Report on Risk assessment

Appendix 2: Risk factors influencing the success of geothermal heating projects in Poland – one of the GEORISK target country.

Inputs from the geothermal district heating plants in Poland

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GEORISK

Table of Contents

Table of Contents 1

Introduction 3

1. Generals 4

1.1. Geothermal energy potential 4

1.2. Geothermal heating uses 4

3. inputs from particular geoDHs in Poland 7

3.1. Geothermal district heating plant in Stargard – feedback from G-Term Energy Sp. z o.o. (geoDH operator) 7

3.2. Geothermal district heating plant in Pyrzyce 11

3.2.1. Historical background 11

3.2.2. Geothermal use 12

3.2.3. Risk considerations 13

3.3. Geothermal district heating plant in Mszczonów 15

3.3.1 Genesis 15

3.3.2. Risk aspects at the stage of ongoing work 18

3.4. Geothermal district heating plant in Poddębice 19

3.5. Geothermal district heating plant in the Podhale region - project carried out by PEC Geotermia Podhalańska SA 26

3.5.1. Geothermal system in brief 26

3.5.2. Main maintenance investments in the geothermal system 27

3.5.4. Operation risk aspects 32

3.6. Geothermal district heating plant in Uniejów 34

3.6.1. Background 34

3.6.2. Exploitation 34

3.6.3. Exploitation issues 35

3.6.4. Risk aspects 35

3.6.5. Project aspects 36

3.6.6. Implementation aspects 36
3.6.7. Exploitation aspects 37
3.6.8. Conclusion 37

Introduction

Poland is among three target countries of the GEORISK project. To gain a direct information and feedback on risk factors affecting the main stages of geothermal projects and how the lack of risk insurance fund had influenced the problems in their realisation and management, IGSMiE PAN sub-contracted the companies operating six geothermal district heating plants existing in the country and asked them for contribution to the register of risk factors affecting the success of geothermal heating projects in Poland (main stages of project, drilling, technical, resource and operational aspects) and assessment of their significance. Furthermore, the operators were asked to express how the lack of a geothermal risk insurance fund had contributed to the potential problems and their opinions on the importance of introducing such a fund for investors and entrepreneurs.

The information and feedbacks received from geoDH operators helped to define essential risk factors and gave direct insight into real problems resulting from the lack of the risk guarantee fund. Simultaneously, the operators provided also several sound concrete arguments why the risk guarantee fund shall be established.

Those valuable inputs were taken into account by IGSMiE PAN and forwarded also to the leader of Task 2.1. “Context and identification of potential risk factors” to consider them during realisation of T.2.1. works.

The inputs obtained from operators of particular geothermal district heating plants in Poland are given further in this text. They concern the cases of following geoDHs: Stargard, Pyrzyce, Mszczonów, Poddębice, Uniejów – all situated within the Polish Lowlands (part of European Lowlands) and Podhale Region – situated within the Inner Carpathians (part of Alpine orogenic belt in Europe). General information on those plants (exploitation parameters, installed geothermal capacities and heat production as in 2018) is also presented.

1. Generals

1.1. Geothermal energy potential

Geothermal energy resources in Poland are hosted mainly by Mesozoic sedimentary formations in the Polish Lowlands (part of the European lowlands) and in the Inner Carpathians (part of the Alpine orogenic belt). Some prospects are also connected with selected areas and locations in the Outer Carpathians, the Carpathian Foredeep and the Sudetes region. The outflow geothermal water temperatures vary from about 20 to 95°C (depths of aquifers up to ca. 4 km). The proven geothermal water reserves amount from several L/s up to 150 L/s. Water mineralisation (TDS) vary from 0.4 to 156 g/L. Geothermal water resources are prospective for heating, agriculture, industrial uses, bathing and recreation, and some other uses. In some localities one may consider CHP (with binary installations; several hundreds kWh – 1 MW of electric power). Main focus shall be on much wider implementation of geothermal energy for heating (space heating) in order limit fossil fuels' combustion, reduce GHG emission, increase the RES use, improve living standards and protect the climate. So far, Poland has been on 12th place in Europe only as far as geoDH systems are concerned (2017 EGEC Market Report).

The geothermal potential and several other factors make possible to increase geothermal share in space heating, first of all in significant number of localities with already operating district heating systems. To make it happen, several measures shall be introduced – including the Risk insurance fund (main objective of GEORISK project). Some incentive schemes have been introduced recently – specially public supportive measures (grants, loans) for drilling exploration geothermal wells and other geothermal infrastructure. However, these incentives shall be followed by public risk insurance scheme (missing so far).

1.2. Geothermal heating uses

Geothermal uses in Poland embrace mainly district heating, as welll as balneotherapy and recreation. Among some other single uses is a large atlantic salmon farming, and a semi-technical wood drying, heating up a football pitch (Kępińska, 2019). What concerns space heating: so far (2019) six geothermal district heating plants have been operating. Five of them are situated within the Polish Lowlands (part of the European Lowlands) - in municipalities of

Pyrzyce, Mszczonów, Poddębice, Uniejów, Stargard and in the Podhale Region (Inner Carpathians) (Kępińska, 2019).

Figure 1 presents the location of geothermal uses in the country (including geoDHs) and table 1 shows main data on geothermal district heating plants as in 2018. Brief characteristics of these plants follows.

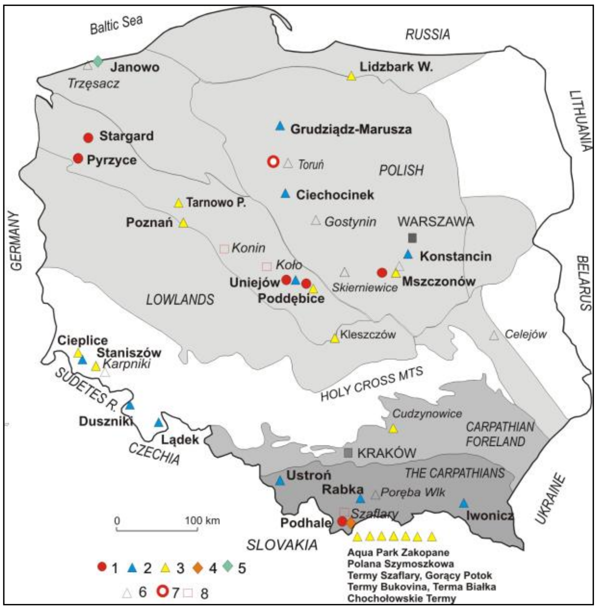


Figure 1. Poland: geothermal direct uses, end 2018 (Kepińska, 2019):

1. district heating plants, 2. health resorts, 3. recreation centers, 4. wood drying, 5. fish farming, 6. recreation centers in realization, 7. heating system in realization, 8. planned CHP installations

Table 1: Geothermal district heating plants in Poland, 2018 (based on Kępińska, 2019)

Locality	Plant Name	Year commis-sioned	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	Geothermal heat production* (GWth/y)	Geothermal share in total prod. (%)
Mszczonów	Geotermia Mazowiecka SA	2000	3.7	8.3	4.6	38
Poddębice	Geotermia Poddębice Sp. z o.o.	2014	10	10	17.6	96.5
Uniejów	Geotermia Uniejów Sp. z o.o.	2006	3.2	7.4	3.30	60
Pyrzyce	Geotermia Pyrzyce Sp. z o.o.	1994	6	22	19.5	63
Stargard	Geotermia Stargard Sp. z o.o.	2012 (re-open)	12.6	12.6	63.9	100

Podhale Region	PEC Geotermia Podhalańska SA	1993	38.8	77.9	141.5	89
Total			74.6	138.2	250.4	

Pyrzyce. The geoDH plant has been operating since 1996. By 2017 the maximum water flow rate from two production wells was ca. 100 L/s of 61°C water (spent water was injected back by two wells). In 2017/2018 a new production well was included into the geoDH system (maximum water flow rate ca. 55 L/s, temperature 65ºC) while all the-so-far 4 wells started to function as injection ones. The plant's maximum installed capacity is 22 MW including 6 MW geothermal. It supplies heat and domestic warm water to over 90% users of the whole town's population (13,000) and meets ca. 60% of total heat demand. In 2018 geothermal heat production was 19.5 GWh (70.2 TJ) and total 31.3 GWh (112.68 TJ).

