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GEOTHERMAL ENERGY IN POLAND: THE STATE-OF-THE-ART IN 1998 AND FUTURE PROSPECTS

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ABSTRACT

The constant geothermal progress in Poland dates back to the 1980's. The country possesses rich low-enthalpy resources found in some 80% of its area. Geothermal use is localized, but in some places can be important (reduction of emissions from coal burning for heating). Direct use is planned to concentrate on space heating, horticulture and recreation (cascaded and integrated systems, applying of abandoned wells). The biggest project ongoing is in Podhale region (elimination of 350,000 tons coal/a); R&D works and cascaded use are advanced there. In 1996, a 50 MWt geothermal heating plant started in Pyrzyce town. Some other projects are ongoing (including water production both for heating and drinking). Basic research, servicing background, high education and promotion are also developed. The UNU Geothermal Training Programme has an important role in creating the core of Polish specialists and geothermal development. Two former Fellows are very active in this field. Among their achievements are PhD. theses, in which they applied knowledge and skills gathered in Iceland.

1. INTRODUCTION

According to the UNU Geothermal Training Programme tradition, each of the Fellows presents the geothermal status in his country during a special seminar. In 1991 and 1994 when geothermal research activity in Poland started to grow, three Polish Fellows gave such reports (in 1998 a brief account was given by the current Fellow). The author of the paper, Fellow of 1994, is honoured to have a chance to again present the state and prospects of Polish geothermics, at the 20th Anniversary Workshop 1998 held in Iceland. Since 1994 constant progress has been observed in this branch in Poland. In view of current research results, Poland can be perceived as resourceful and capable of using geothermal potential. Several activities have been undertaken, with the participation of former UNU Fellows, discussed later.

2. GEOTHERMAL RESOURCES IN POLAND

The Polish territory is built of fragments of three main European geotectonic elements, the platform area (defined as the Central European Province) consists of the East-European Precambrian platform, the

Figure 1: Geothermal resources in Poland; frames show localities where geothermal projects are ongoing (1998), * show health spas using geothermal waters from natural springs or wells (Ney and Sokolowski, 1987)

West-European Palaeozoic platform and the Alpine orogenic area (the Carpathians). The following main geothermal provinces have been distinguished (Ney and Sokolowski, 1987; Sokolowski, 1995): the Sudetes, the Polish part of the platform of the Central European province (the Polish Lowland), and the Polish part of the Fore-Carpathian and orogenic Carpathian province (Figure 1, Table 1).

Poland is characterized by low to moderate heat flow values of 40-90 mW/m^2 while geothermal gradients amount to some 2-3°C/100 m. Therefore, to the depths of 3 km (technically and economically viable at present) low-enthalpy geothermal waters are found, with temperatures of 100-120°C.

Over 80% of the Polish territory is built of Mesozoic-Tertiary sedimentary basins with numerous geothermal aquifers. Of the 251,000 km^2 prospective area, 222,000 km^2 belong to the Central-European province, 17,000 km^2 to the Fore-Carpathian province and 12,000 km^2 to the Carpathian province (Table 1). The characteristics of the main provinces are as follows:

- The Polish Lowland contains 7 geothermal regions. The aquifers are related to sandstones and limestones. The temperatures range from 30 to 120°C (1-3 km). The water salinity (TDS) ranges from 1 to 300 g/dm^3. Geothermal resources have been estimated for over 6,225 km^3 of water with thermal energy equal to 32,458 million toe;
- The Fore-Carpathian province contains aquifers with temperatures of 25-50°C. Geothermal resources have been estimated for 361 km^3 of water containing thermal energy equal to 1,555 million toe;
- The Carpathian province has 100 km^3 of waters with thermal energy equal to 714 million toe.

Taking into account the present prices of conventional energy, feasible geothermal installations can be built in about 40% of the Polish area. Preference is given to the following aquifers: max. depth 3 km, min. flowrate 30-40 l/s and temperatures 65-70°C. Such conditions are frequent in the Polish Lowland while in other provinces they are of local character. From the actual technical and economic point of view, the use factor of geothermal waters is expected to be 0.2 (i.e. some 4 mld toe). This is a lot when compared with the documented resources of coal and hydrocarbons some 17.5 mld toe (Ney, 1997).

