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THE STANDARD SYNOPTIC REPORTS ON GEOTHERMAL POTENTIAL

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ABSTRACT

In the search for cleaner energy, local governments are considering the possible utilization of geothermal heat from both deep and shallow zones. The Polish Geothermal Association is engaged in the preparation of special reports for land-use pre-feasibility plans. Two kinds of complex reports are being prepared - regional and local. Both are based on geological, technical and economic data accessible in published and archived materials. Some basic data are available via the Internet from the www pages of the State Main Statistics Office. The original contributions to the reports are various suggestions concerning methods of heat extraction and utilization, considering local climate, population, topography, recreation facilities and industrial conditions. All kinds of data that contribute to a complex analysis of reported geothermal potential, and their importance, are discussed. This paper is based mainly on experiences from two areas in Poland. One is sited in the northwestern part of the Polish Lowlands, the other in the mountainous area of southern Poland. The former extends over 30 000 km^2 of mostly arable land with over 150 local governments, while the latter, mountainous area with many tourist attractions is divided between several dozen local governments. The report on the former was originally produced in a complex mode for the whole area, and that for the latter was divided into separate sub-reports having a joint core and individual comments, proposals and data, especially those relating to shallow, low-enthalpy geothermal energy.

1. INTRODUCTION

The Polish Geothermal Association (PGA) strongly supports the idea of the preparation of pre-feasibility reports on country geothermal potential for regional and local governments. The action has two aims. One is a gathering of basic geothermal data for land-use and feasibility plans, and the other is largely the promotion of and information on new and waste energy sources, available practically for everyone. Eye-catching drawings, maps and photos are considered as very informative materials supporting merit presentation.

News needs time to sink in, in order to be understood, accepted as public knowledge and, finally, supported (Fig. 1). It has been found that even the best ideas are usually rejected on the spot if they have never been heard about before. This is the purpose of the repeated invitations to geothermal schools sent by the PGA to decision-makers, local government officials and potential investors. These actions have begun to pay off after seven geothermal schools have been run.

The number of requests for consultations and reports related to the geothermal potential of particular areas is slowly growing. Some governmental institutions, regional Energy Conservation Agencies and politicians already support the PGA informative action.

Poland lies between latitudes N49:30 and N54:30. The sun's appearance is erratic, winds are unstable and moderate, and there is a lack of significant geothermal anomaly zones. However, resting at a triple junction of the three geothermal provinces in Europe, Poland has an average heat-flow rate (Plewa 1991) of about 65 mW/m^2, which is higher than the world continental average, and is rich in geothermal waters. The average annual surface temperature is 7 to 9^{o}C.

The need for a clean, sustainable energy source in Poland arises, strangely enough, from the high reserves of coal. Poland, mining over 200 million tonnes annually of black coal and lignite, is over 90% powered by coal energy. The primary users are electric and district heating power stations; however, in most households coal is burned directly in stoves and simple boilers for cooking, space heating and providing domestic hot water. Coal is rich in pyrites and non-flammable dust particles, so that the country is polluted with exhausts containing not only carbon oxides, but also sulphur oxides, and fly ash.

In order to reduce the rate of pollution caused by coal burning, a vast gas network has been developed to supply communal and industrial users with a cleaner energy source. A considerable contribution to the reduction of carbon and sulphur oxide emission has come from the installation of high-efficiency boilers in district heating plants. These reduce emission of sulphur oxides and dust, but carbon oxides are still emitted. The only practical solution for reducing the emission of carbon oxides remains the development of geothermal installations.

Knowledge of the energy potential of geothermal heat in Poland, and proposals for its practical use, were signalled by many geologists, especially after World War II (for example S.Z. Rozycki, J. Golab, K. Schoeneich, S.Sokolowski), but their opinions were either considered as being too futuristic, or simply neglected. The practical use of geothermal energy was introduced due to the determination of Professors R. Ney and J. Sokolowski, who made the first geothermal station in the Podhale region in Poland into a model solution. In particular, J. Sokolowski (1993) was able to convert local people and environmentalists into believers in the superiority of geothermal energy. This was a significant breakthrough in public knowledge, but most of the officials from the country's energy system circles still remained reserved.

