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Original Research

Green energy from mine water: global utilization and a new method for assessing geothermal project viability

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Abstract

The mining industry invests a lot of money and effort in excavating and maintaining large underground networks of interconnected void spaces. This brings a unique opportunity to future engineer and minimize capital costs of mine water geothermal projects, which have wide global potential. This paper provides an update on the state-of-art in mine water driven energy utilization and, using the example of the Upper Silesian Coal Basin (USCB), Poland, presents a simple and fast method for assessment of geothermal project viability based on availability of six categories of nearby energy receptors: single-family housing, multi-family housing, services and large-area retail, office space, large-scale public buildings, active mining sites, and large-scale production plants. Results indicate a high potential for success of mine-water geothermal projects in the highly urbanised USCB. However, the coal mining industry in Poland is in decline so there is a strong tendency to avoid any kind of investment in innovation. The authors argue that this approach, although understandable, is short-sighted, as it overlooks opportunities to promote use of low-carbon energy resources, and create a post-closure "after-life", or support mining communities, sustaining the cultural identity of mining regions. Given that land use categorization and weighting in our method can be adjusted for local or regional conditions, it is readily applicable for assessment of project viability at any prospective mine water geothermal location across the world.

Keywords: mine water; geothermal energy; Upper Silesian Coal Basin; Poland; green energy; green transition

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1. Introduction

Mining activity all around the World has its natural cycle of mine opening, exploitation, closure and post-closure period. The use of thermal energy from mine water that is being continuously pumped from the mine to the surface or that is filling the voids of flooded mine gives the unique opportunity for the coal regions in transition. It is a chance to ensure that mining regions remain active, lively and full of energy even while the mining activity itself decreases or finally stops. At the same time, the uptake of thermal energy from mine water promotes the use of renewable sources of energy and decreasing the carbon footprint, showing a care for global climate issues. Last, but not least, the use of thermal energy from mine water ensures the proper care also for the cultural aspect of mining legacy. The continuity of mine-driven energy gives a specific “after-life” for the mine itself and the possibility for sustaining cultural identity of mining regions. Moreover, as underlined already by Preene and Younger [1] mining activity invests a lot of money and efforts in construction of underground structures that penetrate subsurface for mining purposes. This is a fortunate coincidence, which minimizes the capital costs for geothermal projects.

It is true that there are potential risks of water contamination associated to mine water geothermal projects. Mine water is often highly saline, might have low pH or significant metal content. However, there are ways to overcome these risks. There is a possibility to apply the close loop system: either to re-inject the water into the same underground system after obtaining the thermal energy or to move the heat exchanger underground – to avoid pumping the contaminated water and keep it underground throughout the process, extracting only thermal energy to the ground surface with a help of e.g., pipe with heating/cooling agent submersed in the mine water down the flooded shaft. In case the pumping is being conducted anyway for another reason – the geothermal project is not bringing any additional risks to the water environment as it is not resulting in any additional mine water discharge compared to already existing situation.

Despite these arguments, the actual use of mine-water driven energy stays at surprisingly low level. In 2013, there were less than 20 documented examples of operational geothermal systems on mine sites worldwide [1].

This paper aims to provide an update on the state-of-the-art in mine-water-driven energy utilization, taking into account more recent papers [2,3]. It also proposes a simple and fast method for assessing the potential for successful geothermal project implementation, illustrated with an example from the Upper Silesian Coal Basin (USCB), Poland.

2. Materials and Methods

2.1 Utilization of geothermal energy from mine water

The investment projects for uptake of thermal energy from mine water are known since early 1980s from USA, Germany, Canada, Netherlands, Norway, UK, China, Russia, Spain and Poland. The first thorough review of existing mine water geothermal projects was given by Preene and Younger [1]. Walls *et al.* [2] have updated the state-of-art in mine water driven geothermal energy utilization project with more recent data. Then a comprehensive review by Chu *et al.* [3] updated on the known mine-oriented geothermal projects in a broader sense, not only mine water driven. The current paper presents the most updated review of the state-of-art in mine water driven energy utilization (**Table 1**).

Table 1 Documented examples of low-enthalpy geothermal systems used to exploit energy from mines.

Approximate date of implementation	Location	Description	Parameters	References
Early 1980s	Henderson Molybdenum Mine, Colorado, USA	A system used to heat mine ventilation air and controlling mine working temperature	temperature 29 °C heat capacity 0.79 – 4.1 MW	[1]
1981	Kingston, USA	A heating and cooling system sourced by mine water for recreation center	depth 58 m heat capacity ~100 kW	[4]
1984	Heinrich coal mine, Heisingen, Essen, Germany	A system used to heat nursing home	heat capacity 350 kW	[1,5]
1989	Springhill, Nova Scotia, Canada	A flooded former coal-mines of Springhill contain water recovered at the surface at a temperature of about 18 °C	temperature 20 °C depth 140 m heat capacity 111 kW	[6-8]
1994	Abandoned tin mine, Ehrenfriedersdorf, Sachsen, Germany	A system used for heating a high school		[1,5]
1995	Park Hills, Missouri, USA	A heat system and air-conditioning of the municipal building has been operating since 1995	temperature 14 °C depth 122 m heat capacity 113 kW	[4]
1997	Abandoned tin mine, Ehrenfriedersdorf, Sachsen, Germany	A system used to heat a museum building	heat capacity 82 kW	[1,5]
1998	Folldal mine, Norway	A mine water heat pump system had been implemented at the “Folldal Gamle Gruver” mining museum	temperature 6 °C depth 600 m heat capacity 18 kW	[4]
1999	Shettleston, Scotland, UK	A geothermal project for space heating using mine water from abandoned coal mines working to heat a total of 16 houses supplied with heat from this system.	temperature 12 °C depth 100 m heat capacity 65 kW	[2,9,10]
2000	Lumphinnans, Scotland, UK	A system used to space heating and pre-heating of domestic water	temperature 15 °C depth 172.5 m heat capacity 65 kW	[1]
2000	Zollverein coal mine, Katernberg, Essen, Germany	A system used to heat a school of design		[1,3,5]
2005	Kongsberg mine, Norway	A system used to heat mining museum, banqueting and concert hall	temperature 16.4 °C depth 342 m heat capacity 12−15 kW	[3]
2006	Goyer quarry, Saint Bruno De Montarville, Quebec, Canada	A geothermal system in Canada was installed with use of the mine water. A total volume of flooded mine water of 8,064,000 m^3 used to supply heating and cooling to decentralized system made up by 36 apartments with heat pumps’ capacities amount to 3.6–5.3 kW	heat capacity 3.6–5.3 kW	[11]

