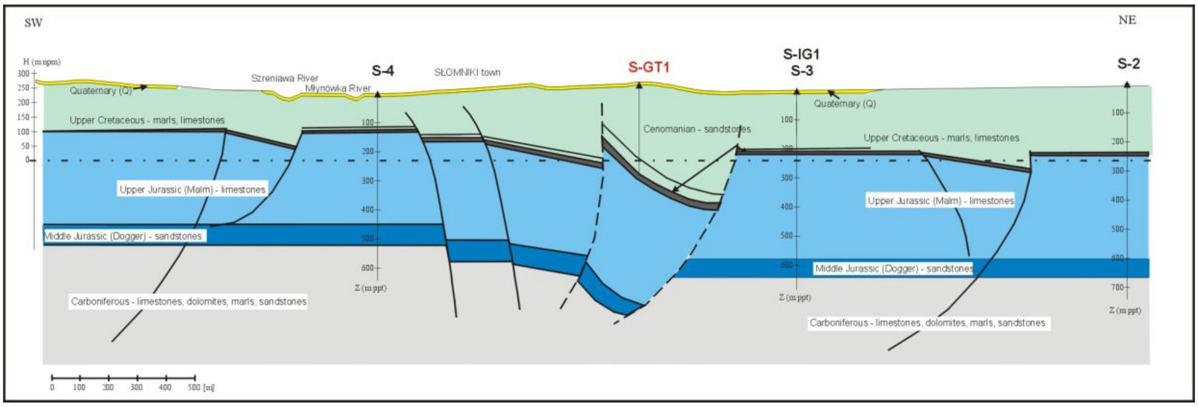

FIGURE 3.6: Geological cross-section through Slomniki area, S-Poland

The system in Slomniki works as an integrated one: maximum 53 m^3/h of 17°C water produced from Cenomanian sandstones and sandy limestones – heat pumps – gas and fuel oil boilers (Figure 3.7). The total installed capacity amounts to 2.3 MWt, including 0.3 MW_t from geothermal water being a low source for heat pumps, while the rest comes from gas and fuel oil boilers. Currently the system supplies the school building and two blocks of flats. When the outside temperature is above - 5°C, the heat delivery is based on geothermal heat pumps; and if it is lower than this value, the system is switched into gas and oil boilers. After cooling down in heat pumps, geothermal water is sent to the water works as drinking water (TDS 0.4 g/dm^3). In the near future, several other public buildings and a residential housing estate will be connected to the system (Bujakowski, 2003).

The case of Slomniki is a good example of moderate – scale installation integrating a low-temperature geothermal energy source and traditional fossil fuels. It is characterised with relatively low investment costs therefore it is possible to be followed by other localities or even individual investors.

