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GEOTHERMAL UTILIZATION POTENTIAL IN POLAND – THE TOWN OF PODDĘBICE

Part 1. Selected reservoir and exploitation aspects of current and further geothermal district heating and other uses' development in Poddębice

ABSTRACT

The paper presents main reservoir parameters, and selected aspects of stable geothermal water production for the needs of current and future district heating and other uses in Poddębice, Poland. These topics, as a part of pre-feasibility study, were elaborated in the framework of the EEA Project “Geothermal utilization potential in Poland – the town of Poddębice”. That town has both prospective resources and ambitious plans of further geothermal uses' deployment for space heating and for wide range of other applications. They will contribute to low-emission heating, improvement the leaving conditions and modern local economy. Poddębice create a good study case for other localities in Poland that have geothermal resources. The paper gives in insight into the analyses, outcomes and recommendations that resulted from common works on Icelandic and Polish partners involved in the Project. Energetic aspects are presented in Part 2. of this paper, which is a continuation of the material presented here.

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KEYWORDS

Geothermal energy, reservoir parameters, exploitation, production simulation, district heating, Poddębice, Poland, EEA, WFM funds

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1. GENERAL INFORMATION ON THE EEA PROJECT “GEOHERMAL UTILIZATION POTENTIAL IN POLAND – THE TOWN OF PODDĘBICE”

As mentioned in the Abstract, the paper presents selected issues elaborated in the framework of the Project “Geothermal utilization potential in Poland – the town of Poddębice” Project under the Fund for bilateral relations, Operational Programme PL04 “Energy savings and promoting RES” (European Economic Area and Norwegian Financial Mechanism 2009–2014 in Poland) (www.eeagrants.agh.edu.pl). This Part 1 addresses main reservoir and long-term stable geothermal water production aspects, while energetic aspects are presented in Part 2 (this volume).

The Project was carried out on the basis of the Project Agreement (115/2016/Wn05/OA-XN-04/D, EOG 2009–2014, dated 18.10.2016) between the National Fund for Environment Protection and Water Management, Poland (Project operator) and The Mineral and Energy Economy Research Institute of the Polish Academy of Sciences (Project leader), and the Partnership Agreement between MEERI PAS and NEA dated 24 August 2016.

The parties of this bilateral Project were:

- Project promoter: The Mineral and Energy Economy Research Institute of the Polish Academy of Sciences (MEERI PAS) in consortium with AGH University of Science and Technology (AGH UST) and in cooperation with Geotermia Poddębice Ltd. and The Town of Poddębice.
- Project partner: National Energy Authority (NEA), Iceland.

The Project promoted the early stage development, strategy planning, capacity building, networking and awareness of geothermal energy use in order to increase the possibility of geothermal resources applications for heating, energy security, energy savings and quality of life in Poland on the basis of a selected town – Poddębice. It was aimed to transfer the knowledge, technologies and best practices of geothermal district heating systems in buildings from Iceland to Poland. Iceland is a leader of this sector in Europe and the world, while in Poland such applications and approach have been at a preliminary stage. The Project contributed to capacity building, increase in competence and knowledge among local stakeholders like operators of geothermal plant, municipal officers, citizens of the Town of Poddębice and others on the opportunities and benefits of the use of geothermal energy as a renewable local source; energy savings and increased security supply; effective implementation of a low-car-

bon economy; building bilateral Polish – Icelandic cooperation; stimulate the development of geothermal heating in Poland.

Thanks to the Project's implementation, cooperation among Polish and Icelandic project partners was initiated which may result in mutual activities on geothermal heating systems and other uses in Poland with the implementation of proven solutions and technologies applied in Iceland. The Icelandic partner gained knowledge and experience of the geothermal heating sector based on parameters and reservoirs typical for Poland and other European countries. This will strengthen its position in possible projects on the international scene. The Project also contributed to increase the awareness of geothermal energy in Poland, especially in Poddębice, feature its possible usages with a special focus on district heating and presenting it to relevant stakeholders.

The Project included several major tasks: 1. Study visit to Poland of representatives of the Icelandic side; 2. Study visit to Iceland of representatives of the Polish side; 3. Study visits' report; 4. Summary Conference; 5. Project management.

The paper presents some outcomes of works resulting from the Study visits to Poland and to Iceland, collected data, research, discussions and Study visits' Report.

2. THE TOWN OF PODDĘBICE AND COMMUNE – GENERAL INFORMATION

The Town of Poddębice is located in the north-western part of the Łódź Region in Poland. It has about 7,750 residents while the Poddębice Commune – about 15,870.

From the geological point of view this is the central part of the Łódź trough – the central part of the Szczecin – Łódź – Miechów synclinium. This area has a good geothermal conditions and prospective potential for space heating and other uses. The geological location of the Town of Poddębice area is shown on Fig. 1.

3. HEATING MARKET AND GEOTHERMAL ENERGY

Before 2013, the main space heating sources in Poddębice were local boiler plants fired by natural gas, fuel oil and coal. They supplied multi-family housing, single-family and own boiler rooms in public buildings.

The situation changed from 2010, when the Poddębice GT-2 well was drilled (October 2009 – January 2010) – and then a geothermal district heating plant was built. Since 2013, that plant has been supplying a district heating grid (for space heating, hot tap water) including many public buildings such as: the Poddębice Health Center, schools, the Poddębice Palace complex, outdoor swimming pools. The Poddębice geoDH is the 6th such heating system in Poland.

