Geothermal energy as an opportunity to improve the security and defense of the country

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ABSTRACT

The article presents the possibilities of using geothermal energy resources in military facilities. The use of geothermal energy is a chance to improve the security and defence of the country. An interesting application of this type of energy is heating of runways or heliports. Wide range of heat pumps applications in military facilities is available. Selected examples of the use of geothermal energy in military facilities are given.

1. INTRODUCTION

The need for safety is a natural factor for existence of human, social groups as well as individual states. It is about security in both a military and political aspect, but also social security, understood as a state of freedom from threats of a living nature and protection of the existential basis of human life and the possibility of satisfying its individual needs (Świerszcz 2017). Therefore, the safety components, in addition to military and political aspects, also involve a number of other factors, including energy, economic and ecologic. Energy security, constituting another component of national security, is understood as a series of measures aimed at ensuring an appropriate and reliable level of energy supplies at reasonable, acceptable prices (Kowalski and Kozera 2009). Its provision belongs to the strategic tasks of the state and is a determinant of the effectiveness of its activities. Many conflict situations in the world contain an element of struggle for energy security, resulting from an increase in the demand for natural resources (conventional) and growing awareness of the gradual depletion of most of them (Jankowska 2015). An excellent alternative is ascribed to the use of ecological and widely available renewable energy resources (RES), which are an opportunity to improve the security of the country, both on a local and regional scale.

One out of the renewable energy sources is geothermal energy, which is the internal heat of the Earth's crust, accumulated in hydrothermal systems or hot dry rock formations. Its resources are renewable, which together with the constant availability and being ecological are one of the biggest advantages of its utilization (Sowiżdżał et al 2017). The constant heat flow from inside of the Earth provides an inexhaustible and essentially unlimited supply of energy for billions of years. These qualities might render the effective use of geothermal potential to bring very good results, both in the context of improving the country's energy security, as well as social and environmental aspects. However, all processes related to the use of geothermal resources can be classified as an element of non-military activities that provide the right conditions for building and strengthening national security (Świerszcz and Osial 2018). What is more, the aspect of using geothermal energy in the context of improving the military security of the country has been the subject of broad considerations worldwide. Numerous publications show a wide array of studies conducted in this area, for example in the United States, and geothermal investments implemented in different military facilities (e.g. Coso Geothermal Field (Monastero 2002)). Also, in Poland the ever-growing interest in the possibilities of using existing geothermal resources in the context of improving the country's defence is observed. The particular solutions are sought to primarily ensure the conditions to preserve the vitality of troops, and their abilities and readiness to undertake and perform all kinds of operational tasks (Świerszcz et al 2018). Achieving an appropriate level of independence of military units, including supply of heat, preparation of hot domestic water, then uninterrupted electric energy supplies, can very positively translate into preparing troops for any possible crisis situations. Currently, there are no known examples of the geothermal energy utilization in military facilities in Poland, nevertheless, the interest in the potential implementation of geothermal installations and their effective usage is increasing (Świerszcz at al 2018). What is more, the use of low- and high-temperature geothermal resources perfectly fits into the idea of intelligent, low-emission, low-energy and autonomous systems – essential in military facilities.

The purpose of this paper is to review existing solutions based on the use of geothermal energy in selected military and non-military facilities all over the world in order to assess its potential implementation under Polish conditions. The article also discusses a number of factors affecting the possibilities of effective geothermal energy management in Poland (resource, legal and financial aspects), in the context of improving the security and defence of the country.

2. THE POLISH ENERGY SECTOR

The Polish fuel and energy sector has been to a large extent based on hard coal and lignite. According to the Statistics Poland (GUS 2018c) in 2017 (as well as in previous years), the most important out of obtained energy carriers was hard coal (57.9%). The second largest carrier in terms of extraction's volume was lignite with a share of 18.7%. Consecutively, the share of natural gas amounted to 5.3%, crude oil was 1.5%, and the remaining, largely renewable energy carriers, equalled 16.6%. In the domestic acquisition (and utilization) of energy from renewable sources (GUS, 2018b), solid biofuels are the dominant item. Their share in obtaining energy from renewable sources in 2017 accounted for 67.87% of the energy obtained from RES, while geothermal energy reached only 0.25%. Heat pumps accounted for 0.65% of renewable energy in Poland (Fig. 1).