Mszczonów. The geoDH has been operating since 2000. Maximum geothermal water flow rate was ca. 16.6 L/s of 42.5°C, TSD were 0.5 g/L. Water was discharged by a single well (no injection). In 2018 the total installed capacity was 8.3 MW (4.6 MW gas boilers, 2.7 MW absorption heat pump, 1 MW compressor heat pump). In 2018 geothermal heat production was 4.6 GWh (16.49 TJ), total 12 GWh (43.2 TJ). After cooling down water is used for drinking. Part of flow rate discharged by the well is sent to recreation centre.

Uniejów. The geoDH has been operating since 2001. The maximum discharge from one production well is 33.4 L/s of 68ºC water and the TDS are ca. 6–8 g/L. Total installed capacity is 7.4 MW (3.2 MW from geothermal, 1.8 MW from biomass boiler and reserve 2.4 MW fuel oil peak boilers). In 2018, 80% of all buildings in that town were supplied by the geoDH. Geothermal heat production was 3.3 GWh (12 TJ), 60% of total production. Part of geothermal water flow has been used for health spa and recreation centre. Besides geoDH some other geothermal uses are at various stages of project realization.

Poddębice. The geoDH has been operating since 2013. It has a 10 MW geothermal capacity based on 68ºC water (average flow rate 32.2 L/s, mineralization 0.4 g/L). The plant supplies several public buildings, school, hospital (and submits water to its rehabilitation part), multi-family houses. In 2018 geothermal heat production was 17.6 GWh (63.36 TJ), i.e. 96.5% of total production. Some part of water stream is sent to swimming pools.

Stargard. The geothermal plant has been operating since 2012 (after renovation). It is based on a doublet of production and injection wells. Maximum water production is ca. 50 L/s of 87□C water. In 2018 the geothermal capacity was 12.6 MW and heat production 63.9 GWh (230 TJ), entirely sold to the municipal district heating plant. That municipal district heating system is basically supplied by coal-fired plant (total capacity 116 MW serving 75% of local population (75,000)). In 2018 geothermal met ca. 27% of total heat demand of that town. The operator of geoDH plans to drill 4 new wells to double geothermal capacity and heat sales to municipal DH.

The Podhale region. The geoDH system has been operating since 1994 (on larger scale since 2001). The total maximum water flow rate (artesian) produced by 3 wells is ca. 297 L/s (since 2017) of 82–86°C water. In 2018 the installed geothermal capacity was 38.8 MW (total 77.9 MW). The geothermal heat production amounted to 141.5 GWh (509.5 TJ), i.e. 89.3% of total production. In 2018 ca. 1600 receivers were hooked to geoDH (mostly in Zakopane – the main city of that region and main heat market; geoDH met ca. 35% of its heat demand). Part of spent geothermal water is injected back by 2 wells while part supplies 2 recreation centres. The Podhale system is among the biggest geoDH in continental Europe. In 2018-2019 works and projects on optimization and extension of that system were ongoing.

3. inputs from particular geoDHs in Poland

Reporting how lack of a geothermal risk insurance fund contributed to the potential problems. The importance of introducing such a fund for investors and entrepreneurs – inputs from geothermal district heating plants

3.1. Geothermal district heating plant in Stargard – feedback from G-Term Energy Sp. z o.o. (geoDH operator)

I. History

Geotermia Stargard was established in 1999 as a joint venture of: DIFCO ENERGI (Denmark), SCANDINAVIAN ENERGY GROUP (Denmark) and ”EKO-INWEST” S.A. (Poland). Almost the entire investment was financed by loan capital – from the PKO BP bank and the capital of the National Fund for Environmental Protection, as well as in cooperation with the municipal heating company (PEC Stargard) and the city of Stargard. The system was a unique design at that time, i.e., it was tied-in only to the return circuit of the PEC heating network. Owing to this, the heating plant did not have the obligation to satisfy the stringent network parameters – which is mostly impossible in Polish realities to rely only on geothermal resources.

The first sale of heat to the district heating network of Stargard was concluded in 2005. However, already after 2 years, the company announced arrangement bankruptcy, and liquidation bankruptcy was announced in 2010. In 2011, the assets of the company were taken over from the receiver by G-Term Energy Sp. z o.o. and in February 2012, after extensive renovation of the system, Geotermia was re-launched. Since 2012, and so far, the system has been functioning with very good operating parameters, currently providing more than 30% of heat in the municipal network (PEC Stargard).

Current exploitation parameters: geothermal water temperature 84°C, max. flow rate 230 m^3/h, TDS ca. 140 g/L.

II. Description of the system

Currently, the heating plant operates 3 wells: one production well (GT-2) and 2 injection wells (GT-1 and GT-3).

Only the GT-1 and GT-2 wells had been used until 2016, but due to the decreasing possibilities of injecting brine to the rock mass, it was necessary to execute an additional sink well. Initially, the vertical GT-1 well (filtered) was used as the production well, while the GT-2 directional well (non-filtered) was to be a sink hole. However, due to the increasing issues with injection, already the previous heating plant operator made a decision to switch the borehole functions, which slightly improved the injection parameters but decreased the extraction capacity of the plant, since currently, at a flow just above 230 m^3/h, the non-filtered GT-2 well is beginning to strongly accumulate sand.

When it comes to the surface plant, as mentioned previously, it is tied-in to the municipal heating network only on the return pipeline. This pipeline is used to collect appropriate volume of district heating water with a temp. of 40-50º C, heated on a 12 MW geothermal exchanger (up to ca. 70-83º C depending on the flow rate), and then sent to the PEC Stargard for additional heating on coal-fired boilers. This solution enables the maximization of geothermal heat generation and, which is noteworthy, the PECStargard boilers in the summer are completely turned off and the entire return flow passes through the geothermal system, which fully satisfies the municipal demand for warm usable water.

III. Analysis of risks associated with the establishment and operation of a geothermal heating plant in Stargard

Given the full story behind the plant in Stargard, we can distinguish the following stages of its operation, which come with specific risk areas described below:

Design stage – due to the lack of experience of the investors, the design stage involved significant mistakes, which contributed to later problems with geothermal energy. Most of all, they were related to the technologies used within the surface plant, which were not adapted to such an aggressive brine.
Possible risk reduction methods – greater propagation of knowledge in the field of geothermal systems and developing a nationwide platform for exchanging experience among the operators of such heating plants.

Project implementation stage – the greatest risks lie in the area of geological drilling results and the very execution of drilling work, since the possibility of correcting the mistakes in the case of deep geothermal boreholes are limited and very expensive. While geothermal resources around Stargard were confirmed as very good, the boring work involved numerous, rather significant mistakes – the directional borehole was incorrectly cemented, which resulted in the inflow of cooler water from higher strata when extracting thermal water, causing lower brine temperature on the head and, in consequence, lower heat generation than potentially possible.
Possible risk reduction methods:
creating a geological risk insurance fund
proper selection of contractors with appropriate experience and resource, guaranteeing the performance of work at a required level.

Operation stage – risks in this field are primarily related to systems exploiting thermal waters with high salinity, which exhibit a tendency to generate continuous silting-up in injection wells.
Possible risk reduction methods – the operators must create provisions for well cleaning costs, even if there is no such a need in a given year. An alternative may be to transfer the risks and costs associated with maintaining the wells in an appropriate condition (in terms of efficiency) onto a specialized entity.

I expansion stage – drilling /execution of the GT-3 borehole

Despite the confirmed, very good geothermal resources and a guaranteed heat take-off, the company was unable to obtain financing for another well for a long time. Because there were no available funding schemes, it was decided to finance the investment from a bank loan. Nonetheless, such a solution was difficult to apply due to the lack of experience of banks in the field of geothermal energy, and if G-Term Energy had not been a part of a very large capital group, which guaranteed the loan, the company would not have had a chance to implement the investment.

II expansion stage – drilling / execution of subsequent GT-4, GT-5, GT-6 and GT-7 boreholes

In 2017, the company signed an agreement for financing the drilling / execution of 4 subsequent boreholes (total investment value of approx. PLN 72 mio), through which the geothermal heat generation will increase almost twofold and the heat demand in Stargard will be satisfied in almost 70%. Similarly to the GT-3 borehole, if the company had not had financial backing from the capital group, it would not have had any chances to implement this project. The reason behind this is the fact that NFEP&WM (National Fund for Environmental Protection and Water Management), when granting funds for more than 50% of the investment value, simultaneously required a collateral of funding reimbursement in the amount of 200% of the financing. No independently functioning entity is able to meet such stringent financial requirements when implementing a project of this scale, relative to its normal operations.