Approximate date of implementation	Location	Description	Parameters	References
2006	Xiezhuang mine, Taian, Shandong, China	A system used to heat mine intake air	temperature 9–12 °C heat capacity 4,343–5,227 kW	[3]
2007	Shaft 302, Marienberg Mine, Sachsen, Germany	A system used to heat a swimming pool. Its heating capacity amount to 690kW	temperature 12 °C depth 144 m heat capacity 690 kw	[1,12]
2007	Jiahe mine, Xuzhou, China	A system used to heat building, mine cooling and wellhead anti-frost	temperature 36 °C depth ~1000 m heat capacity 3722 kW	[3]
2007~2010	Zhangshuanglou mine, Xuzhou, China	A system used to heat building, mine cooling and wellhead anti-frost	temperature 36–37 °C depth ~1000 m heat capacity 12,125 kW	[3]
2008	Mount Wellington Mine, Cornwall, UK	A system used to heat the factory and offices of Kensa Engineering	heat capacity 20 kW	[1]
2009	Novoshakhtinsk, Russia	A heat distribution in three districts and provide heat to a hospital, a school, a vocational school, a kindergarten, administrative offices, and industrial sites	temperature 18–23 °C depth 390 m heat capacity 40 MW	[4]
2009	Heerlen, Netherlands	A largest geothermal district heating systems sourced by mine water	temperature 28 °C depth 700 m heat capacity 700 kW	[13-16]
2009	Freiberg, Saxony, Germany	A geothermal system was also implemented in buildings belonging to the Freiberg University of Mining and Technology and the Castle Freudenstein	temperature 10.2 °C depth 60 m heat capacity 160–180 kW	[4,17]
2009	Bad Schlema, Saxony, Germany	A system used to head a school building	heat capacity 520 kW	[3]
2010	Scranton, Pennsylvania, USA	A cooling purposes of the Center for Architectural Studies of the Marywood University.	temperature 13.9-16.1 °C depth 122 m	[4]
2010	Mieres, Asturias, Hunosa, Spain	A geothermal system has been successfully implemented for two buildings on the campus of the University of Oviedo, for the new Alvarez Buylla hospital and for FAEN Foundation	temperature 17–23 °C heat capacity 1000 kW – university, 3600 kW – hospital 100kW – FAEN Foundation	[18]
2011	Dawdon, UK	A demonstration system to heat buildings at Coal Authority pumping station.	temperature 19 °C heat capacity 12 kW	[1]
2012	Saturn mine, Czeladź, Poland	A pilot system used to heat plant building and support cooling system	temperature 13 °C heat capacity ~ 117,8 kw	[19]
2012	Markham Colliery, Alkane Energy, UK	A system used to control centre of Alkane Energy, a novel application of Ground Source Heat Pump (GSHP) for space heating using a flooded coal mine through an open loop	temperature 15.4 °C depth 235 m	[20-22]

Approximate date of implementation	Location	Description	Parameters	References
		based single shaft system		
2013	Wettelrode, Saxony, Germany	A heating system for the adventure pool, Aqua Marien, a tennis hall, and some supermarkets in Marienberg and the second supply heat to Wettelrode Rohrigschacht mining museum.	Temperature 13 °C depth 283 m heat capacity 47 kW	[4,17]
2014	Zhaolou mine, Shandong, China	A system used to heat mine intake air and underground mine cooling	Temperature 26 °C depth 860–1000 m heat capacity 7,500 kW	[3]
2015	Caphouse mine, Yorkshire, UK	A system used to control National Coal Mining Museum	Temperature 14–15 °C depth 134 m heat capacity 10 kW	[3]
2015	Sobieski mine, Jaworzno, Poland	A system used for sanitary purposes in the mining baths	Temperature 12–14 °C depth 500 m heat capacity 425 kw	[23]
2015	Caphouse Colliery	A closed loop heat exchange unit in the aeration pond (surface) A shell-and-tube heat exchanger	Temperature 14–15 °C heat capacity 10 kW	[24]
2016	Jisan mine, Shandong, China	A system used to heat mine intake air and underground cooling	Temperature 22 °C depth 556 m heat capacity 8,700 kW	[3]
2016	Armada site, Szombierki mine, Bytom, Poland	A system used to heat service building	Temperature 22–24 °C heat pump 10 kW	[25]
2018	Lanchester Wines, Abbotsford Road Gateshead, UK	Lanchester Wines' warehouse facilities at Abbotsford Road	Temperature 11–13 °C depth up to 110 m heat capacity 2.4 MW	[26,27]
2018	Lanchester Wines, Nest Road, Gateshead, UK	Lanchester Wines' warehouse facilities at Nest Road	Temperature 13–14 °C depth up to 131 m heat capacity 1.2 MW	[26,27]
2018	Bochum, Germany	A seasonal underground surplus heat storage	Depth 21 m heat capacity 165 MWh	[28]
2019	Alsdorf, Germany	A closed-loop system was planned for heating one or two buildings belonging to the Energeticon Company from the water flooding the abandoned Anna coal mine via the Eduard Shaft at a depth of about 890 m.	depth 890 m	[4,29]
2023	Baltic Quarter, Gateshead, Tyne and Wear, UK	An incorporation mine water driven energy into Gateshead heat network	Temperature 15 °C heat capacity 6.2 MWh depth 150 m	[30]

