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Geothermal Energy Country Update Report from Poland, 2015 – 2019

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ABSTRACT

The paper updates the status of geothermal energy development in Poland in 2015–2019 since the World Geothermal Congress 2015 (Kępińska, 2015). The country has low-temperature resources suitable for direct applications like space heating, balneotherapy, bathing and recreation as well as some other uses.

In the case of geothermal district heating, six systems were operating at the end of 2018. Their total installed geothermal capacity was ca. 74 MW_{th} and geothermal heat sales / use 813 TJ. A growth of bathing and balneotherapy was continuing: at the end of 2018 there were fourteen recreation centres (including two launched in 2015-2019) and twelve health resorts using geothermal water and heat. In 2015 a large Atlantic salmon farm using geothermal water was opened. Remaining minor geothermal uses are comprised of wood drying, heating up a football pitch, etc. (same as in previous years). These all applications represented in total at least 106 MW_{th} and 1076 TJ of geothermal heat use at the end of 2018 (bulk for district heating). The development of shallow geothermal – ground source heat pumps (GSHP) was persisting. They reached at least 650 MW_{th} and 3100 TJ in 2018. The progress of GSHPs was a part of the progress of the whole heat pumps‘ sector. In 2015–2019 fifteen new geothermal wells were drilled. They will serve mainly for district heating, some for bathing and swimming. The majority of those wells were funded by the public support program introduced in 2015/2016. In July 2019, the next public program to support geothermal development was launched.

In general, the reported years 2015-2019 in Poland were characterized by initiating more heating-oriented geothermal drillings and investments than in the previous 5-year period (mostly thanks to 2015/2016 public support scheme). However, the geothermal share in RES (and total energy) mix was still very small. As for a European comparison, in 2018 the country was in 12th place as far as geothermal district heating is concerned. In the coming years one may expect such heating installations and other uses (mostly thanks to mentioned support programs) and, last but not least, thanks to growing interest and the need to introduce more clean energy carriers into state energy systems, especially in the case of low-emission heating.

The paper indicates also ongoing geothermal investments, projects in various stages of advancement, as well as provides basic information which is usually given in the country reports prepared for WGCs.

1. INTRODUCTION

The paper presents the status of geothermal energy development in Poland in 2015–2019 since the previous 2010–2014 update report submitted for WGC 2015 (Kępińska, 2015).

Geothermal direct applications in the country involve space heating, bathing and swimming (balneotherapy, recreation in other words) and some other single uses. At the end of 2018 six geothermal district heating plants were operating (same as reported in 2015). Space heating shall be a key sector of geothermal uses but no new geoDH was launched in the reported period. However, significant interest in geothermal bathing and swimming was continuing and expressed by next geothermal recreation centres opened in the given years. Geothermal applications involved also one large fish farm (opened in 2015) and some minor uses.

In 2015-2019 geothermal uses in Poland were still on a moderate scale and developing in a shadow of conventional fossil fuels. From the other hand – one shall note a positive fact: in 2015, a public program was launched to support geothermal exploration/research drillings and other infrastructure oriented to energetic uses (space heating, CHP). It has already resulted in granting funds for over 10 new wells (in 2019 drillings, several of them were either finished or in progress). Further applications were awaiting the decisions for funding. In July 2019 the next support program was launched. The expected result is that in the coming years geothermal will be introduced into already operating district heating systems (based on fossil fuels so far).

2. GEOLOGICAL AND GEOTHERMAL BACKGROUND

Geothermal water resources in Poland are of low-temperature type and hosted mainly by Mesozoic sedimentary formations of the Polish Lowlands and of the Inner Carpathians. Some prospective resources are also connected with particular areas and locations in the Outer Carpathians, the Carpathian Foredeep and the Sudetes region (Fig. 1). The so far recorded outflow water temperatures vary from about 20 to 97°C (depths of aquifers up to ca. 3.7 km). The proven geothermal water reserves (for single wells) amount from several L/s up to 150 L/s. Water mineralisation (TDS) varies from 0.4 to 156 g/L. Besides, wide development opportunities are associated with shallow geothermal sector (ground source heat pumps).

