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ENERGY SECURITY IN TERMS OF GEOTHERMAL RESOURCES IN SELECTED REGIONS OF POLAND

Abstract: The study attempts to analyze the need to build subjective Polish energy security in the context of its rich geothermal resources of the various regions of our country. Adoption of these measures allows not only to increase the diversification of sources of energy supply but also brings significant benefits in economic, social and environmental area.
This issue is presented in three aspects:
• Sources and resources of geothermal energy in selected regions of Poland;
• Advantages and disadvantages of using geothermal energy;
• Examples of the use of geothermal energy in some regions of Poland.
The use of geothermal resources may also have significance in no-military defence dimension of the country. To explore the problem in detail, an analytic-synthetic research method was used.
Key worlds: resources of geothermal energy, sources of geothermal energy, geothermal energy, advantages of geothermal energy, disadvantages of geothermal energy

Introduction

One of the significant components of the energy security strategy of Poland is geothermal energy. Its growing importance, especially in the recent years, stems from the dynamics of economic development and numerous global political transformations. As a result of these phenomena, one of the most essential instruments of international influence becomes an energy supply system. Ensuring its supply which is cost-effective and adequate to the needs, while minimizing the negative impact on the environment and living conditions of the population is one of the most vital determinants of the strategy of stability and development of each country.

As far as Poland is concerned, it can be stated that high demand for Polish energy, inadequate level of development of manufacturing infrastructure and transport infrastructure of fuels and energy, high dependence on external supplies of natural gas and on external supplies of crude oil, ecological liabilities determined by the European Union for the year 2020 in the form of quantitative targets, the so-called "3x20", i.e. reducing emissions of greenhouse gases by 20%, reducing energy consumption by 20% (compared with forecasts for the EU for 2020), reaching 20% of renewable energy in the total energy consumption in the EU " unambiguously suggest courses of action that should be taken by the Polish government in building and strengthening the defense strategy of energy security of the country. Its expression could have been noticed in the last Climate Summit (COP21) in December 2015 in Paris, during which the Minister of the Environment, Jan Szyszko, emphatically emphasized the importance of Polish geothermal energy in the production of cheap and clean

[1] Toruńska geotermia w Paryżu, „Nasz Dziennik" as of 3 December 2015 – http://www.naszdziennik.pl/polska-kraj/148251,torunska-geotermia-w-paryzu.html

energy, saying: *"We want to show the Polish geothermal energy as a success on a global scale"*. Subsequently the Minister assured that *"... geothermal energy can rely on large support of the state and thus would be able to quickly implement the latest technology of extraction and use of hot water"*[1].

As shown by the latest forecasts for the development of the global energy sector, in the twenty-first century geothermal energy will note a significant increase in the overall balance of original energy sources.

So why, among others, geothermal energy has to be the resource that can have a positive impact on the subjective state of Polish energy security?

1. Source and resources of geothermal energy in selected regions of Poland

Polish **geothermal resources** based specifically on water and water vapor are **very large**, even huge. The advantage of these resources is their even distribution across 80% of the area of the country and their excellent recognition. These resources are estimated at approximately 34 billion tons of crude oil which is equivalent to approximately 36 billion tons of coal. These data demonstrate **enormous potential of energy resources** which from the technical point of view is possible to use. Research show that in some places to a depth of only 3 km their energy potential is 625 thousand PJ per year, or 387 thousand EJ per year. It should be emphasized that this potential is 99.8% of all renewable energy resources. In fact it should be also noted that one PJ is tantamount to the amount of energy contained in 23 thousands of tons of crude oil.

Generally it can be claimed that the potential of geothermal energy which can be found in the ground exceeds 154 times the annual energy needs of our country. For comparison, there are 198,000 PJ of these resources in Germany. Thus, Poland has three times more resources than our western neighbor.

An important feature of Polish geothermal resources is also their relatively **high temperature**, which, however, depends on the depth and geographical location.

