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Geothermal Energy Country Update Report from Poland, 2010 – 2014

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ABSTRACT

The paper overviews the geothermal energy uses' development in Poland in 2010-2014 since the update report submitted to World Geothermal Congress 2010 (Kepinska 2010). The geothermal capacities and heat production are given as for 2013. The country has low-temperature resources therefore their current and prospective applications involve direct uses for heating (deep, shallow geothermal), bathing and swimming, and some other uses.

In case of the heating sector, six geothermal district heating plants were operational in 2013 (the oldest one in the Podhale region since 1994; the most recent one in Poddebice since 2013). In addition, individual heating systems were in some recreation centers. In 2013 their total installed geothermal capacity was ca. 87.2 MWt and heat sales ca. 633 TJ (including peak boilers it was ca. 147.1 MWt and 745.56 TJ, respectively). Most geothermal heat was produced by the Podhale plant: 300.27 TJ/2013, one of the largest geothermal district heating plants in continental Europe.

In 2013, eleven spas (with formal status of health resorts) using geothermal water for curing were operating (three most recent among them started to apply geothermal waters in 2011, 2012 and 2014). Nine geothermal recreation and balneotherapy centers were on-line (launched in 2006–2014, including four opened since 2010). One may estimate their total capacities for at least 10.34 MWt and heat uses for at least 100.4 TJ in 2013. Other minor uses comprised semi-technical wood drying (some 0.3 MWt, 0.5 TJ/2013) and heating up of a football playground and walking path (ca. 1 MWt and 8.7 TJ/2013 of heat use).

Referring to the geothermal heat pump sector ("shallow geothermal") some faster growth has been observed in recent years. In 2013 they reached at least 390 MWt of capacity and 2,000 TJ of heat (while the number of installations was at least 35,000).

To sum up all direct uses, in 2013, the total installed geothermal capacities (heat pumps including) were at least 488.84 MWt and heat sales/uses were at least 2,742.6 TJ.

In 2010–2014 thirteen new geothermal wells were drilled. They will produce ca. 28–85ºC waters for bathing and recreation mostly and for space heating in some cases.

The investments were accompanied by research, feasibility studies, and some new investment projects. Like in other countries, some R&D works on prospects for geothermal binary power and heat generation (based on ca. 90–120ºC water) and on HDR/EGS was conducted.

As the most prospective for further geothermal development one shall indicate space heating, bathing/recreation, and heat pumps sectors. However, comparing with the geothermal resource base and progress in RES sector as a whole, geothermal heating development has been very slow so far. This situation is caused, to great extent, by a minor role allocated for geothermal in national energy policy, National Renewable Energy Action Plan, as well as lack of adequate public support (specially for drillings), no geological risk guarantee fund and minor role in other official documents (e.g. project of RES Law). These constraints resulted in the fact that prevailing part of new geothermal utilities in 2010–2014 was for bathing/recreation (private investment mostly) and only one new project oriented for district heating was realized.

1. INTRODUCTION

The paper presents the status of geothermal development in Poland during 2010–2014 since the previous update report at WGC 2010 (Kepinska, 2010) and similar update at European Geothermal Congress 2013 (Kepinska, 2013). In 2010–2014 some projects mentioned at that report were finished and several other were underway.

Geothermal use for heating purposes in the country was initiated in the last decade of the 20th century. The experimental stage of the first geothermal plant was opened in the Podhale region in 1992. Since that time five other plants have been launched, including one of them in the reported years 2010–2014. Space heating is a key sector for geothermal. It is also worth to notice a growing interest in bathing and swimming (recreation and balneotherapy) what has been expressed by three new health resorts and four recreation centres opened in given years.

Over the last several years some general documents related to the energy policy of the country were introduced, e.g. the Energy Policy in Poland by 2030 and in Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (and related documents). According to these documents the share of all RES, geothermal including, in the final gross energy consumption (electricity, heat and cold, biofuels) shall reach 15% in Poland by 2020 (in 2012 that share was 11%; http://epp.eurostat.ec.europa.eu). Among the main factors which hamper geothermal deployment are high up-front investment costs, weak legal regulations (in some aspects), and lack of public support for drillings. On the other hand, geothermal should be promoted as one of the most important element of RES mix, especially for heating. More favorable legal regulations as well as economic and fiscal incentives should be introduced. These would serve as the tools to facilitate the geothermal deployment. In 2012, several positive provisions to ease geothermal investments were introduced in the new Geological and Mining Law (see chapter 8). They were treated as the first positive signals whereas the geothermal stakeholders expected further tools which would create a cohesive system, including e.g. establishing the geological risk guarantee fund, and other legal and financial measures (which have not been introduced so far).

2. GEOLOGICAL AND GEOTHERMAL BACKGROUND

The country is characterized by the heat flow values from 20 to 90 mW/m2, while geothermal gradients vary from 1 to 4°C/100 m. Geothermal water and energy resources in Poland are associated with formations of various ages in the Polish Lowlands, the Inner Carpathians, some locations in the Sudetes region, the Outer Carpathians and the Carpathian Foredeep (Fig. 1). In case of the Polish Lowlands (part of the European Lowlands) sedimentary formations dominate the extensive area stretching from the Baltic Sea coast towards central and southern part of a country. They possess significant thicknesses and share of sandstones and carbonates which contain geothermal resources. Sedimentary formations also host geothermal aquifers in the Inner Carpathians (Mesozoic, partly Eocene carbonates – the Podhale region), and in some parts of the Outer Carpathians (Tertiary sandstones, Mesozoic carbonates) and the Carpathian Foredeep. In case of the Sudetes region geothermal aquifers occur in fractured parts of some crystalline and metamorphic formations. The water temperatures at the outflows from the wells (depths up to ca. 3.5 km) recorded so far vary from ca. 20 to about 90°C. The proven geothermal water reserves amount to several L/s up to 150 L/s. Waters are suitable for wide spectrum of direct uses for space heating, agriculture, etc., as well as for balneotherapy and recreation. The best geothermal conditions are found in the Polish Lowlands (Gorecki [ed.], 2006) and in the Podhale region (Inner Carpathians) (Sokolowski, 1993). Wide opportunities are also associated with ground source heat pumps ("shallow geothermal").