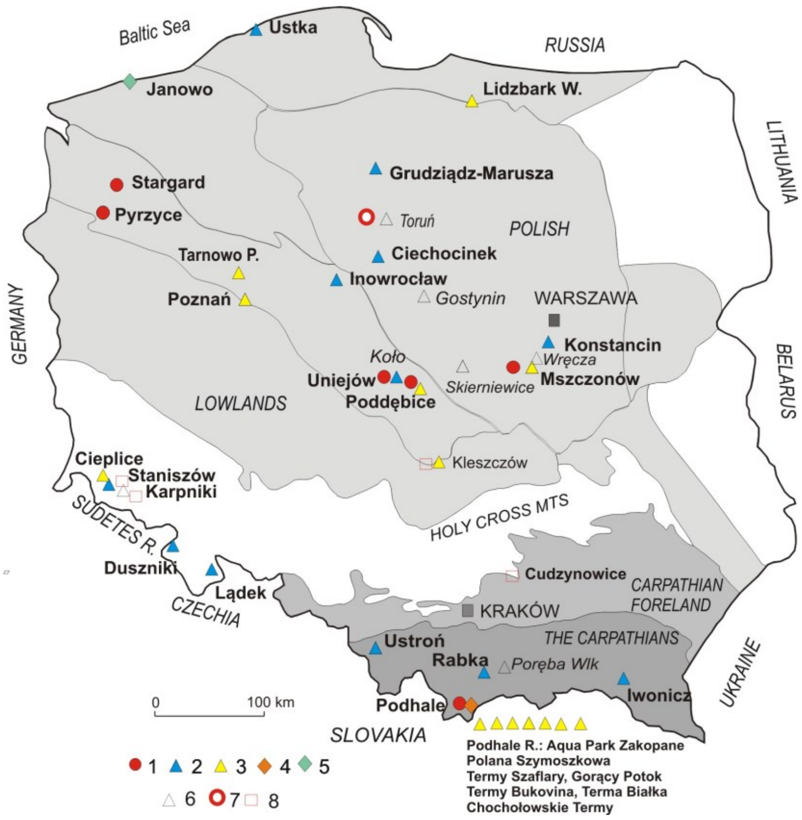

Figure 1. **Geothermal uses in Poland, end 2018.**

1. district heating plants, 2. health resorts, 3. recreation centers, 4. wood drying, 5. fish farming, 6. some recreation centers in realization, 7. heating system in realization, 8. individual heating systems (individual heating systems in some recreation centers are not marked).

3. GEOTHERMAL DIRECT USES 2015-2019 – A REVIEW

3.1 Generals

The chapter gives an overview of geothermal uses in Poland during 2015-2019 (Fig. 1, Tables 3-5). The applications involved space heating, bathing and swimming (balneotherapy, recreation), other single uses, as well as shallow geothermal (compressor heat pumps). Comparing with the situation reported at WGC 2015 the total installed geothermal capacities, heat production / sales increased, thanks to developments in particular geoDHs, recreation centres and geothermal heat pumps.

3.2 Space heating

In 2018 six geothermal space heating plants were operational in the country. Their brief characteristics follows.

The Podhale region. The geothermal district heating system has been operating since 1993 (on larger scale since 2001). Since 2017 total maximum artesian water flow rate produced by 3 wells was ca. 297 L/s (before it was 267 L/s) of 82–86°C water (mineralisation 2.5-2.7 g/L). In 2018 the installed geothermal capacity was 38.8 MW_{th} (total 77.9 MW_{th}) while geothermal heat sales amounted to 451 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 the spent geothermal water was injected back by 2 wells while another part supplied 2 recreation centres. The Podhale geothermal district heating system is among the biggest geoDH systems in continental Europe. In 2016-2018 further works on optimization and extension of that system were ongoing.

Mszczonów. The district heating plant has been operating since 2000. Similar to earlier years, maximum geothermal water flow rate was ca. 16.6 L/s of 42.5°C, while mineralisation was 0.5 g/L. Water was discharged by a single well. In 2018 the total installed capacity was 8.3 MW_{th} (4.6 MW_{th} gas boilers, 2.7 MW_{th} absorption heat pump, 1 MW_{th} compressor heat pump). In 2018 geothermal heat sales was 15.5 TJ (ca. 38% of total heat sales 43.2 TJ); after cooling water is used for drinking. Part of the water flow rate supplies the recreation centre (Termy Mszczonów). Some new projects on more efficient geothermal water and energy management were ongoing (e.g. R+D project on spent water injection into shallow water horizons).