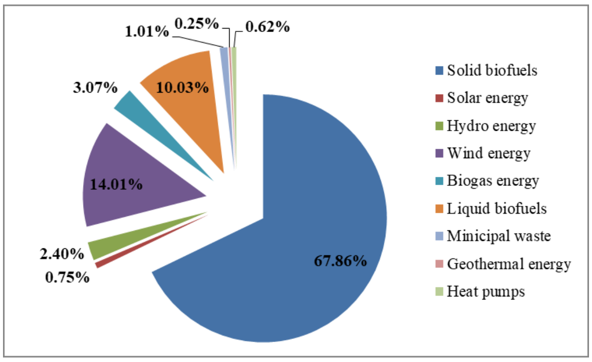

Figure 1: Structure of energy production from renewable sources by carriers in Poland in 2017 (GUS, 2018b).

In 2016, the share of energy consumption in households in the final energy consumption was 30% (Fig. 2). Carbon fuels were the most often consumed, but their share dropped from 35% in 2006 to 33% in 2016. Another carriers were: heat (its share equalled 20% in 2016), natural gas (18%), electricity (13%), other carriers (14%) and liquid fuels (3%). The space heating was the most important direction of energy use with its share amounted to 66.4%. The preparation of hot domestic water (HDW) consumed 15.8% of energy, lighting and electrical appliances 9.7%, and cooking of meals 8% (GUS, 2018a). Analysing the transport sector, over 94% of energy was consumed in the road transport, less than 4% of energy was devoured in the aerial transport, less than 2% in the railway transport, and minimal quantities by inland and coastal shipping (GUS, 2018a).

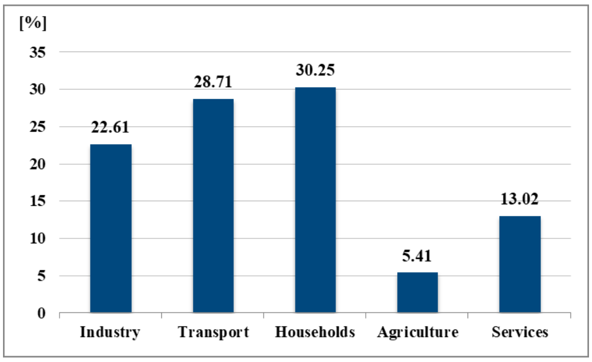

Figure 2: Structure of final energy consumption in Poland by sector, in 2016 (GUS, 2018a).

Therefore, it is fossil fuels that constitute the basic energy carrier in Poland, while the use of renewable energy sources can increase the energy security and make it independent from external energy supplies. For several years, the development of renewable energy has become an important element of Polish energy policy, which results from the necessity to adapt the legal framework to the European Union requirements. The effects of undertaken activities (educational, financial support and others) have effects in the systematic development of this energy industry.

3. SELECTED ASPECTS OF GEOTHERMAL ENERGY DEVELOPMENT IN POLAND

3.1 The energy policy of the country

Being mindful of the need to ensure broadly understood national security, the contemporary *Polish Energy Policy until 2030* (Ministry of Energy 2009) is oriented towards counteracting the phenomenon of energy poverty by improving energy efficiency, reducing emissions of pollutants into the environment and intensified utilization of renewable energy sources. Thus, the draft of *Poland's Energy Policy until 2040* (Ministry of Energy 2018) assumes that the use of geothermal energy in Poland will grow at a rapid rate. Considerably increased utilization of renewable energy sources in a district heating (including geothermal energy) is envisaged. Also, the use of heat pumps in households is to become even more popular.