2.2 Underused potential

Still, the number of realized projects for mine-water driven energy uptake is quite low compared to the potential. According to Díez *et al.* [31] at least approximately 3000 MWt could be used from underground coal mines in the

European Union. If this energy potential were used, an important reduction in emissions of approximately 5 million tonnes of CO_2 per year could be reached. The high potential for further use of thermal energy from mine water has been reported from Canada [32-36], UK, [9,37], Spain [38-40], France [41], Poland [23,25,42-49], Bulgaria [50], Czech Republic [51-54], China [55], USA [56-58], Germany [59,60] and Hungary [61].

The underuse of the potential is very much visible in case of Poland – the country for which coal mining is important part of culture heritage and still significant sector of economy. Even if reported potential is huge, the degree of utilisation of heat energy from mine waters in Poland is very low. In the Lower Silesian Coal Basin, where all the mines are already flooded, the potential extraction of heat from the abandoned Nowa Ruda mine, which contains about 5 million m^3 of water at a temperature of 16–26 °C, at pump rates of 10 l/s (thermal output ~800 kW) and 20 l/s (thermal output 1600 kW) was analysed already over 2 decades ago [45].

For another part of this basin in the Walbrzych area, the possibility of producing thermal energy from mine waters has been reported, but this requires a detailed inventory of the technical condition of the existing shafts [23].

The potential for geothermal energy use of mine waters in the USCB is much higher. The mine waters flowing into all underground coal mines in the USCB contain significant amounts of thermal energy amounting to 270 MJ per second [43]. This is mainly due to huge volumes of pumped mine water: only from decommissioned mines it is estimated to be 80 million m^3/year [42]. The geothermal potential of mine water remains high, even for the abandoned mines in flooding process. Klinger *et al.* [62] have developed numerical models including density and temperature dedicated to the industrial utilisation of the rising mine water for geothermal heat. This is important fact for USCB given the declining the productivity and low profitability of coal mines. As agreed, most of the mines in the region would be closed by 2049. Therefore, the development of geothermal energy projects based on mine water would provide an opportunity to maintain employment and, at the same time, would help to sustain the cultural identity of the mining region.

Still, there have been only a few geothermal energy generation projects brought to the stage of technological design or relatively small-scale investment. A technological design was carried out for a 3,000 kW CHP plant producing 600 kW of electricity from mine water from the decommissioned mine Katowice [44]. This project, however, has not reached the building phase yet. A hydrogeological and hydrogeochemical study of pumped waters from the Bytom mine (northern USCB) as a potential location for heat recovery from underground sources was also carried out [25], followed by a pilot investment resulting in the extraction of energy from mine waters to heat a small office building.

Another pilot investment in Poland, carried out as part of the REMINING - LOWEX (Revitalisation of European Mine Areas) project by SRK S.A. [19] since 2012, allows the extraction of thermal energy from mine water from PG "Saturn" with a temperature of approximately 13 °C. The energy is used to heat the CZOK plant building in Czeladź. The heating power is ~117.8 kW, which is sufficient to secure the heating needs of the CZOK plant building, and supports the cooling system in summer.

Five water-to-water heat pumps operating in a cascade system with a total power of 425 kW were also used at the Sobieski Mine in Jaworzno. The lower source of heat for the heat pump system is mine waters drawn from 500 m below ground level. The temperature of the water flowing out of the underground mine seams is about 12−14 °C. Thanks to the heat pump installation, the water is heated to 55 °C in two independent, hydraulically separated cascades. The installation used was created for the preparation of domestic hot water, which is prepared on an ongoing basis using a shell-and-tube heat exchanger and stored in tanks with a total capacity of 63 m^3. It is then used for sanitary purposes in the mining baths [23].

Compared to this huge potential mentioned above, thermal energy from mine water is largely underutilised. The bottleneck of investment viability is rarely the quantity and temperature of the mine water itself. Much more often, the key step is to ensure the efficient transfer of energy from the point of extraction to the end consumers of thermal energy. The best proof for that is the fact that the two largest projects that have been built use in fact the coolest water streams available in the USCB. However, the key fact is that the mine water geothermal projects have been successful, mainly because the large energy receptors are present directly at the sites where the mine water is being extracted. Therefore, the key element for the success of mine water thermal energy extraction projects is to minimise energy loss during transfer. The planned schemes should focus on heating (and in some cases cooling) the building as close as possible to the point of thermal energy extraction.

2.3 Method for estimation of success potential for mine water geothermal projects

This paper aims at providing the proof that there is still huge potential for mine-water driven thermal energy extraction in Poland. For this reason, the study was carried out to analyse locations in the USCB, including both active and abandoned coal mines. In most of these mines, water is pumped through the main shaft; in some cases the pumping is currently done via the shafts of neighbouring mines, but there is still a potential to reach mine water. As stated above, the key bottleneck is the presence of potential energy receptor in the vicinity. Therefore, the immediate vicinity (up to 1 km) of active and decommissioned coal mines were analysed in terms of the current land use function. The main shafts of the given mine were located on the ortophoto map. Then the area within 1km radius was analyzed to identify characteristic features easy to recognize on the aerial photo. The potential energy receptors identified in the vicinity of mining sites were grouped into six categories: single-family housing (*SH*), multi-family housing (*MH*), services and large-area retail, office space (*SO*), large-scale public buildings (*PB*), active mining site (*MI*), large-scale production plants (*PP*).