Poddębice. The geothermal district heating plant has been operating since 2013. It has a 10 MW_{th} geothermal capacity based on 68ºC water (average flow rate 32.2 L/s, mineralisation 0.4 g/L). The plant supplies public buildings, a school, a hospital (and sends water to its rehabilitation part), and multi-family houses. In 2018 the geothermal heat sales was 50 TJ (96.5% of total production). Some part of the water stream supplies swimming pools. Next types of geothermal uses were at various stages of realization and planning. Among them was a big project using geothermal water for rehabilitation and removing barriers for disable persons.

Pyrzyce. The district heating plant has been operating since 1996. In season 2017/2018 a new production well was included into the geoDH system (maximum water flow rate ca. 55 L/s, temperature 65°C, mineralisation 150 g/L) while all four older wells (two production and two injection) started to work as injection ones. The plant's maximum installed capacity is 22 MW_{th} including 6 MW_{th} geothermal. It supplies heat and domestic warm water to over 90% of users of the whole town's population (13,000) and meets ca. 60% of total heat demand. In 2018 geothermal heat sales was 57 TJ (total 112.68 TJ).

Stargard. The geothermal heating plant has been operating since 2012 (after renovation). It is based on a doublet of production and injection wells. In 2018 maximum water production was ca. 50 L/s of 87°C water (mineralisation 156 g/L). The geothermal capacity was 12.6 MW_{th} and heat sales 230 TJ (entirely sold to the municipal district heating plant). That municipal district heating system is supplied by a coal-fired plant (total capacity 116 MW_{th} serving 75% of local population, 75,000). In 2018 geothermal met ca. 27% of the total heat demand of Stargard. In 2019 the operator of the geothermal plant started to drill two of four planned new wells to double geothermal capacity and heat sales to municipal district heating.

Uniejów. The district heating plant has been operating since 2001. The maximum discharge from one production well is 33.4 L/s of 68°C water and the TDS are ca. 6 g/L. The total installed capacity is 7.7 MW_{th} (3.2 MW_{th} geothermal, 1.8 MW_{th} biomass boiler and reserve 2.4 MW_{th} fuel oil peak boilers). In 2018 ca. 80% of all buildings in that town were supplied by the geoDH. Geothermal heat sales were 9.6 TJ (60% of total sales). Some new connections to geoDH were done in 2017–2018. Part of the geothermal water flow has been used for a spa and recreation centre (maximum 27.8 L/s of 42°C water; ca. 1.5 MW_{th}) which is also heated by geothermal energy. Part of the spent water flow rate (8.3 L/s, 28°C) is used to heat up a football pitch (ca. 0.3 MW_{th}, 5.5 TJ) and walking paths. Uniejów has a status of health resort (since 2012). Besides geoDH some other uses were at various stages of project realization and preparation.

To sum up the geothermal district heating in Poland in 2018: the total installed geothermal capacity of six geoDHs was 74.3 MW_{th} and geothermal heat sales 813.1 TJ. In particular geoDHs geothermal share in total heat production / sales ranged from 38 to 100%. In some cases, geothermal heat prices were competitive with prices of heat derived from fossil fuels like gas, and even coal, on occasion (Pająk & Bujakowski, 2018).

In the case of individual space heating, geothermal waters (28–80°C) were used to supply a school complex, hotel buildings, spa facilities and for heating up water for swimming pools and spa treatments in several localities. Also several recreation centers had individual geothermal heating. According to available information and evaluations these types of applications could reach in total at least 11 MW_{th} and 100 TJ in 2018 (Table 3, Table 5).

3.3 Bathing & swimming

In 2015-2019 in twelve health resorts geothermal waters were used for various treatments (two more than reported in 2010-2014). In particular cases approved water reserves varied from ca. 0.5 to 56 L/s while outflow temperatures ranged from ca. 20 to 90°C. In several cases outflow water temperatures were below 20°C (due to flow rate lower than approved maximum one) – such waters were heated up for spa treatments. Hence, their geothermal capacities and heat uses were not taken into account in 2015-2019 statistics and not given in Table 3 and Table 5.

At the end of 2018 fourteen geothermal recreation centers were operating. That number included three new centers opened in reported years: two large ones in the Podhale region (the 6th and 7th centers there!) and one in another part of the country.