At present, the geothermal district heating system (geoDH) supplies 100% of all users connected to the heating grid, i.e. 50% of the town's area. The rest of the heat demand (inc-

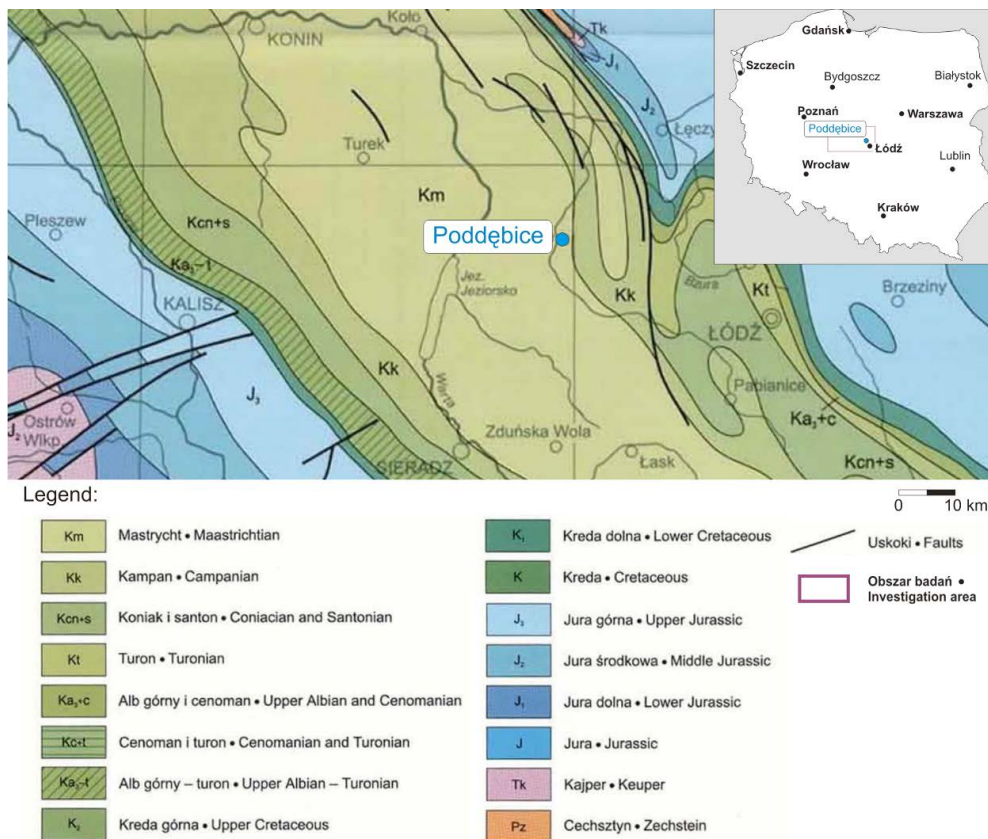


Fig. 1. Geological map section of central Poland without the Cainozoic deposits and the location of the Poddębice area (based on Dadlez, Marek, Pokorski 2000)

Rys. 1. Lokalizacja obszaru Poddębica na tle fragmentu mapy geologicznej Polski środkowej bez osadów kenozoicznych (na podstawie Dadlez, Marek, Pokorski 2000)

luding institutions, service and production establishments) is covered by individual sources. GeODH's further expansion is planned as well as other geothermal uses.

The total heat demand in the Town of Poddębice is ca. 17 MW_{th}. Currently geothermal energy covers 5 MW_{th} of it. Further development plan (version minimum) assumes that in the coming years 2 MW_{th} will be covered by a heat pump (based on geothermal) and ca. 3–5 MW_{th} by gas peak boiler (reserve one).

4. THE HISTORICAL BACKGROUND OF THE PODDĘBICE GEOTHERMAL PROJECT

The beginnings of the project date back to 1999 year when the first “Project on geological prospecting of geothermal water resources in The Town of Poddębice” (Górecki et. al. 2000) was prepared by “Geos” (Geosynoptics Society) associating mainly the researchers from

AGH UST. It assumed the exploitation of geothermal waters by the doublet of production and injection wells.

Later on in the period 2000–2007 several changes of the concept of use of geothermal waters in the Poddębice were made, including e.g. reversal of the doublet (Górecki et al. 2003). In 2007 (Górecki et al. 2007), the final version led to the implementation of the geological project approved by the municipal authorities and the Geotermia Poddębice Ltd. Company. In February 2008 the project gained the approval of the Commission for Hydrogeological Documentation of the Ministry of Environment of Poland. According to the project, the development plan assumed the drilling of one borehole to the depth of 2,039 m, and then the production of geothermal water from the Lower Cretaceous aquifer. The project assumed the use of ca. 62°C water with mineralization ca. 11 g/L, and the outflow of about 180–190 m³/h for a wide range of applications: from recreation through balneotherapy to heating purposes as well. The Project also assumed that after extraction of the heat and cooling down to about 30–35°C geothermal water would be discharged into the Ner river.

The 50% of the funds for drilling came from the National Fund for Environment Protection and Water Management and the remaining 50% from the Poddębice Community as the only owner of the Geotermia Poddębice Ltd. The Poddębice GT-2 well was drilled in 2009–2010.

5. GEOLOGICAL CONDITIONS

The Town of Poddębice is located in the central part of Permian–Mesozoic Mogilno–Łódź trough – part of large the Szczecin–Łódź–Miechów trough, extending from the Fore–Sudetic monocline to the mid–Poland swell. From the east the Łódź basin borders with Kujawy swell – a tectonic unit with strongly developed salt tectonics. The basin touches the Mogilno through from the NW.

The geological structure of the Łódź basin is complex, which is mainly connected to salt tectonics. This phenomenon caused local disconformities, rapid changes of sediments' thickness, especially in the proximity of anticline structures, that were formed within surrounding areas during the upper Triassic, upper Cretaceous and during the late of Cretaceous and Palaeogene periods. The creation of anticlinal structures in the Poddębice area was caused by underlying salt layers' tectonic dislocations that used to be active during the sedimentation of Mesozoic rocks. The incomplete development and small thickness of the surrounding salt pillows sediments, e.g. Lower Cretaceous formations was caused by regional salt tectonics where salt structures penetrated or uplifted the Cretaceous layers, among others – salt anticlines of Koło and Poddębice (Fig. 2).