Presentation of the advantages of using geothermal heating systems is somewhat difficult due to a lack of many good examples, but negative examples of traditional heating systems are at hand (Fig. 2).

Cooling towers, which waste heat energy by definition, poorly insulated hot-water pipelines, smoky chimneys, and antediluvian furnaces and boilers of 35% efficiency are easy to find.

For example, the amount of energy wasted in one giant power and heating station due to its hot exhausts, temperature drop in pipelines (Figs. 4 & 5), low-efficiency radiators at the users' end, and leakage of hot water is measured in thousands of TJ annually. Moreover, the giant heating systems emit an accordingly high amount of CO_2, which cannot be absorbed by the green environment around.
However, a chance for a change is coming. Official advisors to the Ministry of Power currently present the opinion that the mammoth district heating stations with hundreds-of-kilometres-long distributory network systems, which deliver water of temperatures well over 100^0C to the users, should be replaced by a dispersed system of energy producers.

Apart from the necessity of solving problems with waste energy and pollution, Poland has some other specific advantages in promoting geothermal energy. These are as follows:

1) Several thousand abandoned wells exist in Poland (Bojarski 1996), two, three or more thousand metres deep. Some of the existing wells may be turned into geothermal energy suppliers by down-hole heat exchangers or, more efficiently, as the case may be, by pumping out geothermal water.

2) Numerous large district heating systems, with modern coal or gas boilers and a distributory pipeline network, growing in number in most of the towns and cities in Poland are, in principle, easily convertible to a geothermal heating source.

3) The geological structure of Poland to a depth of over 3000 m is well known, and geophysical, geological and hydrogeological data have been published or are available in archives.

Thus, turning geothermal energy into a common source of heat will be simple, if local governments are convinced of the practical and economic reality of such a move. This is the situation that the Polish Geothermal Association is dealing with.

The synoptic information packets to be delivered to interested local authorities are normally divided into sections containing information on geology, geothermal potential and pre-feasibility studies. Presentations of cases of wasted energy, in particular illustrated with pictures or simple diagrams, have considerable impact on public knowledge.

2. ECONOMIC AND ENGINEERING STUDY

2.1. Basic information

Basic knowledge on the geothermal potential of Poland is gathered on the basis of published and archived data. Geothermal structures are outlined with respect to structural maps of the base and top of water-bearing formations.

Heat flow is determined from a published contour map of heat-flow density in Poland (Plewa 1991), which is based on a limited number of boreholes. Therefore, local values are checked with available data from the nearest exploration borehole.
Hot-water-bearing formations, named after stratigraphic units, are characterised with quantitative data, i.e. regional structure, thickness, depth, porosity, average temperature, and hot-water volume.

2.2. Estimations

The geothermal heat potential is estimated by various methods of calculation. The following factors are usually taken under consideration:
1 - The total heat content in rocks and water;
2 - The 3^oC drop of rock massif temperature;
3 - The total heat content in geothermal waters; groundwater temperature drop to 20^oC; groundwater temperature drop to 8^oC;
5 - Natural heat-flow energy at various depths of penetration i.e. at 400, 3000, 5000 and 7000 m;
6 - Reinjection and various means of heat extraction applied i.e. down-hole heat exchanger, pumping-out of water.

Maps of temperature distribution at depths of 1000, 2000, 3000, 5000 and 7000 m are produced; combined with maps of thermal capacity and conductivity they provide essential information on the expected heat productivity of a single well. For areas expected to be deficient in geothermal waters, down-hole heat exchangers are considered a proper solution.

As a basic solution the construction of deep, geothermal wells with reinjection doublets is proposed.

For the less productive wells, down-hole heat exchangers (Morita et al. 1992) are suggested as the most suitable solution. This concerns mostly already existing wells, which have either been abandoned by the petroleum industry or are dry, drilled by a geological survey for cartographic or general purposes (Bojarski 1996).

