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Geothermal Energy Country Update Report from Poland, 2020– 2022

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ABSTRACT

The paper updates the status of geothermal energy development in Poland in 2020–2022 since the World Geothermal Congress 2020+1 (Kępińska, 2020).

The country has low-temperature geothermal resources suitable for direct applications like space heating, balneotherapy, bathing and recreation as well as some other uses. In case of geothermal district heating seven systems were operating at the end of 2022 (including one launched in 2022). Their total installed geothermal capacity was at least ca. 93.4 MW and geothermal heat production at least 1 121 TJ (about 26% and 22% more than in 2019, respectively). A growth of bathing & swimming sector was continuing: at the end of 2022 there were eighteen recreation centers, sixteen of them in operation (four launched in 2020–2022) and twelve health resorts using geothermal water and heat. The development of individual heating in dozen big geothermal centers was observed. Other uses included a large Atlantic salmon farm, as well as several types of applications on a small scale (wood drying, snow melting, heating up a football pitch, cosmetics production, CO_2, etc. – some as in previous years, some new). These all applications represented in total at least 190 MW and 1 447 TJ of geothermal heat at the end of 2022 (bulk for district heating, and individual heating –the latter estimated very roughly). The development of shallow geothermal – ground source heat pumps (GSHP) was persisting. They could reach at least 900 MW and 4 600 TJ in 2022 (rough estimations). The progress of GSHPs was a part of the progress of the whole heat pumps sector. In 2020–2022 about eight new geothermal wells were drilled. They will serve mainly for district heating, some for bathing & swimming. Majority of those wells and other investments aimed at geoDH development were done thanks to several public support programs introduced in 2015/2016 and available in reported years.

In general, as the former reported period 2015–2019, also 2020–2022 period was characterized by more geothermal drillings and investments, especially in district heating sector (mostly thanks to the public support programs). The development of bathing & swimming sector was continuing. A Multiannual Program for the Development of the Use of Geothermal Resources for Poland until 2040, with a perspective until 2050, was announced in 2022.

However, the geothermal share in Renewable Energy Sources (RES) (and total energy) mix was still very small. Among the arguments for the wider geothermal use development are, inter alia, the needs to increase local energy uses, security of energy supply, and to prevent energy poverty – these aspects are more and more important in recent years. In the coming years one may expect more intense geothermal use development in the country, especially for district heating (mostly thanks to the mentioned support programs).

The paper indicates also ongoing geothermal investments, some pre-investment works, as well as provides several basic information usually given in the WGC country reports. One shall remember that the reported years 2020–2022 were affected by pandemic and then by energy crisis caused by Russian invasion on Ukraine in February 2022. Many economic sectors in many countries were impacted by those facts, including geothermal branch.

1. INTRODUCTION

The paper presents the status of geothermal energy development in Poland in 2020–2022 since the previous 2015–2019 update report for WGC 2020+1 (Kępińska, 2020).

Geothermal direct applications in the country involved mostly space heating, bathing & swimming, and, in single cases, some other uses. At the end of 2022 seven geothermal district heating plants were operating (six reported in 2015–2019 and one new launched in 2022). Four next geothermal recreation and similar centres were opened.

However, in reported years geothermal uses were still on a limited scale. On the other hand, the number of drillings and other investments oriented to introduce geothermal into district heating systems (and for some other uses) was growing. It was thanks to several public support programs, launched gradually since 2016. In 2020–2022 dozen next projects received support (grants, loans) for drillings and other investments. Some of them were completed, some were in progress. Recent call was in fall 2022, results were expected in first half 2023. In previous reported period 2015–2019, those programs resulted e.g., in granting funds for drilling over 10 geothermal wells. One shall also note the publication in 2022 the Multiannual Program for the Development of the Use of Geothermal Resources for Poland until 2040, with a perspective until 2050.

Please note that the authors presented the figures on main geothermal uses in the country as in 2022 (district heating, some individual heating installations, shallow geothermal – ground source heat pumps), while some other uses as in 2021 or in earlier years. The tables at the end of this text follow the templates from former country updates (and references are made to them in the

text of this paper). Moreover – some information is also included into the tables elaborated and requested for WGC2023 country updates and submitted as separate files (references are made to some of these Tables, too).

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. Mineral concentration of exploited waters vary from 0.4 to about 160 g/l. Besides, wide development opportunities are associated with shallow geothermal sector (ground source heat pumps).