The Łódź basin area was crossed by an axis of maximal subsidence of the Upper Cretaceous basin. Thus, its sediments in the Poddębice area are of its maximum thickness, approaching up to 2600 and 3000 m (near Koło and Turek, respectively), whilst in the Poddębice vicinity ca. 1952 m.

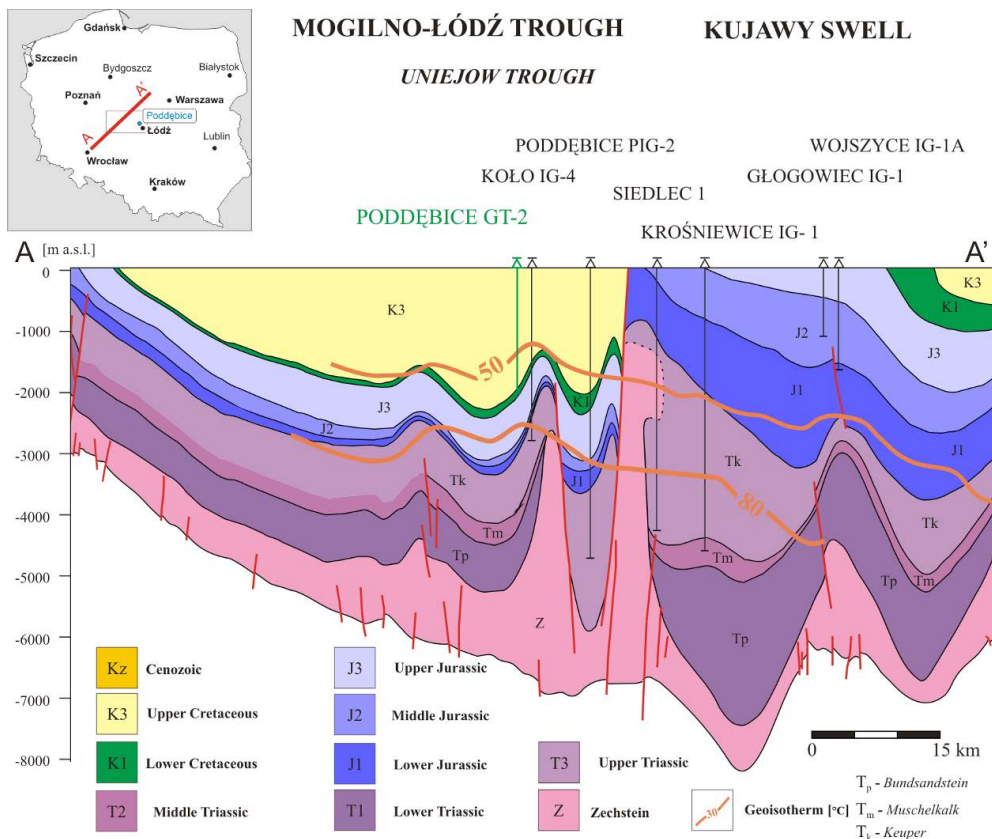


Fig. 2. Geological cross-section through the Polish Lowlands with location of wells in Poddębice area (based on Górecki et al. 2006)

Rys. 2. Przekrój geologiczny Niżu Polskiego z lokalizacjami otworów w rejonie Poddębic (na podstawie Górecki red. i in. 2006)

Rock formations aged from Permian, through Triassic, Jurassic, Cretaceous to the Quaternary periods are present in the geological structure of the described area.

Geothermal aquifer – the subject of exploitation in Poddębice – is hosted by the Lower Cretaceous sandstones (Albian, Aptian and Barremian stages). They are located at a depth interval of 1962–2063 m beneath the surface in the Poddębice GT-2 well, with claystone interbed in the interval of 2001–2004 m. The top part of the sandstone (above the clay layer) contains a rock skeleton of high purity with locally occurring glauconite, and is characterised by better reservoir parameters (porosity of 17%). In the lower part of the profile, that is deeper than 2027 m beneath the surface, interlayers of mudstone are present, quartz grains are smaller, whilst porosity is of about 14%. The clay content in the footwall of the sandstone reaches a level of 23%. The thickness of the sandstone layers is 98 m (considering the clay interbed of a 3 m thickness).

5.1. The main features of geothermal reservoir rocks

In the Poddębice area the main geothermal aquifer is hosted by Lower Cretaceous sandstones – fine-grained, locally medium-grained. The top of the reservoir in the Poddębice GT-2 well was confirmed at a depth 1962 m beneath the surface, whilst its base at a depth of 2063 m.

The geothermal water is artesian – a static water table occurs at 26 m above the surface. The top part of the water-bearing complex (up to the surface) is composed of grey, fine-grained, comparatively pure sandstones aged at Lower Albian. An intercalation of fuscous claystone and mudstone is present in the 2001–2004 m depth interval, grey fine-grained sandstones occur at a lower level, deeper than 2027 m beneath the surface – with a scant amount of mudstones.

Quartz strongly dominates in the mineralogical composition of sandstones, constituting 95% of the detritus volume. Accessory components are particles of silica rocks, feldspar, glauconite and clay minerals. Sandstones contain mainly a siliceous cement with the minor addition of secondary carbonate or clay (illite) cement. Quartz grains are rounded and well-sorted, their size ranges from 0.2 to 1.3 mm.

The Lower Cretaceous sandstones are rather homogenous. Aquifer horizons are characterized by high porosity (13.7–17.0%) and permeability (87.98–1021.10 mD). The analysis of the core samples shows that the content of carbonates (components of cement) – calcite and dolomite is minor; in a majority of the samples lower than 2.0% of calcite and 1.0% of dolomite.