Cheaper, but not necessarily more economic, installations are as follows:

- Shallow (less than 400 m deep) wells with a reinjection system. One well 400 m deep may provide water at 20^0C, which, with the use of a heat pump, may give an output power of 5 kW/l/^{0}C. Production of 5 litres of water per second, and a 6^0C drop in the temperature of water which is put back into the same well, equals 130 kW of thermal power. About 40 kW of electric, gas or oil power would however be needed to power the heat pump.

- Shallow water wells. Water wells, which supply households with fresh water, could be utilized as a source of heat, if the temperature drop in the water pipeline system was not greater than 3^0C. Out of several intakes, some would be used for heat extraction, and the cooled-down water could be mixed with water coming from other intakes. The expected power calculation would be similar to that described above.

- Down-hole heat exchangers in shallow wells. Installation of down-hole heat exchangers in shallow wells is recommended when groundwater in a reservoir is flowing, thus cooled-down water is substituted by in-flowing water of higher temperature. It is estimated that at least 50 kW of thermal power can be extracted out of a well, if the flow rate in the heat exchanger is 3 l/s and the temperature drop is 4^0C.

- Utilization of atypical geoheat and waste heat energy sources (Ostaficzuk 1996; Malolepszy & Ostaficzuk 1999), namely:

- Mine waters. In mining areas of Poland the recent exploitation of coal is accompanied by pumping out of about 0.8 million m^3 water daily from down-mine, of which over 0.5 million m^3 daily is let into rivers (Ney, 1992; MOSZNiL 1999). Water temperature in many mines exceeds 25^0C (Kurowska 1999). Use of the heat of mine waters is recommended wherever applicable, i.e. in coal mining regions. There are two ways of using mine-water heat, which are alternately considered: direct use, and with a heat pump support.

- Mine ventilation air. Each coal mine is ventilated via several vertical shafts, which exhaust 10 000÷20 000 m^3 of air per minute. The temperature of ventilation air at a shaft outlet is lower that that of mine waters, because of a decompression effect. Heat from ventilation air may be used via a heat exchanger installed in or near the ventilation shaft outlet, or by delivering that air via ventilation pipes directly to the user, e.g. the balloon cover of a sports arena.

- Down-mine heat exchangers. In mines over 1000 m deep, heat exchangers can be installed in the fill of abandoned mining corridors. Thick-walled pipes should be insulated, and filled up with liquid. Down-mine heat exchangers may operate as heat collectors in winter and as heat distributors in summer.

The following recommendations for the use of heat from down-mine are given. Coalmine heat can be added to existing heating systems at the ground surface, can be considered a lower heat source to a heat pump, or can be directly used in fish-farms and in snowmelt installations. The last installation can be used in summer for the cooling of asphalt surfaces, e.g. in car parks or on bridges. Another application of down-mine heat exchangers already considered is in cooling down burning coal seams behind the fire dam.

- Abandoned mine heat. Heat from abandoned mines can be extracted in two ways: by down-mine heat exchangers installed in mine fill or in waters in mine spaces left without fill. Considerations are given to another method of extracting heat from an abandoned coal mine - a production well drilled down to mine spaces.

- Mine waste heaps, settlement pool heat and swamp heat. Coalmine wastes contain up to 10% of dispersed coal substance, which is subjected to slow oxidation. In a country where more than 200 million tonnes of coal is extracted annually, piled wastes are producing heat, which dissipates uselessly at present. Dr A.Dybciak from the Nowa Ruda coalmine has decided to seize this power (Fig. 6).

Considerations are given to coupling that heat source with geothermal heat, which is extracted from mine waters or from swamp waters, whichever is more applicable. Swamp heat exchangers are, generally, more fitting as a supplementary heat source for individual users, to be combined with other heat sources and to be used for collecting cold in summer.