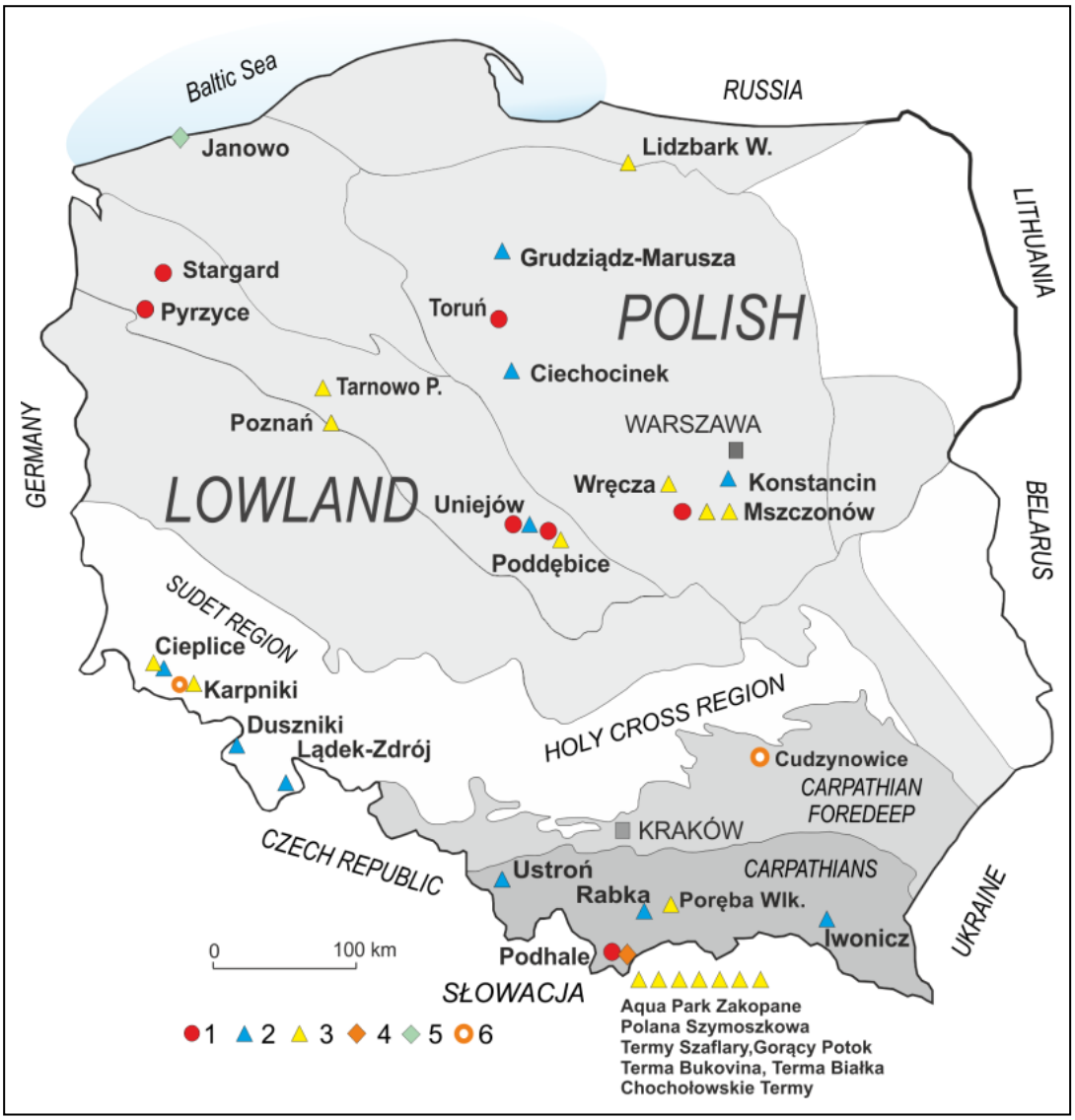

Figure 1. Geothermal uses in Poland, 2022.
1. District heating plants, 2. Health resorts, 3. Recreation centers, 4. Wood drying, 5. Fish farming, 6. Individual heating systems

3. GEOTHERMAL DIRECT USES 2020–2022 – A REVIEW

3.1 Generals

The chapter gives a review of geothermal uses in Poland in 2020–2022 (Fig. 1, Tables 3–5 at the end of this text, Table 3, Table 4 – new templates not included). As given in introduction, they involved space heating, bathing & swimming, other single uses, shallow geothermal (heat pumps). Comparing with situation presented at WGC 2020+1 the total installed geothermal capacities, heat production (sales) increased somehow. In 2021, in Poland there were 36 approved geothermal water reservoirs (for total of 148 approved ground water reservoirs). From the given number of geothermal reservoirs, 19 were exploited for practical uses. In 2021, total geothermal water intake amounted to 11 462 426 m^3 (*Balance*…, 2022). No electrical power using geothermal fluid was generated – neither in conventional way (no high-enthalpy geothermal potential in the country) nor in binary systems. Hence Table

1 and Table 2 (new templates) are empty as far as geothermal is concerned. Some pilot geothermal binary CHP systems are expected in coming years.