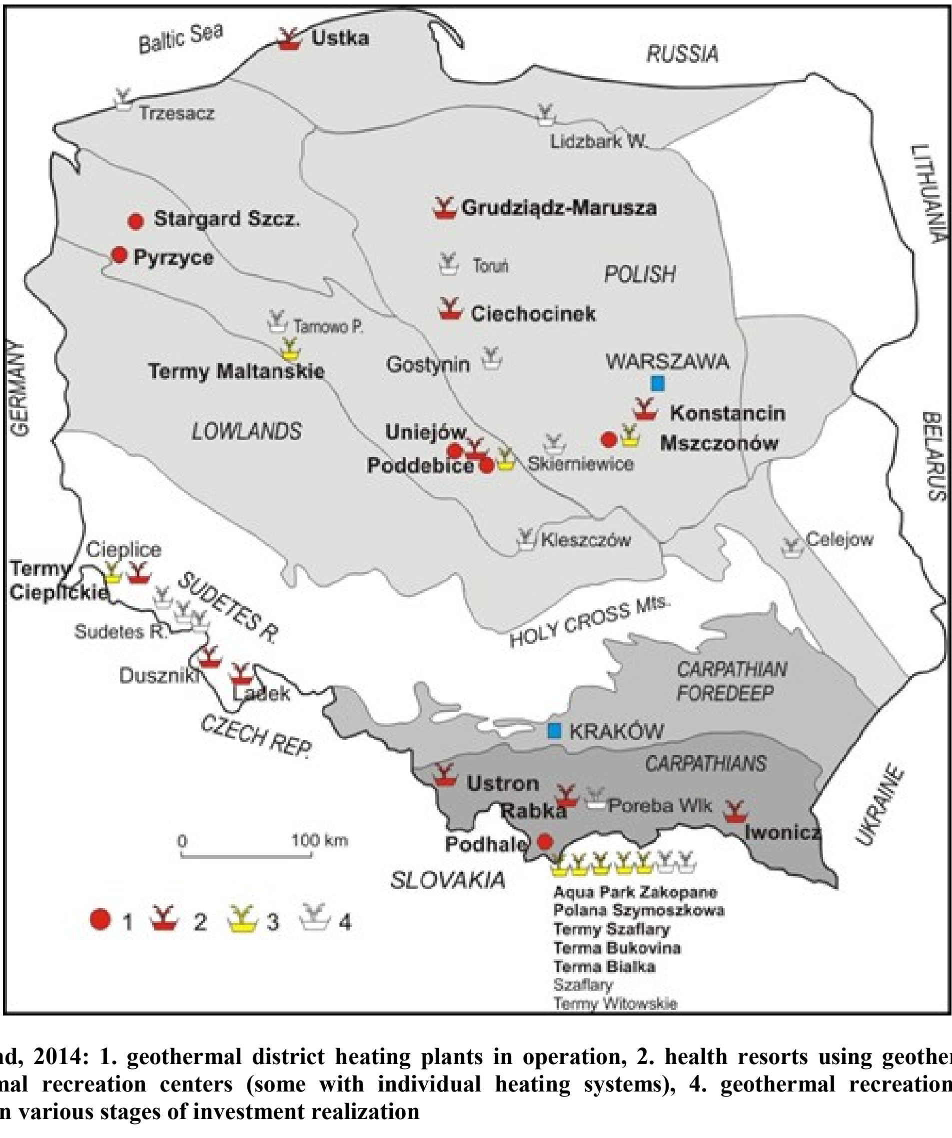

Figure 1. Poland, 2014: 1. geothermal district heating plants in operation, 2. health resorts using geothermal waters, 3. geothermal recreation centers (some with individual heating systems), 4. geothermal recreation/balneotherapy centers in various stages of investment realization

3. GEOTHERMAL DIRECT USES

3.1 Generals

In 2010–2014 geothermal energy was used in several localities mainly for heating, bathing and swimming (balneotherapy/recreation), and extracted via heat pumps (Fig. 1, Tables 3–5). Comparing with data from WGC 2010 (Kepinska, 2010), the total installed geothermal capacity and heat sales have increased, resulting mostly from further heat sales increase in the

Podhale region, re-launch of plant in Stargard Szczecinski, opening a new heating plant in Poddebice and by further geothermal heat pump development.

Taking into account the data from particular geothermal plants, at the end of 2013 the installed geothermal capacity (heat pumps excluded) totalled 98.84 MWt and with the shallow heat pumps not less 488.84 MWt. Geothermal heat sales / uses (without heat pumps) was ca. 742.6 TJ (including 633 TJ for space heating) and not less than 2742.6 TJ heat pumps including (Table 5). One shall add that in case of bathing facilities where geothermal waters were used to fill pools or for curative treatment, the capacities and heat production were evaluated using the standard equations (as given in Tables 3 and 5) and information on real conditions in which these installations were working. In case of heat pumps that data are more accurate than in the past thanks to better statistics and market monitoring initiated in recent years by Polish Organisation of Heat Pumps' Technology Development (Table 4).