For example, at the depth of 1.5-3.5 km one can find water at the temperature of 20 to approximately 80-90 degrees Celsius (with prevailing temperature of 90 degrees – at the depth of 3 km). At this temperature, one geothermal hole is able to provide the power of 1-2 MW. In some cases, there can be found water whose temperature exceeds 100 degrees Celsius; at the depth of 5 km – the temperature is 300 degrees Celsius; and at the depth of 7 km – reaches even 350-400 degrees Celsius (Koziowski, 2008; cf. Legutko, 2003)[2].

At this point the following question arises: What are the geothermal resources in different regions of Poland?

As a matter of fact, the distribution of geothermal resources in Poland, as mentioned before, is different depending on the geographical location and its geological structure. Referring to the division of Poland into provinces, it can be concluded that the most-favored in terms of geothermal energy are the three provinces which are illustrated in Fig. 1:

- Polish Lowland Province,
- Sub-Carpathian Province,
- Carpathian Province.

[2] As noted by prof. R. H. Koz³owski, Poland by having such high temperatures is "a ready-made boiler into which water needs to be poured to get vapor; geothermal vapor (i.e. hot rock energy) out of which with the use of turbine and generator, electric current is obtained". This Polish technology is recognized in the world, but not by the Polish former government (E. Kopacz's government). – Ibid; According to the concept of **Polish Laboratory of Radical Technologies**, drilling at such depths can be used with the **multi-concentric bore technology so called Jet Stinger** brought over from the United States by prof. Bohdan M. Żakiewicz. - Ł. Legutko, 2 Bałtyki ciepłej wody pod Polską? Energia tania, choć …, 2003.