Table 1: Main characteristics of geothermal provinces and regions in Poland (modified from Ney and Sokolowski, 1987)

Geothermal provinces and regions	**Surface (1000 km²)**	**Water resources (km³)**	**Water resources (M toe)**	**Ongoing projects 1998**
Central Europe province (Polish lowland)	222	6,225	32,458	
1. Grudziadz-Warsaw region	70	2,766	9,835	Mszczonow, Zyrardów, Skierniewice
2. Szczecin-Lodz region	67	2,854	18,812	Pyrzyce
3. Fore Sudetic-North Holy Cross r.	39	155	995	
4. Pomorze region	12	21	162	
5. Lublin region	12	30	193	
6. Peribaltic region	15	38	241	
7. Podlasie region	7	17	113	
Fore-Carpathian province	17	361	1,555	
Carpathian province	12	100	714	Podhale region
TOTAL	**251**	**6,687**	**34,727**	

3. THE STATUS OF GEOTHERMAL ENERGY IN POLAND

3.1 Geothermics in the energy policy

Similar to other renewable energy sources, geothermics in Poland grow in importance only locally (and will continue to do so in the future). In some localities, however, it can become a significant factor in environmental protection and the energy market. Geothermal research and projects are not fully co-ordinated yet. Besides, financial support from the budget and beyond-budget sources is still insufficient. Among the main constraints there are competitive prices of conventional energy, political and social problems connected with the modernization of the coal mining industry and maintaining the level of employment. However, the growing interest of local self-governments and individual customers should enhance geothermal development. Proper legal regulations and preferences are needed.

Aside from ecological reasons, geothermics should be preferred in Poland in view of the European Community prospects. The country must fulfil many preconditions, to make practical use of renewable energy. By the beginning of the coming century it is expected to reduce dust and gas emissions to the admissible level established by the EU. At present, emissions caused by fossil fuel combustion are in almost all cases (ash, SO_x, NO_x, CO_2) higher in Poland than elsewhere.

Along with air pollution, there also exist other kinds of impact connected with conventional energy sources of the mining, power and heat industry (solid pollutants constitute 60% of all industrial waste): contamination of rivers with mining brines, soil contamination with hydrocarbons, distortion of the groundwater systems, surface disturbances, etc. This can be reduced to some extent, if not eliminated, by using geothermal energy. In Poland, this means decreasing the low-emissions from the combustion of considerable amounts of coal in low-efficiency heating plants (Ney, 1997).

3.2 Types of geothermal application and methods of exploitation

Reservoir conditions, technical and economic factors, market demand and climate predetermine types of geothermal direct applications in Poland. Expected applications include:

- Space heating;
- Horticulture (greenhouse farming, heated soil cultures);
- Drying (agricultural, industrial and wood products);
- Fish farming;
- Balneology and recreation.

Methods of geothermal exploitation will be realized in closed systems (doublets of production and injection wells) in the following forms:

- „Deep geothermics": water production from deep wells (up to 3 km). When new wells have to be drilled, this method turns out to be expensive (which can hinder or even stop investment). Here the idea of adaptation for geothermics of abandoned wells, seems to be promising - some thousand wells have been drilled throughout Poland so far and in part of them geothermal aquifers were encountered. Such methods may result in saving 40-50% total investment costs of the project. The results of initial research and development studies on this problem are very interesting.
- „Shallow geothermics": water production from shallow wells. Thermal energy is extracted mostly with heat pumps or borehole heat exchangers. This method is under study and in the first stage of implementation, but it should prove to be much cheaper, faster in realization and sufficient for a number of uses. Both abandoned wells can be adapted and new ones drilled. Heat extraction from coal mine discharge waters is also being considered (e.g. Malolepszy, 1998).
- Utilization of geothermal springs: warm water (20-45°C) is used by several spas for therapeutic purposes (Figure 1). Among the oldest ones are Cieplice Resort (dating back to the 12th century) and Ladek Resort (11th century). At present eight out of 36 Polish spas apply warm water from springs or wells (Sokolowski, Sokolowska and Kepinska, in print).