3.2 Space heating

District heating. In 2022 seven geothermal space heating plants were operational – six plants reported in former years and one opened in autumn 2022. In single cases an individual heating was in place. Following there is a brief characterization of these geothermal district heating systems.

The Podhale region. The geothermal district heating project has been in progress since 1993 (on a larger scale since 2001). The total maximum artesian water flow rate discharged by 3 wells was 297 l/s of 82–86°C (mineralization 2.5–2.7 g/l). The installed geothermal capacity was 40 MWt. Geothermal heat production amounted to 653 TJ (sales were ca. 10% less). The share of natural gas for heat production in peak season was ca. 2–3%. In 2022 about 2000 receivers were hooked to geoDH (mostly in Zakopane – the main city of that region and main heat market; geoDH met ca. 40% of its heat demand). Part of spent water was injected back by 3 wells while part supplied 2 recreation centres. The Podhale geothermal heating system is among the biggest ones in continental Europe. In 2020–2022 further investments on optimization and extension of that system were ongoing (e.g., in 2023 installed geothermal capacity was increased up to 70 MWt).

Mszczonów. The plant has been operating since 2000. Similar to earlier years, in 2022 maximum flow rate was ca. 16.6 l/s of 42°C water (mineralisation 0.5 g/l). Water was discharged by a single well (no injection). The total installed capacity was 8.3 MWt (4.6 MWt gas boilers, 2.7 MWt absorption heat pump, 1 MWt compressor heat pump). In 2022 geothermal heat production was 14.04 TJ (31% of total production). After, cooling water was used for drinking (via local water network). Part of water stream supplies the recreation centre and, since 2021, a unique deep spot for free diving (ca. 45 m of depth; more: chapter 3.3.). Some additional projects were ongoing, including a new production well (finished at beginning of 2023).

Poddębice. The plant was launched in 2013. It has a 10 MWt geothermal capacity based on 68ºC water (maximum flow rate 70 l/s, mineralization 0.4 g/). The plant supplies heat for public buildings, school, hospital (and water to its rehabilitation part), multi-family houses. In 2022 geothermal heat production was ca. 56.4 TJ (over 97.5% of total production – rest was provided by peak gas boilers located in several places of the municipal heating network). Part of geothermal water stream and heat supplied a big recreation and hydrotherapy center opened in mid-2022 (which replaced former outdoor swimming pools complex). Water was also used for drinking (on a moderate scale so far). Additional types of geothermal uses were at various stages of realization and planning.

Pyrzyce. The plant was launched in 1996. Maximum flow rate is 55 l/s of 65ºC water (mineralization 150 g/l). Since 2017/2018 one production and four injection wells have been operating. The maximum installed capacity was 22 MW_t including 6 MWt geothermal. The plant supplied heat and warm tap water to over 90% users of the whole town (population 13,000) and met ca. 60% of total heat demand. In 2022 geothermal heat production was 70.2 TJ.

Stargard. The plant has been operating since 2012 (after renovation). In 2022 it was operated with two production and five injection wells. Maximum production was 88.9 l/s of 87–90°C water (mineralization 156 g/l). The geothermal capacity was 18.45 MWt and heat production 284.2 TJ. The heat was sold to the municipal district heating plant. That municipal system was supplied mostly by coal-fired plant (total capacity 97.9 MWt serving about 75% of population, 75,000). In 2022 geothermal share in total heat sales to the city was 41.7% (https://pec.stargard.pl/pec/system-cieplowniczy/). In recent years four new geothermal wells were drilled. It was to increase productivity and injectivity, to increase geothermal capacity and heat sales to municipal grid. Two of those wells were drilled in 2020–2022, and two in 2015–2019.

Uniejów. The plant has been operating since 2001. The maximum discharge from production well was 33.4 l/s of 68ºC water, mineralization 6–8 g/l. The total installed capacity was 7.4 MWt (3.2 MWt geothermal, 1.8 MWt biomass boiler, reserve 2.4 MWt fuel oil peak boilers). In 2022 ca. 80% buildings in that town were supplied by the geoDH. Geothermal heat production was 9 TJ (60% of total sales). Some new connections to geoDH were done in 2020–2022. Significant part of geothermal water flow has been used for spa and recreation centres which are also partly heated by geothermal. Some spent water stream was used to heat up a football court, and walking paths. Uniejów has a status of health resort (since 2012). Besides geoDH and mentioned uses, some other types of applications were implemented or were at various stages of project realization (see e.g., sections 3.3, 3.4).