Also, the Polish legislation system has started to transform in the geothermal-friendly way (Kępińska 2018). Obviously, most of the on-going regulations are derived from the European Union, that allow not only for proceeding the efficient, sustainable exploitation and utilization of geothermal energy, but also urge our country to take the following steps essential for the dynamic development of the broadly understood renewable energy sector. The most important domestic act on exploration, recognition and exploitation of geothermal reservoirs is the *Geological and Mining Law* (Journal of Laws 2017 Item 2126), however, supported by numerous ministerial regulations. The newest edition of the aforementioned act facilitates procedures that need to be taken in case of engaging any geothermal project, especially in case of acquiring the concession. Moreover, the important, fundamental factor for the development of the geothermal energy sector in our country is also assigned to the on-going work on the strategic document *State Resource Policy* (Ministry of Environment 2019), which began in 2017. Geothermal energy was included in the second pillar of the document, i.e. *Acquisition of raw materials from mineral deposits and the heat of the Earth* (PIG-PIB 2019). The utilization of thermal water potential for heat production requires the introduction of a stable system for the non-current development of geothermal energy sector (PIG-PIB 2019). The *State Resources Policy* initiates activities aimed at the compilation of appropriate legal regulations, procedures for the assessment of geothermal installations' projects in terms of: optimal location, rational use of heat resources, avoidance of conflicts of interest and estimation of geological and economic risks (PIG-PIB 2019).

3.2 Current possibilities for financial support obtainment

In addition to an extremely important legal and formal aspect, the possibility of obtaining a financial support dedicated to any geothermal projects remains a fundamental issue that might have a direct impact on the development of any undertaken enterprise. As it is widely known, high investment expenditures is a relevant issue, often leading to the abandonment of potential investments. The opportunity for having a financial backing is of great importance especially in areas of high geological risk.

The possibility of obtaining a government subsidy for each of the geothermal investments that meet the established criteria is an issue conducive to the popularization and thus to the development of the geothermal energy sector in Poland. This factor may be also beneficial from the point of view of raising the broadly understood national defence (Świerszcz and Osial 2018). Currently, the financial support for the Polish geothermal energy sector is provided mainly by the National Fund for Environmental Protection and Water Management (NEEP&WM 2019). The main goal is set as utilisation of geothermal energy resources for heating purposes and generation of electricity, for the period from 2014 to 2025 (NEEP&WM 2019). Three relevant programs have been launched for potential investors in case of geothermal energy sector. There are as follows: *Geology and Mining – Part 1) Recognition of the geological structure of the country and management of mineral deposits and groundwater resources; Improvement of Air Quality – Part 1) Energy use of geothermal resources; Operational Program Infrastructure and Environment – Activity 1.1. Supporting the production and distribution of energy from renewable sources* (co-financed from the Cohesion Fund) (NEEP&WM 2019). These priority programs of the NEEP&WM fit into the national energy policy that is focused on increase the share of RES in the energy mix and promotion of green energy, including geothermal resources, simultaneously, reducing or even covering the costs of potential geothermal investment.

So far, several applications under the *Geology and Mining Program* have gotten a positive opinion and some of them (inter alia towns of Szaflary, Lądek-Zdrój, Sochaczew, Sieradz, Koło, Tomaszów Mazowiecki) have signed agreements with NEEP&WM, the others are still waiting for the decision of the Main Geologist of the Country (Kępińska 2018, Sowiżdżał et al 2019). The beneficiaries were given the financial support covering 100% of eligible costs – summarily above 100 million PLN. Also, within the *Operational Program Infrastructure and Environment,* four geothermal projects concerning the utilisation of geothermal energy (i.a. GeoDH Toruń, GeoDH Podhale, G-Term Energy, Bania Tourist Complex) have been accepted and given over 70 million PLN (Sowiżdżał et al 2019). The rational effect of the programs implemented by NEEP&WM is the implementation of new geothermal installations and increase in the efficiency of currently existing. As a result, the increase in the utilisation of geothermal energy resources and technologies' development might help to fulfil economic, environmental and social objectives in Poland. It can also reduce the dependence on fossil fuels, providing the country with the energy security and conducing to the diversification of internal energy resources.

3.3 Geothermal resources

No legal and political solutions may bring the intended results if geothermal investments are not located in places within areas of a suitable geothermal potential and an appropriate market of energy consumers. Thusly, a number of geological, economic factors and conditioning dependent on macro-environment will affect the cost-effectiveness of a geothermal installation in a given location. What is more, each geothermal project should take into account the local conditions and needs of the recipients – hence the occurrence of huge differences between individual concepts implemented under different hydrogeothermal conditions and the legal and financial environment is observed.

Geothermal resources in Poland are relatively well recognized due to the publication of *Geothermal Atlases* series (Górecki (Ed.) et al 2006-2013, Sowiżdżał et al 2016) and several different studies on geothermal energy sector (Wójcicki et al (Ed.) 2013, Bujakowski and Tomaszewska (Ed.) 2014).