In most cases, cascaded use is preferred as most efficient. Some of the geothermal installations will operate as coupled systems with heat pumps, peak gas boilers and other renewables.

3.3 Institutions involved in geothermal activities

The constant progress in activities aimed at geothermal utilization in Poland dates back to the 1980s. They were originated at the Mineral and Energy Economy Research Centre of the Polish Academy of Sciences (re-named in 1998 into Institute - PAS MEERI) and University of Mining and Metallurgy in Cracow. The institute is a geothermal leader in Poland, carrying out a broad range of researches and development projects; its team designed and started up the first Polish experimental geothermal plant (Sokolowski et al., 1992). Research projects are also conducted to some extent by a few other institutions. Their financing comes mostly from the state budget (of the Committee for Scientific Research).

Commercial geothermal investments are presently realized by three joint-venture companies. Their main share-holders are the National Fund for Environmental Protection and Water Management, localities interested in the projects and operation companies. Investments are financed from Polish means (National Fund for Environmental Protection and Water Management, Ecofund, counties, geothermal companies) and foreign sources (PHARE Fund, World Bank, Danish Government).

Several Polish companies undertook co-operation with investors supplying specialist services and equipment. This created technical and servicing background for geothermal investments, giving favourable prospects for the future - growing impact of Polish thought and employment benefits. Research and promotion are also stimulated and realized by the Polish Geothermal Association.

3.4 Geothermal research

Along with feasibility studies and utilization projects, there is a gradual development of detailed research on geothermal reservoirs and systems under exploitation conducted for already operated fields, applying proper geothermal methods, as well as useful methods of hydrogeology and oil/gas exploration. Many of them were initiated by former UNU Fellows. Presently, the largest scale research is conducted in the Podhale region. This area is best known, even if some problems are still to be sorted out. The amount of data, and the role and scope of research will increase along with geothermal progress in Poland. The research covers the basic spectrum of geothermal issues, focussing on the geology of geothermal systems, reservoir engineering, modelling and monitoring. Other processes are also controlled (scaling, corrosion) and further aspects taken into consideration.

3.5 Geothermal education and promotion

In the last few years, geothermics have been included in the syllabuses of the University of Mining and Metallurgy, Cracow – a prominent Polish academic centre. In 1996 a new line „Petroleum geology and geothermics" was introduced at the Faculty of Geology, Geophysics and Environmental Protection. At the Faculty of Fossil Fuels and Energy, geothermics was created as a subject for specialization. The first specialists are expected to graduate in 2000. Geothermics is also included in the syllabuses of other universities and of Postgraduate Environmental Studies. It has also been chosen as the topic of several M.Sc. theses. Conferences and courses play an important role in the dissemination of knowledge, research results and promotion. It is worth mentioninng the courses jointly organized by the Polish Geothermal Association with the PAS MEERI. Among international events, one should notice the Field Trip into Slovakia and Poland preceding the World Geothermal Congress in Italy, 1995.

An exceptional place in education and promotion is held by the PAS Geothermal Laboratory (in the Podhale region) where a geothermal system *works* and wide information is available. A special education programme has been prepared by the author of this paper, which treats geothermal promotion as an obligation for a former UNU Fellow (Kepinska and Nagel, 1997). A similar information role is played by the geothermal heating plant in Pyrzyce town. Thus, the knowledge of geothermics and its social approval are gradually reaching wider and wider circles of society and decision-makers.

4. GEOTHERMAL PROJECTS CURRENTLY (1998) REALIZED IN POLAND

The most advanced geothermal projects are realized now in the towns of Pyrzyce, Mszczonów, Skierniewice and Żyrardów (the Polish Lowland Province) and in the Podhale region (the Carpathian province; Figure 1). Some other projects are in the first stage of investment or about to be realized.

4.1 The Pyrzyce project

The town of Pyrzyce is located in NW-Poland (population ca. 13,000). It belongs to the large Szczecin-Lodz Region (prolonged to west in the German territory, where geothermal waters are used in some places). The best aquifers occur in the Lower Jurassic sandstones (total porosity 20-30%) at depths of 1.5-1.6 km. The total reservoir thickness amounts to some hundreds of metres. Reservoir temperatures are in the range of 70°C. The total dissolved solids reach 120 g/dm^3.