Toruń. The plant was opened in October 2022. It is based on a doublet of wells. Approved reserves are about 90 l/s (*Balance ...,* 2022) of 62ºC water, geothermal capacity is 18 MWt. The plant, owned by Geotermia Toruń Ltd., supplies heat to the nearby Academy of Social and Media Culture complex and to part of the municipal district heating system (owned by the state PGE Toruń company). Geothermal accounts for about 8% in the district heating system. The remaining amount of heat in that network comes from gas CHP (91%) and biogas plant (below 1%). Annual geothermal heat sales are planned to reach 234 TJ (https://torun.naszemiasto.pl/torun-cieplownia-geotermia-oficjalnie-otwarta-czerpie/ar/c1-9038775). Geothermal heat produced in several months of 2022 was estimated for about 40 TJ.

Sum up the geothermal district heating in Poland in 2022: the total installed geothermal capacity of seven geoDHs was 93.4 MWt, i.e. 26% more than in 2019, and geothermal heat production 1121 TJ (about 22% more than in 2019). In particular geoDHs geothermal share in total heat production/sales ranged from ca. 30 to 100%. Geothermal heat prices were relatively stable and competitive with prices of heat derived from fossil fuels like gas, and even coal, what was especially visible in 2021–2022.

Individual space heating based on geothermal water (ca. 28–80ºC) supplied school complex, hotel and spa facilities in two localities (on a moderate scale) in 2021. Moreover, dozen recreation centers were heated by their own geothermal systems. According to available information from previous years and rough indicative assumptions for 2021, those types of applications could reach in total at least 52 MWt and 100 TJ (including ca. 1.5 MWt and 1 TJ for the afore-mentioned school, hotel and spa

complex in two localities, 2021). These numbers give a general idea that shall be refined in the coming years (Table 3, Table 5). In addition, some recreation centers were supplied with heat by geothermal district heating systems.

3.3 Bathing & swimming

The category "bathing & swimming" includes health resorts and recreation centers. In 2020–2022 twelve health resorts use geothermal waters for various treatments (the same localities as reported in 2015–2019). Approved water reserves varied from ca. 0.6 to 57 l/s while outflow well head temperatures from ca. 20 to 90°C. In several cases outflow temperatures were below or around 20ºC (due to flow rate lower than approved reserves), so as such waters were heated up for spa treatments.

In 2021, 2022 at least 16 geothermal recreation centers were operating. Many of these centers are capable of receiving up to several thousand people a day. The given number of 16 centers included 4 new ones opened in reported years, namely: in Wręcza near Mszczonów (among the biggest in Europe, supplied with water and heat by own well); in Mszczonów – deep spot for free diving (ca. 45 m deep) supplied with 40ºC water from this same well which provides heat for geoDH and baths. This is one of a deepest such spots in the world and among a few ones supplied by geothermal water and heat; in Poddębice (modern geothermal recreation and hydrotherapy center which replaced former outdoor swimming pools); in Outer Carpathians (Poręba Wielka) – it uses geothermal water discharged by a well drilled in the 1970s, adapted for geothermal water production in last decade). Due to various reasons, two recreation centres reported in the former country update report (2015–2019) were not operating constantly in 2021, 2022. Information on geothermal bathing & swimming in 2020–2022 is given in Table 3 and Table 5.

Estimations made on a basis of accessible information, former reports, etc., indicated that the total geothermal capacity and practically usable heat for bathing & swimming (i.e. in the ranges between inlet and outlet geothermal water temperatures for various treatments, pools, facilities, etc.) in 2022 could be very roughly estimated for at least 40 MWt and 200 TJ (Table 3, Table 5), since the access was difficult (if possible at all, e.g., when complex technical configurations are in place, some facilities do not provide relevant information or do not have relevant records). The authors are aware of the imperfections of the given information. Geothermal bathing & swimming represents a very attractive sector, both for the users and for local economic development. In the coming years its further development is expected.

3.4. Aquaculture, other uses

In 2020–2022 other geothermal uses were as follows (usually single cases, on a moderate scale): aquaculture; wood drying; heating up of a football court, walking paths; snow melting (parking area); cosmetics production; agri-food processing; pilot algae cultivation (biotechnology); use of geothermal water for drinking purposes; extraction of bath salts; carbon dioxide extraction. Among the listed uses, an Atlantic salmon farm has been operating on a wider market scale since 2015. In the former country update report (2015–2019) its geothermal capacity was evaluated at 2.1 MWt and heat use for about 18 TJ. Some data are given in current report.