Amount of clay fraction, in the footwall (Barremian sandstones) reaching 23%, increases with depth in sandstones.

An impermeable Hauterivian formation occurs from the depth of 2063 m beneath the surface (mudstones and claystones) which underlies the Lower Cretaceous geothermal aquifer. Sealing beds transit into a carbonate Upper Jurassic formation at a depth of 2070 m beneath the surface.

Water discharged by Poddębice GT-2 well shall be characterized as 0.043% geothermal water containing mainly sodium bicarbonate and calcium hydrogen carbonate. Neither potentially toxic ingredients of natural origin nor indicators of contamination from the external environment were indicated. Water is characterized by softness (total hardness 98 mg/dm³ CaCO₃), neutrality (pH = 7) and a low iron content (0.35 mg/dm³). According to qualitative analysis from 2010 geothermal water contains some gasses like CO₂, N₂ and minor content of methane and ethane.

According to qualitative analysis from 2010, geothermal water contains some gasses like CO₂, N₂ and a minor content of methane and ethane. However, the conditions of gas sampling and significant contamination by external atmospheric oxygen resulted in the analysis not being representative from the quantitative point of view. The gas analysis shall be carried out again for samples taken in proper way.

Basic information on Poddębice GT-2 well and its hydrogeological parameters can be given as follows (Hydrogeological documentation... 2010; Annex... 2014):

- drilling period: 10.10.2009 – 28.01.2010,
- total depth of the well: 2101.0 m,
- position of wellhead / ground level: 120.83 m a.s.l / 119.5 m a.s.l),

- depth of geothermal aquifer: 1957.0–2059.0 m,
- total reservoir formation thickness: 102 m,
- effective thickness: 98 m,
- location of Johnson screen filter/active production interval/: 1957.0–2059.0 m (102.0 m),
- intergranular reservoir sandstones' porosity: 16–23% (no secondary porosity),
- effective porosity of sandstones: 13.7–17.0%,
- permeability: 87.98–1021.10 mD, (average PERM = 176.5 mD),
- productivity index PHI*NET = 17.76 nV/V,
- productivity coefficient PJI*NET=17.76 nV/V,
- artesian outflow: 116.5 m³/h, s = 26 m a.g.l, calculated wellhead static pressure 2.6 at – values at particular construction/dimensions of wellhead (observed during pumping tests both in 2010 and 2014),
- water mineralization: 432 mg/L,

Water age: ca. 10 000–14 000 years (most likely), while according to 13°C analysis the age of geothermal waters was estimated at ca. 27 thous. of years.

5.2. Exploitable reserves of geothermal water discharged by Poddębice GT-2 well

Exploitable reserves of the Poddębice GT-2 water intake were determined by “Dodatek nr 1 do dokumentacji hydrogeologicznej otworu Poddębice GT-2” (“Appendix 1 to Hydrogeological documentation of Poddębice GT-2 well”). That document was accepted by the Łódź Province Marshal. The results of well testing conducted on 29–30 October 2014 served as a basis of determining exploitable reserves.

Approved exploitable reserves of the Poddębice GT-2 water intake amount to Q = 252 m³/h at a dynamic water table (in heated up well) at a depth of 85.3 m b.g.l. and the water wellhead temperature 68.4°C. The mining area equal to the concession area amounts to 7.18 km² (Table 1).

Table 1

Poddębice GT-2 well – main information on approved water reserves based on 2014 tests (acc. to Annex to Hydrogeological documentation 2015)

Tabela 1

Otwór Poddębice GT-2 – główne informacje na temat zatwierdzonych zasobów wód na podstawie testów hydrodynamicznych z 2014 r.

(wg Dodatku nr 1 do „Dokumentacji hydrogeologicznej...” 2015)

Name of well	Approved exploitation resources	Wellhead temperature for a given flowrate	Static water level in a heated-up well	Dynamic water level in a heated-up well for a given flow rate	Water type Mineralization
Poddębice GT-2	252 m ³ /h	T = 68.4°C Q = 252 m ³ /h	h = 145.5 m a.s.l.	H = 60.2 m a.s.l. Q = 252 m ³ /h	HCO ₃ -Na-Ca 432 mg/L
Exploitation reserves of water intake	252 m ³ /h				
Mining area = 7.18 km ²					

6. CURRENT GEOTHERMAL ENERGY AND WATER USES IN PODDĘBICE

In 2012–2014, a 10 MW_{th} geothermal heating plant as well as hot water pipelines were built in Poddębice. They allowed to transport geothermal heat to all public facilities and multi-family residential buildings.

Heat supply to the consumers started in February 2013. In total, Geotermia Poddębice Ltd. Company supplies heat to nearly 100 buildings (6,000 people). The closure of 3 local boiler stations (which currently serve as peak and reserve sources) contributed to air protection by reducing gases and dusts' emission. The total length of heating transition network, distribution network and grid connections is over 12 km.

Currently (2017) geothermal water and energy is used for:

- district heating,
- balneotherapy,
- swimming pools,
- drinking (the latter on a limited scale so far – in Geothermal Water Drinking Bar).

The sketch showing current and planned geothermal energy and water uses in Poddębice based on water discharged by Poddębice GT-2 well (Fig. 3) is shown on Fig. 4.