Following accessible information and assumptions made by the author the total geothermal capacity and heat for bathing and swimming in 2018 were estimated to be at least 17 MW_{th} and 137 TJ (Table 3, Table 5; remembering the difficulties to access data on part of the facilities and accurate evaluations).

Several centers used geothermal water both for bathing and swimming and for heating their objects or warm water preparation (as given in chapter 3.2). Moreover, some operated 0.5–1 MW_{th} compressor heat pumps to extract more heat from geothermal water before its surface disposal (total ca. 3–4 MW_{th} more; chapter 3.5, Table 4). In at least one of the centres, geothermal heat was applied for snow melting (chapter 3.4).

3.4. Aquaculture, other uses

Since 2015 an Atlantic salmon farm using geothermal water has been operating (Janowo at the Baltic coast). Geothermal water was applied for culturing and for heating the farm's facility. For 2018 geothermal capacity could be roughly evaluated for 2.1 MW_{th} and heat use for 17.8 TJ. In the case of biotechnology, in 2018 an experimental algae cultivation applying geothermal water was initiated in Poddębice heating plant.

One shall also mention (as in former update reports): semi-technical wood drying (MEERI PAS installation in the Podhale region – ca. 0.3 MW_{th} and 0.6 TJ): heating up of a football pitch and walking paths (ca. 0.3 MW_{th}, 5.5 TJ; Uniejów), snow melting (on parking area, etc. in at least one of the geothermal recreation centers (Podhale region; assumed 0.5 MW_{th} and 2 TJ in 2018) (Table 3, Table 5).

In several localities geothermal water has been served as the source to extract the iodine-bromine or cosmetic salts and CO_2. Waters are sometimes bottled as medicinal or mineral waters. Another sector of geothermal water uses was related to cosmetics' production (gradually developing).

3.5 Geothermal heat pumps

In 2015–2019 a progress in shallow geothermal development was continuing (www.portpc.pl). According to Heat pumps barometer (EurObserv'ER 2018; https://www.eurobserver.org/online-database/), by the third quarter of 2018 the GSHPs' sales amounted to 5660 units positioning Poland in fourth place in the sales ranking of GSHPs, in EU-countries. On the other hand, The Market Report published by Polish Organisation of Heat Pumps' Technology Development evaluated the number of GSHPs' sales in Poland for ca. 4 800 units in 2018 (but it may not give a full picture of the market; Lachman, 2019). Comparing, for example, 2017 to 2018, the annual growth was ca. 5% in 2018. One may estimate that at the end of 2018 the number of GSHPs reached ca. 56 000 units, while their total capacity was at least 650 MW_{th} and heat production 3100 TJ. The deployment of GSHP was a part of an entire heat pumps' market development in Poland in 2018 (and in several former years): e.g. 20% in case of heat pumps for central heating and even 31% in the air / water heat pumps' market (year on year). In addition, the share of heat pumps in newly built single-family buildings has increased: every seventh such building is heated by a heat pump (Lachman, 2019).

3.6 Summary of geothermal uses in 2018

Taking into account the data from particular geoDHs and other types of direct uses (except for GSHPs), at the end of 2018 their total installed or calculated geothermal capacity was at least 106 MW_{th} (70% in district heating). Geothermal heat sales (in case of district heating systems) and used (in other installations) were at least 1076 TJ (ca. 76% in district heating) (Table 4, Table 5). Adding shallow geothermal (GSHPs), it was at least 756 MW_{th} and more than 4176 TJ in total. These figures do not include the values of geothermal capacities and heat uses in some recreation centers (bathing and swimming). So real total geothermal capacities and heat uses in 2018 could be somehow higher (by several percent).

4. GEOTHERMAL DRILLINGS

In 2015–2019 fifteen new geothermal wells were drilled (Table 6); the prevailing number of them in 2018-2019 (8 wells). They were mostly exploration / research ones located within the Polish Lowlands while three were exploitation ones. They gave a total depth of about 26.6 km. The wells discharge 28–92°C waters (up to 97.5°C in reservoir) with flow rates 28–250 m^3/h (one well was negative – so it is planned to serve as a deep BHE. Most of them will serve as producers for the needs of geoDH (existing, new DH), some for bathing and swimming centers. Almost all wells were funded by grants or loans from a public support program launched in 2015/2016. Total costs spent for 12 drillings in 2015-2019 were about 190 mln PLN (Polish zlotys). That figure included ca. 166 mln PLN from supportive measures (ca. 44 mln USD; 1 USD ~3.8 PLN as in September 2019).