In case of biotechnology, an experimental algae cultivation was conducted in Poddębice. It was expected that in coming years it would be continued on a larger scale by a market company producing dermo-cosmetics. One shall also mention: semi-technical wood drying (MEERI PAS installation in the Podhale region), heating up of a football court and walking paths (Uniejów), snow melting (parking area, etc. in at least one of geothermal recreation centers at Podhale region). In several localities geothermal water served as the source of iodine-bromine or cosmetic salts and CO_2. Waters were sometimes bottled as medicinal or mineral waters. Other sector of geothermal water uses was related to cosmetics production (gradually developing). R&D works on spent geothermal water desalination were conducted. Information on aquaculture and some other uses is given in Table 3 and Table 5.

3.5 Geothermal heat pumps

In 2020–2022 the progress in shallow geothermal development was continuing. According to Polish Organisation of Heat Pumps Technology Development, PORT PC, in those years total sales of geothermal heat pumps, GSHPs, were estimated at 18 110 units (https://portpc.pl/port-pc-2022-rok-pomp-ciepla-w-polsce/; https://portpc.pl/pdf/10Kongres/5.2_Ryzynski_Grzegorz.pdf). Taking into account estimations for former years (based on 2018 data from PORT PC, EurObserv'ER, and evaluations made for earlier years assuming a linear growth trend; Kępińska, 2020) and some other, one may assume the total number of geothermal heat pumps in 2022 at around 80 150 units. In 2022 GSHP sales reached 7 200 units (compared to 5 650 units in 2021 – lower sales because of pandemic circumstances). The total installed capacity was estimated at least 900 MWt. Moreover, taking into account the average 2 000 equivalent full-load heating hours / year (capacity factor of 0.23; Lund & Toth, 2021), one obtained ca. 4 600 TJ geothermal heat production (average COP 3.5). In 2022, GSHP sales reached 7 200 units (compared to 5 650 units in 2021). It is worth noting that according to PORT PC statistics, in 2017–2021 for large GSHP installations, in which the total length of heat exchangers in a single installation equal to approximately 10 000 m, the total capacity was estimated for ca. 19 MWt. In recent years works continued to assess capacity and heat production by GSHPs therefore some corrections were expected (more accurate figures on annual market sales available in last several years vs. difficulties in precise estimations for many previous years).

The development of GSHPs was a part of an entire heat pumps' sector development – with main share of air-to-water types. Moreover, several geothermal recreation centers operated 0.5–1 MWt compressor heat pumps (sometimes also absorption) to extract more heat from geothermal water (in 2022 it could be in total up to 10 MWt or more).

Regarding the growth of the whole heat pumps market in Poland in 2022, it is worth to quote some key information published by PORT PC in February 2022 (https://portpc.pl/port-pc-2022-rok-pomp-ciepla-w-polsce/):

- The number of GSHPs sold in 2022 increased by 28% compared to 2021,
- In 2022, the number of air-to-water heat pumps sold in the country increased by 137% compared to 2021 and amounted to 188 200 units. This means an over 100-fold increase in the market of air-to-water heat pumps in the last 10 years in Poland,
- That increase was facilitated by the "Clean Air" support program,

- In 2022, almost one of every three devices for space heating sold in Poland was a heat pump.

3.6 Summary of geothermal uses

Taking into account the data from particular geoDHs and other types of direct uses (except for GSHPs), at the end of 2022 their total installed or calculated geothermal capacity was at least 189 MWt (about half for district heating). Geothermal heat production (in case of district heating systems) and use (in other installations) was at least 1447 TJ (Table 4, Table 5). These figures do not include some recreation centers that use geothermal water and geothermal heat in individual heating systems (it is hoped that it will be possible to make relevant surveys in next years). Adding shallow geothermal (GSHPs), it could be in total at least 1 089 MWt and more than 6 047 TJ in 2022. As already pointed out, these are tentative numbers.

4. GEOTHERMAL SHARE IN CURRENT RES MIX AND IN OFFICIAL PROGNOSIS

According to the Central Statistical Office (Berent-Kowalska *et al.*, 2022), in 2021 the RES share in total primary energy acquisition in Poland was 21.12% (536 072 TJ). The contribution of particular renewables was as follows: solid biofuels 69.35%, wind 10.90%, liquid biofuels 8.10%, hydro 1.57%, municipal wastes 1.16%, geothermal 0.22%, heat pumps (all types, including geothermal) 2.89%. The input of RES to whole H&C sector was 23 511.4 TJ (general 2022 data were not yet available during preparation of this article in spring 2023). In the coming years there were premises that the geothermal heat share will increase somehow thanks to already existing district heating networks, as well as other planned district heating networks with geothermal share (as given earlier chapters). One may also expect an increased share of shallow geothermal in H&C sector.