The geothermal heating plant in Pyrzyce was commissioned in 1996. The aquifer is tapped in two production and two injection wells. Production from one well is 47 l/s of 61-63°C water. With its installed capacity of 55 MWt, the plant covers the heat demand of the whole town, supplying central heating (95/45°C) and warm water to 12,000 customers. The plant operates as an integrated system: heat exchangers-absorptive heat pumps-gas boilers. With water production of 94 l/s, a capacity of 15 MWt is obtained from geothermal water; the rest (40 MWt) comes from heat pumps and condensation gas boilers. The geothermal share in such a system changes from about 60% in winter to 100% in summer (hot water for household use). The plant replaced 68 traditional heating plants (20,000 toe/a). The dust and SO_x emissions were eliminated totally, whereas NO_x and CO_2 emissions were reduced 12 and 5 times, respectively. The geothermal plant in Pyrzyce is one of the biggest and most advanced in Europe. Geothermics is expected to spur the development of the city and its surroundings, and apart from the district heating system, is planned for use in recreation and agriculture (Sobanski, 1996).

4.2 The Skierniewice, Zyrardow, Mszczonow projects

These towns are located in Central Poland in the Grudziadz-Warsaw region. The best aquifers occur in the Mesozoic sandstones. The Jurassic aquifer (0.7-1.2 km thick) is situated at depths of 1.5-3 km. Reservoir temperatures range from 40 to 80°C. The flowrate is estimated at 28 l/s, TDS 120 g/dm^3. The Cretaceous aquifer is situated at depths of 1.5-1.7 km. The reservoir temperatures range from 40 to 50°C, flowrate is assessed at 28-56 l/s, TDS are very low: 1-2 g/dm^3. The plan is to use the geothermal energy for heating, agriculture and recreation. The latter is promising, as that area forms a recreation background for the two biggest Polish cities, including Warsaw - the capital.

In the cities of Skierniewice and Zyrardow (40,000 population each) the tests of two deep wells (2.5-3 km) were successfully conducted in the last years. At present (autumn 1998), the projects require further funding. For both cities, the integration of the geothermal heating systems with absorptive heat pumps and boilers is planned. This will eliminate 70,000 t coal/a (Bujakowski and Balcer, 1997). Geothermal heat can also be used for a greenhouse complex - one of the biggest in Central Europe.

In the town of Mszczonow (6,000 population) the most advanced geothermal project in Central Poland is realized. It concerns the exploitation of the Lower Cretaceous sandstones, containing high quality drinking water. The novelty of this project lies in water production from an abandoned well, for both space heating and drinking: heat extracted from geothermal water (ca. 40°C) with a heat pump and heat exchangers, will be used for space heating, while cooled geothermal water will then be directed to the customers as potable and sanitary water (Bujakowski and Balcer, 1997).

Since 1996, the target project „*The pilot station for water and heat recovery from the reconstructed well Mszczonów IG-1*" has been conducted by the PAS Geothermal Laboratory (financed by the Committee for Scientific Research and the Mszczonów county). The pilot station is expected to be started up in 1999. The described solution is prospective for geothermal conditions in Poland and even in other European countries. Locally, it may solve two significant problems: supply of a clean energy carrier and of high quality drinking water (deficient in many regions).

4.3 The Podhale region project

4.3.1 Background

The Podhale region (475 km^2) is situated in the Carpathian province (Figures 1 and 2). The only Polish mountains of alpine character (the Tatras) are located there. This region is believed to be one of the most attractive regions in Poland and Europe with exceptional natural, cultural and tourist features. For years the excessive pollution has exerted an unfavourable influence on the natural environment. The most serious are air, water and soil pollution due to coal burning for heating purposes. In past years a lot of activities have been undertaken to stop the degradation. The most efficient is the project of a big-scale utilization of geothermal water for space heating and other purposes, started in 1987 (Ney and Sokolowski, 1987; Sokolowski, 1988, 1993). The Podhale region has excellent geothermal conditions. Geologically, it belongs to extensive Tertiary tectonic depressions, now surrounding the older (Palaeozoic-Mesozoic) massives (mainly in the Slovakia territory).