One shall point out that in 2015-2019 a positive change occurred compared to the 2010-2014 period (marked by the stagnation especially in geothermal drillings for heating due to the closure of public support program in 2012): in 2015 a new state program to support research drillings and other infrastructure for geothermal district heating and CHP was launched. The allocation of its first part in the forms of grants (up to 100%) and loans (up to 40–50 % of eligible costs) was ca. 200 mio PLN / for wells and 500 mio PLN for other infrastructure. Next support program was launched in 2019 (total 600 mio PLN for drillings, surface heating infrastructure, etc.). In 2018–2019 next decisions on financing the drillings of several wells were issued (wells aimed at providing geothermal to already existing heating grids in several municipalities; in 2019 some of those drillings were in progress). In that group was also a geothermal plant in Stargard which started drilling two of the planned four new wells to increase geothermal heat production.

Taking the above into account, by 2020 and beyond one may expect the completion of at least 10 new geothermal wells. They should allow the introduction of geothermal into already existing district heating systems in several towns and to develop other uses.

5. PROFESSIONAL PERSONNEL ALLOCATION

A number of professional full-time personnel with academic degrees employed in various geothermal activities (scientific and research entities, geothermal plants, other installations, drilling, servicing, consulting companies) can be roughly estimated for ca. 130 persons as for the end of 2018 (Table 7). Those numbers had not substantially changed since the former report. In addition, significant numbers of technical personnel have been working in recreation centres (ca. 10–150 prs/centre, depending on its size), in health resorts, district heating plants, drilling companies, etc. (not included into this total estimation).

6. INVESTMENTS IN GEOTHERMAL SECTOR

On a basis of available information and evaluations one may estimate that geothermal investments in 2015–2019 were at the level of at least 370 mln USD (1 USD = 3.8 PLN as in October 2019). They included (Table 8):

- Research & development (seismic survey and other research, drilling nine exploration/research wells),
- Field development (drilling three production wells, other works and equipment for geothermal district heating plants),
- Utilization: at least 300 mln USD which included: investments in operating geoDHs and one geoDH under construction (most of the funds spent after 2016 since the launch of the new public program to support the energetic geothermal uses projects). Years 2012–2016 were impacted by stagnation in the heating sector that had been lasting since the closure of the previous public support program in 2012); bathing & swimming centers (prevailing amount from the given total sum spent mostly for several big operating centers and one huge center under construction). For several private investments (bathing and recreation, other uses) relevant information was not available.

The investments in the shallow geothermal sector in 2015–2018 could be evaluated for ca. 84 mln USD.

7. PROJECTS UNDERWAY AND PLANNED

In 2015–2019 along with drilling activities several other geothermal investment activities were ongoing. They were mostly oriented for space heating, some for bathing & swimming (recreation). The summary of many of them follows.

- Investments to increase geothermal capacities, heat extraction and hooking new consumers in all six operating geoDHs. In one case a new production well was drilled and configuration of exploited wells was optimised (Pyrzyce plant). As mentioned before, in 2019 the operator of Stargard plant started drilling two of the planned four new wells to double geothermal capacity and heat production. In the city of Toruń the construction of a geothermal heating center was initiated (it will base on the well doublet drilled several years ago and is funded by public support). In the Podhale region the works aimed at introducing geothermal to Nowy Targ (one of the main cities in that region) and to some other localities were in progress – geothermal heat will come from a deep well (funded by public support) the drilling of which was planned to start in 2019. The plans to supply geothermal energy to local district heating systems were under elaboration also for some localities in other regions of Poland;

- Further investments in recreation and balneotherapy: among them was the construction of a huge center in Wręcza (central Poland, opening expected in 2020). In recent years a new well was drilled to supply that center with water and heat. Another large balneotherapy / recreation project (as part of a wider initiative) was ongoing in Poddębice town. Also, in some other localities geothermal recreation projects were in progress or in preparation;

- Several pre-investment works and feasibility studies for various sites meeting the interest shown by local authorities and private investors.