5. GEOTHERMAL DRILLINGS

In 2020–2022 at least eight new geothermal wells were drilled (Table 6): injection, production and exploration (research), aimed mostly to introduce geothermal into next district heating grids. Their total depth was about 19.2 km. The wells discharge 40–90°C water with flow rates of 50–250 m^3/h. Their funding came from public programs (grants, partial grants, and loans). Several additional wells were in process of drilling and expected to be completed in 2023. Drilling of some more wells was planned to start in 2023–2024 (as a result of funding granted in 2nd half 2022).

In the years after 2022 one may expect the completion of about ten or so wells. They will be implemented mostly as part of investments focused on connecting geothermal into some of the existing district heating systems.

It is also worth to mention the project of an extra deep well (ca. 7 km) in the Podhale region, which was granted public funding in recent years. It has several objectives, including recognition of deep geological structures of that region, potential deep geothermal aquifers, and feasibility of their exploitation for energy production. Drilling started in March 2023.

6. PROFESSIONAL PERSONNEL ALLOCATION

A number of professional full-time (and also part-time) personnel employed at various geothermal activities (scientific and research entities, geoDHs, other installations, servicing, consulting companies, geological survey) can be roughly estimated for ca. 160 persons in 2022 (Table 7). Furthermore, significant number of technical personnel (services, treatment, management, etc.) was working in recreation centres and health resorts (not included into total estimation here).

7. GEOTHERMAL DEVELOPMENT SUPPORT PROGRAMS

In 2019–2022, several public priority programs were available to support (as grants or loans) the geothermal (deep geothermal) development for heating/energetic uses. Those programs had been gradually introduced since 2016. Thanks to them, in 2019–2022 some twenty geothermal wells were drilled, some were in progress, and some next decisions on financing the drillings were issued. In 2020–2022 the following public priority programs were available (operated by the Ministry of Climate & Environment, and the National Fund for Environment Protection & Water Management; www.klimat.gov.pl; www.nfosigw.gov.pl), i.e.;

- *Accessing geothermal waters in Poland* – supporting the exploration and recognition of geothermal reservoirs in order to include geothermal into the existing and planned district heating systems,
- *Polska Geotermia Plus* – to increase the use of geothermal resources in the country,
- *County Heating* – program for local governments, towns below 100,000 residents (https://www.cire.pl/ artykuly/serwis-informacyjny-cire-24/155698-nfosigw-chce-teraz-rozwijac-programy-wsparcia-geotermii,-biogazowni-i-przydomowych-magazynow-energii),
- *The EEA FM Environment, Energy and Climate Change program, Energy program area* – to support the increased energy production from renewable sources,
- *Supporting investments related to the production of energy from renewable sources together with their connection to the distribution / transmission grid, priority axis I of the Operational Program Infrastructure and Environment 2014–2020* – to support the construction or reconstruction of RES generation units, including geothermal (above 2 MW).

Geothermal heating could be also supported by various programs addressing thermal retrofitting, energy efficiency increase, air quality improvement, etc.

In case of shallow geothermal, the “Clean Air” program to support, among others, heat pumps development in the country (including GSHPs), has been available since 2020. In January 2023, the share of GSHPs in the "Clean Air" program was as much as 3.84% (over 18 000 units) of the total number of applications for replacement of heat sources, and still increases. Some other programs have also facilitated that development.

8. INVESTMENTS IN GEOTHERMAL SECTOR

For 2020–2022, the evaluation of investments in geothermal sector was based on publicly available information. They are indicative numbers giving an insight into the level of public funding both in reported years and partly in the next few to come.

They contain the amounts of funds allocated by large public programs (section 7), the calls for proposals of which were issued in 2020–2022. Some of those amounts were already spent for investments, some were granted but relevant investments (and expenditures) were either in progress in 2022 or were to start in 2023. Table 8 shows the amounts allocated by several public programs active in 2022–2022: both already granted, intended to be granted, issued, as well as some investment costs incurred from other sources.

The division into Field development and Utilization from public funds (Table 8) is partly arbitrary (approx. 50% for each category), and those were funds mainly for drillings, surface heating infrastructure, etc. The category Utilization includes also several completed large recreation investments funded by public or private sources (referred to in section 3.3, although not all).