4.3.2 Main geothermal parameters and method of exploitation

Geothermal artesian aquifers occur in the Middle Eocene and Mesozoic limestones, dolomites and sandstones, which underly the Palaeogene flysch (max. thickness 2.5-3 km). The main aquifer is characterized by the following max. parameters: reservoir temperature 90-100°C (wellhead temperatures 80-93°C); production from an individual well 55-140 l/s; total reservoir thickness some hundred metres; TDS in the range of 0.1-3 g/dm^3; wellhead static pressure 27 bar. This is an excellent fracture-type reservoir, controlled tectonically, with permeability to 1000 mD.

Since the 1970's, geothermal water (wellhead temperatures of 26-36°C) discharged by 2 wells has been used in swimming pools in Zakopane - the main centre in the Region.

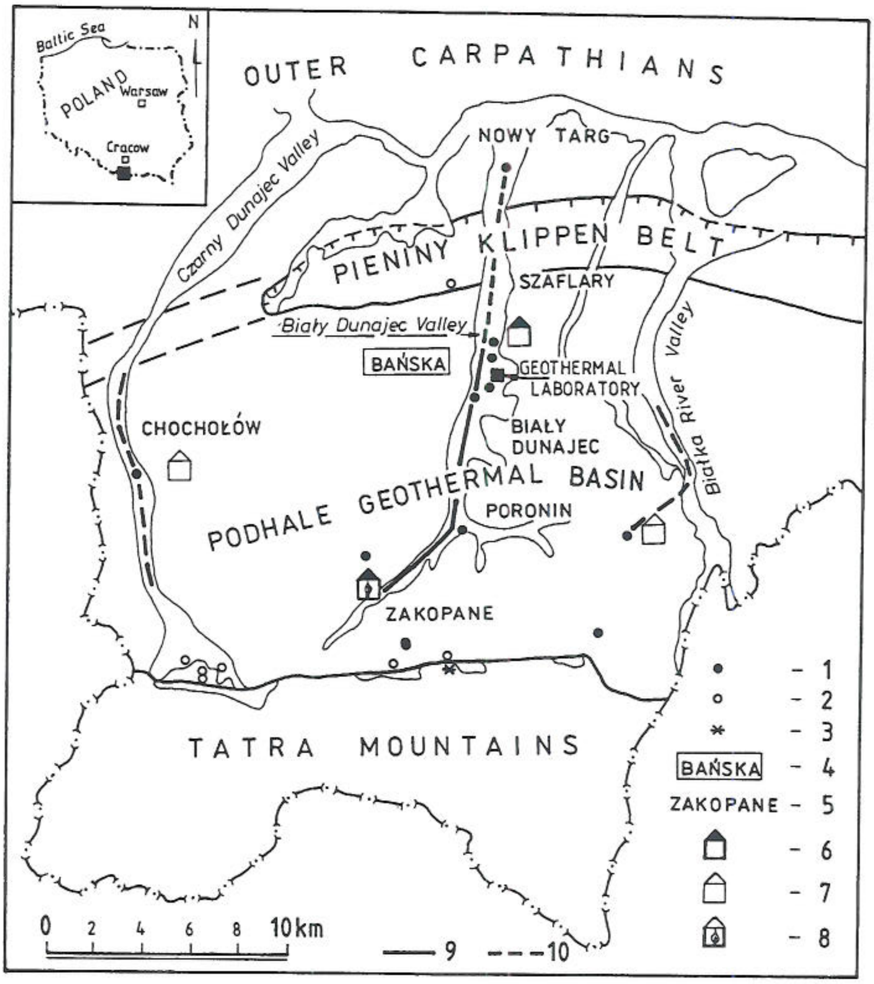

Figure 2: Sketch of the Podhale region (S-Poland) and geothermal heating network (under construction); 1. Geothermal wells (T_w>20°C); 2. Other wells; 3. Geothermal spring (existing till the 1960s); 4. Locality with geothermal district heating system on-line; 5. Localities planned to be geothermally heated (the years 2000-2002); 6. Geothermal heating plant 50 MWt (commissioned in 1998); 7. Geothermal heating plants planned; 8. Central peak heating station 50 MWt (commissioned in 1998); 9. Main transmission pipeline (under construction); 10. Transmission pipelines planned