  The research, R+D+I activities were also ongoing. They included, among others:

- Research, R+D+I on various topics, e.g.: geothermal water desalination; injection of spent geothermal water into shallower water horizons; geothermal uses in agriculture; aquifer/underground thermal energy storage; energetic optimisation of geothermal systems; etc.;

- First three geothermal projects funded by the EEA financial mechanism performed jointly by teams from Poland, Iceland, Norway (and EGEC in one case) in 2016–2017 (www.eeagrants.agh.edu.pl; www.pgi.gov.pl/geothermal4pl.html). Next project proposals were in preparation throughout the course of 2018–2019.

- Participation in some EU-supported projects, eg. GeoPlasma-CE (https:// portal.geoplasma-ce.eu), GEORISK (www.egec.eu).

8. LEGAL AND ECONOMIC ASPECTS

In 2015–2019 several geological aspects of geothermal development had relatively proper legal backgrounds thanks to several provisions of Geological and Mining Law (2017) (even if the investors claimed these were long procedures). However, another basic document – i.e. the RES Law (2018; initial text 2014) is oriented towards electricity and does not pay sufficient attention to renewables' H&C sector. In 2018 the works began on the development strategy for the heating sector. It will take RES into account so as also geothermal energy. The entrepreneurs point out the need to introduce more clear and relevant provisions in several other principal laws and codes.

As given in chapter 4, regarding economic conditions of geothermal sector's development – in contrary to previous reported years, in 2015/2016 a positive change took place. It was expressed by introducing a state program to support geothermal research drillings and other investment activities. Next program was launched in July 2019. In addition some other EU- and state programs were available for geothermal projects. These acted as a breaking of the slowdown in geothermal heating sector that had been lasting since 2012 (when the former support program was closed).

In the group of state policy and strategy documents dedicated to energy and raw materials which had been introduced in recent years or are under preparation – some refer, inter alia, to geothermal energy (as a part of RES or directly), e.g.: the Strategy for Responsible Development (www.miir.gov.pl/strony/ strategia-na-rzecz-odpowiedzialnego-rozwoju/); the State Raw Materials' Policy (not introduced yet) (www.psp.mos.gov.pl). It is hoped that geothermal heating development will be also facilitated by the programs dedicated to thermal retrofitting and air quality improvement. In the view of above-mentioned facts, in the coming years one may expect more geothermal installations in Poland, especially as far as the heating sector is concerned.

9. GEOTHERMAL SHARE IN CURRENT RES MIX AND IN OFFICIAL PROGNOSES

According to the Central Statistical Office (Berent-Kowalska et al., 2018) in 2017 the RES share in total primary energy acquisition was 14.10% (383 168 TJ). The contribution of particular renewables was as follows: solid biofuels 67.9%, wind 14.0%, liquid biofuels 10.0%, hydro 2.4%, municipal wastes 1.01%, geothermal 0.25%, heat pumps (all types) 0.62%. The input of RES to the whole H&C sector was 14.68% in 2017 (general 2018 data were not yet available during preparation of this article). According to the European Union and state documents (Directive 2009/28/EC; National Renewable Energy Plan, NREAP, 2010), the RES' share in final gross energy consumption in Poland shall reach 15% by 2020 while in 2017 it was 10.97%. Furthermore: NREAP (2010) prognosed the share of geothermal in H&C as 3% by 2020. So in 2017 and 2018 the geothermal share in RES sector was far below that prognosis. For the coming years there are some premises that this share will increase somehow thanks to already existing as well as envisaged several next geoDHs. One may also expect an increased share of shallow geothermal in the H&C sector.

10. CLOSING REMARKS

In 2015–2019 some further progress of geothermal sector was observed in Poland compared to the previously reported period of 2010-2014. It resulted from increased heat production and sales by six geoDHs and increased uses in some bathing and swimming centers (especially that several of them are large recreation centers capable of hosting 2-3 thousand visitors/hr). All geoDHs contributed to limit the GHGs emissions, in all of them works were ongoing or planned to connect new consumers. However, no new geoDH was constructed in 2015-2019 – due to the lack of sufficient public support in the earlier period 2012– 2015. Further development of shallow geothermal was observed (as part of the whole heat pumps' sector deployment in several past years).