The success potential index (*SP*) for mine water geothermal project is calculated by the simple equation (Equation 1):

$$SP = SH \times W_{SH} + MH \times W_{MH} + SO \times W_{so} + PB \times W_{PB} + MI \times W_{MI} + PP \times W_{PP} \quad (1)$$

where:

- *SH*, *MH*, *SO*, *PB*, *MI* and *PP* indicate presence (value = 1) or absence (value = 0) of the respective land use category in the vicinity of the assessed mining site;

- W_{SH}, W_{MH}, W_{SO}, W_{PB}, W_{MI} and W_{PP} are the weights assigned for each of the land use categories taken into account during the assessment.

The idea behind the application of weights is that the presence of various categories in the vicinity of a mining site does not equally affect the potential success of the geothermal project. For example, the presence of large concert or sports hall affects the potential success of the project much more than the presence of single-family housing neighbourhood. Both land use categorization and applied weights can be adjusted for local or regional conditions. In this way the proposed method is flexible and allows for worldwide application.

3. Results

The proposed method for fast and simple assessment of potential for successful geothermal project implementation has been applied for USCB. This coal basin is the largest one in Poland and one of the largest in Europe and it is located in the South part of Poland. In 1990, which is the year from which the coal mining in Poland have drastically changed in trend from the top production into constant decline, there have been 60 individual mines in the basin. Since then, the majority of mines have been subsequently abandoned and some of still active mines have been grouped into larger units. However, most of the mines active in 1990 still keep independent underground structure. For this reason, 50 mining and post-mining locations have been analysed in the current study. The individual locations and the presence vs. absence of the respective land use categories in its vicinity have been listed in the **Table 2**, and **Table 3** presents the weights used in case of USCB.

Table 2 Analysis of potential customers for mine water as a heat source in the immediate vicinity of active and decommissioned mines.

Active and decommissioned mines in Upper Silesian Coal Basin	**Single-family housing (SH)**	**Multi-family housing (MH)**	**Services and large-area retail, office space (SO)**	**Large-scale public buildings (PB)**	**Active mining site (MI)**	**Large-scale production plants (PP)**
Closed mine Gliwice	x	x	x	x		
Closed mine Pstrowski	x	x	x		x	
Closed mine Powstańców Śląskich	x	x	x			
Closed mine Piekary	x	x		x		
Closed mine Grodziec	x	x				
Closed mine Paryż	x	x	x	x		
Knurów-Szczygłowice mine part Knurów	x	x	x		x	
Knurów-Szczygłowice mine part Szczygłowice	x	x			x	
Sośnica mine	x	x	x		x	
Closed mine Makoszowy	x		x			
Ruda mine part Bielszowice	x	x			x	
Closed mine Szombierki	x	x	x	x		x
Bobrek-Piekary mine part Bobrek	x	x	x		x	x
Closed mine Centrum		x	x			x
Closed mine Siemianowice	x	x	x			x
Closed mine Saturn	x	x	x			
Closed mine Sosnowiec	x	x	x			x

Active and decommissioned mines in Upper Silesian Coal Basin	**Single-family housing (SH)**	**Multi-family housing (MH)**	**Services and large-area retail, office space (SO)**	**Large-scale public buildings (PB)**	**Active mining site (MI)**	**Large-scale production plants (PP)**
Closed mine Kazimierz - Juliusz	x	x	x			
Closed mine Porąbka- Klimontów	x	x	x			
Ruda mine part Pokój	x	x	x	x		
Ruda mine part Halemba	x	x		x		
Closed mine Kleofas	x	x	x			
Closed mine Katowice	x	x	x	x		
Closed mine Wieczorek	x	x		x		
Mysłowice-Wesoła mine part Mysłowice	x	x	x			
Closed mine Niwka-Modrzejów	x	x				x
Closed mine Jan Kanty	x	x	x	x		
Closed mine Dębieńsko	x	x		x		x
Closed mine Śląsk	x	x				
Staszic-Wujek mine part Wujek	x	x	x		x	
Staszic-Wujek mine part Murcki Staszic		x			x	
Closed mine Boże Dary	x	x				x
Mysłowice-Wesoła mine part Wesoła	x	x			x	
Piast-Ziemowit mine part Ziemowit	x	x			x	
Sobieski mine	x	x			x	x
Piast-Ziemowit mine part Piast	x	x			x	
Brzeszcze mine	x	x		x		
Silesia mine	x	x			x	x
ROW mine part Rydułtowy	x	x		x	x	
ROW mine part Chwałowice	x	x		x	x	
ROW mine part Marcel	x	x		x	x	
ROW mine part Jankowice	x	x		x	x	
Closed mine JAS-MOS	x	x			x	
Borynia-Zofiówka-Bzie mine part Borynia	x	x		x	x	
Borynia-Zofiówka-Bzie mine part Zofiówka	x	x			x	
Pniówek mine	x	x			x	
Janina mine	x	x			x	x
Closed mine Krupiński	x	x				
Borynia-Zofiówka-Bzie mine part Bzie	x				x	x
Bolesław Smiały mine	x	x	x		x	

Table 3 The weights used in analysis of potential customers for mine water as a heat source case of Upper Silesian Coal Basin.