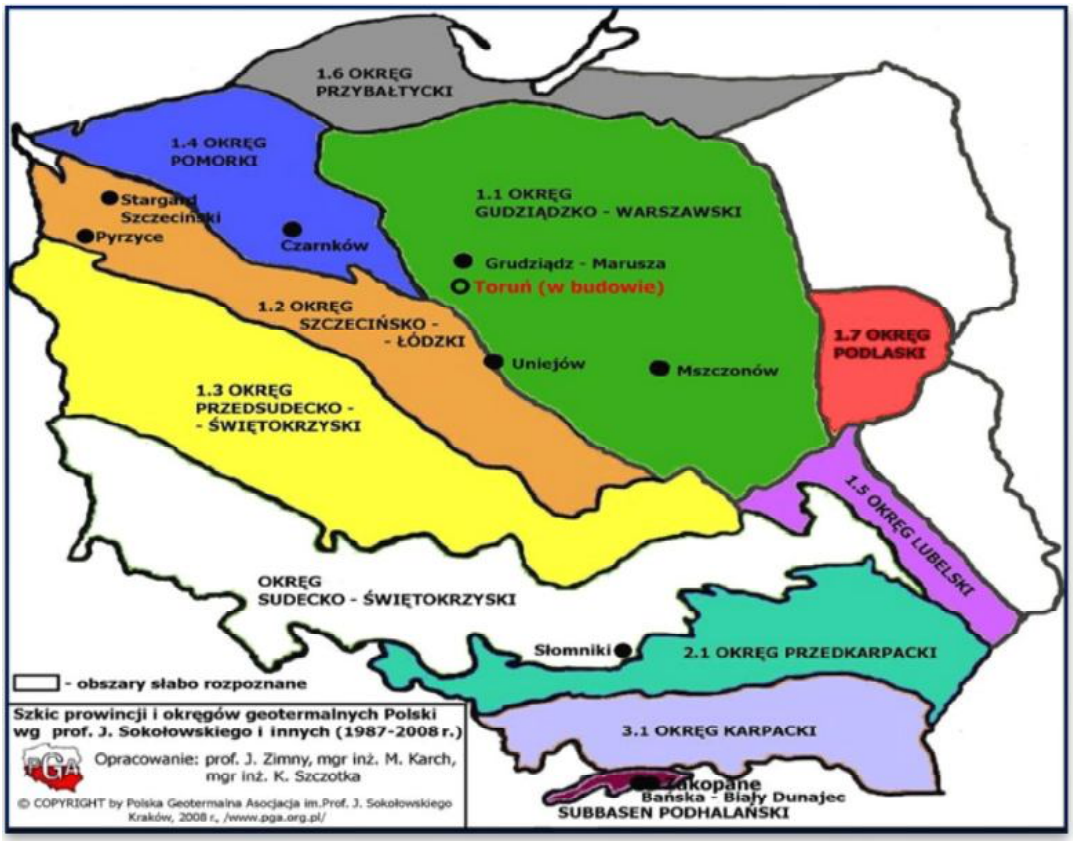


Figure 1. Location of provinces and regions (districts) with geothermal resources
Source: https://www.google.pl/search?q=z%C5%82o%C5%BCa+geotermalne+w+polsce+-+obraz

Polish Lowland Province (Central European) occupies an area of approximately 222 thousand of squared kilometers and includes seven geothermal regions such as Grudziadz-Warsaw Region, Foresudetic-Swietokrzyski Region, Szczecin-Lodz Region, Pomeranian Region, Baltic Region, Podlasie Region and Lublin Region. The temperature of geothermal water in these areas ranges from 30-130 degrees Celsius at the depth of 1-3 km. The most rich in water are the Grudziadz-Szczecin and Warsaw-Lodz Regions. Both regions occupy about half of the territory of Poland, whereas the amount of water in them is approximately 90% of all geothermal resources in Poland. **The total value of the resources of the Polish Lowland Province is estimated to be more than 6225 km² of water whose thermal energy is equivalent to 32458 million tons of coal equivalent (about35 billion tons of coal).**

Sub-Carpathian Province covers an area of approximately 16 thousand km². On this area geothermal waters reach the temperature of 25-50 degrees Celsius. **The total value of these local resources is estimated at more than 362 km² of water whose thermal energy is equivalent to 1555 million tons of coal equivalent (1.7 billion tons of coal).**

Carpathian Province covers an area of approximately 12 thousand km². Geothermal waters in the area reach the temperature of 60-90 degrees Celsius. **The total value of geothermal resources in the region is estimated at over 100 km² of water whose thermal energy is equivalent to 714 million tons of coal equivalent (0.8 billion tons of coal).**

Another regions of Poland which have interesting geothermal prospects are **Sudety** where geothermal waters can be found in crevices of rocks, and **the area of Podhale** (Tytko, 2011, p. 267).

At the regional level, according to the Polish Geothermal Association, temperatures of approx. 100°C **are in the Mazowieckie Province, Wielkopolska Province, Lubuskie Province, Malopolska Province and Zachodnio-Pomorskie Province** and locally in other parts of the country (Wiśniewski, 2011, p. 67) – as shown in Fig.2.