As the milestones for geothermal development in the country one may point to the launch of the state support programs in 2015/2016 and 2019. By 2019 the 2015/2016 program has already resulted in granting funds for drilling over ten exploration/research wells (some were already completed in 2018–2019). Most of these wells will serve as suppliers of heat to some existing municipal DHs (in some of the cases injection wells will also be drilled). In the coming years some more dynamic geothermal use development in Poland is expected – especially for space heating but also for other uses (bathing and swimming, etc.) and in shallow geothermal. This is of the utmost importance since geothermal is a prospective measure to introduce low-emission heating, improve quality of life and enhance sustainable development. Geothermal uses development shall be also facilitated by some state policies that had been introduced since 2015/2016. Therefore, it is hoped that at the next WGC2023 more than six geoDHs will be reported. Better economic and regulatory conditions for the geothermal sector introduced in recent years shall result in its more dynamic development in the years to come. However, several indispensable regulatory and economic measures are waiting for introduction in the country (e.g. the risk guarantee fund, fiscal incentives for investors and final energy consumers) to ease geothermal investments and make geothermal heat more competitive with other energy sources (mostly coal in the case of Poland).

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TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2018 (other than heat pumps), POLAND

1) I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish farming
K = Animal farming
S = Snow melting
H = Individual space heating (other than heat pumps)
D = District heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 ($MW = 10^6$ W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 ($TJ = 10^{12}$ J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization: Flow Rate (kg/s)	Temperature (^oC) Inlet	Temperature (^oC) Outlet	Enthalpy[2)] (kJ/kg) Inlet	Enthalpy[2)] (kJ/kg) Outlet	Capacity[3)] (MWt)	Annual Utilization: Ave. Flow (kg/s)	Energy[4)] (TJ/yr)	Capacity Factor[5)]
Podhale[1]	D	297.0	87	55			38.8	146.8	451.0	0.38
Pyrzyce[1]	D	55	65	28			6	33.4	57	0.15
Mszczonow[1]	D	16.6	42	12			3.7	9.6	15.5	0.14
Uniejow[1]	D	33.4	68	48			3.2	20.8	9.6	0.29
Stargard[1]	D	50.0	87	64			12.6	53.6	230.0	0.43
Poddebice[1]	D	70.0	68	54			10.0	30.5	50.0	0.05
Uniejow[2]	O	8.3	28	20			1.0	8.3	5.5	0.56
Kleszczów	H	41.7	52	na			na	2.2	7.8	
Cudzynowice	H	27.8	28	na			na	0.8	1.0	
Karpniki	H (+B)	12.2	54	35			0.97	0.004	0.01	<0.01
Staniszów	H	5.7	37	na			na	0 in 2018	0.0	

Zakopane Aqua Park	B	13.9	37	28			0.52	6.9	8.2	0.50
Zakopane Szymoszkowa	B	19.4	27	23			0.32	2.1	1.11	0.01
Terma Bialka	B	7.9	38	28			0.37	7.8	10.3	0.87
Terma Bialka[3] */tent./*	H	7.9	74	50			3.0	7.9	30.0	0.32
Terma Bukovina */tent./*	B	13.3	38	28			0.56	8.4	11.1	0.63
Terma Bukovina[3] */tent./*	H	13.3	64.5	38			2.0	11.2	30.0	0.46
Termy Szaflary	B	6.9	38	30			0.2	6.9	6.9	0.9
Termy Szaflary	H	6.9	55	40			0.4	6.9	10	*0.8*
Gorący Potok	B	21.9	40	34			0.6	21.0	16.6	0.9
Chochołowskie Termy[8]	H	21.2	89.8	40			4.4	7.9	21	0.15
Chochołowskie Termy[8,9]	B	21.2	89.8	40			4.3	7.9	21	0.15
Chochołowskie Termy[8]	S	2.0	60	40			0.5	0.8	2	
Termy Uniejow	B	27.8	45	32			1.5	17.6	30.1	0.64
Termy Mszczonow	B	4.2	32	28			0.07	4.2	1.5	0.68
Poddebice	B	70.0	38	28			0.23	5.6	3.7	0.14
Kleszczów	B	41.7						2.2	na	
Cieplice	B	~7.5	36-39	26			0.3	6.0	10.0	0.90
Ladek	B	16.6	20-44	30-34			0.56	5.5	5.84	0.35
Duszniki	B	5.5	19-21	19			0.05	5.5	0.7	0.44
Ciechocinek[4]	B+O	56.8	27-29	~20			1.9	4.2	2.8	0.05
Konstancin	B	2.5	29	~20			1.8	0.1	0.14	0.01
Ustron	B	0.6	28	~20			0.02	0.13	0.14	0.22
Iwonicz[5]	B+O	11.4	21	10			0.52	0.5	0.7	0.04
Grudziądz-Marusza[6]	B	5.5	20-22	~20				0.03		
Rabka[6,5]	B+O	1.8	28	~20				0.07		
Inowrocław[6]	B	1.6	23.5	20				0.73		
Ustka[6]	B	3.3	20.5	~20				0.02		
Termy Maltanskie Poznan	B	2.8	38	28			0.12	0.3	0.39	0.10
Termy Cieplickie *(tent.)*	B	12.5	36	27			0.47	5.0	5.94	0.40
Tarnowo Podgórne	B	62.5	38	28			2.62	<0.01	<0.01	<0.001
Lidzbark Warminski[6]	B	33.4	24	22				<0.01		
Janowo	F	50.0	27	~ 17			2.1	13.5	17.8	0.27
Podhale Region[7]	I						0.3		0.6	0.06
TOTAL		~1268.3					~106.00		~1075.98	