Fig. 3. Geothermal well head (Poddebice GT-2) and heat central in the background

Rys. 3. Głowica geotermalna (Poddebice GT-2) z ciepłownią w tle

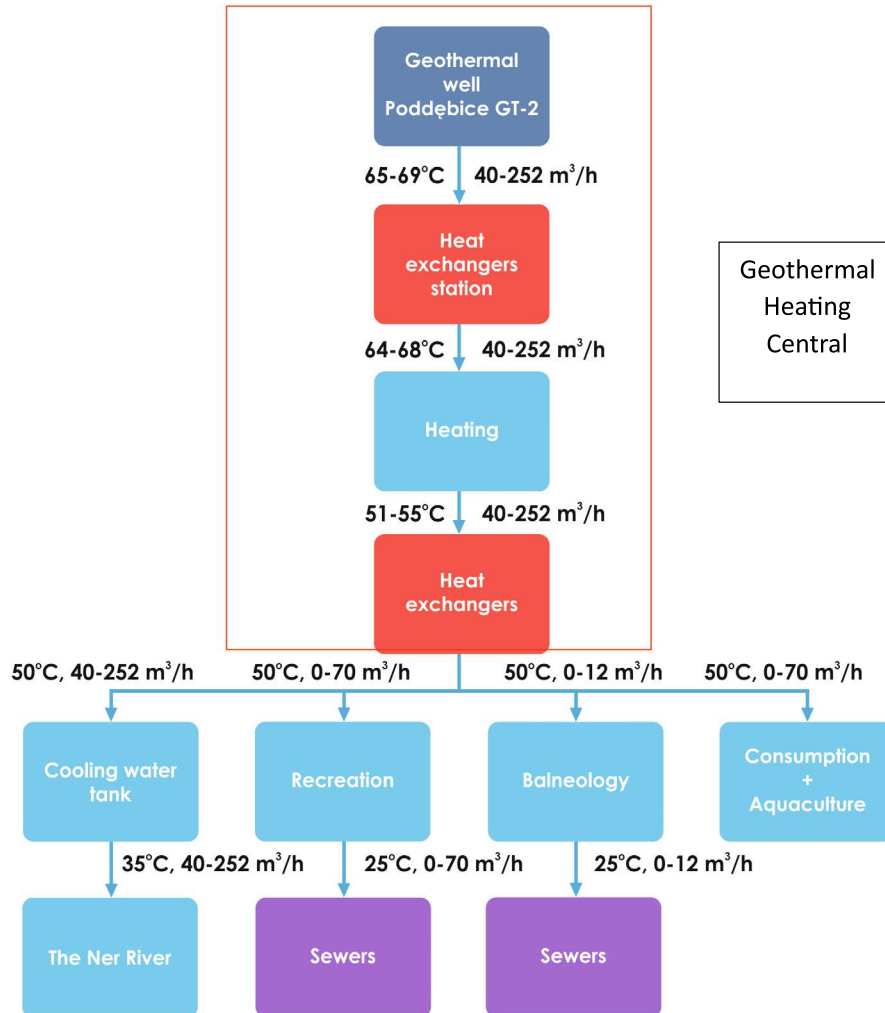


Fig. 4. A sketch showing current (2016–2017) and planned geothermal energy and water uses in Poddebice

Rys. 4. Schemat prezentujący obecne (2016–2017) i planowane wykorzystanie wód i energii geotermalnej w Poddebicach

Figure 5 shows a map of buildings connected to the geothermal district heating network in the Town of Poddebice (as in 2016).