3.2 Space heating

In 2014 six geothermal space heating plants were operational (Tables 3 and 5): in the Podhale region (since 1994), in Pyrzyce (since 1996), in Mszczonow (since 1999), in Uniejow (since 2001), in Stargard Szczecinski (since 2012, re-opened after closure in 2008) and in Poddebice (since 2013).

3.2.1 Podhale region.

In that region, since 1994, the biggest geothermal district heating project in the country has been underway. The main geothermal aquifer – a subject of exploitation, is hosted by the Triassic and Eocene carbonates (depths of 2.5–3.5 km). Reservoir temperatures reach up to 80–90°C. The maximum flow rates vary from 50 to 150 L/s of 82–86°C water. The TDS are ca. 2.5 g/L (Kepinska, 2010). In 2013 the installed geothermal capacity was 40.7 MWt (total ca. 80.8 MWt gas and fuel oil boilers including), geothermal heat sales was 300.27 TJ (total 393.12 TJ). By the end of 2013, 1,483 receivers were connected to the geothermal heating grid (individual houses, multi-family buildings, hotels and boarding houses, schools and other buildings).

It is worthly to note that the Podhale geothermal district heating system belongs to the largest ones in Europe for its geothermal / total capacity and heat production.

Since May 2008 a part of the geothermal water after cooled down in the heat exchangers has been supplied to a bathing centre "Termy Szaflary". Soon it will also supply a second bathing centre, the construction of which is about to finish in fall 2014.

Along with the heating system (operated by PEC Geotermia Podhalanska SA) the basic research and R&D works on cascaded uses have been run by the MEERI PAS. The system comprises semi-technical wood drying installation as given in a previous report (Kepinska, 2010), while other uses were not in operation (Table 5).

Thanks to the geothermal heating, the annual average concentrations of particulate matter PM_{10} and SO_2 have dropped by about 50% in comparison to the period before this heating type was put on-line. In 2010–2013 the CO_2 emissions were reduced by 33.53–37.38 thousand tones per year (total 142.83 thousand).

3.2.2 Pyrzyce.

The heating plant has been operating since 1996. The geothermal aquifer is hosted by the Jurassic sandstones (depths of 1.5–1.6 km). It is exploited by two production and two injection wells. The maximum flow rate is 100.1 L/s of 61°C water. The TDS are 120 g/L. After optimisation works in recent years the plant's maximum installed capacity is 28 MWt including 16 MWt high-temperature gas boilers and 12 MWt geothermal heat exchangers (which cooperate with absorption heat pump /max. 20.4 MWt/ referred in past years, Kepinska, 2010, 2013). The plant supplies heat and warm water to over 90% of the town's population (13,000) meeting ca. 60% of total heat demand. In 2013, geothermal heat sales were ca. 54.6 TJ (Table 3) while total heat sales was 104 TJ/y.

3.2.3 Mszczonow.

The heating plant has been operating since 2000. Maximum geothermal water flow rate is ca. 16.6 L/s of 42.5°C, while TDS are 0.5 g/L. Water is produced from the Cretaceous sandstones by a single well reconstructed and adapted for geothermal purposes (no injection). After modernisation in recent years, in 2014 the total installed capacity was 8.3 MWt (4.6 MWt gas boilers, 2.7 MWt absorption heat pump and 1 MWt compressor heat pump). The plant uses geothermal water for district heating, drinking and for heat and water supply to recreation centre. The district water of higher parameters 80/60°C is heated by heat extracted from geothermal water and gas boilers fitted with 2.7 MWt absorption heat pump (AHP). In 2012 a 1 MWt compressor heat pump (CHP) was added to extract more geothermal heat from the AHP outlet water thus supplying separate lower temperature (70/50°C) heating systems at receivers. Geothermal water cooled down by the CHP is then sent to water works. Part of the geothermal water stream discharged by the well is directly sent for pools in recreation centre "Termy Mszczonowskie" (opened in 2008). In 2013 geothermal heat sales was 15.76 TJ (ca. 38% of total heat sales of 41.26 TJ from district heating plant in Mszczonow).

3.2.4 Uniejow.

The district heating plant has been operating since 2001. Geothermal aquifer is hosted by the Cretaceous sandstones at the depth of ca. 1.9–2 km. The maximum discharge from one production well is 33.4 L/s of 68°C water while TDS are ca. 5 g/L. The exploitation system includes also two injection wells. The total installed capacity of the plant is 7.4 MWt including 3.2 MWt from geothermal, 1.8 MWt from biomass boiler and reserve 2.4 MWt fuel oil peak boilers. In 2013, 80% of all buildings in the town (including all public ones) were supplied by this plant. Geothermal heat sales were 19.2 TJ (Table 3) while total amounted to 24 TJ. The works on connecting new receivers are planned.

Since 2008, a part of the geothermal water has been used in the geothermal recreation centre "Termy Uniejow" for pools and curative treatments (ca. 8.4 L/s of 42°C water; ca. 1 MWt, 7.7 TJ). The centre is also heated by geothermal energy. Some amount of spent water (ca. 5.6 L/s, 28°C) is then used to heat up a lawn of a football playground (ca. 1 MWt, 8.7 TJ). Some new types of geothermal uses are under consideration.