Land use category	Weights	Rationale for given weight
Single-family housing (SH)	1	– Need for development of district heating network - large capital expenditures – A small demand for heating of single consumers – Potentially demanding decision-making process and investment arrangements
Multi-family housing (MH)	3	– Easier decision-making process and investment arrangements compared to SH – Higher demand for heating one building compared to SH
Services and large-area retail, office space (SO)	4	– Much easier decision-making process and investment arrangements compared to SH

Land use category	Weights	Rationale for given weight
		higher demand for heating one building compared to SH and often also compared to MH
Large-scale public buildings (PB)	5	– Much easier decision-making process and investment arrangements compared to SH – Very high demand for heating – High demonstration and green energy promotion potential – additional argument for public owners
Active mining site (MI)	2	– Ownership relations are regulated, so much easier decision-making process and investment arrangements compared to SH – Mining is a declining industry - shorter lifetime perspective for the investment
Large-scale production plants (PP)	4	– Easier decision-making process and investment arrangements compared to SH – Demand for heating depending of production process but often quite high – Demonstration and promotion potential is not as strong argument as in the case of PB

The results of the assessment are presented in table form (**Table 4**). For better illustration the individual sites have been grouped into categories as shown in Table 4 and then plotted over the regional map (**Figure 1**).

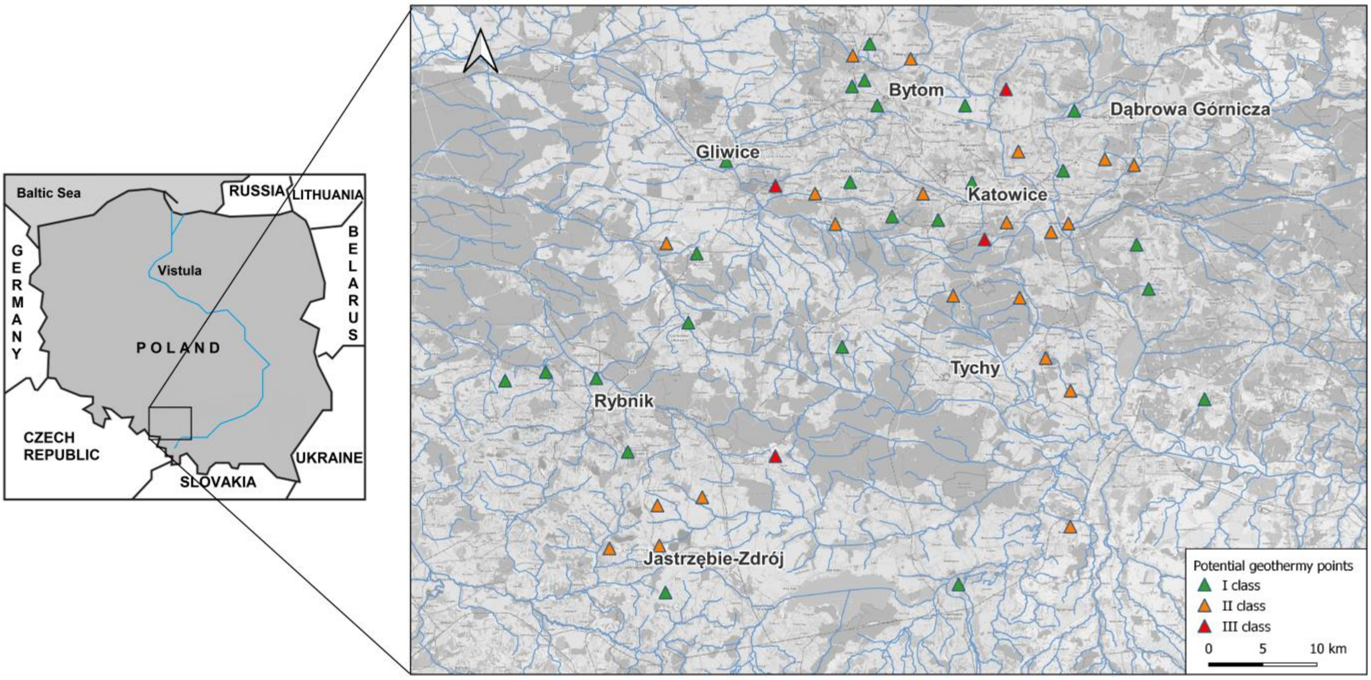

Figure 1 Map of potential customers for mine water as a heat source in the immediate vicinity of active and decommissioned mines.

Table 4 The ranking of potential customers for mine water as a heat source in the immediate vicinity of active and decommissioned mines.

No.	Active and decommissioned mines in Upper Silesian Coal Basin	Success potential index (SP)	Classes based on SP values
1	Closed mine Szombierki	17	I class
2	Bobrek-Piekary mine part Bobrek	14	
3	Closed mine Gliwice	13	
4	Closed mine Paryż	13	
5	Ruda mine part Pokój	13	
6	Closed mine Katowice	13	
7	Closed mine Jan Kanty	13	
8	Closed mine Dębieńsko	13	
9	Closed mine Siemianowice	12	
10	Closed mine Sosnowiec	12	
11	Closed mine Centrum	11	
12	ROW mine part Rydułtowy	11	
13	ROW mine part Chwałowice	11	
14	ROW mine part Marcel	11	
15	ROW mine part Jankowice	11	
16	Borynia-Zofiówka-Bzie mine part Borynia	11	
17	Closed mine Pstrowski	10	
18	Knurów-Szczygłowice mine part Knurów	10	
19	Sośnica mine	10	
20	Staszic-Wujek mine part Wujek	10	
21	Sobieski mine	10	
22	Silesia mine	10	
23	Janina mine	10	
24	Bolesław Śmiały mine	10	
25	Closed mine Piekary	9	II class
26	Ruda mine part Halemba	9	
27	Closed mine Wieczorek	9	
28	Brzeszcze mine	9	
29	Closed mine Powstańców Śląskich	8	
30	Closed mine Saturn	8	
31	Closed mine Kazimierz - Juliusz	8	
32	Closed mine Porąbka- Klimontów	8	
33	Closed mine Kleofas	8	
34	Mysłowice-Wesoła mine part Mysłowice	8	
35	Closed mine Niwka-Modrzejów	8	
36	Closed mine Boże Dary	8	
37	Borynia-Zofiówka Bzie mine part Bzie	7	
38	Knurów-Szczygłowice mine part Szczygłowice	6	
39	Ruda mine part Bielszowice	6	
40	Mysłowice-Wesoła mine part Wesoła	6	
41	Piast-Ziemowit mine part Ziemowit	6	
42	Piast-Ziemowit mine part Piast	6	
43	Closed mine JAS-MOS	6	
44	Borynia-Zofiówka-Bzie mine part Zofiówka	6	
45	Pniówek mine	6	
46	Closed mine Makoszowy	5	III class
47	Mine Staszic-Wujek mine part Murcki Staszic	5	
48	Closed mine Grodziec	4	
49	Closed mine Śląsk	4	
50	Closed mine Krupiński	4	