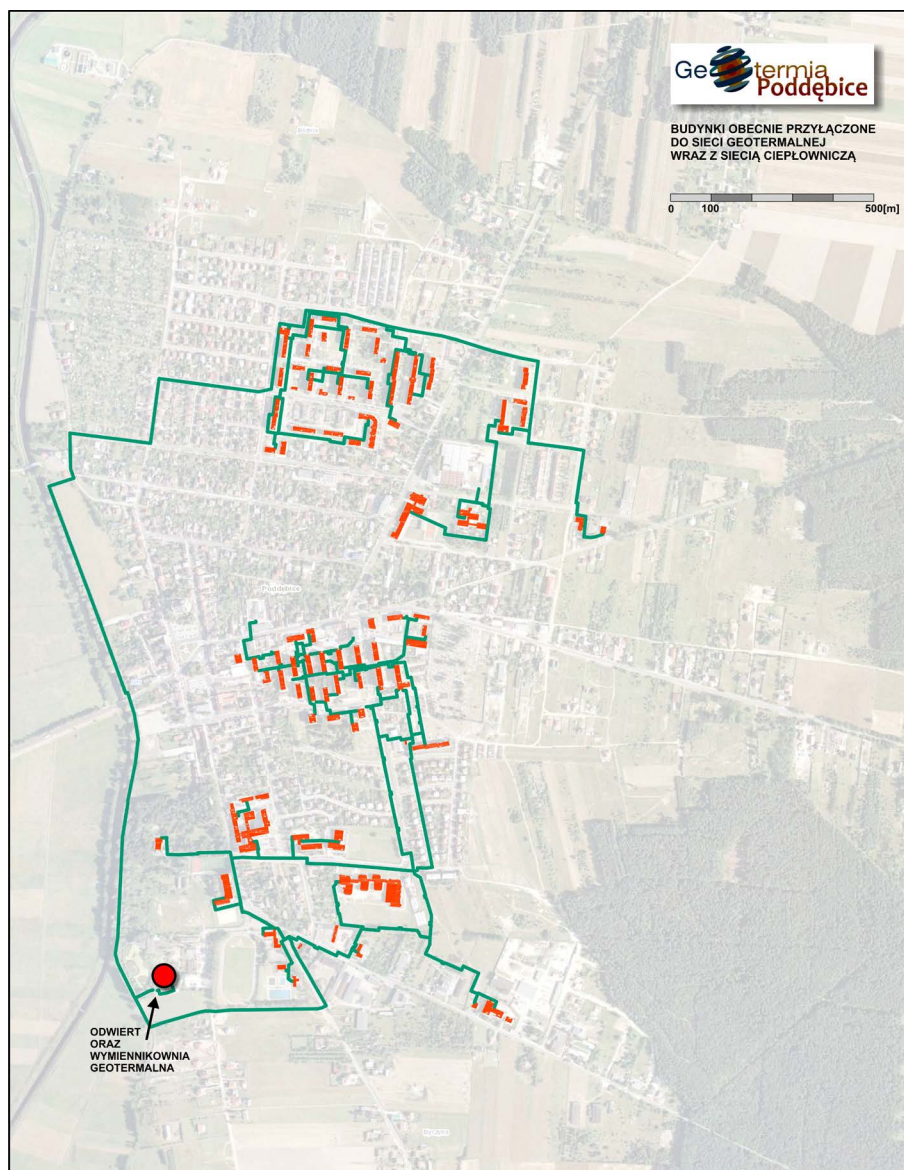


Fig. 5. Map showing the buildings connected to the geothermal district heating network in the Town of Poddębice, 2016. The geothermal district heating serves ca. 6000 people in residential buildings, public and office buildings. Part of the current geothermal district heating was constructed by Geotermia Poddębice Sp. Ltd., part – constructed by the Municipality, one part existed before geothermal heat was introduced (supplied by 3 local coal-gas boiler plants)

Rys. 5. Lokalizacja budynków związanych z geotermalną siecią ciepłowniczą w Poddębicach w 2016 r. Ogrzewanie geotermalne zaopatruje ok. 6000 osób w budynkach mieszkalnych, biurowych i budynkach użyteczności publicznej. Część obecnego systemu ciepłowniczego została zbudowana przez Geotermię Poddębice Sp. z o.o., a część przez gminę Poddębice. Sieć istniała częściowo przed podłączeniem geotermii (3 kotłownie węglowo-gazowe)

7. GEOTHERMAL HEAT SALES AND ECOLOGICAL EFFECT

The geothermal heat sales in 2013–2016 and the obtained ecological effect in Poddębice are shown in Table 2 (annual heat losses in the distribution network are ca. 10%).

Table 2

Geothermal heat sales in Poddębice, 2013–2016

Tabela 2

Sprzedaż ciepła w Poddębicach w latach 2013–2016

Year	Heat sales [GJ/y]
2013	15 002
2014	39 733
2015	47 277
2016	56 470

The ecological effect as aggregated values of reduced / avoided pollutants thanks to the replacement of hard coal by geothermal heat corresponding to heat sales at the level of 56.47 TJ in all of 2016 (as provided by Geotermia Poddębice Ltd.; Table 2) can also be estimated as follows: CO₂: 5500 Mg; CO: 25.8 Mg; SO_x: 42.1 Mg; TSP (total suspended particles): 25.8 Mg; NO_x: 8.3 Mg.

The above-figures consider coal with a calorific value of 25 MJ/kg, ash content of 5%, sulfur content of 1.02%. The emission factor values used in calculations were taken according to the “Emissions from combustion of fuels – boilers with a nominal thermal capacity up to 5 MW” guidelines developed by the National Center for Balancing and Emissions Management, KOBiZE (Warsaw, January 2015).

8. DEVELOPMENT PLANS OF GEOTHERMAL ENERGY USES IN PODDĘBICE

The Board of Geotermia Poddębice Ltd. together with the Poddębice Town Council plan to develop the district heating system also in other parts of the city (a single-family residential area) aimed at the reduction of low emission. This requires that the second stage of the geothermal water use (with heat pump considered) needs to be developed in the heating plant, what will allow the geothermal resources in Poddębice to be managed more effectively and rationally. The main geothermal future targets are:

- extension of district heating networks with grid connections and nodes of a total length of 34.2 km,
- extension of the heat source by adding heat pump/s with ca. 14 MW_{th} capacity.

At the beginning of 2017 the strategic development plans included:

- extension the pond for cooling geothermal water – by increasing its volume by approx. 1,500 m³ and two-staged transmission (length 9 m x 50 m wide) – in 2017,

- expansion of heat source by the second stage of heat extraction from geothermal water from 50 to 35–30°C – in 2–3 years,
- development of the geothermal heating grid in order to limit low emission – in 2–15 years – Construction the connection to the Zoo Safari Borysew (geothermal water and likely heat) in 1–2 years,
- construction of the graduating towers as successive degrees of heat extraction from geothermal water and its further cooling – this will allow it to be sent to the local waterworks (MPWiK) and to be introduced into the municipal water supply system – 1–3 years,
- construction of the facility for farming fish, shellfish, algae etc. Such activities are intended to be developed in partnership with the investor possessing the know-how and with financial investor.
- as given before, current geothermal capacity is 5 MW (from geothermal water – by heat exchangers only) and this will not change in the coming years. Total installed geothermal capacity is 10 MW.

8.1. Simulation of the water level during the production of geothermal water by the Poddębice GT-2 well – a Lumped Parameter Modelling

In order to maintain proper and sustainable long-term geothermal water production to cover current and future increased heat demand both for district heating and other uses, one has to monitor, learn and model geothermal reservoir. This is even more important since the operator must predict and know how the aquifer will respond for increased production. Those issues were considered and selected results are presented in next two subchapters.

8.2. Source of input data for geothermal water production simulation in Poddębice

In the case of the Poddębice geothermal aquifer, the input data for the model came from the monitoring of the main parameters of the geothermal water produced by the Poddębice GT-2 well, monitoring at some key points of the surface geothermal system in the period from 2012–2016 (the initial period after drilling the well and the start of its production). The data and information were provided by Geotermia Poddębice Ltd. during the Study visit to Poland – Poddębice in September 2016 as well as in the course of further contacts.