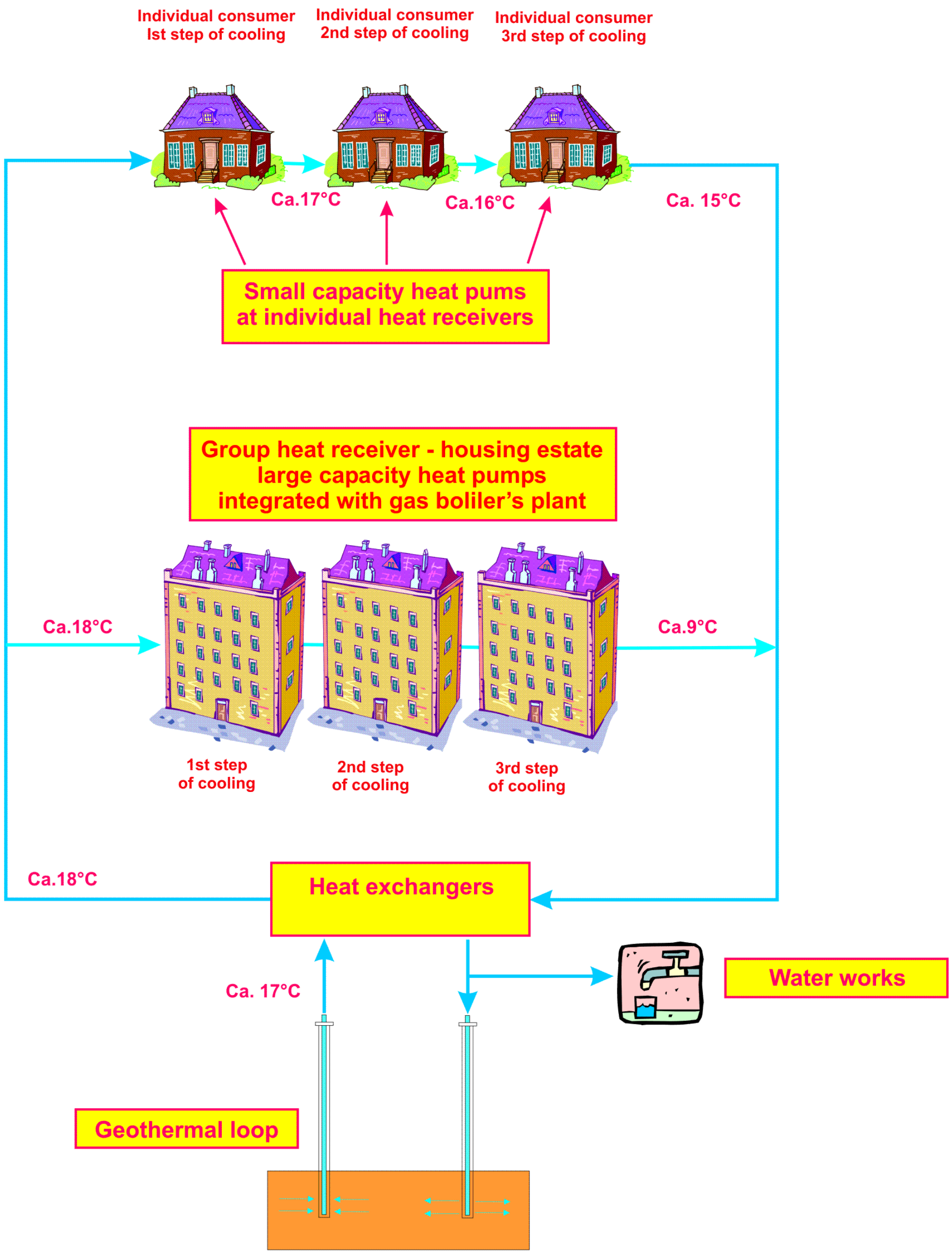

FIGURE 3.7: A sketch of a geothermal plant in Slomniki

7.7 Geothermal heat pumps

Interest in using heat pumps in the geothermal sector has been slowly but gradually rising in the country, although the progress can not yet be compared with the leading European countries, such as Sweden, Switzerland or Germany. Heat pumps have been working in three geothermal space-heating plants (Table 3.3): in Pyrzyce (two pumps of 20.4 MW_t total capacity); Mszczonow (2.7 MW_t); and in Slomniki (0.32 MW_t). The first heat pump, using as a low heat source ventilation air from a coal-mine with a temperature of 16-19°C, was installed in 1997 in the Upper Silesia Coal Basin. Currently, it is not in operation after the mine was closed. However, practical implementation of geothermal heat contained in ventilation air and warm waters pumped out from the underground mines forms a very prospective option, more broadly discussed in Lecture 2. Besides, medium- and small capacity heat pumps based on ground or groundwater are installed for individual consumers and office buildings. Very roughly, one can suppose a number of at least 700-1000 such pumps within the country (installed capacity ca. 10 MW_t and heat production ca. 80 TJ/a). The interest in using heat pumps should increase, especially when the home-made devices which are cheaper than the imported ones will become available on the market.

8. GEOTHERMAL INVESTMENTS UNDERWAY (2003)

Different stages of four geothermal investment projects were underway in the autumn 2003 (Figure 3.3). Some of them concerned the continuation of projects which had already been partly on-line, while some of them were new ones.

The Podhale region (the Carpathian Province**):** The regional district heating system was planned to be finished in 2005. In Zakopane – the main city of the region, a large geothermal bathing centre has been in construction (see Lecture 4 for details);

Uniejów (the Polish Lowland Province): Works going on connecting new heat consumers. Geothermal swimming pool – a part of a future aqua-park, was expected to start in autumn 2003. The R&D on curative features of geothermal water were being conducted, which had to be followed by the construction of a balneotherapeutical centre;

Duszniki (the Sudetes region): So far, ca. 19°C water discharged by one geothermal spring and cold mineral water were used for medical purposes. Recently, a deep (1695 m) well was drilled, and over 30°C water was obtained. Because of highly curative features, it will be implemented for healing treatments and a thermal pool, thus increasing the curative capabilities and scope of services offered in this very popular spa (Dowgiallo and Fistek, 2003);

Stargard Szczecinski (the Polish Lowland Province): Construction of a geothermal space-heating plant in the town with a population of 75,000. The project has been conducted by the limited liability company 'Geotermia Stargard'. In 2001-2003, a deep production (2672 m) and deviated injection well (2960 m) were drilled (the latter being the first directional geothermal well in Poland). The surface distance between the wells is 8 m, while the downhole distance within the reservoir is 1500 m (Kozlowski and Malenta, 2002). The aquifer is situated within the Jurassic sandstones. During the initial well tests, outflow of 87°C water was obtained.