It is worthly to note that geothermally-based activities drive an impressive dynamic economic development of this historical town and absorption of significant amount of national and EU-funds (infrastructure, regional development), create new jobs and present an offer attractive for many tourists. In 2012, Uniejow received a formal status of health resort.

3.2.5 Stargard Szczecinski.

The plant was re-open in 2012 again (closure in 2008–2012) after, among others, some rehabilitation works in wells and surface equipment. It is based on a doublet of production (depth of 2,672 m) and deviated injection (2,960 m) wells. The aquifer is situated in the Jurassic sandstones. The production well discharges maximum ca. 50 L/s of 83°C water (average 39-50 L/s). In 2013, the geothermal capacity was 12.6 MWt and geothermal heat sales were 168.07 TJ (K. Zablocki, pers. communication). Geothermal heat is extracted by heat exchangers and then sold to the nearby coal-fired municipal district plant (total capacity 116 MWt serving about 75% of local population (75,000).

3.2.6 Poddebice.

In that municipality, construction of a geothermal district heating plant was commissioned in 2012. The plant of 10 MWt geothermal capacity is based on 71ºC water discharged by a single production well (depth of 2,101 m, aquifer hosted by the Cretaceous sandstones) drilled in 2010 (maximum flow rate 52.7 L/s, TDS 0.4 g/L). The plant started geothermal heat sales in 2013 with 15 TJ supplying some public buildings, school, hospital, several multi-family houses. Part of water stream is sent to outdoor swimming pools and for rehabilitation treatment in a hospital. No peak boilers are installed directly at the plant; they are located in several local heating stations and will be used when necessary to increase the temperature of the water heated up by geothermal during the coldest periods. As in case of nearby Uniejow town, geothermal activities are expected to enhance innovative economic and social development of this locality what has been already observed.

To sum up geothermal uses based on sales by district heating systems, in 2013 the total installed capacity of six geothermal district heating plants listed above was 147.1 MWt of which 82.2 MWt (55.9%) came from geothermal parts. The total heat sales by those plants were about 745.56 TJ, of which 573 TJ was geothermal (ca.76%), and the rest came from peak sources. The largest total installed (80.8 MWt) and geothermal capacity (40.7 MWt) is the plant in the Podhale region (300.27 TJ in the total heat sales of 745.56 TJ in 2013), being also among the largest geothermal district heating systems in Europe. It is also worthly to mention significant geothermal heat sales by the plant in Stargard Szczecinski: 168.17 TJ/2013.

Except district heating systems, in cases of some new bathing and recreation centers, geothermal waters (discharged by wells serving these objects; temperatures 72–64.5°C) are used both to supply pools and other facilities and for centers' individual heating and preparation of warm tap water (then cooled waters is used for pools and other spa treatments). For two such centers one may estimate (following some available information and data; eg. Kepinska, 2013) that the heating capacities might reach ca. 5 MWt while heat usage ca. 60 TJ in 2013 (Table 3, Table 5). These centers also apply compressor heat pumps to increase the efficiency of heat extraction from geothermal water before its disposal into surface streams (no injection).

3.3 Bathing& swimming and other uses

In 2014, geothermal waters were used for bathing and swimming (also named balneotherapy) in eleven health resorts. Many of them have long historical tradition while the three youngest ones received formal health resort status in recent years: in 2009 Grudziadz-Marusza, in 2012 Uniejow (in former report they were listed as recreation centers; Kepinska, 2010), and Ustka Spa (geothermal water started to be used for treatment in late 2014).

Waters are discharged by natural springs and wells (the Sudetes area) or wells (other areas), their approved reserves vary from ca. 2 to 200 m^3/h while outflow water temperatures are in the range of 20–87°C (Table 3, 5). In single cases some by-products, like iodine-bromine, cosmetic salts, and CO_2 are extracted from geothermal waters, also the cosmetics based on geothermal water are produced.

In 2014, nine geothermal recreation centers were operational: five in the Podhale region, three in the Polish Lowlands and one in the Sudetes region. From that number four centers were opened in the reported period 2010–2014: one in the Podhale region ("Terma Bialka", 2012), two in the Polish Lowlands (Poddebice, "Termy Maltanskie" in Poznan, 2013) and one in the Sudetes region ("Termy Cieplickie", 2014). Some centers use waters discharged by new wells drilled specially to supply them, some based on wells operating earlier for heating purposes. In 2014 at least fourteen further investments oriented for bathing and recreation were at various stages of realization (chapter 7).

For installations in health resorts and recreation centers that use geothermal water due to their therapeutic properties geothermal capacities / heat uses were estimated taking into account the maximum / average annual water flow rates and temperatures at inlet and outlet from pools and other facilities. For this group total geothermal capacity and heat consumed in 2013 were estimated at about 10.34 MWt and 100.4 TJ (three localities were not considered since either small water flow rates from the wells implying their low temperatures therefore the waters are additionally heated up before using or the utility was in an initial stage of operation and relevant data were not available). Some of the centers use geothermal water both for suppling the pools and other facilities and for heating their objects and warm water preparation (e.g. "Terma Bialka", "Terma Bukovina") (as given in subchapter 3.2). Some utilities operated compressor heat pumps also (ca. 3-4 MWt more, included in the heat pumps sector; subchapter 3.4), including the case when a heat pump was used to increase geothermal water temperature before sending it to the pool.