Possible risk reduction methods – creating a fund, which would act as a guarantor for the liabilities of the entities implementing geothermal projects on confirmed reservoir resources. This would help heating plants in gaining access to external financing sources on favourable terms, and simultaneously, would not require direct involvement of State budget funds.

IV. Summary/conclusions

Based on the experience arising from the construction and operation of the geothermal system in Stargard, it can be concluded that the functioning of geothermal heating plants is associated with risk and barrier areas, overcoming or mitigating of which exceeds the possibilities of such plants operating individually. In particular, this applies to:

The geological risk associated with the drilling of first exploration boreholes. The currently applied tool for solving this issue is the financial support for exploration boreholes as part of exploring the geological structure of the country. Without a doubt, it can be stated that a much better instrument would be a geological risk fund – from the perspective of both the State budget (does not require involving such large funds), as well as the beneficiaries – providing higher availability and flexibility of the financing.

Acquiring funding for further expansion of the plant – in this case, it also seems that a fund acting as a guarantor for private entities would be a better tool than direct subsidy-based support. This is due to the fact that an active fund would lead to a naturally increased interest in this type of investments among private financial institutions and investors, which would surely result in much faster and effective development of the geothermal heating sector in Poland.

3.2. Geothermal district heating plant in Pyrzyce

3.2.1. Historical background

The history of the Geothermal heating plant Pyrzyce began in the early 90's with drilling geothermal boreholes. Four wells, two production GT1 and GT3 and two injecting GT2 and GT4 were created. Drilling was completed in 1993.

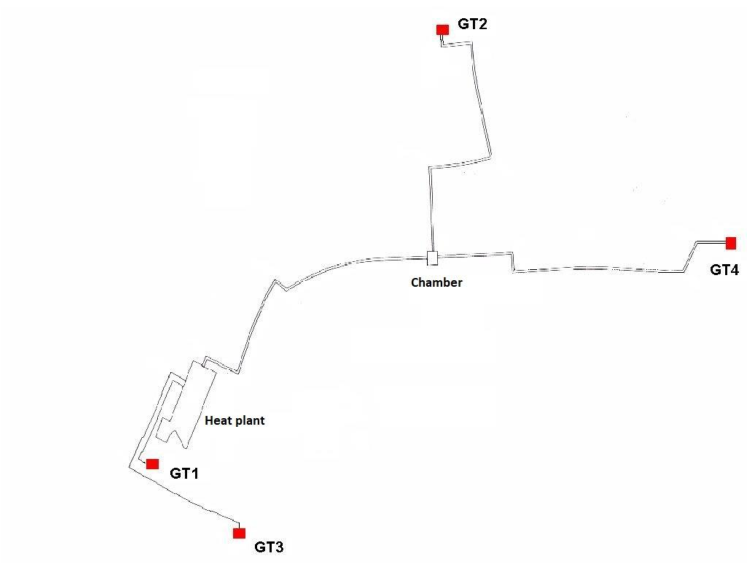


Diagram of location of drilling wells

Drilling was financed from the state budget funds for R&D drilling and Danish state funds. Because Pyrzyce did not have a district heating network, based on dispersed local boiler rooms, the decision to build a geothermal heat plant entailed the need to involve large financial resources. The entire investment included the construction of a geothermal and technological installation as well as transmission networks with heat distribution centers.

3.2.2. Geothermal use

Geotermia Pyrzyce partnership was established at the end of 1994. And starting from 1995 it proceeded to complete the investment and start the utilization phase.

Measuring pumping indicated the possibility of obtaining 300 m3 / h of thermal waters at 61ºC at an average pressure of 5 bar.

From the beginning of the drilling, we recorded a progressive colmatization. As a result, the utilization possibilities determined by the measuring pumping have been systematically decreasing.

We started the first regeneration works in 1998. The works included the necessity of mechanical cleaning of the tubular columns and deacidification of the deposit

The works were carried out in the following years:

1998 – purification pumping of injection holes GT2; GT4

2001 – drilling well reconstruction GT2

2004 – drilling well reconstruction GT2 and GT4

It can be assumed that the one-off cost of the simplest clean-up is PLN 200,000

In 2004, we were forced to develop a comprehensive concept of injectivity increase of GT2, GT4 and GT3.

The costs of these works have been set at approximately PLN 2 million.

The geothermal projects implemented in this period in Poland were pilot projects and therefore burdened with various errors.

The errors occurred mainly at the stage of constructing the installation and its implementation.

Among the errors that occurred during building of the Pyrzyce heating plant were:

materials used on transmission pipelines. As a result, the entire transmission system had to be covered with material

technological installations have been replaced with stainless steels or polyester resins

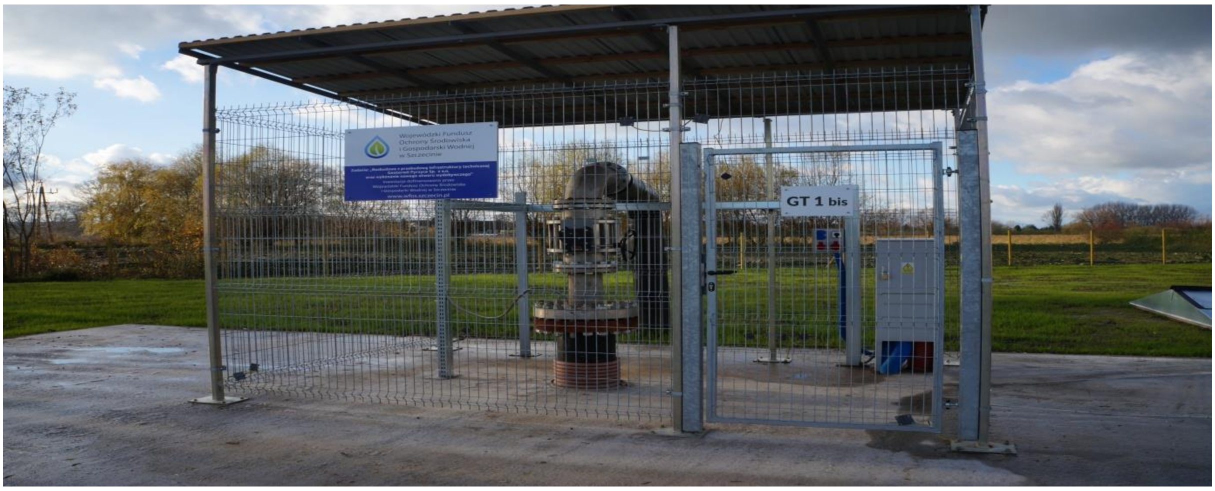
incorrect estimation of the power demanded by customers

Problems that we encountered during utilization:

worsening working conditions of the GT2 drilling hole due to worse absorption parameters than GT4 colmatation (plugging) of GT2 and GT4 sanding of the drilling well GT3

In the financial situation of the heat plant, bearing these costs was difficult and even impossible. The heating plant used own funds as well as loans and subsidies.
In the following years, other methods were sought to maintain the efficiency of the geothermal system, such as:
Soft acidizing
Super soft acidizing

These methods have been studied under various programs, i.e. LIFE + or GEKON.
These programs gave the opportunity to finance works for which no heating plant could afford. All activities were aimed at maintaining a 50% share of geothermal energy in total production. In 2016, after a 20-year drilling operation, a decision was made to execute a new GT1bis drilling well. It is a directional well with the “S” profile as the exploitation well, all other wells perform the role of injection wells. The drilling was financed with aid from a loan. The basic premise to justify the construction was to maintain at the assumed (at least 50%) level and not to allow the increase in energy prices as a result of switching to energy from gas combustion.