4. Discussion

The results of the study are indicating very high potential for success of mine-water based geothermal projects. The *SP* values for all 50 mining and post-mining sites that were analysed are in the range from 4 to 17. As much as 45 sites show *SP* values of 6 or more. The weights assumed in the process of calculation of *SP* are of course highly subjective. However, no matter which set of weights would be assumed it is clear that at least 2 land use categories were identified in the vicinity of all 50 analysed sites. In most cases 3–4 categories were identified. Therefore, the potential for success of mine water based geothermal projects is very high. This is facilitated by the high degree of urbanisation in the USCB.

5. Conclusions

Surprisingly, not so many mine water geothermal projects are implemented in reality both worldwide as well as in the USCB, Poland. Quite probable explanation is the financial aspect: the investment projects, although profitable in the long term, still require certain upfront expenditures. The coal mining industry in Poland is a declining branch and therefore there is a strong tendency to avoid any kind of investment in innovation, such as geothermal projects. This is true for most of mining companies, which are currently receiving public financing to finalize their last years of functioning smoothly. Investing in geothermal projects seems highly redundant in such situation. It is similarly difficult when the mine is finally closed and gets managed by restructuring company. As restructuring means usually selling all land and property left after mining period and minimizing all acute post-mining risks, the investments in geothermal projects are also not on the top of priority list. The authors believe that this approach, although understandable, is a big mistake, as it is huge opportunity that is being missed. There is an urgent need for more activity in the public sector at all levels: national, regional and local. The examples from closed mines Saturn and Szombierki show that with the help of projects co-financed from public funds the geothermal installations are successfully implemented and work there for years. With the proper impulse from public authorities much more projects could be built and this Polish mining region could promote the use of renewable sources of energy and decreasing the carbon footprint as well as ensure the proper care also for the cultural aspect of mining legacy.

Declarations

Availability of Data and Material

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Competing Interests

The authors have declared that no competing interests exist.

Author Contributions

GG: Conceptualization, Methodology, Investigation, Writing - Original Draft; AS: Investigation, Writing - Review & Editing, Visualization.

References

1. Preene M, Younger PL. Can you take the heat? – Geothermal energy in mining. Mining Technol. 2014:123(2);107-118. DOI
2. Walls DB, Banks D, Boyce AJ, Burnside NM. A review of the performance of minewater heating and cooling systems. Energies. 2021:14(19);6215. DOI
3. Chu Z, Dong K, Gao P, Wang Y, Sun Q. Mine-oriented low-enthalpy geothermal exploitation: A review from spatio-temporal perspective. Energy Convers Manage. 2021;237:114123. DOI
4. Ramos EP, Breede K, Falcone G. Geothermal heat recovery from abandoned mines: a systematic review of projects implemented worldwide and a methodology for screening new projects. Environ Earth Sci. 2015:73:6783–6795. DOI
5. Wieber G, Pohl S. Mine water: a source of geothermal energy–examples from the Rhenish Massif. In: Proceedings of 10th International Mine Water Association Congress, Karlsbad, 2008 Jun 2-5.
6. Jessop AM, Ghomshei MM, Drury MJ. Geothermal energy in Canada. Geothermics. 1991:20(5-6):369-385. DOI
7. Jessop A, MacDonald J, Spence H. Clean energy from abandoned mines at Springhill, Nova Scotia. Energy Sources. 1995:17:93–106. DOI
8. Jessop A. Geothermal energy from old mines at Springhill, Nova Scotia, Canada. In: Proceedings of World Geothermal Congress, Florence, Italy, 1995 May 18-31. Auckland: International Geothermal Association. 1995.
9. Walls D, Burnside NM, Boyce AJ. 'Old versus new' : comparing mine water geothermal systems in Glasgow [Internet]. In: Proceedings of World Geothermal Congress 2020+1, Harpa, 2021 Oct 24-27. [cited YEAR Month 27]. Available from: https://strathprints.strath.ac.uk/82106/.
10. Banks D, Athresh A, Al-Habaibeh A, Burnside N. Water from abandoned mines as a heat source: practical experiences of open-and closed-loop strategies, United Kingdom. Sustain Water Resour Manag. 2019:5:29-50. DOI
11. Raymond J, Therrien R, Hassani F. Overview of geothermal energy resources in Québec (Canada) mining environments. In: Proceedings of 10th International Mine Water Association Congress, Karlsbad, Czech Republic, 2008 June 2-5. Sydney, Canada: International Mine Water Association (IMWA). 2008.
12. Matthes R, Schreyer J. Remediation of the Old Wismut-Shaft 302 in Marienberg and Installation of a Technical Plant for Geothermic Mine Water Use (Ore Mountains, Germany). In: Proceedings of International Mine Water Symposium 2007, Cagliari/Sardinia, Italy, 2007 May 27– 31.
13. Bazargan Sabet, B, Demollin E, Van Bergermeer J. Geothermal use of deep flooded mines. In: Proceedings of International symposium on post-mining, Nancy, France, 2008 Feb 6-8.
14. Op't Veld P, Malolepszy Z, Bojadgieva K, Vetrsek J. Geothermal development of low temperature resources in European coal mining fields, The EC REMINING—Lowex project. In: Proceedings of the World Geothermal Congress, Bali, Indonesia, 2010 Apr 25-30. Hague, Netherlands: International Geothermal Association. 2010.
15. Verhoeven R, Willems E, Harcouët-Menou V, De Boever E, Hiddes L, Op't Veld P, et al. The EC-REMINING—Lowex project in Heerlen the Netherlands: transformation from a geothermal mine water pilot project into a full scale hybrid sustainable energy infrastructure Mine Water 2.0. In: Proceedings of the 8th International Renewable Energy Storage Conference and Exhibition (IRES 2013), Berlin, Germany, 2013 Nov 18-20. Amsterdam: Elsevier. 2014.
16. Verhoeven R, Willems E, Harcouët-Menou V, De Boever E, Hiddes L, Op't Veld P, et al. Minewater 2.0 project in Heerlen the Netherlands: transformation of a geothermal mine water pilot project into a full scale hybrid sustainable energy infrastructure for heating and cooling. Energy Procedia. 2014:46;58-67. DOI