In addition to the above listed, one shall mention other uses (Table 3, Table 5) like semi-technical wood drying at MEERI PAS Geothermal Laboratory in the Podhale region (ca. 0.3 MWt and 0.5 TJ/2012) and heating up of a football playground and walking path (1 MWt, 8.7 TJ/2013) mentioned above as a part of the multipurposed uses in Uniejów town. These remaining uses are estimated for total of ca. 1.5 MWt and ca. 9.2 TJ of heat in 2013.

In 2013 installed geothermal capacity for all the above listed uses (heating, bathing and swimming and others) was about 98.84 MWt (bulk for geoDH: 82.2 MWt). Total geothermal heat sales (by district heating systems) and used / consumed in case of other installations was ca 742.6 TJ.

3.4 Geothermal heat pumps (P. Lachman, S. Kaletka (Polish Organisation for Heat Pumps Technology Development))

The geothermal heat pump (GSHP) sector has been characterized by a very moderate growth for many years while faster development occurred in several recent years. On the basis of previous evaluations (Kepinska 2013) and a more detailed market survey on heat pumps' sales in 2011–2013, initiated on a regular basis by the Polish Organisation for Heat Pumps Technology Development (www.portpc.pl), one may estimate that in 2013 geothermal heat pumps represented at least 390 MWt of installed power and at least 2,000 TJ of produced heat (Table 4). The number of geothermal heat pumps (various types: water/water, water/brine, horizontal and vertical loops) was evaluated for at least 35,000. Individual GHPs have thermal capacities from about 10 kWt up to 70–150 kWt. The largest single units reach 1 MWt and slightly more. Some of them work in several geothermal utilities (eg. Mszczonow plant, some recreation centres).

The biggest heating installation based on GSHP in Poland (hospital in Szczecin municipality) has the installed power of ca. 2.6 MWt (240 vertical holes, each of 52 m depth; (www.portpc.pl), it is probably also the largest one in Europe(!).

In later years, an increase in sales of various heat pump types (incl. GSHP) was observed: in 2011 it was the level of 10,000 units (about 30% sales increase compared to 2010), in 2012, more than 12,600 units (nearly 20% sales growth compared to 2011) and in 2013, above 15,000 units. In those numbers were ca. 6,000 GSHP units sold in 2011, ca. 5,100 GSHP units sold in 2012 and ca. 5,000 units sold in 2013.

4. GEOTHERMAL DRILLING

In 2010–2014, thirteen new geothermal wells were drilled (Table 6) (a 14th well was at an initial stage of drilling in fall 2014): one exploration and one production (deviated) well in the Podhale region (ca. 2.2–3.4 km of depth/), seven exploration ones in the Polish Lowlands (ca. 1.8–3.3 km), one exploration well in the Outer Carpathians (negative – considered as deep BHE) and three exploration ones in the Sudetes region. They gave a total depth of ca. 28 km. The wells encountered ca. 28–85^{o}C waters. One shall note that the bulk of them were aimed to be transferred into exploitation wells producing water for bathing and recreation, while only some primarily for heating.

Moreover, one old hydrocarbon exploration well was reconstructed and adopted for geothermal water exploitation for bathing and balneotherapy (the Outer Carpathians), three wells in the Polish Lowlands were proof-tested or reconstructed (for this same purpose), one injection well (drilled in 1989 in Podhale) was deepened in 2014 (from ca. 2,390 m TVD to ca. 2,600 m MD).

In fall 2014, from among the given number of newly-drilled wells three were working as producers. Operational was also one old adapted/reconstructed well. Several other wells were expected to be put online if formal procedures and /or surface infrastructure investments would be finished. However, in the coming years one may expect much less new geothermal drillings specially for heating due to the termination of public financial support (managed by the National Fund for Environmental Protection and Water Management) for exploration drillings aimed at energetic use of geothermal resources in 2013, as already observed that decision has a negative impact especially for the development of geothermal heating sector.

5. PROFESSIONAL PERSONEL ALLOCATION

In 2014, a number of professional full-time personnel at various fields of geothermal activities (scientific institutions, geothermal plants and other installations, consulting companies) might be estimated for ca. 160 persons (Table 7). Along with openings of new geothermal bathing and recreation centres significant growth of number of various technical personnel took place (ca. 20–100 prs/centre, depending on its size).

6. INVESTMENTS IN GEOTHERMAL SECTOR

The investments in the geothermal sector in 2010–2014 can be very roughly estimated to at least 397 million USD (Table 8). This evaluation refers to the research & development (incl. exploration drillings), field development (production drillings, surface equipment) and utilization according to the available information provided by the operators of the geothermal installations and tentative estimates of costs in cases when exact information was not available (mostly on private funds). Prevailing part of these funds (over 85%) was spent for construction, infrastructure and equipment of new recreation and balneotherapy centers (not for heating systems). A significant sum also went to cover exploration drilling costs (which were aimed mostly as production wells for bathing/recreation). The given figures do not include the non-investment funds for R&D works, various studies and projects made by several institutions, agencies and paid from various sources.

7. PROJECTS UNDERWAY AND PLANNED

In 2010-2014, several geothermal investment projects (oriented mostly for bathing and recreation) were completed or underway. Several research R&D works were finished or were in progress. Their summary follows.