The basic step to develop geothermics in the Podhale region was taken in 1981 when results obtained from deep (5,261 m) well Banska IG-1 revealed aquifers with favourable parameters (Ney and Sokolowski, 1987). This caused further broad activities. In particular, they resulted in constructing the first Polish experimental geothermal plant (in 1995 re-named a Geothermal Laboratory) by the PAS MEERC (Sokolowski et al., 1992). In 1993, several houses in the nearby village Banska started to be supplied with geothermal heat from that plant. In order to construct a large-scale geothermal heating network in the Podhale region, a commercial company, Geotermia Podhalañska Co., was established in 1994. By autumm 1998 it had installed a geothermal network in about 200 buildings. Further R&D activities and experimental uses have been realized by the PAS Geothermal Laboratory.

So far, the geothermal system is based on the doublet of the production and injection wells. Production amounts to 8-16 l/s of 76-80°C water. The static artesian pressure is 26 bar, TDS some 2,6 g/dm^3. The aquifer is situated at depths of 2560-3345 m. Maximum capacity is about 13 MWt geothermal (water cooled to 20°C); now it is about 6 MWt (water cooled to about 45°C). Geothermal heat is transmitted to the fresh water in heat exchangers. After heat extraction, the geothermal water is injected back to the same reservoir (open hole 2117-2394 m). Heated fresh water (65-78°C) is supplied to customers, who have individual exchangers for taking the heat from the distribution system.

At present, activities in the Podhale region concentrate on construction of a large-scale regional geothermal heating network and secondly on research and development work and experimental cascaded use.

4.3.3 Construction of a large-scale regional geothermal heating network

The above project is realized by the Geotermia Podhalañska Co. (headed by a UNU Fellow from 1991). By the year 2001, the company will supply geothermal heat to some 8,000 customers in the central part of the Podhale Region (Figure 2), with the city of Zakopane (population 30,000) - one of the two biggest towns of the Region (Dlugosz, 1997). The next biggest city of Nowy Targ (population 30,000) is planned to be connected in the years 1999-2002. The project will aid in the elimination of 350,000 ton coal/year and most of the gas and dust emissions (Table 2).

Table 2: Ecological effects due to the realization of geothermal heating network in the Podhale region (from Dlugosz, 1997)

Type of emission	Present level (ton/year)	Planned level (ton/year)	Reduction rate (%)
CO_2	239,367	21,418	91
SO_2	1,119	0	100
NO_x	195	18	90
CO	557	11	98
Dust	300-400	0	100

In autumn 1998, work was concentrated on introducing geothermal heat to Zakopane and connecting ca. 25% of all its customers by the year 2000. As a whole, ca. 70% of all buildings in this city are planned to be connected. Heat supplies will principally be based on geothermal power, with gas boilers in peak periods. Already completed in the years 1996-1998: two geothermal wells (a doublet); a geothermal heating station (installed capacity 50 MWt geothermal); a central peak heating station in Zakopane (50 MWt); part of a transmission pipeline linking the geothermal station with the central heating station in Zakopane (ca. 6 km of 14 km planned). The total investment cost amounts to some 70 million USD. The project is financed by the National Fund for Environmental Protection and Water Management, Ecofund, PHARE Fund, the Danish Government, the World Bank and the Geotermia Podhalanska Co's own means. The price of geothermal heat will be up to 20% lower than traditional heating plants. After the investment has been completed in the central part of the Podhale region, the work will be continued in its western and eastern parts (Figure 2).

4.3.4 Research and development work and experimental cascaded use

These projects are conducted by the PAS MEERI Geothermal Laboratory. They concentrate on cascaded use of geothermal water after passing through heat exchangers, and the use of thermal energy in the returned water (from customers in the heating network). The 20-65°C waters are applied for several purposes.

The cascaded use system consists of the following main elements (Figure 3):

- District heating system (ca. 200 buildings in Bañska village; operated by the Geotermia Podhalañska Co.);
- Space heating and warm water supplied to Geothermal Laboratory objects;
- Wood drying chambers;
- Greenhouses;
- Fish farming (African sheatfish - *Clarins gariepinus*);
- Foil tunnels for plant growth on heated soil.