Wellhead GT1bis

3.2.3. Risk considerations

Design and implementation risks

As it results from the described experiments, these factors were errors resulting from the lack of experience in the field of geothermal installations, risks resulting from high corrosivity of geothermal waters or inaccurate identification of the customers' needs

Drilling risks

Since drilling GT1, GT2, GT3 and GT4 were not carried out from the heating plan's funds, this is not a subject to analysis, however these aspects occur in the case of the GT1 drilling.
In the case of the GT1bis drilling, the risk related to the lack of obtaining the planned parameters was lower due to the good knowledge of the existing geothermal system. Drilling works, however, carried a high risk and it was impossible to achieve the assumed parameters related to the profiling of the borehole. In our case, the work went according to plan and project assumptions. In this case, using the loan, a mechanism was used to reward the assumed parameters, in case of failure costs would however remain on the side of the heat plant and would pose a significant financial problem.

Utilization risks

The 20-year utilization of the geothermal heat plant has shown the necessity of incurring a number of costs that go beyond the normal cost of the utilization of the heat plant.

From our experience, there are various forms of financing geothermal activity, but they are highly diverse and apply various criteria. An additional difficulty is the fact that they only apply periodically.

This analysis is an attempt to justify the cost-effectiveness and necessity to introduce geothermal activity insurance forms. This is obviously a great simplification and concerns a 20-year utilization period.
The actual costs incurred by Geothermal Pyrzyce for the repair works discussed in point 2 amounted to approximately EUR 1.8 million. Assuming the existence of a fund insuring the risks associated with the operation of geothermal systems and incurring annual contributions

to this fund in the amount of EUR 12 000. Euro (the amount based on the information from the existing system in France) costs of the heating plant are as follows:

20 x 12 000 = 240 000 EUR

if only as a result of the compensation proceedures, we would receive a 50% reimbursement, that would amount to:

1,8 mln x 50% = 0,9 mln EUR

Thus, incurring insurance costs at the level of PLN 240,000 euro, over the period of 20 years, there would be a chance to reduce the costs of the heat plant to 900,000 EUR.
This justifies in our opinion the legitimacy of further works in this direction.

3.3. Geothermal district heating plant in Mszczonów

3.3.1 Genesis

The geothermal borehole IG-1 located in Mszczonów was constructed in the years 1976-1977 as part of geological research and for exploration of oil and gas. The borehole was drilled to a depth of 4119 m, the geological goal was achieved, while not finding the presence of hydrocarbons. Then the hole was completely eliminated.
Hole reconstruction project was developed at the initiative of the Mszczonów authorities. Geotermia Mazowiecka S.A. was established for this purpose. The commune obtained co-financing on the basis of the application prepared by the Institute for Mineral Resources and Energy PAN. Work began in 1997.
Geothermal water captured from the Mszczonów IG-1 borehole from a depth of approx. 1600-1700 m has a temperature of approx. 42 ° C and a mineralization of 0.5-0.6 g / dm^3. The main method of using geothermal water are energy goals, that is heat intake for the purpose of supplying the municipal heating network, recreational purposes and also drinking purposes after cooling and conditioning.
1.2 The main stages of the reconstruction of the Mszczonów IG-1 borehole

Stage I:

• Drilling works and securing the hole
• Providing a reservoir zone
• Introduction of installations and consumables

Stage II:

• Cleansing pumping (2 performance levels)
• First series of geophysical measurements with a set of PL probes
• Chemical analysis of water
• Analysis of sand
• Testing the technical condition of the hole by the thermovision camera
• Measuring pumping 21 days
• Chemical and isotopic analyzes of water,
• Hydrodynamic tests (3 performance levels)
• Chemical analysis of water
• Analysis of sand
• Second series of geophysical measurements
• Pre-operation pumping
• Third series of geophysical measurements with a set of PL probes

(Figure No. 1 Mszczonów IG-1 well after reconstruction)

The whole done work was very important for the success of the entire project. It enabled obtaining a good technical condition of the well, determining conditions that prevail in a given wellbore and exploiting geothermal waters from a given well. In addition, drilling exploitation resources have been documented and specified. The reconstruction of the hole was the beginning of a huge investment which aimed to use geothermal energy for the heating needs of the inhabitants of Mszczonów, that is the construction of, among others, a geothermal plant in the city.

The works provided very valuable information, including: skrócic

• Characteristics of deposit parameters of the aquifer: water efficiency and temperature and the level of the dynamic water table
• Characteristics of physicochemical parameters of waters
• Characteristics of sandy material
• Information on the water-bearing capacity
• Information on the age of the Lower Cretaceous aquifer

• Testing the technical condition of the hole

Basic technical data of the extracted minerals:

The volume of extraction: 20.0-60.0 m^3 / h

Temperature of geothermal water: 40-42 ° C

Water table level: static approx. 53.0 m bgl, dynamic (max.) Approx. 78.0 m bgl (below ground level). As mentioned before the reconstruction of the Mszczonów IG-1 geothermal well enabled the geothermal water exploitation, which resulted in many economic, social and environmental effects in Mszczonów. Thanks to investments, Mszczonów gained a pro-ecological source of heat, a swimming pool with numerous attractions, sports facilities, the development of local crafts and trade, and thus new jobs.

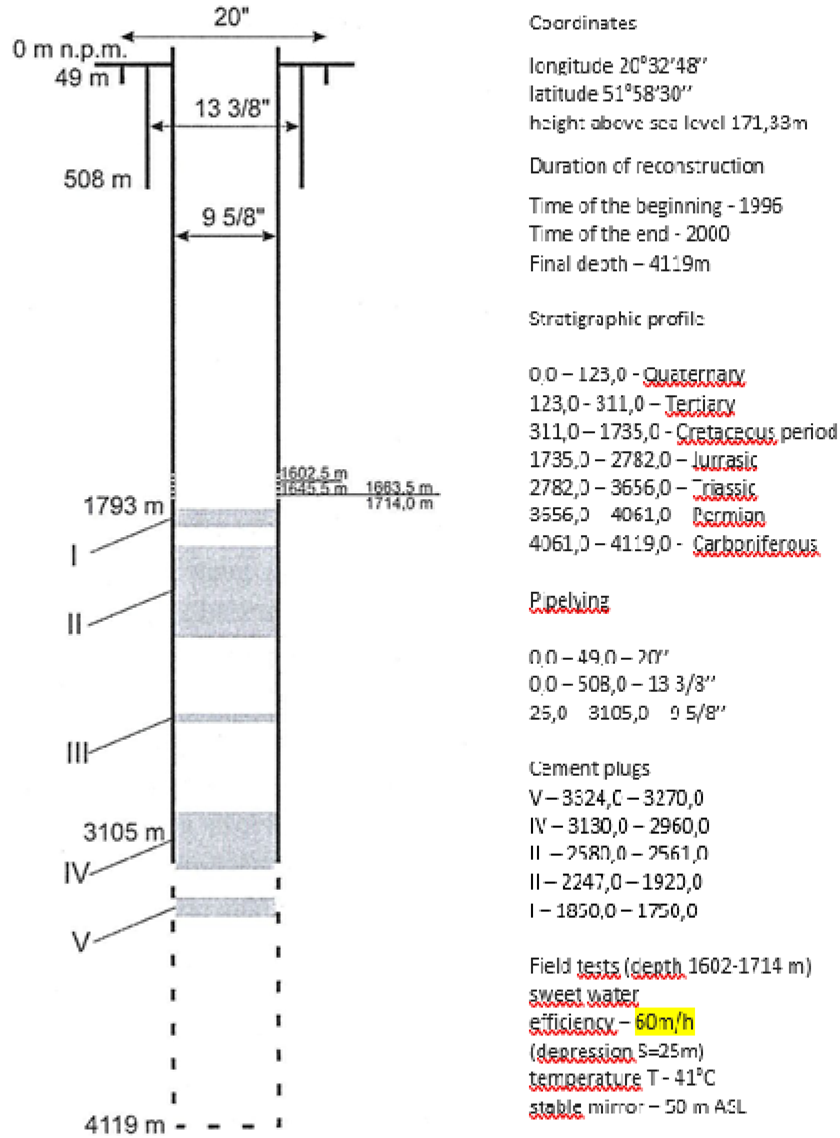


Figure No. 1 Mszczonów IG-1 well after reconstruction

3.3.2. Risk aspects at the stage of ongoing work

Geotermia Mazowiecka S.A. has been exploiting Mszczonów IG-1 geothermal hole for many years. From the point of view of our company it is quite specific when it comes to achieving the commercial purposes. This specifity results from the fact that it was not a hole drilled from scratch by our company, but a hole that was subject to reconstruction. This reconstruction was the first in Poland complete reconstruction of an old liquidated exploration well for geothermal purposes. The entire investment was connected with the risk of failure, and basically the company together with the partners involved in the project was on its own without the possibility of financial risk insurance related to the actions taken. I believe that there are many risk aspects at various levels of geothermal investments both those from scratch and those that rely on the use of already existing wells.