7.1 Investments works:

- The Podhale region: drilling the third production well was done in 2012-2013 to supply more clients via existing district heating network; in 2014 deepening one of two injection wells; works to increase the distribution network and connect new receivers to geothermal grid; modernization and optimization the surface infrastructure; plans to increase the efficiency of energy extraction from geothermal water;

- Mszczonow town: optimization of district heating system by adding a 1 MWt compressor heat pump to extract more heat from geothermal water, this additional heat supplies new separate low-temperature heating system (2012);
- Poddebice town: geothermal district heating plant (supplying water also for recreation center) was opened in 2012 (heat sales started in 2013). In fall 2014 successful tests to increase water production were conducted (drilling the injection well is also considered). Works on extension of the heating system, construction of recreation centre and accompanying infrastructure are ongoing. Some other types of geothermal uses are planned;
- Pyrzyce town: implementation of a method to prevent scaling and corrosion in geothermal wells, modernisation works on surface infrastructure, extension of heating grid, project to drill new exploitation well;
- Uniejow town: extension of geothermal heating grid (drilling of a new injection well is considered), new types of uses are planned. Modernisation of local infrastructure and dynamic development of the city as a geothermal health resort's is ongoing (so far ca. 100 mio € from national and EU-funds was acquired for these aims);
- Stargard Szczecinski: project to enlarge the geothermal heating plant's capacity and to drill a new well;
- Works on optimization of technological schemes and increasing the efficiency of energy extraction from geothermal waters in several geothermal district heating systems and recreation centers,
- Ca. fifteen projects of geothermal recreation centers' construction in various stages of realization: two in the Podhale region (in addition to five already operating) to be opened in 2015; in the Outer Carpathians; several projects in the Polish Lowlands based on newly-drilled or reconstructed wells (in some cases combination with heating of centers' facilities and with district heating systems; some projects in the Sudetes region.

7.2 Pre-investment works:

- In 2013-2014 some pre-investment works and feasibility studies were in progress, e.g. related to some localities in the Outer Carpathians where former oil and gas wells may serve for geothermal exploitation for recreation and heating (expected water flow rates 17.7–19.5 L/s, wellhead temperatures 45ºC and 95ºC; Hajto et al. 2011).

7.3 Research, R&D works:

- Several R&D projects on various geothermal aspects were done in 2010-2014, e.g. elaboration of project guidelines for injectivity improvement methods of reservoir rocks in the geothermal plants (Kepinska, Bujakowski [eds] et al. 2011); geothermal waters' desalination methods (Tomaszewska 2010); wells and aquifer treatments (Pyrzyce – EU Program Life +);
- Some projects focused on particular wells meeting the interest of local communities or private entrepreneurs, e.g. reconstruction of well done in 1970s prospective for balneotherapy (Poręba Wlk) or feasibility study and project of adaptation of newly-drilled dry well as deep BHE (both cases in the Outer Carpathians area);
- Two research projects to define potential HDR systems (Wojcicki et al., 2013), areas and conditions for binary co-generation based on ca. 90-120ºC waters (Bujakowski, Tomaszewska [eds] et al., 2014) were conducted.

In 2011-2013 geothermal conditions and resources for several regions of the country were summarized in atlases of the Western Carpathians, Eastern Carpathians and Carpathian Foredeep (Górecki [ed] et al. 2011, 2012, 2013). Along with similar earlier works for the Polish Lowlands, the Małopolska Region and the Upper Silesia Region cover over 80% of Polish territory and serve as comprehensive sources of data and information for scientists and potential investors.

To draw attention on the geothermal potential suitable for space heating and to enhance its practical uses' deployment the Polish Geothermal Society presented several years ago a concept of geothermal energy development in the Polish cities. It is addressed to the municipalities located in areas prospective in terms of resources, possessing heating networks, heat market, etc. where geothermal energy can be successfully introduced. The concept has gained recommendations of some representatives of the government and the parliament, and one shall believe that it will enter into implementation stage. It is in line with the outcomes and recommendations of two important European projects focusing on wider geothermal energy uses on this continent, i.e. "Promote geothermal district heating systems in Europe" (GeoDH), 2012-2014 (www.geodh.eu) and "Geothermal communities – demonstrating the cascaded use of geothermal energy for district heating with small scale RES integration and retrofitting measures" (GEOCOM), 2010-2015 (www.geothermalcommunities.eu).

8. LEGAL AND ADMINISTRATION ASPECTS OF GEOTHERMAL USES DEVELOPMENT

By 2011, the activity aimed at geothermal water management (exploration, exploitation) was the subject of two-stage licensing procedures by the minister of the environment. The new Geological and Mining Law (entered into force in 2012) simplified some procedures by, among others, introducing a single system of licensing and transfer it to the regional administration. Other provisions facilitating geothermal activities include: exemption from royalties for geothermal water exploitation; exemption from fees for the geological information used for project purposes; reduction of fees for the use of geological information in order to exploit geothermal water; cancellation of licenses for exploration and prospecting of geothermal water (just geological works project to be approved by the regional administration); shortening the exploitation license procedures by reduction of the duties of cooperation with other bodies while issuing the decision on concession.

Very important for the development of geothermal energy was an access to public support for the projects. By 2012 such a role was played by the program "Energetic use of geothermal resources" (managed by the National Fund for Environment Protection and Water Management). That program supported, in particular, geothermal exploration wells (up to 50% of eligible costs), R&D, and other works. Unfortunately, in 2013 it was closed, which – as mentioned – has and will result in significant slowdown (almost complete suppression) of investments especially in the heating sector. There are no more other relevant sources of public support for drillings proposed and another important supportive tool has been missing so far, i.e. the geological risk insurance fund postulated to be introduced by the professionals (Kepinska, Tomaszewska, 2010; www.geodh.eu).