9. DATA SIMULATION

Axelsson (1989) presents the theoretical background for lumped parameter modelling of pressure change (water level) as a response to production from geothermal systems. During the last three decades such models have been used quite successfully to model, and manage,

geothermal systems worldwide (Axelsson et al. 2005). The lumped parameter models consist of several tanks and resistors, which simulate the fluid storage capacity and flow resistance, respectively, of geothermal systems. The pressure response of the models can, therefore, be used to simulate the pressure response of geothermal systems, as well as other hydrological underground systems.

It has become customary to simulate pressure or water level data from geothermal systems with both open and closed models (Fig. 6). The open models simulate systems where production and recharge eventually equilibrate, while closed models have no recharge. At a constant rate of production, the pressure declines continuously in the latter. Calculating future predictions with both model versions, therefore, provides conservative as well as optimistic predictions.

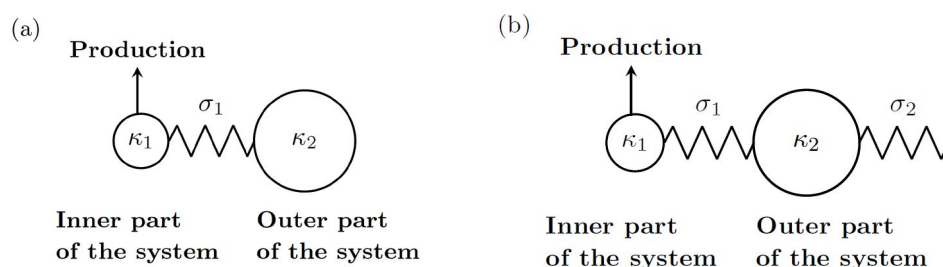


Fig. 6. Schematic pictures of (a) closed two tanks model and (b) open two tanks model which are used to model the reservoir system. Both systems are composed of two tanks, k_1 and k_2 , that represents the inner and outer part of the geothermal system. The connection between the tanks is represented with a flow resistance s_1 . For the open two tanks system the outer part is connected to an infinite reservoir with a flow resistance s_2 . The data was fitted via the least square norm to the water level and production data. There was little visual difference between the open and closed model. The data is rather noisy and the model does not follow the major jumps well but as we can see from Figure 7 it roughly manages to reproduce the gross trend of the water level data

Rys. 6. Schemat modeli (a) dwóch zbiorników zamkniętych oraz (b) dwóch zbiorników otwartych, które zostały wykorzystane do modelowania systemu. Oba schematy zakładają połączenie dwóch zbiorników k_1 i k_2 i reprezentują opór hydrauliczny s_1 . Połączenia pomiędzy zbiornikami uwzględniają strefę przepuszczalności dla wariantu (b) część zewnętrzna jest połączona z nieskończonym zbiornikiem o oporności hydraulicznej s_2 . Kalibracji modelu, tj. poziomu zwierciadła wody i wydajności dokonano przy wykorzystaniu metody najmniejszych kwadratów. Różnicę pomiędzy modelami a i b są niewielkie. Dane wejściowe są niskiej jakości i powinno się ich używać raczej do wyznaczania trendów niż do odwzorowania dokładnych przebiegów zmian parametrów w czasie

The best models (open and closed systems) were used to do 5-years' predictions for three different production scenarios:

- a) 20 kg/s,
- b) 30 kg/s,
- c) 70 kg/s – 252 m³/h – i.e. approved water reserves planned to be fully used.

In the 3rd production scenario shown in Fig. 7 – 70 kg/s (252 m³/h), the average water level for the open system shall quickly settle to 40 m, while the water level for the closed system will go below 60 m in the 5th winter (i.e. during heating seasons).

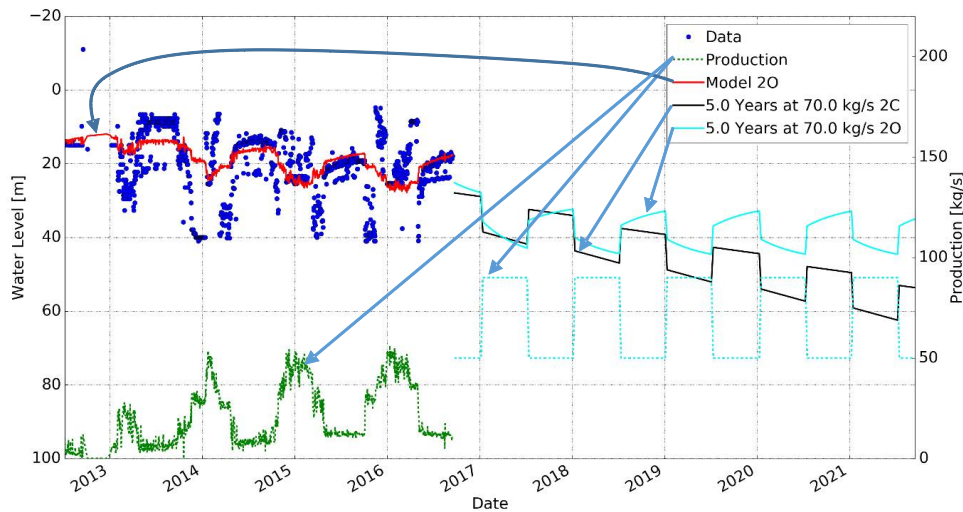


Fig. 7. Projection of the water level for the system in response to periodic step like production. The production has a yearly average of 70 kg/s and is shown with a dashed black line. The projected water level is shown with a solid black line. 2O – open tanks' reservoir model, 2C – closed tanks' reservoir model

Rys. 7. Przewidywany poziom zwierciadła wody w otworze dla systemu geotermalnego w reakcji na zmianę w czasie produkcji. Średnia roczna produkcja zaznaczona na wykresie czarną linią wynosi 70 kg/s. 2O – model zbiorników otwartych, 2C – model zbiorników zamkniętych

9.1. Some hydrogeological aspects that may affect long-term geothermal water production in Poddębice

According to regional hydrogeological recognition of Poddębice area, the well supply derives most probably from the eastern direction. The recharge area most probably is related to outcrops of the Lower Cretaceous formation located ca 15 km in the east of Poddębice GT-2 well. No or a negligible low hydraulic connection exists between the overlying Upper Cretaceous sediments (caprock).