In total, costs of investments completed or in progress in 2020–2022 (some expected to start, continue, finish after 2022) could be roughly evaluated for at least approx. USD 308 million (USD – PLN exchange rate, end of 2022, Central European Bank). Investments in ground source heat pumps sector were not taken into account here (for 2015–2018 they were estimated for ca. 84 million USD; Kępińska, 2020).

9. INVESTMENT PROJECTS UNDERWAY AND PLANNED

In 2020–2022 along with new drillings and other investments listed before, the several other geothermal investments were ongoing. They were mostly oriented for space heating, some for recreation, e.g.:

- Investments to increase geothermal capacities, heat extraction efficiency, and to connect new consumers into operating geoDHs,
- Investments to introduce geothermal into next district heating systems (based on wells drilled thanks to support programs),
- Further investments in recreation and balneotherapy, some other fields,
- Pre-investment works and feasibility studies related to various localities.

Along with the investment works, feasibility studies, pre-investment works, as well as research and R+D+I activities were conducted in 2020-2022, e.g., R+D+I on various topics related to geothermal uses; deep BHE; ATES; UTES; water desalination; agriculture; biotechnologies; shallow geothermal, etc.

National and international projects were conducted by academia and other teams funded by Polish sources as well as the EU, EEA FM and NFM funds, and other mechanisms.

10. LEGAL BACKGROUND, STRATEGIC DOCUMENTS

The references and provisions related to geothermal energy and investments could be found in various key national and EU-legal acts and other documents valid in reported period. Among the state strategic documents related to energy introduced in recent years, several refer in general to geothermal development, e.g.: Poland's National Energy and Climate Plan for the years 2021-2030 (NECP PL), Energy Policy of Poland until 2040, National Plan for Reconstruction and Resilience.

In details, geothermal energy development is a subject of, inter alia, the following documents elaborated in recent years:

- *Multiannual Program for the Development of the Use of Geothermal Resources" for Poland until 2040, with a perspective until 2050* – initiated by the Ministry of Climate and Environment, elaborated in 2021 (announced in 2022). It is based on three pillars: 1. Research, 2. Execution and implementation of pilot installations, 3. Implementation, education and promotion (https://www.gov.pl/web/klimat/mapa-drogowa-rozwoju-geotermii-w-polsce),
- *The Strategy for Responsible Development by 2020 with 2030 perspective* (www.gov.pl/ documents/33377/436740/SOR.pdf). As a part of this Strategy, the Ministry of Climate and Environment conducts activities to support the development of geothermal use in Poland, e.g., strategic project *Development and use of geothermal potential in Poland*. The project includes the implementation of several tasks by various entities. The project will run until June 2024. The Ministry also initiates and finances some geothermal research (carried out mainly by the Polish Geological Institute – State Research Institute; https:// www.gov.pl/web/klimat/geotermia).

One shall point out that many initiatives, research, R+D+I works have been constantly carried out for many years by scientific and research entities leading geothermal sector in the country, like AGH–University of Science and Technology, MEERI PAS, Polish Geothermal Society, some other.

11. CLOSING REMARKS

In 2020–2022 some further progress of geothermal energy uses was observed in Poland as continuation of more dynamic process initiated during in 2015/2016 thanks to several public support programs. Some increase in geothermal heat production and sales by seven geoDHs and uses in bathing & swimming centers was observed (with difficulties in 2020–2022 due to pandemic). In 2022 geothermal energy was introduced into one district heating system –after ten years since the previous launch of geothermal plant in Poddębice. Despite of pandemic years, four big geothermal recreation centers were opened. Some other uses were continued or extended. Further development of shallow geothermal was observed (part of the progress of the whole heat pumps sector).

At the end of 2022, total geothermal capacities, and heat production (deep geothermal, shallow geothermal (GSHPs), various uses) could be in total at least 1 089 MWt and probably more than 6 047 TJ. As already pointed out, these are tentative numbers.

The last few years, including 2020–2022, have brought many activities aimed at increasing the geothermal uses in Poland, primarily in low-emission heating. This was in the form of the implementation of another dozen or so wells and other investments. It was possible mainly thanks to significant public support programs, introduced gradually from 2016 and available also in the reported years. Therefore, it should be expected that geothermal components will be included into a few more district heating networks in the country. Another important fact was e.g., elaboration of the Multiannual Program for the Development of the Use of Geothermal Resources for Poland until 2040, with a perspective until 2050 (announced in 2022).