Poland has low-temperature geothermal resources connected mostly with Mesozoic sedimentary formations. Hydrogeothermal energy resources in Poland are accumulated in underground water reservoirs in various stratigraphic units and at various depths in areas of the Polish Lowlands, the Carpathians and in some locations in the Sudety Mts and Carpathian Foredeep. The most perspective area is connected with the Polish Lowlands where geothermal water resources are reservoirs in Mesozoic aquifers, particularly in Lower Cretaceous and Lower Jurassic clastics rocks and with Podhale area (Inner Carpathians), where operates the largest and the oldest geothermal installation in Poland. The aquifer comprises Middle Triassic limestones and dolomites.

In order to ensure the maximization of benefits resulting from the geothermal energy management, it is always important to analyse the existing geothermal resources in a given location. In many regions of Poland there is still unexploited significant geothermal potential, however, it should be borne in mind that not within every place of our country there are enough geothermal resources that can be effectively used for energetic purposes. In this case, it may be reasonable to consider using heat pumps.

4. TECHNOLOGICAL ASPECTS OF THE GEOTHERMAL RESOURCES' UTILIZATION FOR IMPROVING NATIONAL AND LOCAL SECURITY

In areas where geothermal waters with appropriate parameters occur, it is possible to build geothermal district heating plants supplying the surrounding population with thermal energy and hot domestic water. When geothermal resources are found in areas of military facilities, they can be successfully used to supply military buildings with heat, as well as to provide hot water. The possession of a local energy source, which in this case is geothermal energy accumulated in deeply deposited aquifers, allows to gain the energy independence through military bases. Geothermal energy is an attractive form of renewable energy because it provides continuous energy supply and therefore can be used as a basic source of energy. And for military purposes, huge amounts of energy are needed, moreover, it must be constantly delivered to military facilities. The costs for supply of both energy and water in these often specific conditions are high. Therefore, alternative solutions are sought. Hence, the use of geothermal energy can be of vital importance for any military facilities, especially in the context of stable energy supplies. On the other hand, in the case of accessing deep water-bearing horizons for military purposes, either logistics aspect and long-time of investment implementation might constitute a problem. Shortening the drilling time of boreholes and increasing the efficiency of geothermal energy utilization are particular challenges for the military sector, and the solutions gotten within these fields may also have a positive effect on the implementation in civil investments (Canes et al 2010). Analysing the technological aspects of the use of geothermal energy for military purposes, in some locations it may be reasonable to use this type of energy in permanent military bases for heating and cooling buildings (through construction of geothermal installations). On the other hand, due to the minimal logistic requirements, installations of heat pumps can be used more widely - both in stationary and mobile conditions (Canes et al 2010).

Increasing the self-sufficiency of airports, through the possibility of implementing geothermal solutions is also an important aspect in either military and non-military aspects (Barrett and DeVita (Ed.) 2015). Among airports that have decided to implement geothermal energy for heating and/or cooling their buildings (or parts of them), one can mention, airports in Portland, Juneau, Nantucket, University Port (Barrett and DeVita (Ed.) 2015), Oslo (Eggen and Vangsnes 2005), Thessaloniki (Mendrinos and Karytsas 2003), Paris (EGEC 2014), Frankfurt (Sanner et al 2003) or Tibet (Zhen et al 2017). The majority of these airports are dominated by the implementation of ground source heat pump technology, which results from the availability of proper geothermal resources (Barrett and DeVita (Ed.) 2015).

Not without a significance, there is a need to maintain the good condition of communication routes (access roads, pavements, etc.), airport plates or landing fields, enabling continuous and safe operation of a given unit, which is particularly difficult in the winter months due to the prevailing weather conditions (Spitler and Ramomoorthy 2000). A practical and harmless to the environment solution that has been successfully implemented in several countries around the world, including Iceland (Björnsson 2010), Japan (Morita and Tago 2000, Nagai et al 2013) or the United States (Ho and Dickson 2017), is the utilisation of geothermal energy (Lund 1999, Jelisejevs 2001). In general, de-icing systems can be classified in two main categories: direct use of geothermal energy (so-called deep geothermal) or using the potential of shallow geothermal energy based on heat pump technology (Ho and Dickson 2017). The implementation of geothermal snow melting/de-icing system brings numerous benefits, including independence from external energy providers, increased safety in pedestrian and vehicle traffic (Spitler and Ramamoorthy 2000), reduction of maintenance costs for road infrastructure and equipment (Ho and Dickson 2017). In addition, the de-icing system based on the use of geothermal medium in the form of hot water/vapour circulating in the network of pipes placed under the surface is characterized by significant energy savings and lower emissions of harmful carbon dioxide (Wang and Chen 2009). The experience of countries using the geothermal potential for the de-icing of terrain in the winter period shows that it can be a strategic solution not only for civilian objects, but also for military or public entities.