The mineralization value of the geothermal water in Lower Cretaceous reservoir increases precipitously in the north-west direction, i.e. in the area of the Uniejów 1 well where it totals 21.9 g/dm³. This phenomenon may be related to the elevation of the Lower Cretaceous formation between Poddębice and the area of the Uniejów 1 well, resulting in the accumulation of “heavy” waters high in TDS in the vicinity of the Uniejów 1 well, which due to the structural elevation (barrier) does not flow down towards the Town of Poddębice. Moreover, the water does not flow down also towards Uniejów town as the mineralization of the exploited water varies between 6.7–8.8 g/dm³ and the water is a of chloride-sodium type.

CONCLUSIONS AND RECOMMENDATIONS

The simulation of the previous geothermal water production by Poddębice GT-2 well using Lumpfit program assumed two models of geothermal aquifer in Poddębice – an open one (optimistic) and a closed one (pessimistic). Such models are typically applied especially when one has pressure /water level monitoring data from one or even few wells and only short a production history is available (as in case of the Poddębice GT-2 well). The main conclusions that can be drawn for these simulations is that the previous production was not aggressive and the water level was not decreasing. Since the production is not aggressive it is difficult to predict the water level/pressure changes in the system, but these predictions shown here are indications of what can happen if the production is increased.

However, the short production history implied short reliable predictions for the future (2017–2022).

In addition – taking the geological and hydrogeological situation of the Poddębice area into account, one may expect that the considered geothermal aquifer can be placed somewhere between 2O and 2C models. This suggestion is, among others, due to the tectonics of its area (see cross-section in the former chapter) where both continuous and discontinuous forms (faults) are present. They resulted from halotectonics (i.e. tectonics caused by unstable salt layers and structures) as well as other tectonic events. Therefore, locally they can modify (or act as a kind of barrier) and affect recharge and low conditions even if the structures and aquifer itself are generally of an open character in a regional scale.

Geological and hydrogeological circumstances are important for the interpretation of the current simulation, future predictions and recommendations (as to optimal production rates, injection/no injection of spent water, a need for proper further monitoring, measurements etc.).

The interpretation and prediction for next several years of the water level in Poddębice GT-2 well's simulation shall take into account and indicate that – even in the case of a forecasted stable water level in the 2O model – some decrease of water level / pressure may appear. This probability shall be taken into account by the geothermal system operator and further careful monitoring of reservoir and production parameters is of utmost importance. It is also recommended to repeat the water level simulation using the Lumpfit program in course of further geothermal water production when more monitoring data are available thus more information on real geothermal reservoir's response for long-term water production.

If the heating system will be enlarged and more water is needed, then at least one production well should be drilled and one or two injection wells as well. It is very important to reinject the spent water into to geothermal system when more water is produced from the geothermal reservoir to make sure the water-level/pressure does not decrease too much. The effect could be that the pumps have to be lowered below the casing of the wells and the cost of pumping can become too big a portion of the management cost of the system.

Surface explorations such as magnetotelluric (MT), shallow gradient wells, gravity or other methods are needed before further drilling is decided on. It is important to locate the production and injection wells carefully to make sure that the injected fluid does give pressure support to the system but minimize the cooling effect.

Further well tests and interference tests should be performed and more advanced reservoir and production model of Poddębice aquifer and its response for long-term production / exploitation. This shall be done by applying e.g. the advanced numerical code TOUGH (international standard for geothermal reservoir modelling and simulation): with all the information already available (geology, hydrogeology, production, well parameters etc.) it can be used to simulate the natural state and the production history of geothermal aquifer in Poddębice.



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POTENCJAŁ DLA ROZWOJU WYKORZYSTANIA ENERGII GEOTERMALNEJ W POLSCE – MIASTO PODDĘBICE

Część 1. Wybrane aspekty złożowe i eksploatacyjne obecnego i planowanego geotermalnego systemu ciepłowniczego w Poddębicach

STRESZCZENIE

Artykuł przedstawia główne parametry złożowe i wybrane zagadnienia związane ze stabilnym wydobywaniem wody geotermalnej dla potrzeb systemu ciepłowniczego w Poddębicach – obecnie pracującego i rozbudowanego (jak jest planowane). Prezentowany materiał został opracowany jako część wstępnego studium możliwości w ramach Projektu EOG „Potencjał dla rozwoju wykorzystania energii geotermalnej w Polsce – Poddębice”. Wymienione miasto posiada zarówno perspektywiczne zasoby, jak i znaczące plany rozwoju wykorzystania energii geotermalnej w ciepłownictwie i w szerokim zakresie innych zastosowań. Wykorzystanie zasobów geotermalnych przyczynia się do rozwoju niskoemisyjnego ciepłownictwa, poprawy warunków życia oraz do rozwoju nowoczesnej lokalnej działalności gospodarczej. Poddębice są dobrym przykładem dla innych miejscowości w Polsce, które posiadają zasoby geotermalne. Artykuł przedstawia wybrane analizy, wyniki oraz rekomendacje, które są efektem wspólnych prac zaangażowanych w projekt partnerów z Islandii i Polski. Aspekty energetyczne przedstawiono w Części 2. artykułu, która jest kontynuacją prezentowanego tutaj materiału.

SŁOWA KLUCZOWE

Energia geotermalna, parametry złożowe, eksploatacja, symulacja produkcji, ciepłownictwo sieciowe, Poddębice, Polska, fundusze EOG, NFM



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