17. Kranz K, Dillenardt J. Mine water utilization for geothermal purposes in Freiberg, Germany: determination of hydrogeological and thermophysical rock parameters. Mine Water Environ. 2010;29:68-76. DOI
18. Jardón S, Ordóñez A, Álvarez R, Cienfuegos P, Loredo J. Mine water for energy and water supply in the Central Coal Basin of Asturias (Spain). Mine Water Environ. 2013:32(2):139-151. DOI
19. Tokarz M, Mucha W. Wykorzystanie energii geotermalnej pochodzącej z odwadniania zakładów górniczych, na przykładzie rozwiązań zastosowanych w SRK SA Zakładzie CZOK w Czeladzi. Technika Poszukiwań Geologicznych. 2013;52(1);103-114.
20. Athresh AP, Al-Habaibeh A, Parker K. Innovative approach for heating of buildings using water from a flooded coal mine through an open loop based single shaft GSHP system. Energy Procedia. 2015;75:1221-1228. DOI
21. Al-Habaibeh A, Athresh AP, Parker K. Performance analysis of using mine water from an abandoned coal mine for heating of buildings using an open loop based single shaft GSHP system. Appl Energy. 2018;211:393-402. DOI
22. Burnside NM, Banks D, Boyce AJ, Athresh A. Hydrochemistry and stable isotopes as tools for understanding the sustainability of minewater geothermal energy production from a 'standing column'heat pump system: Markham Colliery, Bolsover, Derbyshire, UK. Int J Coal Geol. 2016;165:223-230. DOI
23. Woźniak J, Pactwa, K. Possibilities for using mine waters in the context of the construction of heat energy clusters in Poland. Energy Sustain Soc. 2019;9(1):13. DOI
24. Burnside NM, Banks D, Boyce AJ. Sustainability of thermal energy production at the flooded mine workings of the former Caphouse Colliery, Yorkshire, United Kingdom. Int J Coal Geol. 2016;164:85-91. DOI
25. Janson E, Boyce AJ, Burnside N, Gzyl G. Preliminary investigation on temperature, chemistry and isotopes of mine water pumped in Bytom geological basin (USCB Poland) as a potential geothermal energy source. Int J Coal Geol. 2016;164:104-114. DOI
26. Banks D, Steven J, Black A, Naismith J. Conceptual modelling of two large-scale mine water geothermal energy schemes: Felling, Gateshead, UK. Int J Environ Res Public Health. 2022;19(3):1643. DOI
27. Monaghan AA, Adams CA, Bell RA, Lewis MA, Boon D, González Quirós A, et al. Geological factors in the sustainable management of mine water heating, cooling and thermal storage resources in the UK. In Geological Society, London, Energy Geoscience Conference Series. London: The Geological Society of London. 2025. DOI
28. HeatStore [Internet]. National project in Germany. [cited 2024 Dec 19]. Available from: https://www.heatstore.eu/national-project-germany.html.
29. Yu X, Lin B, Zhai C, Zhu C, Regenauer-Lie K, Chen X. Enhanced Coalbed Methane Extraction by Geothermal Stimulation in Deep Coal Mines: An Appraisal. arXiv preprint arXiv:2102.02348, 2021. DOI
30. IEA Geothermal 2023. Case study: mine water heat network, UK. Last accessed 19th of December 2024. Available from: https://drive.google.com/file/d/1xlVCiyqM3b7JQsYJHfJl0YzTugweSL_Q/view.
31. Díez R, Díaz-Aguado M. Estimating limits for the geothermal energy potential of abandoned underground coal mines: a simple methodology. Energies. 2014;7(7):4241-4260. DOI
32. Ghomshei MM, Eng P, Geo P. Geothermal energy from Con Mine for Heating the City of Yellowknife, NWT: A concept study. Vancouver: The University of British Columbia. 2007.
33. Noble R. They seam to have a solution. Historic coal mine gives back to the town. Can Min J. 2012;133(4):36-37.
34. Raymond J, Therrien R. Low-temperature geothermal potential of the flooded Gaspé Mines, Québec, Canada. Geothermics. 2008;37(2):189-210. DOI
35. Raymond J, Therrien R. Optimizing the design of a geothermal district heating and cooling system located at a flooded mine in Canada. Hydrogeol J. 2014;22(1):217-231. DOI
36. Raymond J, Therrien R, Gosselin L. Low-temperature geothermal energy in mining environments. CIM Journal. 2010;1(2):140-149.