Due to the wide range of research and implementation of technologies for using heat from the ground and relatively low level of education and knowledge in this area at that time was a novelty and unknown for the inhabitants of Mszczonów. Lack of awareness of the potential of geothermal energy for heating and recreation purposes could lead to possible protests.

The research and the entire process associated with the well reconstruction was also associated with purely technological factors that may have occurred at the stage of even pumping of geothermal water, i.e. changes in temperature and the amount of water pumped.

The economic factor is another aspect. The change of the way the city was supplied with heat resulted in the need to modernize the entire district heating system. It was a very high investment cost not only because of the well reconstruction itself but also because of the modernization of the entire system. No one at this stage, ie in the 90's, was able to guarantee that the investment in the old well will be profitable and give the city tangible benefits. To this must be added the costs associated with the pumping of geothermal water, as well as the high competitiveness of the use of heat from conventional sources.

In connection with the above risk aspects, it cannot be concealed that the lack of a geological risk insurance fund is one of the most important brakes of geothermal development in Poland. Maybe one should take an example from other European countries where there is a lot of experience in conducting geothermal projects (eg France, the Netherlands, Italy) and which have various types of insurance systems, guaranteeing some safety in conducting works both at the research and operational stage.

3.4. Geothermal district heating plant in Poddębice

SUMMARY OF GEOTHERMAL WATER RESOURCES

as of 31.12.2018

Type of resource	Geothermal water		
	m^3/24 h	m^3/y	Water type
Exploitable	6048	2 207 520	HCO_3-Na-SiO_2-Ca
Industrial	6048	2 207 520	
Non-industrial	-	-	
Losses	-	-	

Geotermia Poddębice Sp. Z o.o. has a license no. 13/2011 issued by the Minister of the Environment on 30.12.2011, for the extraction of geothermal water from the Lower Cretaceous formations in the Poddębice GT-2 intake, amended by the decision of the Marshal of the Łódź Province no. RŚV.7422.100.2015/2016.BC of 06.06.2016 in the amount of 252 m^3/h. The concession was granted for a period of 25 years (text attachment no. 1). The geothermal shot in Poddębice consists of a vertical exploitation borehole Poddębice GT-2 drilled to a depth of 2101 m b.g.l. . The water-bearing layer consists of sandstones of the Lower Cretaceous in the interval 1957.0-2059.0 covered by a rod filter made of stainless steel of Johnson type with a ϕ 65/8". The geothermal water from the well has been used for recreational purposes in outdoor swimming pools since July 2012 and for heating public buildings (including schools, hospitals and offices), from 2014 also for multi-family buildings in the entire city of Poddębice, and from March 2014 in the Geothermal water Pump Room.

In February 2015, "Appendix No. 1 to the hydrogeological documentation establishing the exploitation resources of the Poddębice GT-2 geothermal water intake from the Lower Cretaceous formations in Poddębice" was prepared. It was adopted by the Marshal of the Łódź Province on 05 March 2015. The issued decision approves the exploitation resources of the intake in the amount of 252 m^3/h with a dynamic water table in a heated borehole at the level of 60.2 m above sea level and the temperature at the outflow of 68.4 °C.

Underground geothermal waters are exploited by Geothermia Poddębice Sp. Z o.o. for heating purposes, i.e. for heating a part of the city (buildings of LO, Poddębickie Centrum Zdrowia, Zespół Szkół Ponadgimnazjalnych, Gimnazjum, Zespół Pałacowo-Parkowego) located in the immediate vicinity of the borehole and multi-family residential buildings initially heated from the Zielona, Krasickiego and Cicha boiler rooms.

In the future, it is planned to connect the single-family housing estate and thermal swimming pool buildings with a recreational area and hotel facilities to the heating network. After some heat is transferred to the heat exchangers, the geothermal water will be used for the functioning of the swimming pools in the designed water park and after a simple treatment will be introduced into the existing water supply network and for rehabilitation, as well as for drink and cosmetic purposes. The used geothermal water will be partially discharged into the Ner river after heat transfer, which corresponds to the records of the water permit granted to Geothermia Poddębice Sp. Z o.o.

The Poddębice GT-2 well is located in the north-western part of the Łódź Province, within the Poddębice commune, in the town of Poddębice. The city of Poddębice is the seat of the county and has about 8 thousand inhabitants.

The A2 motorway passes about 10 km north of Poddębice, and the railway line, the so-called coal route, connecting Silesia with Gdynia, passes about 1 km from the city. The city is crossed by a network of local roads.

The geothermal water intake is located on plot No. 4/3, owned by Geotermia Poddębice, at 17 Mickiewicza Street, in the south-western part of the city.

This area is located next to investment areas planned for activities related to the use of geothermal water. The Ner River flows from the west at a distance of about 160m.

The development of the plot on which the drilling is located is typically industrial. Currently, on the partially hardened square, there is a heat exchanger building and equipment related to the production of thermal energy: heat exchangers, surface filters, control and measuring equipment, building of the geothermal borehole head, earth tank no. 1 for cooling geothermal water with a measuring well discharged to the Ner river.

The environment in the area of the Poddębice GT-2 borehole was transformed as a result of urbanization processes. Currently, it is a peripheral part of the city in the vicinity of which there are investment areas for technical infrastructure related to the use of geothermal water and recreation (park – Garden of the Senses) and external thermal pools, and from the side near the Ner river the area is still used for agricultural purposes (meadows and pastures).

The area around the intake reaches the ordinate of 119.5 m above sea level.

The GT-2 Poddębice hole area is located within the Odra River basin, in the eastern part of the Warta Region, on the right bank of the Ner River, which is the right-bank tributary of the Warta River. The Ner valley is filled with haracte silts, sands and river gravel, which are typical river sediments.

The GT-2 Poddębice borehole is located in the central part of the Permian-Mesozoic geological unit called the Łódź Basin, which is an element of the geological structure of the Polish Lowlands.

The geological structure of the Łódź Basin is complex, which is connected with halotectonics. The movement of salt masses results in local gaps and erosion, rapid changes in the thickness of sediments, especially in the area of anticline structures, which in this area were formed in the upper Triassic, upper Cretaceous (coniacian) and at the turn of Cretaceous and Palaeogene.

Sometimes incomplete formation and small volume of Lower Cretaceous sediments within salt pillows is caused by regional changes. There are salt structures that pierce or dam up chalk sediments, including salt anticline in the area of Koło and Poddębice. The Upper Cretaceous deposits are therefore maximum thick, reaching 2600 m in the area of Koło and 3000 m in the area of Turek. In the region of Poddębice the thickness of the upper Cretaceousis is 1952 m.

The oldest rocks drilled by the Poddębice GT-2 borehole are the upper Jurassic (haracte) sediments formed in the carbonate facies, represented by light grey marl and marl limestone, sometimes sandy. The ceiling of the upper Jurassic was drilled at a depth of 2070 m below ground level. The lower Cretaceous deposits are already located above them. Within the GT-2 Poddębice borehole sandstones were found in the interval 1962-2063 m and are divided by a clay insert at the depth of 2001-2004 m of medium-grained yellow colour.

Shortened stratigraphic profile of the Poddębice GT-2 borehole

QUATERNARY	**0,0- 10,0 (10)**
CRETACEOUS	**10,0-2070,0 (2060)**
Late cretaceous	**10,0-1962,0 (1952)**
Maastrichtian	10,0-200,0 (190)
Campanian	200,0-625,0 (425)
Santonian	625,0-1185,0 (560)
Coniacian	1185,0-1375,0 (190)
Turonian	1375,0-1655,0 (280)

Cenomanian + upper Albian	1655,0-1962,0 (307)
Early Cretaceous	**1962,0-2070,0 (108)**
lower Albian + Aptian + Barremian	1962,0-2063,0 (101)
Hauterivian	2063,0-2070,0 (7)
Late Jurassic (Portland)	**2070,0-2101,0 (undrilled)**

The water-bearing level in the Poddębice GT-2 hole is the Lower Cretaceous rocks. The aquifer series is formed by porous fine-grained sandstones, medium-grained in some places. The ceiling of the aquifer in the Poddębice GT-2 borehole is at a depth of haract. 1962 m b.g.l. and the slope at a depth of 2063 m b.g.l. . The water in this layer is under high hydrostatic pressure – the water table stabilizes at a height of 26.0 m above the ground level (determined on the basis of head pressure).