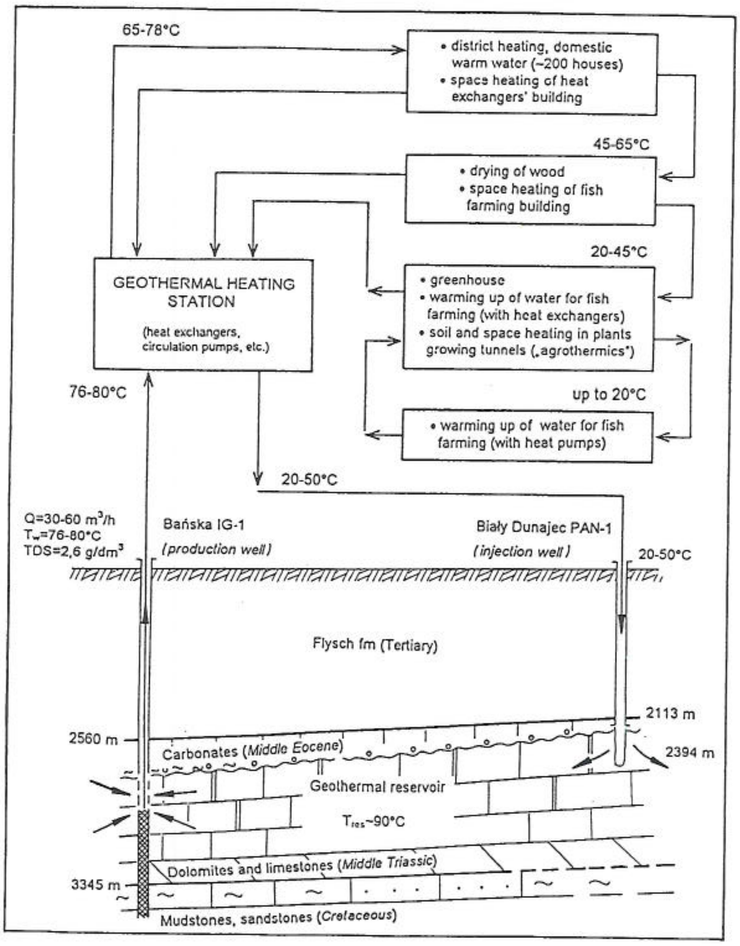

Figure 3: Sketch of the geothermal cascaded use in the PAS MEERI Geothermal Laboratory (the Podhale Region, S-Poland)

In the mentioned objectives, geothermal energy is recovered in the range of 80-45°C or even below 20°C; in the lowest range of temperatures it is used for water preparation in fish farming with the use of a heat pump. In 1998 the project *„The use of geothermal energy to intensive vegetable growing and fish farming"* was completed. The results clearly show that heated soil makes it possible to grow crops in the Podhale Region with its severe climate conditions. The project was conducted using Polish experiences gathered during the operation of similar objectives, based on traditional energy carriers or waste heat (Rosik-Dulewska, 1996). The experimental methods are expected to win the approval of local farmers and other investors (all over Poland). This has already been observed, especially with fish farming. The Geothermal Laboratory deals also with the monitoring of geothermal systems. At present, it conducts the project *„Integrated monitoring system of geothermal water and installations"* (financed by the Committee for Scientific Research). Additionally, it conducts geothermal education and promotion (mentioned previously). Apart from the discussed uses, there is a growing interest in applying geothermal water for recreation. Two such big projects are about to start.

To sum up, there are premises to treat geothermics as an important factor in environmental protection and the economic development of the Podhale Region. Social acceptance of its special role is evidenced by the position it occupies in the *Development Strategy for the 3rd millennium*. It is also worth noting that Zakopane is a candidate city for the organiser of the 2006 Winter Olympic Games; this will spur geothermal promotion and development, if we are really to have "ecological Olympic Games".

4.4 Other geothermal projects ready for realization

Since the 1980s aside from the present ongoing projects, the PAS MEERI (including the Geothermal Laboratory where the author is employed) and other companies have prepared a lot of projects for a number of Polish voivodeships (13 out of 49), counties and cities, e.g. Warsaw (the capital of Poland) and some recreation centres. They often make use of abandoned wells, cascaded and coupled systems. These projects are in the first stage of realization or await decisions on financing.