[1] Geothermal district heating systems: given are geothermal installed capacities and heat sales

[2] Uniejow - O: heating up the football pitch and walking paths

[3] Compressor heat pumps installed

[4] Ciechocinek: O - extraction of iodine-bromine salts

[5] Iwonicz, Rabka: O - extraction of iodine-bromine salts, production of cosmetics

[6] Bathing and swimming centres that used limited amounts of max. water flow rates. Due to low water temperatures (even below 20ºC), waters were heated up before their use) therefore data on geothermal capacities and energy are not given in Table 3 and Table 5

not all parameters are given. Sometimes water is even heated up for spa treatments

[7] Podhale region: I - wood drying

[8] Chocholowskie Termy: figures for particular uses acc. to available data and author's assumptions (geothermal heat and water is used in a complex way)

[9] - geothermal water used to heat up water in swimming and bathing pools and partly to maintain stable temperature

General notes:

a. Information given in Table 3 is based on data from operators of geothermal installations; "Balance of mineral deposits' resources in Poland as on 31 December 2018" (2019); Kępińska 2015, other sources.

b. Data on some bathing and swimming installations are tentative or based on earlier numbers (Kępińska, 2015). For some bathing/recreation installations outlet water temperatures were assumed.

na – not available

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2018, POLAND

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or water temp. (°C)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]	Heating Equivalent Full Load Hr/Year[4]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Groundsource and groundwater heat pumps	(-7) - 20	10 - 200 (largest ca. 1 MW)	> 56 000	V, H, W	3.5 to 6 /ave. 4.2/	3800	> 3100	ca. 20-30% devices used for cooling;
TOTAL		> 650 MW	> 56 000				> 3100	

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2018

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001
2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x
0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154
3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW=10^{6} W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% capacity all year

4) Other than heat pumps

5) Includes drying or dehydration of grains, fruits and vegetables

6) Excludes agricultural drying and dehydration

7) Includes balneology

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	> 10.77	> 99.81	> 0.29
District Heating [4]	74.3	813.1	0.37
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming	~2.1	17.80	0.27
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]	0.3	0.6	0.06
Snow Melting *	0.5	2.0	0.13
Bathing and Swimming[7]	> 17.03	> 137.17	0.26
Other Uses (specify) **	~1.0	~5.5	0.17
Subtotal	> 106.0	1075.98	0.31
Geothermal Heat Pumps	> 650	> 3100	
TOTAL	> 750.03	> 4175.98	

* Estimation (Chocholowskie Termy parking area, etc.)

** Heating up of footbal pitch and walking path (Uniejow)

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2015 TO DECEMBER 31, 2019 (excluding heat pump wells)

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)		8	1		19.0
Production	>150° C					
	150-100° C					
	<100° C		6			7.6
Injection	(all)					
Total			14	1		26.6

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	10	90	30			30
2016						
2017						
2018						
2019	10	40	30			50
Total						

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN 2015 - 2018, US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	5.6	8.10	40.8		5	95
2000-2004	0.3	11.36	37.91		5	95
2005-2009	15	15	100		80	20
2010-2014	64.5	19.3	313		80	20
2015-2019	37.7	32.5	300		75 [1]	25

[1] High percentage of private funding resulted mostly from Utilisation - investments in bathing and swimming sector. In case of Research & Development (sp. drillings) and Field development the percentage of public funding (grants, loans) was up to 50-100% in particular projects (specially drillings)