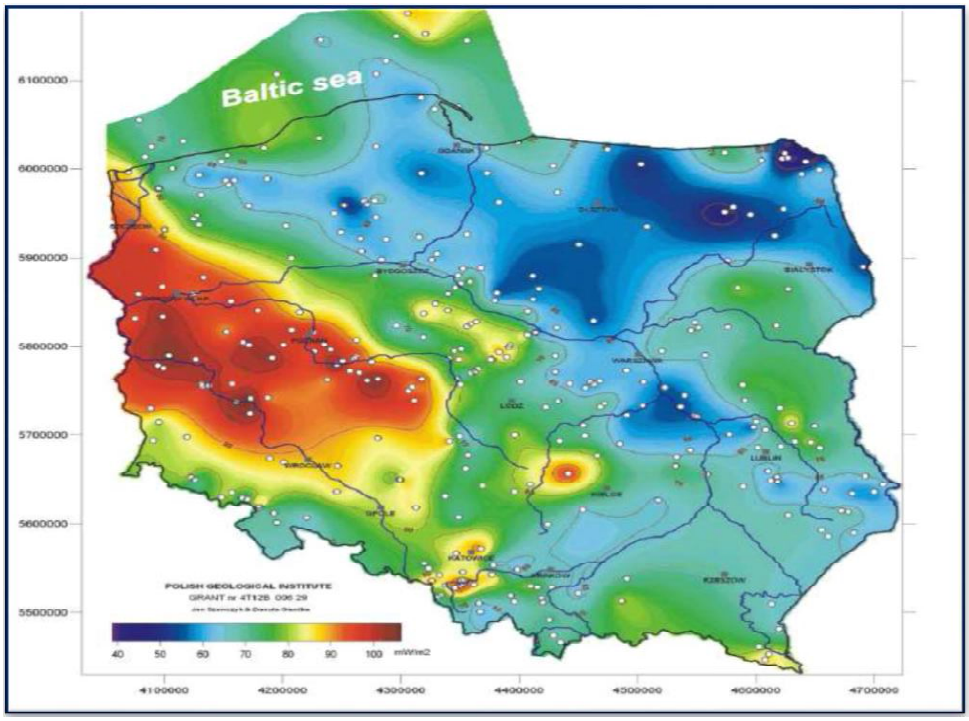


Figure 2. Map of the density of geothermal waters heat flow
Source: https://www.google.pl/search?q=geotermia+polska+mapa&espv=2&biw=1006&bih=752&tbm=isch&imgil

Tab. 1 presents various regions of Poland with regard to their geological formation, amount of geothermal waters, water temperature and energy resources contained within.

Tab. 1. List of the regions of Poland

NAME OF THE REGION/ DISTRICT	AREA (km^2)	GEOLOGI-CAL FORMATION	AMOUNT OF GEOTHER-MAL WATERS (km^3)	WATER TEMP. (°C)	ENERGY RESOURCES ($Ex10^6$ PJ)
Grudziadz-Warsaw	70 000	Cretaceous / Jurassic Triassic **Total**	2766 344 **3100**	70	18
Szczecin-Lodz	67 000	Cretaceous / Jurassic Triassic **Total**	2580 274 **2854**	85	21
Foresudetic-Swietokrzyski	39 000	Permian / Triassic	155	90	13
Pomeranian	12 000	Permian / Carboniferous / Devonian / Jurassic / Triassic	21	65	3
Lublin	12 000	Carboniferous / Devonian	30	0	4
Baltic	15 000	Cambrian/ Permian / Mesozoic	38	65	4
Podlasie	7 000	Cambrian / Permian / Mesozoic	17	65	2
Fore-Carpathian	16 000	Triassic / Jurassic / Cretaceous / Tertiary	362	80	5
Carpathian	13000	Triassic / Jurassic / Cretaceous / Tertiary	100	70	3

Source: T. Tytko, Odnawialne ırydia energii, Eurogospodarka, Warszawa 2011, s. 266.

2. Advantages and disadvantages of using geothermal energy

The use of geothermal waters to produce energy depends mainly on their **heating medium temperature**. Research confirmed by numerous experiments show that both power plants as well as heat and power plants based on geothermal waters are a great opportunity for Poland in the economic and ecological dimension. This is the result of such **advantages of geothermal energy** as (Legutko, 2003):

✓ renew ability;

✓ ecological character – no pollution of the natural environment: the atmosphere, hydrosphere, lithosphere, and biosphere;

✓ prevalance;

✓ decentralization, i.e. obtaining energy from the sources that are close to potential users, which allows to reduce the losses associated with the transmission of energy at a distance and the independence of small regions and local populations;

✓ idependence of climactic and weather changes;

✓ possibility to use existing wells, which guarantees economic justification for creating geothermal heating installations;

✓ constant flux of thermal energy for several decades;

✓ independence of energy costs from energy source prices;

✓ independence from the supplies of fossil fuels;

✓ lower cost per unit for acquiring geothermal heat as compared with conventional heating plants;

✓ lower cost of geothermal energy as compared with other fossil fuels because of the automatic outflow of hot water onto the surface by means of a closed duct system followed by their reinjection into the reservoir after dissipating heat;

✓ possibility to use source energy directly without the conversion to another energy – when ground waters are confined; however, when energy comes directly from rocks there is a need to use surface water or other liquids as a carrier;

✓ impossibility of transporting geothermal energy over long distances, which prevents the monopolization of energy solutions.