In case of geothermal energy (as well as in case of other RES) no support scheme for generation / sales of renewable heat exists. It is neither envisaged by the NREAP nor by governmental project of RES Law.

In light of the above, one shall state that better provisions of the new Geological and Mining Law introduced in 2012 has not been accompanied so far by other relevant tools which would create proper system facilitating geothermal development, especially for heating. Also the heat pump sector ("shallow geothermal") develops with practically no public support. Professional and industrial entities are still waiting for the implementation of the EU Directive on RES provisions recognizing the importance of heat pumps and deep geothermal in the RES mix.

9. THE SHARE OF GEOTHERMAL IN CURRENT RES MIX AND IN OFFICIAL DOCUMENTS

In 2011, the total RES energy acquisition in Poland achieved ca. 325 234 TJ, i.e. 11.2% of total primary energy acquisition (Berent-Kowalska et al., 2012). The energy sector is dominated by coal with a growing contribution of natural gas. The dominant share in RES mix came from solid biomass (85.57%). The next were: liquid biofuels (5.54%), wind (3.55%), hydro (2.58%), biogas (1.76%), biodegradable municipal wastes (0.41%), solar (0.13%) while geothermal energy was 0.16% only and heat pumps (all types) was 0.29% (installations in private households were not included in this latter share). Final brutto RES energy consumption was 303,698 TJ including 218,141 TJ for the heating sector (cooling being a small portion), 46,479 TJ for electricity generation and 39,078 TJ for transport. The domination of the heating sector in the RES mix is striking but the geothermal contribution to it is very small; this is because the fact that geothermal so far has been not developed accordingly to the resources' potential, market and social interest.

According to the "Energy Policy of Poland by 2030" and "National Renewable Energy Action Plan" (NREAP), in 2020 RES shall reach 15% in gross final energy consumption. In the case of the heating and cooling sector, final energy consumption in 2020 is expected to be 5,921 ktoe, with the dominance of biomass – 86% share of all RES. The share of solar energy is set at 8.5%, while the forecasted share of geothermal energy is very low: 3% (without heat pumps), similar as heat pumps' share – 2.5% (including geothermal, hydrothermal and aerothermal ones). The NREAP does not include geothermal electricity generation (binary systems), even on a small scale (single devices with a capacity of tens – hundreds of kWe). From the other side, governmental project of RES Law involves introduction of factor 1.4 in case when such generation will develop.

Although the official prognoses predict a very low share of geothermal in the RES mix, it should be always pointed out that Poland has prospective resources especially for wide heating applications as well as for bathing and balneotherapy. As mentioned above, in certain cases one may also consider the binary systems (co-generation of power and heat).

10. CLOSING REMARKS

During the reported period of 2010–2014 some further progress in geothermal direct applications in Poland has been made. One new geothermal district heating plant was opened, one was re-launched (in total six geoDH were operational in 2014). While the heating sector presented rather moderate development, a growing interest was observed in geothermal bathing (recreation) which dominated geothermal uses deployment (except heat pumps): three spas and four new recreation centers started to use geothermal water and energy (from among the total number of 11 and 9, respectively). The projects of about fifteen such facilities were in various stages of realization in 2014. Further heat pumps' development was recorded to at least 390 MWt and 2,000 TJ.

These facts resulted in the total level of ca. 488.84 MWt of installed geothermal capacity and 2,742.6 TJ of heat use for the whole country at the end of 2013 as compared to the level of 281 MWt and 1,501 TJ in 2008 (Kepinska, 2010).

It is also worth noting that just in Poland are (probably) the largest heating installations on European continent working in 2013, both in case of "deep" and "shallow" geothermal: the Podhale region geothermal district heating system (installed geothermal capacity 40.7 MWt and heat sales 300 TJ/2013) and GSHP installation (hospital) in Szczecin town: installed power of 2.6 MWt.

The country possesses the circumstances conducive to geothermal uses deployment: prospective resources, potential receivers, as well as high level and scientific commitment, wide experience of servicing companies, contractors of installations, etc. One shall add the need to implement national and international documents to increase the RES use and follow sustainable energy development. Operating plants, environmental effects, social and economic benefits suggest that more dynamic geothermal development is possible. Particularly prospective is the heating sector. Moreover, geothermal heat prices are competitive with heat from fossil fuels (even with coal in some cases), stable and slightly lower than heat from burning natural gas (Pajak, Bujakowski, 2013). This fact also justifies the purposefulness of geothermal heating development on a much wider scale. However, this sector needs proper legal and supporting measures (as mentioned in chapter 8).

The promising branch represents also recreation and balneotherapy. In some locations the prospects exist for binary cogeneration (based on ca. 90–120ºC water). Further GSHP development is expected, following the progress observed in recent years.

To facilitate the geothermal deployment some regulations and faster administrative procedures were put into force in the new Geological and Mining Law in 2012. It was expected that they would effectively work thanks to the introduction of complementary relevant provisions in e.g. new Law on RES and at least by maintaining the measures of public support for the drillings. Such a system is indispensable to make geothermal more competitive and marketable than the heat coming from other energy sources – especially fossil fuels (coal, which dominates energy sector in Poland).