37. Bailey MT, Gandy CJ, Watson IA, Wyatt LM, Jarvis AP. Heat recovery potential of mine water treatment systems in Great Britain. Int J Coal Geol. 2016;164:77-84. DOI
38. Menéndez J, Ordóñez A, Álvarez R, Loredo J. Energy from closed mines: Underground energy storage and geothermal applications. Renew Sustain Energy Rev. 2019;108:498-512. DOI
39. Loredo C, Ordóñez A, Garcia-Ordiales E, Álvarez R, Roqueñi N, Cienfuegos P, Burnside NM. Hydrochemical characterization of a mine water geothermal energy resource in NW Spain. Sci Total Environ. 2017;576;59-69. DOI
40. Matas A, García-Carro F, Loredo J. Characterization of Laciana Valley District mine water as geothermal resource. EDP Sciences. 2018,51,01003. DOI
41. Hamm V, Sabet B. Modelling of fluid flow and heat transfer to assess the geothermal potential of a flooded coal mine in Lorraine, France. Geothermics. 2010;39(2):177-186. DOI
42. Janson E, Gzyl G, Głodniok M, Markowska M. Use of Geothermal Heat of Mine Waters in Upper Silesian Coal Basin, Southern Poland – Possibilities and Impediments. Mine Water and Circular Economy. 2017;415-421.
43. Solik-Heliasz E. Geothermal energy resources in waters from subsurface hard coal, zinc and lead ore mines in the Upper Silesian Coal Basin. Arch Min Sci. 2010;55(4):961-972.
44. Solik-Heliasz E, Skrzypczak M. The technological design of geothermal plant for producing energy from mine waters. Arch Min Sci. 2009;54(3):563-572.
45. Malolepszy Z. Preliminary numerical simulation of heat exchange in abandoned workings of former coal mine Nowa Ruda. In: Proceedings of the ninth international symposium on heat transfer and renewable sources of energy, Szczecin; Poland; 1 July 2002.
46. Malolepszy, Z. Low temperature, man-made geothermal reservoirs in abandoned workings of underground mines. In: Proceedings of the 28th workshop on geothermal reservoir engineering, Palo Alto, CA, USA, 2003 Jan 27-29. Stanford, California: Stanford University. 2003.
47. Malolepszy Z, Ostaficzuk S. Geothermal potential of the Upper Silesian Coal Basin, Poland. *Bulletin d'Hydroge'ologie, Editions Peter Lang, Université de Neuchatel, 1999, 17, 67-76*.
48. Malolepszy Z, Demollin-Schneiders E, Bowers D. Potential use of geothermal mine waters in Europe. In: Proceedings of the World Geothermal Congress, Antalya, Turkey, 2005 Apr 24-29. Sibayak, Indonesia: International Geothermal Association. 2005.
49. Chudy K. Mine water as geothermal resource in nowa ruda region (SW Poland). Water. 2022;14(2):136. DOI
50. Bojadgieva K, Benderev A, Gerginov P, Hristov V. The abandoned underground Cherno More coal mine (se bulgaria)–a source of low grade geothermal energy. Comptes rendus de l'Académie bulgare des Sciences. 2013;66(4):565-572.
51. Uhlík J, Baier J. Model evaluation of thermal energy potential of hydrogeological structures with flooded mines. Mine Water Environ. 2012;31(3);179-191. DOI
52. Petričko P, Kupka D, Koloničný J, Richter A. Economy of heat recovery from mining water in Ostrava region conditions. EDP Sciences. 2018;168:08005. DOI
53. Michálek B, Holéczy D, Jelínek P, Grmela A. Využití tepelné energie důlních vod zatopených hlubinných dolů. Acta Montanistica Slovaca, Ročník. 2007;12:92-98.
54. Vokurka M, Antonín KUNZ, Zapletal P, Klimesch M, Paulíková K, Sládek V, et al. Analysis of the Geothermal Energy Utilization of Mine Water from Rožná I Mine, Czech Republic. GeoScience Engineering. 2021;67(4):135-143. DOI
55. Cheng WM, Qi YD, Yu YB, Pan G. Integrated utilization of low-grade thermal energy in hot coal mine. J Coal Sci Eng. 2013;19(1):26-32. DOI
56. Bao T, Meldrum J, Green C, Vitton S, Liu Z, Bird K. Geothermal energy recovery from deep flooded copper mines for heating. Energy Convers Manage. 2019;183:604-616. DOI
57. Liu Z, Meldrum J, Xue P, Green C. Preliminary studies of the use of abandoned mine water for geothermal applications. In: Proceedings of the International Foundations Congress and Equipment Expo 2015, San Antonio, Texas, 2015 Mar 17-21. Washington, D.C., USA: American Society of Civil Engineers (ASCE). DOI

58. Richardson J, Lopez D, Leftwich T, Angle M, Wolfe M, Fugitt F. The characterization of flooded abandoned mines in Ohio as a low-temperature geothermal resource. Geol Soc Am Spec Pap. 2016;519:19-41. DOI
59. Wieber G, Stemke M, Wonik T, Enzmann F, Kersten M. Stratification Dynamics and Geothermal Potential of a Deep Shaft in the Flooded Wolf Mine, Siegerland/Germany. Mine Water Environ. 2019;38(2):325-334. DOI
60. Ramos EP, Falcone G. Recovery of the geothermal energy stored in abandoned mines. In Clean Energy Systems in the Subsurface: Production, Storage and Conversion. Berlin, Heidelberg: Springer. 2013; 143-155. DOI
61. Tóth A. Geothermal potential of an abandoned copper mine. In: Proceedings of the 2nd International Conference on Advances in Energy Engineering, Bangkok, Thailand, 2011 Dec 27-28.
62. Klinger C, Charmoille A, Bueno J, Gzyl G, Súcar BG. Strategies for follow-up care and utilisation of closing and flooding in European hard coal mining areas. Int J Coal Geol. 2012;89:51-61. DOI