In the area of Poddębice GT-2 intake there are no other geothermal water intakes. The nearest geothermal heat plant in Uniejów is located about 15 km to the north-west, which uses geothermal water from the level of lower Cretaceous. The waters of the Uniejów region are of the chloride and sodium type with total mineralization of about 6.7 g/l haracterized by a self-outflow of 67 m^3/h and a water temperature of 67.4^{O}C.

The Poddębice GT-2 exploratory and production borehole was drilled between October 10, 2009 and January 28, 2010 to a depth of 2101.0 m.

On the basis of the measurement pumping performed between 28.09 -.09.10.2010 for the needs of "Hydrogeological Documentation determining the exploitation resources of the Poddębice GT-2 geothermal water intake in Poddębice" the exploitation resources were determined in the amount of: productivity Q = 190 m^3/h, with depression in the well s = 50.2 m and water temperature at the outlet 71°C.

In connection with the planned expansion of the heat network and the planned inclusion of new customers, Geotermia Poddębice decided to increase industrial resources from the GT-2 Poddębice borehole.

At the moment, the exploitation resources of the geothermal water intake from the Poddębice GT-2 borehole amount to: the efficiency Q = 252 m^3/h, with depression in the heated borehole of 85.3 m.

Physico-chemical analyses and radioactivity studies of water taken from the opening of Poddębice GT-2 show that it is fresh water suitable for consumption.

The submersible pump in the geothermal borehole is located at a depth of about 100.0 m, i.e. 40.0 m deeper than the depth of the dynamic water table found during the measurement pumping with a capacity of 252.0 m^3/h. In order to "collect" the self-outflow, a surface pump with a capacity of up to 140 m^3/h was used, placed in a concrete manhole near the borehole.

This pump is used for maintenance work in the well or service of the submersible pump or also in the case of a possible failure of the submersible pump or the need to supply into the network a capacity higher than the self-flow capacity, but not exceeding 140 m^3/h.

Management of water and geothermal energy

Based on the programme concept, Geothermia Poddębice Sp. Z o.o. intends to realise:

District heating

Recreation

Balneology

Consumption

Aquaculture

Cosmetics

Spatial concept of geothermal water management from the Poddębice GT-2 well

Heat is transferred from the heat exchanger plant via pipelines to three existing housing estate boiler plants at: Zielona Street, Krasickiego Street and Cichej Street, which are peak and reserve sources.

Geothermal water, by successively releasing its heat, is repeatedly in cycles with an increasingly lower temperature ceiling. First of all, it is used for domestic hot water and winter heating. Geothermal heat in individual boiler plants is the primary source, while oil boilers are the peak source.

Exploitation of water from a geothermal water reservoir does not require complicated technologies, but the receiving installations already require large financial outlays.

The operating costs of the water intake are related to the use of the deep-well pump and the measurement and control equipment. The costs will also be generated by periodical cleaning of the well hole, as well as by periodical water quality checks and inspections and servicing of control, measurement and control equipment.

CONCLUSIONS

The geothermal plant in Poddębice works on the basis of one extraction borehole enabling proper exploitation of geothermal water with the flow rate of 252 m³/h. Geothermal boreholes shall be carefully designed due to their heterogeneous geological structure and salt structures in the area of Poddębice. In our case, due to the fact that fresh water was obtained, an additional trial operation was necessary in order to confirm the quality of geothermal water. Therefore, it seems necessary to insure against geological risks.

Geothermal waters in the Poddębice region are under considerable hydrostatic pressure, in the area of fine-grained sandstones of the Lower Cretaceous are characterized by an efficiency of 116.5 m³/h, where the water table stabilizes 26.0 m above the ground level. Self-flow is a blessing, but in case of the necessity to perform work in the borehole and a working district heating system, self-flow is difficult to control and stop, so as to deliver heat to the grid.

The geothermal waters captured by the 'Poddębice GT-2' borehole can be haracterized as fresh waters fit for consumption. And this is a blessing: for installation, for balneology and rehabilitation, and for drinking purposes.

The rational exploitation of the aquifer shall be carried out smoothly, without any sudden changes in performance. This is where another problem arises during operation. Failures involving pump units are not insured by insurance companies. None of them wants to take the risk associated with the failure, and thus the inability to provide heat to customers included in the geothermal heat network. It is also known that the operation of extraction and re-plugging of the pumping aggregate lasts from a few to several hours, provided that you have a reserve aggregate. The worst scenario that can happen is when there are severe frosts, and it is not possible to provide heat. Such a situation requires insurance, which so far has not been possible to obtain.

3.5. Geothermal district heating plant in the Podhale region - project carried out by PEC Geotermia Podhalańska SA

3.5.1. Geothermal system in brief

PEC Geotermia Podhalańska S.A. was established in 1993, as one of the first company using renewable geothermal heat sources in Poland. For the start, first few buildings in Banska Nizna were connected to the district heating network. Currently the company is the largest provider of ecological geothermal heat in Poland. The company profile covers primarily the generation, transfer and distribution of heat. Its operation has contributed greatly to the improvement of environmental conditions. New customers are constantly connected to its grid, which is powered approx. by 90% by geothermal sources, thus allowing to further reduce emissions. By connecting new buildings the volume of CO_2 emission reduction in the past 25 years has exceeded 533,000 tons.As per 31st December 2018 the heating grid (of a length of 113.2 km) of PEC Geotermia Podhalańska SA served 1,630 buildings, whereas the subscribed heating capacity amounted to 69.11 MW. The geothermal system of PEC Geotermia Podhalańska S.A. consists currently of three production wells Bańska IG-1, PGP-1 and PGP-3, two injection wells Biały Dunajec PAN-1 and PGP-2 (part of cooled spent water is disposed into the river /after additional lowering temperature in cooling towers). The geothermal plant Bańska Niżna generates heat for the purposes of heating and hot tap water by means of hot water extracted from geothermal aquifer. The thermal capacity of heat exchangers located in the boiler house is 38.8 MW. Geothermal water is produced from its aquifer located at a depth of approx. 2.3 – 3.3 km by the following production wells:

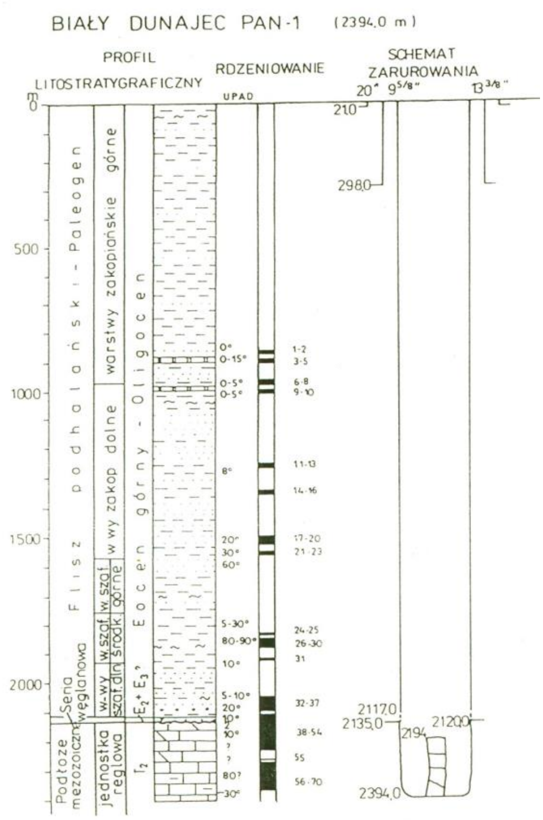
Name:	Flow rate, m^3/h (approved)	Temperature [°C]	Static wellhead pressure [bar]
Bańska IG-1	120	82	27
Bańska PGP-1	550	86	29

Name:	Flow rate, m^3/h (approved)	Temperature [°C]	Static wellhead pressure [bar]
Bańska PGP-3	400	85,5	20.75

3.5.2. Main maintenance investments in the geothermal system

2.1 Production well Biały Dunajec PAN-1.

Original architecture of the well is give below.