As far as the advantages of geothermal resources are concerned, it must be emphasized that the energy sourced from them is environmentally friendly. The amount of pollution emissions that get into the environment from the geothermal plants is to a large extent smaller than in case of the heating plant. A meaningful example of such a situation is a geothermal plant in Konin. Taking it as an example, it turns out that the geothermal plant with a nominal capacity of 12 MW largely eliminates gaseous and dust pollutants, as shown in the Table 2 below.

Tab. 2. Pollution emissions from the heating plant and the geothermal plant in Konin

ELEMENT	POLLUTION EMISSIONS FROM THE HEATING PLANT E_1 (kg/year)	POLLUTION EMISSIONS FROM THE GEOTHERMAL PLANT E2 (kg/year)	PERCENTAGE REDUCTION IN EMISSIONS $100\%x(E_1-E_2)/E_1$ (%)
Benzo(a)pyrene	18,85	-	100,00
Soot	848,25	-	100,00
Dust	530 156,36	17,01	100,00
CO_2	24 700 630	2 303 639,10	90,69
CO	117 812,52	316,69	99,73
NO_x	47 125,01	2 252,03	95,22
SO_2	188 500,04	-	100,00
Aliphatic hydrocarbons	23 562,50	105,09	99,55
Aromatic hydrocarbons	23 562,50	45,04	99,81

Source: T. Tytko, Odnawialne ırydia energii, Eurogospodarka, Warszawa 2011, s. 282.

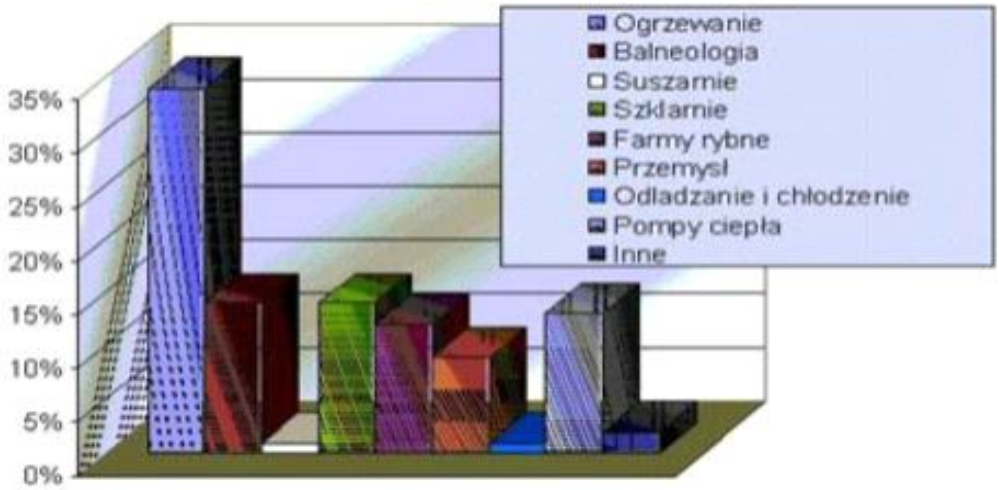
In addition to the positive features of geothermal resources, there are also **some negative ones** namely (Gyrecki, 1999, p. 32):

- possibility of causing environmental problems during the exploitation of geothermal energy in case of release of geoliquid – harmful gas, i.e. Hydrogen sulfide H_2S which should be absorbed in the appropriate systems, and Radon – the product of disintegration of radioactive uranium, which can be released along with vapor out of a geothermal well;
- high initial investment;
- strong dependence of the economic results on the heat sales;
- problem of corrosion of the system and clogging of deposits;
- limitation to the areas where geothermal water can be found.