In Stargard Szczecinski, there is no need to construct heating distribution networks and related facilities, as this city possesses large and well-functioning instalments. Therefore, the project focuses on constructing a geothermal base load plant which will consist of a geothermal doublet and heat exchanger units (Figure 3.8). Geothermal heat will be extracted by heat exchangers (total capacity 14 MW_t), and then it will be sold to the existing coal-fired municipal district heating plant (total capacity 116 MW_t) serving about 75% of the local population. This plant will distribute geothermal heat to the consumers in the town through the existing 37 km long heating network and over 250 heat exchanger substations. In such a way, a considerable part of coal burning will be eliminated by geothermal energy (Kozlowski and Malenta, 2002).

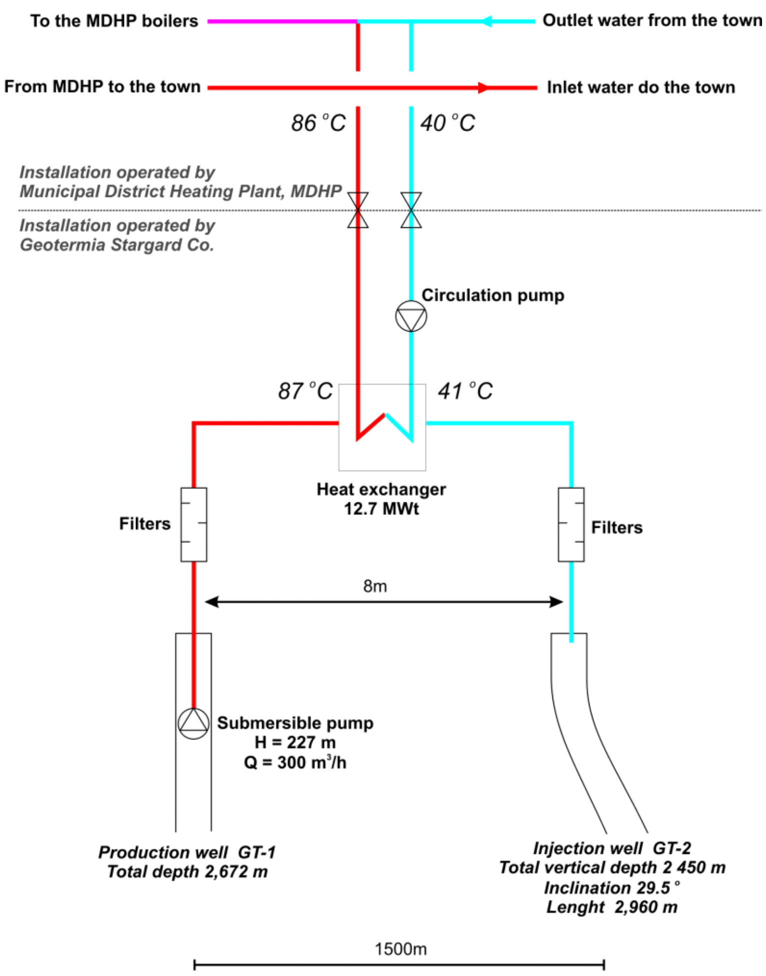

FIGURE 3.8: Stargard Szczecinski - a sketch diagram of a geothermal plant (Kozlowski and Malenta, 2002)

In 2001, the existing municipal heating used over 45 000 tonnes of fine coal while the amount of related emissions were as follows: SO_2 – 466 tonnes; CO – 304 tonnes; CO_2 – 98,747 tonnes; NO_2 – 182 tonnes; dust – 255 tonnes; soot – 2 tonnes (Kozlowski and Malenta, 2002). The geothermal plant is expected to be put into operation in December 2003. It is planned that about 300 TJ/a of geothermal heat will be delivered to the municipal district heating network. Geothermal is assumed to fully cover the heat demand for preparation of tap water in the summer period; while during the heating season, geothermal will be supported by heat produced by the existing coal-fired municipal plant. Geothermal heat production will make it possible to reduce the yearly consumption of coal by 33% (15,194 tonnes/year) as compared to 2001.