Drilling time: 6 February 1989 7 November 1989.

Casing pipes:

0 – 23 m 20”

0 – 295 m 13”

0 – 2135 m 9 5/8”

Due to the decay of 9 5/8” casing pipes a result of corrosion, the well was out of service from 2003 to 2011.

In July – September 2011 the following reparation works were carried out:

1. Sealing of 9 5/8" pipes with concrete within the section of 355 - 360 m.
2. Cleaning of pipes 9 5/8"
3. Borehole geophysical logging and assessment of condition of 9 5/8” pipes.
4. Installation of 7" pipes.
5. Cementing works in the 7” pipe column.
6. Preparation of the well for the acidizing treatment.
7. Acidizing of the reservoir zone.
8. Restarting of the well.

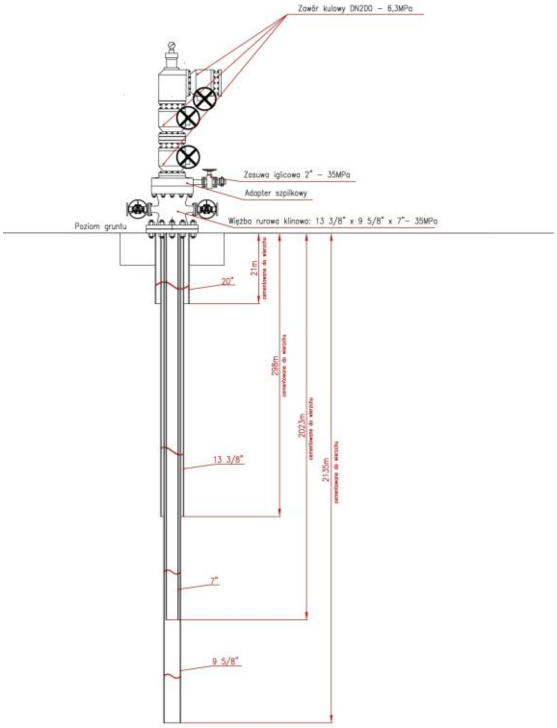
The investment sum amounted to ca. PLN 3,150,000 (including a 50% subsidy from the Regional Operational Programme).

After the maintenance works the piping structure was as follows:

0 – 21 m	20”
0 – 298 m	13”
0 – 2135 m	9 5/8”
0 – 2023 m	7”

Pipe head diagram of Biały Dunajec PAN-1 with casing pipes after a reconstruction performed in 2011 are presented on the picture below.

Schemat zagłowiczenia otworu PAN-1 wraz z rurami okładzinowymi



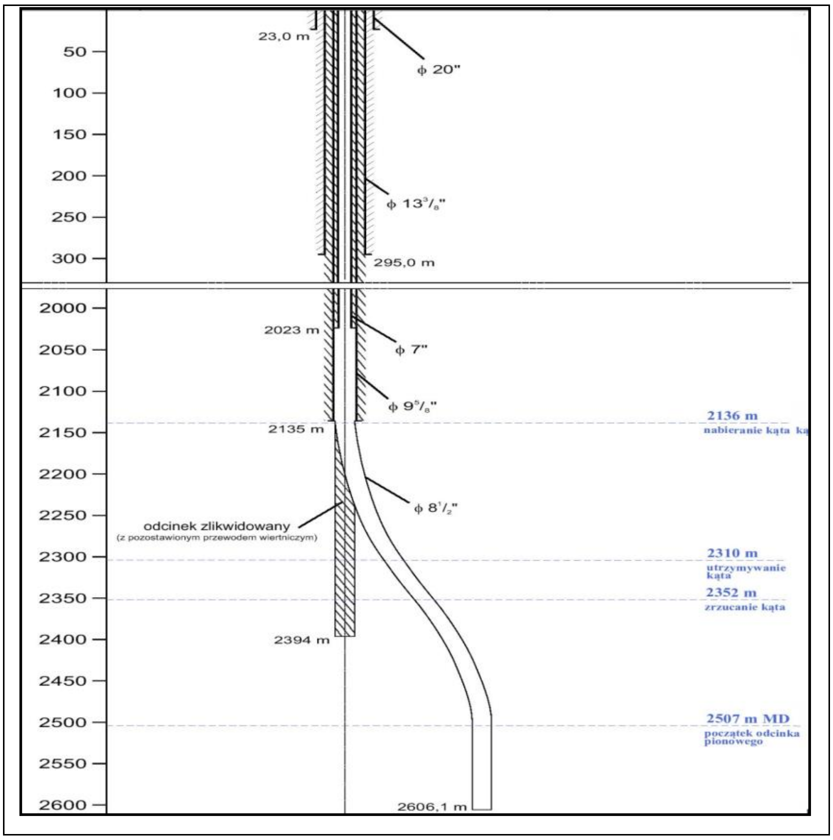
After the reconstruction done in 2011, Biały Dunajec PAN-1 well operated only until 2014. Due to the deteriorating injectivity parameters, it had to be deepened in order to reach the more efficient part of the aquifer. The works on deepening the well lasted 21 July – 5 October 2014. The investment cost was PLN 7,022,000 and it was financed by own funds of Geotermia Podhalańska S.A.

After the directional deepening of the bore, the piping structure was as follows:

0 – 23 m 20”
0 – 295 m 13”
0 – 2135 m 9 5/8”
0 – 2023 m 7”
2135 - 2606,1m non-piped bore (8 ½”)

Well structure after its deepening is presented below.

Depth [m]	Bore structure	Remarks



3.5.3. Geothermal pipelines

The geothermal pipelines of PEC Geotermia Podhalańska S.A. are classified as follows:
Production pipelines – from the wells to the boiler house;
Cooled water pipeline – from boiler house to Biały Dunajec pumping station,
Injection pipelines – from pumping station in Biały Dunajec to injection wells.

During the initial stage, the pipes were made of black steel of ST37 type. The corrosive properties of geothermal water (which were revealed during the operation) have forced us to look for solutions that would reduce or eliminate the corrosive effect of geothermal water. Between June 2008 and October 2009 the 'Retrofitting of geothermal pipeline with tight-fit HDPE inserts' was performed. These works included the following operations:

- Cleaning geothermal pipelines from internal sediments and rust,
- Inserting of HDPE pipe of an outer diameter equal to the nominal diameter of the retrofitted pipeline,
- Preparation of collar connections of pipelines with elbows,
- Filling of pipeline elbows with HDPE material by rotatory forming,

- Installation of elbows in the pipeline, connection and startup.

The investment cost amounted to PLN 1,367,000 and was financed with own funds of Geotermia Podhalańska

Retrofitting of pipelines

Part of the pipes were not fitted with HDPE due to technical problems of the side of the contractor. The problematic sections were located in two throughputs under the Biały Dunajec river. These throughputs were completed in 2018 by the replacement of two pipes made of ST37 steel into acid-resistant steel.

Also the pipeline providing water form Bańska PGP-1 well to the boiler house and the pumping pipelines from the pumping station to the Biały Dunajec PAN-1 and Biały Dunajec PGP-2 wells were modernised. Pipelines were made of acid-resistant steel.

The pipeline investment cost amounted to PLN 3,194,000 and was financed with own funds of Geotermia Podhalańska.

2.3 Acidizing of the Bańska PGP-3 production well

After the drilling of Bańska PGP-3 bore in 2013 the process of output intensification (acidizing) of geothermal aquifer was performed. After the tests after drilling phase, a capacity of 290 m^3/h was obtained. As this output was not satisfying and it did not correspond with the nearby Bańska PGP-1 (550 m^3/h), the acidizing was repeated in 2017. Capacity rise reached approx. 40%.

Net cost of acidizing amounted to 1,826,000 (including a subsidy of 51.64% from the Innovation & Environment Operational Programme).

Acidizing works in progress, Bańska PGP-3 geothermal well.