Practically, all of these installations have to be combined with heat pumps (Rybach 1998). This diminishes their economic coefficients by approximately 1/3, but still remains attractive for users dispersed in the countryside or living close to existing low-temperature sources of heat.

This section of a report is supplemented with a matrix worksheet with algorithms and unit values. Quick calculations are done, after unit values are substituted according to local data. This allows for general assessment of energy potential, and amounts of fuel saved. Therefore, one can easily calculate economic risk before any further planning is done.

Availability of heat energy from various sources is presented for a standard sheet map quadrangle (1:50 000), 1 km^2 of terrain, an administration unit (of varying acreage), and for selected spots.

2.3. Recommendations

The next set of information provided to potential users relates to possible applications of geothermal heat under local conditions. Normally, the head of local government is given a report containing all the available information on the geothermal potential of his administration area, and a pack of pre-feasibility proposals tailored to local needs. Special proposals are given after engineering studies have been carried out. Climate conditions, population density, heat energy requirements, existing heating systems, development prognoses and master plans all are analysed, and solutions are recommended.

Low-temperature geothermal energy must be hybridized with electric or gas heating systems - for cooking, powering pumps and providing additional heat at peak demand in heavy winters. For smaller installations, for individual users, electricity is usually considered as a coupling source of energy, while for bigger users (e.g. district or communal installations) gas is usually better as a powering source to be coupled with geothermal facilities.

Recommendations are of two kinds. One is made according to realistic possibilities, and the other relies on further inventions.
Amongst the realistic recommendations are:

- District space heating.
- Individual space heating.
- Domestic water heating.
- Fish farming.

Fish farming seems to be one of the most practical solutions for rural communities. Poland in medieval times had many ponds in which fish were produced in great quantity for court, nobles and innkeepers, where anybody could eat them.

Recently, most fish farms have been abandoned in a central planning era, and due to climate changes. The use of cheap heating energy may help in the restoration of former fish farm utilities, and help local people in their economic struggles. The above recommendations apply to existing situations, are understandable by the local public, and may be realized without much risk (Fig. 7).

The proposals for which realization will need additional investment planning are:

- Sports facilities.

For communities with sporting traditions, general recommendations are made for building sports centres, which would use geothermal energy. Outlets of the mine ventilation air, or down-mine waters, are especially good for the exploitation of geothermal heat with minimum engineering investment.

The following solutions have been taken into consideration already for specific locations. An all-season golf course with drying and snowmelt installation, an ice-hockey stadium, a toboggan course, a soccer stadium with snowmelt and drying installation, a recreational ski-slalom course, an Olympic training centre with space heating and swimming pools, and open-air tennis courts with drying systems. In particular, snowmelt systems may work at temperatures as low as 15^0C and even less, and may be installed at the end of cascade utilization of geothermal heat.

- Recreational facilities.

In many local communities, unemployment rate has risen, while production in local manufacturing or on farms has diminished. Those located in mountainous areas or on intensive traffic routes (e.g. near international border crossings) are recommended to build recreational facilities for tourists and passers-by. According to specific location and the kind of geothermal heat source, swimming pools, fitness clubs, or even new spas are recommended, and location of sports-halls and other auditoria are suggested wherever warm air from mines is available.

- Food-processing.

With the end of a central planning system, farmers and gardeners have trouble selling their fresh products, either due to a lack of time for marketing or because of a seasonal lack of demand. Co-operative food-processing facilities would provide a positive solution, especially if clean geothermal energy were available at an acceptable price. Fruit drying and freezing, producing juices and jams on a local need, could provide eco-clean food for markets in neighbouring agglomerations.

- Hay dryers.

Hay dryers are not common in Poland for economic reasons. If energy were cheaper, many farmers would consider having one, because of the unstable summer weather conditions; a considerable amount of hay rots in the fields in the wait for sunny days. The use of heat remaining in return waters from geothermal installations would help.

- Snowmelt systems.