5. ROLE OF THE UNU GEOTHERMAL TRAINING PROGRAMME IN GEOTHERMAL DEVELOPMENT IN POLAND

So far, three Fellows from Poland have completed the UNU Geothermal Training Programme in Iceland: two in 1991 and one in 1994. One Pole is also graduating in 1998. We hope that in the coming years other Fellows from our country will also have a chance to attend the training programme. All Fellows who completed the training were employed in the PAS MEERI, pioneering in geothermal development in Poland. They worked in the team elaborating the first geothermal projects in Poland, e.g. designed and supervised the first Polish Experimental Geothermal Plant. Till now, two former Fellows are active in geothermics in the Podhale Region, whereas the 1998 Fellow works at Silesian University.

All the Polish Fellows agree that the training equipped them with very extensive and professional knowledge (inaccessible in Poland in such a scope as in Iceland). We learned modern techniques and methods. Much could be profited from the training thanks to the versatile preparation of the Fellows during their studies and some previous professional experience. This created a basis for further development of knowledge gathered in Iceland, in respect to Polish geothermal conditions.

The topics of the reports on reservoir modelling and temperature aspects of the Podhale field, prepared during training, were then continued and supplemented. In particular this resulted in two PhD dissertations (first in Poland strictly on geothermics): in 1996 „*The physical model of the Podhale geothermal reservoir*" by P. Dlugosz (1991 Fellow) and in 1997 „*Geological and geothermal model of the Podhale Basin*" by the author of this paper (Kepinska, 1997). The latter was granted a prestigious annual Reward of the Polish Academy of Sciences in 1997.

The gathered knowledge facilitates our regular daily work and the undertaking of new projects. Since 1994 P. Dlugosz has presided over the Geotermia Podhalańska Co. constructing a large-scale geothermal heating system in the Podhale. He specializes in reservoir engineering. The author of this paper is employed as a tutor in the PAS Geothermal Laboratory. She deals with geothermal research, direct uses, and data elaboration from new wells invested by the Geotermia Podhalańska Co. In the near future, she hopes to start a new interesting project on fluid and heat circulation in the Podhale geothermal system (to some extent, inspired by the Training). She is also involved in education, having many chances to present Icelandic geothermics as a model example of successful development.

The training was successful because of high scientific levels and perfect organization. Professionalism and involvement of all teachers have had a positive effect on us, given inspiration towards further work, regardless of the time elapsed from training. Now we can see the actual results related to it. All persons involved in the training have a share in our success. Another precious experience to be remembered by all of us is the feeling of unity of purpose in the international geothermal community - born among special people and in a special place - Iceland. The exceptional majesty of Icelandic nature made many of the Fellows think of the fragility of human technology severed from natural laws; Icelandic society is a prominent case of respecting natural laws on behalf of successful and sustainable development - a perfect example to follow.

To sum up, let me quote a proverb heard from the 1994 Chinese fellow: *„If you have a friend even in a distant part of the world, he will become your neighbour one day".* I am sure the Icelandic people have many neighbours by now ...

ACKNOWLEDGEMENTS

In the 20th Anniversary of the UNU Geothermal Training Programme in Iceland, all the Polish Fellows: Maria Gladysz (1991), Piotr Dlugosz (1991), Beata Kepinska (1994) and Zbigniew Malolepszy (1998) extend congratulations to Director Dr. Ingvar B. Fridleifsson, Dr. Einar Elíasson - who recommended the first Polish fellows, to the teachers, administration staff and all involved persons. We express our gratitude to the heads of the United Nations University, Icelandic Authorities and Orkustofnun - the National Energy Authority for the Fellowships, imparted knowledge and skills. The time spent together on work at Orkustofnun, field trips and social meetings shall stay in our kind memories forever.

On the threshold of the third millennium we wish you satisfaction and achievements in educating geothermists all over the world. We hope to see you in Poland as our guests so that we can present our geothermal advancements in which you share. Speaking for herself and in the name of the Polish Academy of Sciences, the author of the paper extends her thanks for the honour of being invited to participate in the Anniversary and the delivery of this paper.

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