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STANDARD TABLES

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2013 (other than heat pumps), POLAND

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*-Geotermia Podhalanska	D (+A)*	125	87	55			40.8	91	300.27	0.23
Pyrzyce	D	100.1	61	28			12	44.2	54.6	0.15
Mszczonow	D	16.6	42	12			3.7	11	15.7	0.14
Uniejow	D	33.4	68	42			2.1	13.9	19.2	0.29
Stargard Szczecinski	D	50	83	64			12.6	38.9	168.07	0.43
Poddebice	D	52.8	71	54			10	12.2	15	0.05
Uniejow**	O	8.3	28	20			1	8.3	8.7	0.26
Aqua Park-Zakopane	B	13.9	37	28			0.52	6.9	4	0.24
Szymoszkowa-Zakopane*****	B	22.2	27	23			0.3	11	3	0.32
Terma Bialka *(tentative)*	B	8.9	38	28			0.37	8.9	11.7	1
Terma Bialka***** /tentative/	H	8.9	74	50			3	8.9	30	0.32
Terma Bukovina */tentative/*	B	11.2	38	28			0.46	11.2	14.6	1
Terma Bukovina*****/tentative/	H	11.2	64.5	38			2	11.2	30	0.46
Termy Szaflary	B	6.9	38	32			0.23	6.3	5	0.69
Termy Uniejow	B	8.3	42	30			0.5	8.4	13	0.82
Termy Mszczonow	B	4.2	32	28			0.07	4.2	1.5	0.68
Poddebice	B	5.6	38	28			0.23	5.6	3.7	0.14
Cieplice	B	7.5	36-39	26			0.3	6	10	0.9
Ladek	B	13.8	20-44	30-34			0.7	9.8	12	0.54
Duszniki	B	5.5	19-21	19			0.05	5.5	0.7	0.44
Ciechocinek	B	56.8	27-29	20			1.9	4.2	2.8	0.05
Konstancin	B	2.5	29	12			1.8	0.1	0.2	0.01
Ustron	B	0.9	28	11			0.6	0.4	0.6	0.03
Iwonicz***	B+O	3	21	10			1.4	0.4	0.6	0.01
Grudziadz-Marusza****	B	5.5	20-22	20						
Rabka****	B+O	1.2	28	20						
Termy Maltanskie Poznan	B	10.5	38	30			0.44	5.3	10	0.72
Termy Cieplickie *(tentative)*	B	12.5	36	27			0.47	12.5	7	0.47
Ustka *(since late 2014, no data)*	B									
TOTAL		607.2					98.84	346.3	742.6	

H = Individual space heating (other than heat pumps); D = District heating (other than heat pumps); A = Agricultural drying (grain, fruit, vegetables); B = Bathing and swimming (including balneology); O = Other

* Podhale: (+A) - wood drying in PAS MEERI facility (ca. 0.3 MWt, 0.5 TJ/2013); ** Uniejow - O: heating up the lawn of football playground and walking path; *** Iwonicz: O - extraction of iodine-bromine salts, production of cosmetics; **** Grudziadz Marusza, Rabka - the centres use limited amount of water (max. 20-22 deg C or even less) therefore not all parameters are given. Water is heated up for spa treatments; ***** Compressor heat pumps installed (not included into the numbers given in this table)

Note: data for some bathing (recreation) uses tentative and based on Kepinska 2010, 2013

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2013, POLAND

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

1) Report the average ground temperature for ground-coupled units or average w ell w ater or lake w ater temperature for w ater-source heat pumps

2) Report type of installation as follow s: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = w ater source (w ell or lake w ater)
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 w ater 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 (all)	(-7) - 20	10 - 200 · 390 000	ca. 35 000	V, H, W	3.5 to 6 /ave. 4.2/	3800	> 2000	ca. 20-30% devices used for cooling; exact data not know n
TOTAL		> 390 000	ca. 35 000				>2000	

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2013, POLAND

1) Installed Capacity (thermal pow er) (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. (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
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

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	5.0	60	0.38
District Heating [4]	82.2	573.0	0.22
Air Conditioning (Cooling)			
Wood Drying	0.3	0.5	0.11
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	10.34	100.4	0.31
Other Uses - heating playground, walking path	1.00	8.7	0.28
Subtotal	98.84	742.6	0.24
Geothermal Heat Pumps (CHP)	> 390	>2000	0.17
TOTAL	488.84	2742.6	

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2010 TO DECEMBER 31, 2013 (excluding heat pump wells), Poland

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

Purpose	Wellhead Temperature	Number of Wells Drilled: Electric Power	Direct Use	Combined	Other (specify)	Total Depth (km)
Exploration[1)]	(all)		10 (<100°C)*, **			20
Production	>150° C					
	150-100° C					
	<100° C		1***			3.4 MD
Injection	(all)		2 new			4.5
			1 'old' deepened			ca. 0.2 MD
Total			13			ca. 28.1

* wells drilled on a basis of licenses for exploration drillings (but mostly aimed at water production)
** one well negative (no geothermal water found)
*** well drilled on basis of license for exploitation/production well
Note: in addition to given in the Table, four well previously drilled were reconstructed / adopted for geothermal production, 2010-2013

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

(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)
2014	10	90	30			30

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN 2010-2013 (US$), Poland

Period	Research & Development Incl. Surface Explor. & Exploration Drilling (Million US$)	Field Development Including Production Drilling & Surface Equipment (Million US$)	Utilization: Direct (Million US$)	Utilization: Electrical (Million US$)	Funding Type: Private (%)	Funding Type: Public (%)
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

* Rough estimation (specially for utilization - private funding)