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TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT
AS OF 31 DECEMBER 2022 (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. (°C) - outlet temp. (°C)] 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. (°C) - outlet temp. (°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

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					Capacity[3]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
Podhale[1]	D	297.0	87	55			34.0	160.0	652.6	
Pyrzyce[1]	D	94.5	65	28			6.0	24,4	70.2	
Mszczonow[1]	D	16.6	42	12			3.7	10.5	14.0	
Uniejow[1]	D	33.4	68	48			3.2	20.8	9.0	
Stargard[1]	D	55.6	87	64			18.5	51.7	284.2	
Poddębice[1]	D	70.0	68	54			10.0	32.2	51.2	
Toruń[1]	D	89.0	62				18.0		~40.0	
15 localities[2]	H	7.9–22.8	28–74	35–50			~52.0	0.4–4.4	~100.0	
12 health resorts, 16 recreation centers[3]	B	0.5–70.0	20–90	20–40			40.0	0.1–21	200.0	
Janowo[4]	F	50	27	~17			2.1	13.5	17.8	

Podhale region[5]	I						0.3		0.6	
Uniejów[6]	O	8.3	28	20			1.0	8.3	5.5	
Chochołowskie Termy[7]	S	2.0	60	40			0.5	0.8	2.0	
TOTAL							**~189.3**		**~1447.1**	

[1] Geothermal district heating systems: given are geothermal installed capacities and heat production
[2] Rough estimation for two localities (small scale use) and thirteen recreation centers, partly based on 2019 data and indicative assumptions (see chapter 3.2.)
[3] Partly based on 2019 data
[4] Rough estimation as for 2019
[5] Wood drying (estimation as for 2019)
[6] Heating up the football pitch and walking paths (as for 2019)
[7] Snow melting – parking area (as for 2019)

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 2021 (2022); Kępińska 2020, other sources.

b. Data on some bathing&swimming installations tentative or based on earlier ones (Kępińska, 2020). For some bathing/recreation installations outlet water temperatures were assumed. Some installations were not taken into account (see text)

na – not available

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2022, 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; H = horizontal ground coupled; W = water source (well or lake water); O = others (please describe)

(TJ = 10^{12} J)

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 – assumed 2 000 hrs/yr for this 2020-2022 Country Update

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	6 - 200 (ave. 10.2 kW, large ca. 1 MW)	> 80 150	V, H, W	3.5 - 6	2 000	> 4 600	at least ca. 30% devices used for cooling
TOTAL		> 900 MW	> 80 150				>4 600	

Note: rough estimations.
Moreover, several geothermal recreation centres operated 0.5–1 MW_{th} compressor heat pumps (sometimes also absorption) to extract more heat from geothermal water (in 2022 it could be in total up to 10 MW_{th} or more). Not included here

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2022

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°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. (°C) - outlet temp. (°C)] x 0.1319
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154 (TJ = 10^{12} J)

[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]	> 52	> 100	
District Heating [4]	93.4	1121.2	
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming	~2.1	17.80	
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]	0.3	0.6	
Snow Melting*	0.5	2.0	
Bathing and Swimming[7]	> 40	> 200	
Other Uses (specify) **	~1.0	~5.5	
Subtotal	> 189.3	> 1 447.1	
Geothermal Heat Pumps**	> 900	> 4 600	
TOTAL	> 1 089.3	>6 047.1	

* Estimation (parking area, etc.)
** Heating up of footbal pitch and walking paths
*** Estimation

Note: Category “Individual space heating”: in case of dozen recreation centers that used geothermal water both for bathing&swimming and for heating their objects or warm water preparation: thirteen such centers were considered (for which indicative figures either from previous years were available or some rough assumptions were made). Their heating capacities could reach even at least 50 MW and at least approx. 100 TJ in 2022 (number in this category are supplemented by some small facilities). These numbers are very rough

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2020 TO DECEMBER 31, 2022 (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)		2			3.692
Production	>150°C					
	150-100°C					
	<100°C		2			5.822
Injection	(all)		4			9.676
Total			8			19.190

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
2022	20	50	30			60
Total						

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN 2020–2022, 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	25
2020-2022[1]	70,0	115,0	142,0		8	92

[1] For 2020–2022, evaluation of investments is indicative, gives an insight into the level of funding both in reported years and partly in the next few.

Data for given years contain the amounts of funds allocated from large public programs available in 2020–2022.
Some of those funds were already spent for investments, some were granted while relevant investments were either in progress or will start after 2022.
The division into Field development and Utilization from public funds is partly arbitrary. Private share probably underestimated.
1 USD =4.6808 PLN (average, Central European Bank, 31 Dec'2022).
Investments in GSHPs sector were not taken into account here (for 2015–2018 estimations were ca. 84 million USD; Kępińska, 2020).