3.5.4. Operation risk aspects

The geothermal boiler house is the main heating plant of PEC GP SA, where approx. 90% of capacity comes from geothermal sources. In case of an increased heat demand above the capacity of the geothermal source, gas boilers and ultimately also the fuel oil boiler. Thanks to this production structure, heat prices are acceptable to the customers. The reduced output of the geothermal system during breakdowns, repairs or other damage, the production share of the peak source, that is central boiler house, increases, thus leading to a negative economic outcome.

Therefore, it is of key importance to maintain the production infrastructure from geothermal water (wells, pipelines) in good technical condition, in order to secure the supplies and profitability of the Project.

Operation risks:

Aggressive and corrosive impact of geothermal water on system elements made of carbon steel. One of the solutions is the replacement of existing pipes or use of corrosion-resistant materials in new pipelines.
The clayey sediment carried by the water and dissolved ferrous compounds may be and are the reason of clogging of the reservoir rocks in the injection wells. The reduction of injectivity

properties may have direct impact on heat production capacity. This can be solved by stimulation treatments (acidizing) which are, however, costly.
Due to the expansion of the district heating and connection of new customers, the geothermal source had to be expanded with a new bore, named Bańska PGP-3.
Without this expansion and a new well, the increased heat demand would have to be covered with gas or oil, thus leading to a significant growth of price of GJ.
In spite of the confirmed abundant geothermal resources and a guaranteed receiving (purchase) of heat, the company could not obtain funding for drilling a new well for a long time (!).
The company also submitted a subsidy application for this purpose, which was yet rejected due to its commercial character, thus forcing the company to the bank loan option. To gain credits in banks was practically impossible.
Commercial banks do not have any experience in the funding of geothermal projects, and thus find it very difficult to provide them with the necessary capital. The risk rate has been normally judged as high. As a result, banks were and are not interested in the funding of such projects or require high securities and offer high interest rates.
Ultimately, PEC Geotermia Podhalańska S.A. obtained a support in form of a loan granted by the Regional Fund for Environment Protection and Water Management in Krakow. However this involved the mortgaging of the company's real property. Without such securities it would have been impossible to gain the funding.

From the above 'study case' it is clear that some geological / geothermal fund and risk insurance fund could greatly facilitate the investment processes by providing either access to external funding (other than subsidies) or to limit the investment risk. The funds could also directly finance certain geothermal projects or act as a loan security.

In the course of years, due to the constant development of the district heating network and connecting of new customers, as well as the growth of heat capacity, the investments aimed to increase level of use of geothermal system were necessary.
The maintenance and construction works within the geothermal system require significant investments. In order to finance the expenses on geothermal infrastructure the Company used subsidies and own funds.

The gathering of funds for the investments lasted ever several years, which has stretched their performance in time and limited the development. Without external funding (subsidies) some of them could not have been completed.

Having considered the above and the experience gained by the Company in the course of its operation, it is to be stated that the lack of geological risk security fund is one of the main drawbacks of the development of geothermal systems in Poland.

3.6. Geothermal district heating plant in Uniejów

3.6.1. Background

There are three geothermal wells in the Uniejów municipality.

The first (IGH-1) was drilled in 1978 as part of exploration for oil and natural gas conducted by the Polish Geological Institute.

Two more wells were created in 1990 and 1991 (PIG/AGH-1 and PIG/AGH-2). These are wells drilled into the same aquifer as the 1978 well located in the Upper Cretaceous layer. Geothermal water is extracted using the PIG/AGH-2 well. It is characterized by a water capacity of 68 m^3/h at a pressure of 1.6 bar, a temperature of 68ºC and a mineralization of outflowing water of 7.8 g/l.

3.6.2. Exploitation

In 1999, a limited liability company Geotermia Uniejów was founded, whose founders were the Uniejów municipality and the Provincial Fund for Environmental Protection and Water Management in Łódź. The following year, an investment was initiated involving the joining of two wells with a discharge pipeline, the construction of a rinsing water tank, heat exchanger equipment along with an oil peak load boiler room and the installation of heating networks with connections and thermal nodes in the city.

In order to increase the production capacity of the geothermal heating plant, drilling work was carried out involving the mechanical cleaning of the PIG/AGH-2 production well and

PIG/AGH-1 injection well, perforation of the filtration zone, acidification of boreholes and air-lift well cleaning. A submersible pump was installed in the production borehole allowing for an efficiency increase of up to 90 m^3/h.

3.6.3. Exploitation issues

The year 2001 is the beginning of the technological exploitation of the geothermal heating system in Uniejów for heating purposes.

Although the results of test pumping were very good, the PIG/AGH-1 injection capacity of the PIG/AGH-1 borehole decreased very quickly. The absorption capacity of the filtration zone dropped by more than 50% over one year, which limited the possibility of supplying heat from the geothermal heating plant section and increased the operating costs due to the need to heat the buildings with heat obtained from the combustion of fuel oil. Very expensive acid treatment of the clogged filtration zone shortened the patency and forced to increase the discharge of extracted geothermal water to the surface watercourse.

3.6.4. Risk aspects

The main operational problem of the geothermal system in Uniejów from the beginning of the launch have been difficulties related to the injection of cooled geothermal water into the aquifer. This resulted in additional costs which could not always be passed on to heat consumers and consequently led to losses for Geotermia.

In 2005, the subsidy obtained from the National Fund for Environmental Protection and Water Management in Warsaw allowed for the re-cleaning of the filtration zone of the injection well and the reconstruction of the oldest well and launching it as another injection borehole.

As part of the obtained subsidy, the following works were carried out:

In the PIG/AGH – 2 production well:

- cutting-out of Ø $6^5/_8$”" pipes at a depth of 200 m
- tightness test of the inter-circular space between Ø $9^5/_8$” and Ø $6^5/_8$” pipes and the sealing of the interstice space

- suspension of the submersible pump on new discharge pipes

In the PIG/AGH - 1 injection hole:

- acid treatment
- measurement pumping
- performance of tests to check the capacity of the borehole by production and injection pumping of PIG/AGH - 2 → PIG/AGH -1
- repeating the acid treatment, collection of the post-reaction residue liquid using a nitrogen unit, measurement pumping for one day, and production and injection pumping of PIG/AGH - 2 → PIG/AGH -1 with a submersible pump

• In the IGH-1 injection well:

- fracking of Ø $4^{1}/_{2}$” filter
- acid treatment
- collection of post-reaction residue liquid using a nitrogen unit,
- measurement pumping
- repeating the acid treatment, collection of post-reaction liquid using a nitrogen unit, measurement pumping for one day, and production and injection pumping of PIG/AGH - 2 → IGH -1 with a submersible pump

3.6.5. Project aspects

Factors that cause later operational problems are errors resulting from the use of pipelines identical to those for oil and gas production wells. Unfortunately, geothermal water is corrosive because of high content of chlorides which leads to the corrosion of steel pipes and, consequently, to penetration of water from higher layers with a much lower temperature into wells that conduct hot water. This reduces the power of the geothermal heating plant and the need to replace the piping, entailing huge financial costs.

3.6.6. Implementation aspects

At the stage of trial pumping, too little attention was paid to the use of appropriate filters before injecting water back into the aquifer, which has already led to the clogging of the filtration zone in the aquifer.

3.6.7. Exploitation aspects

As a consequence of mistakes made at the stage of designing and executing the geothermal boreholes, there were, and still are, problems with injection of water after receiving heat from it for reheating in the aquifer from which the water was extracted. This leads to the limitation of mining possibilities directly related to the ability to receive cooled water by the injection well or wells. This is directly related to the increase in the costs of heat supply to consumers and the increase in pollutant emissions by limiting the possibility of producing heat from a Renewable Energy Source, which geothermal water undoubtedly is.

3.6.8. Conclusion

The creation of a geological risk insurance system in Poland at the design and production stage and related drilling works would significantly reduce the risk of unsuccessful exploration work and accelerate the development of geothermal energy. The best insurance system at this stage would be government insurance, because it will be difficult to find a commercial insurer willing to bear significant risks associated with the use of geothermal water, where expenditures amount to millions of zlotys.

Another aspect is the insurance of heating geothermal systems during operation related to the corrosiveness of the piping of wells, surface pipelines carrying geothermal waters and the clogging of the filter zone of the injection wells.

In addition to insurance, a good idea would be providing for the possibility of obtaining operating subsidies from government and self-government institutions dealing with environmental protection in our country and in the European Union.