3. Examples of the use of geothermal energy in some regions of Poland

In Poland, geothermal waters are most frequently used for heating – in heat engineering, spa treatment sector, recreation and balneotherapy, and in the case of high temperature water – in energy production. Chart 1 shows these data in percentages.

Chart 1. Use of geothermal resources



Source: Potencjai energetyki geotermalnej i kierunki jej wykorzystania, in: www.plan-rozwoju.pcz.pl/wyklady/ener_srod/rozdzial4.pdf

In the years 2012-2013, in Poland there were more than 20 systems using water and geothermal energy (Ккpicska, 2013, pp. 7-10), i.e.:

- **six geothermal plants** – in Podhale (PEC Geotermia Podhalacska SA);in Pyrzyce (Geotermia Pyrzyce Sp. z o.o.); in Mszczonow (Geotermia Mazowiecka SA); in Uniejyw (Geotermia Uniejyw Sp. z. o.o.); in Stargard (G-Term Energy – former name PUC Geotermia Stargard Sp. z o.o.); in Poddebice (Geotermia Poddкbice Sp. z o.o.);
- **ten spas –** in Cieplice Slaskie Zdroj, in Ladek Zdroj, in Duszniki Zdroj, in Ciechocinek, in Konstancin, in Ustron, in Iwonicz Zdroj, in Maruszy near Grudziadz, in Rabka Zdroj and in Uniejow
- **eight recreation centers and swimming pools –**in Podhale (Aqua Park Zakopane,Termy Szaflary – former nameTermy Podkarpackie, Kapielisko Geotermalne Szymoszkowa w Zakopanem, Terma Bukowina, Terma Biaika – former name Terma Bania); in Polish Lowlands (Termy Mszczonowskie, thermal swimming pools in Poddebice and Termy Maltanskie in Poznan);
- **other applications –**wood drying, thermophilic fish farming, in winter heating football fields, sidewalks, airport runways, highways, intersections, etc.

Below, in tables, there are given the main parameters of the above geothermal systems and their basic applications.

Tab. 3. Application of geothermal systems in Poland in network heat engineering

System	Application	Parameters of geothermal water		Installed/ estimated power		The use / sale of heat	
		max. capacity	max. temperature	total	from geothermal energy	total	from geothermal energy
		m^3/h	°C	MW_t	MW_t	TJ/r	TJ/r
Podhale - heating plant	heat engineering, recreation	670	86	80,8	40,7	512,94	362,85
Mszczonow - ciepłownia	heat engineering, recreation	60	41	112	3,7	33,02	11,84
Uniejow - ciepłownia	heat engineering, recreation	120	68	5,0	3,2	19,625	15,97
Stargard Szczecinski	heat engineering	100	78		12,6		91,0

Source: B. Kкpicska, Wykorzystanie energii geotermalnej w Polsce, 2012-2013, „Technika Poszukiwac Geologicznych Geotermia, Zrywnowaïony Rozwyj", nr 1/2013, w: https://www.min-pan.krakow.pl/.../TPG2013/01-(I)-14-kepinska-pol.pdf.

Tab. 4. Application of geothermal systems in Poland in recreation and balneotherapy

System	Application	Parameters of geothermal water		Installed/ estimated power		The use/ sale of heat	
		max. capacity	max. temperature	total	from geothermal energy	total	from geothermal energy
		m^3/h	°C	MW_t	MW_t	TJ/r	TJ/r
Kapielisko Geotermalne Szymoszkowa - Zakopane	recreation, heat engineering	80	27	0,3	0,3	3,0	3,0
Terma Bukowina	recreation, balneotherapy, heat engineering	40	64,5	1,35	0,35	1	11
Aqua Park Zakopane	recreation	130	28-36	0,23	0,23	1,8	1,8
Termy Mszczonowskie	recreation	15	32	1,3	1,3	2,7	2,7

Source: B. Kкpicska, Wykorzystanie energii geotermalnej w Polsce, 2012-2013, „Technika Poszukiwac Geologicznych Geotermia, Zrywnowaïony Rozwyj", nr 1/2013, w: https://www.min-pan.krakow.pl/.../TPG2013/01-(I)-14-kepinska-pol.pdf.