Poland is plagued by damage caused by salt which, mixed with sand, is extensively used in winter for de-icing and snowmelting of side-walks, pavements and road surfaces - especially pedestrian crossings, bridges and parking areas. Soils become saturated with salt so that trees in avenues die, and pedestrians have their shoes spoilt; the most expensive damage is that to vehicles, which are subjected to salted sand-jetting while they are on the move. Using thermal snowmelt systems in crucial places would reduce salt damage accordingly, and also increase road traffic safety in winter (Fig. 8). All such damage is apparent and obvious to the public, so that proposals for snowmelt systems working on a waste-water heat are received with at least passing interest.

- Other recommendations.

Among “others”, various forms of heat storage are recommended. Most of the described geothermal heat sources, except deep wells, are fit to be seasonal heat stores. All heat sources, on the other hand, could be seasonally utilized as stores of “cold”. In Poland, air conditioning is not yet very common, but it is a good time to introduce cooling installations when heating systems are modernised. Having that in mind (Ostaficzuk, 1996), a description of possible heat/cold storing facilities is included in recommendations.

3. CONCLUSION

Standardisation of reports on geothermal heat potential, as recommended by the PGA, makes possible the rapid and comprehensive unified description of many areas. The energy balance may be easily provided for an area according to its administrative, regional or standard sheet boundaries.

Somewhat futuristic plans may have a psychological impact on the imagination of local planners, designers and potential clients. Even if they do not accept these plans, they will more easily accept more realistic recommendations. Therefore, more imaginative proposals are opening the public’s mind to basic solutions.

The growing number of requests from local governments, public organisations, private developers and tourist resorts for more detail consultations, directed to the PGA, are a direct result of standardised informative action.

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Fig. 1. Local people need to be convinced. At first, presentations on advantages of geothermal energy are usually met with reactions from total lack of interest to fascination. Spectators watching a speech delivered by knowledgeable guest from Iceland. Coalmine town, Southwestern Poland, 1999.

Fig. 2. Heating season begins; Zakopane, Poland; sunset time. (Photo taken in 1993, before the modern district heating system was installed).

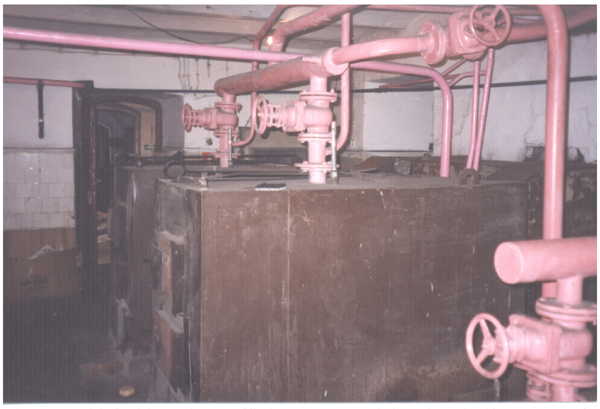

Fig. 3. Old-fashion, low efficiency central heating boiler; one of many open furnace, coal powered pollutant.

Fig. 4. Waste heat escapes its chance for utilization everywhere - at the taxpayer's cost; heat escaping funnels, district heating and electric power plant; Warszawa, Poland. Outside temperature -18°C (18°C below freezing point)

Fig. 5. Heat escaping from insufficiently insulated, district heating, delivering pipes could be easily utilized in direct-use snowmelt systems, without additional producer cost. A heating-pipe course in Warszawa, Poland, after the night snowfall. Winter, 1998/99; outside temperature -12°C (12°C below freezing point).

Fig. 6. Some coal mine waste heaps stay hot inside for over 50 years (here, >250°C at depth 5 m). In the background, totally oxidised heap; Southwest Poland.

Fig. 7. Natural Earth's heat comes out with artesian waters what is watched closely by the prominent geothermic scientist. Zakopane, Poland, 1999.


Fig. 8. Zigzagging path of a district heating power-line, and salted asphalt roads look very alike except that asphalt is wet with highly corrosive brine. Sosnowiec, Poland; -8^{o}C (8^{o}C below freezing point).