During project preparation, special attention was paid to economical aspects to obtain low production costs per geothermal heat unit and its price, therefore making it competitive with the heat received so far by burning coal – the basic and the cheapest energy source. The heat sales price was negotiated at a level equal to 3.8 USD/1 GJ (Kozlowski and Malenta, 2002).

9. RESEARCH IN PROGRESS AND PROJECTS PLANNED

It should be pointed out that apart from the plants on-line and investments under realization, many assessments and projects on geothermal use have been prepared over the last decade for many regions, towns and facilities in Poland. They concentrate on geothermal heating, mainly in the Polish Lowland Province, which is characterised by good geothermal parameters suitable for this type of use (Ney and Sokolowski, 1987; Sokolowski 1993; Górecki [ed.], 1995: Hurter and Haenel [eds.], 2002). When new projects are prepared, the experience of the existing operations is taken into account to minimise the risk and investment costs and to make the projects profitable in specific circumstances also with the traditional fossil fuels and other local renewables in mind.

The research, R&D works, elaborated projects, and activities planned include different schemes and solutions:

- The adaptation of abandoned wells;
- Geothermal heat pumps;
- Cascaded and multi-purpose systems;
- Integrated and distributed energy systems.

These solutions provide particular chances for geothermal development in Poland by reducing investment costs, increasing the effectiveness of investments, and expanding the market. The area which shows great promise for development is bathing and recreation, especially if new facilities would be constructed as a part of the multi-purpose or space-heating oriented projects. Apart from installations based on geothermal energy, systems integrating geothermal with other renewables and even traditional energy carriers are taken into account, depending on local conditions.

However, as given in Section 4, the level and conditions of financing of many innovative and feasible projects are insufficient, particularly from the Polish sources, which is the main obstacle to a wider geothermal use in the country. One should also mention insufficient support by the governmental policy, which could encourage and promote such activities. Despite this, the plants in operation, investments, research, and projects have an impact on the gradual development of geothermal and its social acceptance.

10. INNOVATIVE GEOTHERMAL CONCEPTS AND THEMES

Some innovative geothermal concepts and themes have been initiated in Poland:

- Geothermal heat recovery from underground mines;
- Research of thermal conditions of salt-dome structures and evaluation of their practical implementation as geothermal heat sources.

Recovery of geothermal heat from underground mines is a specific but prospective subject. This idea still awaits practical realization. Research and project studies are continuing on this subject (Malolepszy, 1998; Malolepszy, 2000; Bujakowski, 2001). Salt diapirs – specific tectonic structures formed of Permian saline formations (Bujakowski [ed.] et al., 2003; Pajak et al., 2003) are a subject of the newest research. Such structures are present in the Polish Lowland Province and in other European countries, e.g. Germany. These two issues are discussed in more detail in Lecture 2.

Recently, the possibility of power and heat co-generation using binary schemes has been considered. It may be based on over 90°C waters which were tapped in some deep wells (over 3 to 4 km) or are expected to occur especially within the Podhale region (the Carpathian Province) and within the Polish Lowland province.

11. CLOSING REMARKS

Poland is a country where geothermal has been used on a limited scale for space-heating for a dozen years. Although lacking in spectacular geothermal manifestations, the country has a considerable low-enthalpy potential, placing it among the most prospective countries in Europe. Geothermal energy, similar to other renewables, develops in the shadow of the traditional power industry, the coal industry in particular. 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.

Geothermal seems to gain a significant share particularly in the local heating market in many regions, which will mitigate the level of emissions from the burning of fossil fuels both at a local and regional scale. A high potential for geothermal energy use also exists in the agricultural and food sector, aquaculture, balneotherapy, and recreation, which can be realized in cascaded or multi-purpose schemes.

Experiences thus far indicate that for further successful progress in geothermal energy implementation, it is necessary to limit investment costs so as to make geothermal energy more competitive and marketable than the heat obtained from other sources. With this in mind, emphasis is placed on the construction and planning not only of large facilities based on deep wells, but also of smaller installations which make use of the existing wells, shallow ground and aquifers, and which can work as cascaded and/or integrated systems. In operational geothermal plants, the cost of heat production and sale are lower than for fossil fuels, e.g. gas, oil and electricity, and comparable with the costs for coal (the cheapest but the most contaminating energy source in Poland). It is worth noting that geothermal instalments and the heat itself are heavily taxed.

Geothermal facilities in use or under construction will surely provide further arguments for the feasibility and profitability of geothermal energy, thus facilitating the raising of funds for research and project delivery, and helping to elevate geothermal energy to the more important role in the renewable energy sector and in Poland’s sustainable development, which it undoubtedly deserves.