Tabl. 5. Application of geothermal systems in Poland in SPAS

System	Application	Parameters of geothermal water		Installed/ estimated power		The use/ sale of heat	
		max. capacity	max. temperature	total	from geothermal energy	total	from geothermal energy
		m^3/h	°C	MW_t	MW_t	TJ/r	TJ/r
Cieplice Sląskie Zdroj	balneotherapy	27	36-39	0,3	0,3	10,0	10,0
Ladek Zdroj	balneotherapy	50	20-44	0,7	0,7	12,0	12,0
Ciechocinek	balneotherapy	204,5	27-29	1,9	1,9	2,8	2,8
Duszniki Zdroj	balneotherapy, other, CO^2 recovery	20	19-21	0,05	0,05	0,7	0,7

Source: B. Ккpicska, Wykorzystanie energii geotermalnej w Polsce, 2012-2013, „Technika Poszukiwac Geologicznych Geotermia, Zrywnowaïony Rozwyj", nr 1/2013, w: https://www.min-pan.krakow.pl/.../TPG2013/01-(I)-14-kepinska-pol.pdf.

Tabl. 6. Other applications of geothermal systems in Poland

System	Application	Parameters of geothermal water		Installed/ estimated power		The use/ sale of heat	
		max. capacity	max. temperature	total	from geothermal energy	total	from geothermal energy
		m^3/h	°C	MW_t	MW_t	TJ/r	TJ/r
Podhale	other: wood drying, fish farming, heating airport runways, sidewalks, air-conditioning			1,0	1,0	2	2
Uniejow	other: heating football fields	20	28	1,0	1,0	4,4	4,4
Lubatowka	other: recovery of mineral salts from geothermal water	11,0	24,5				

Source: B. Ккpicska, Wykorzystanie energii geotermalnej w Polsce, 2012-2013, „Technika Poszukiwac Geologicznych Geotermia, Zrywnowaïony Rozwyj", nr 1/2013, w: https://www.min-pan.krakow.pl/.../TPG2013/01-(I)-14-kepinska-pol.pdf.

Conclusion

Poland is one of the European countries with the largest geothermal resources of diversified temperatures depending on the geographical location of a particular area of the country. Therefore, nowadays, waters and geothermal energy are a great opportunity and also a challenge for energy security and self-sufficiency of

communes, districts, provinces, and the entire country. Awareness of this fact shows more and more pronounced increase in interest in the use of these resources (national wealth) – compared to previous years.

Official forecasts assume a very favorable local share of geothermal energy in the energy market in Poland. Main benefits resulting from its use are connected with the supply of heat to the local consumers and the protection of the environment due to the limited amount of pollution produced by traditional heating systems based on coal. Geothermal energy should be promoted due to the benefits previously mentioned in the article as well as due to the fact that Poland has adopted greater commitments in the use of country's renewable energy sources (RES), which was confirmed by the declarations of representatives of the Polish Government during the Climate Summit organized in December 2015 in Paris (COP21). Thus, by the year 2030 there should be created tens of geothermal plants in Poland.

Available in Poland geothermal resources, their thermodynamic parameters, as well as their arrangement on the territory of the country, could allow for creation of the concept of an et work of energy in dependent, energy efficient and resistant to destruction, centers to carry out of defence tasks. An prelude to the implementation of such a concept, will be an introduction of energy-independent heating systems of the places, on which are spread garrisons and facilities critical infrastructure of the state.

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