Below, some selected manners of practical geothermal energy management for heating/cooling of buildings or de-icing of communication routes, which may affect broadly understood national security, both on a local and regional scale, are presented. However, it should be remembered that the possibility of any project implementation is conditioned by geothermal resources available in a given location, geology, atmospheric conditions, as well as environmental and economic factors (Zwarycz 2002).

4.1 Geothermal application for heating and cooling

Examples of aerodrome facilities that exploit geothermal energy as a source of heat and/or cold are airports for instance in the United States or Norway. In these cases, ground heat pump (abbr GSHP) technology, using the potential of shallow geothermal energy for both heating and cooling buildings (or parts of them) has been applied.

Juneau Airport. As part of the project of modernization and expansion of the terminal, the city of Juneau received a grant for the implementation of a modern heating and cooling system of the building using geothermal energy and ground heat pump technology. The system consists of a grid of 108 holes with a depth of 107 meters each and 31 heat pumps. The working fluid is a mixture of 88% water and 12% methane and circulates in a closed system (HDPE pipes) with a total length of nearly 26km. In addition, the system not only provides heating and cooling power, but also is used to keep outside walkways without snow and ice during the winter season (Barrett and DeVita (Ed.) 2015).

Portland Airport. The city of Portland has also received a grant for the implementation of a heating and cooling system for the building using low-enthalpy geothermal resources and ground heat pump technology. This was the result of a thorough reconstruction of the terminal, aimed at reducing the emission of pollutants within the airport's area. The system consists of 120 holes 152 metres deep each, arranged in a grid with a step of 6 metres. The working fluid circulates in a closed system (HDPE pipes) with a total length of over 37km. The airport owns also a system for monitoring energy savings obtained due to the implementation of renewable technology, and thus financial savings (Barrett and DeVita (Ed.) 2015).

In turn, at **Gardermoen Airport** in Oslo (Norway), the most significant Norwegian ground source heat pump system is used for heating and cooling of the building (Midttømme et al 2016). The so-called down source of heat for the GSHP is one of the largest groundwater reservoirs in Norway. The system consists of 18 holes (9 production and 9 injection) with a depth of 45 meters and a diameter of 450mm (Eggen and Vangsnes 2005). This system covers the total cooling demand of the aerodrome, of which 25% (2.8 GWh/year) is a free cooling by direct heat exchange with cold ground water, and 75% (8.5 GWh/year) is an active cooling by heat pump (Midttømme et al 2016). The annual heat production is on average 11GWh (Eggen and Vangsnes 2005). The idea of the system operation is shown in the diagram. In addition, this system is being used for de-icing of the aerodrome plate (Eggen and Vangsnes 2005).

4.2 Geothermal application for removing snow&ice

Analysing the problem of removing snow cover or ice from communication routes, it turned out that the most common solution is mechanical removal of snow dumps, use of road salt or chemicals, or electric heating system (Wang and Chen 2009). However, these systems have numerous drawbacks, are inefficient and in some cases economically unjustified, or may lead to damage to infrastructure and/or machines. What is more, all of those are associated with a significant emission of pollutants into the environment, which is incompatible with the ecological policy of the European Union (Ho and Dickson 2017). A solution based on the use of the potential of geothermal energy, passes the exam in many countries, worldwide.

The perfect example might be **Iceland**, where the de-icing system of roads, pavements and parking lots has been operating for more than two decades (Ragnarsson 2015) raising the standard of living, as well as the safety, among others, in Akureyri or Reykjavik. The system is based on the use of a mixture of waste water returning from (geothermal) district heating network (66%; 35°C) with geothermal water (34%; 80°C). This system indicates the possibility of the effective cascade utilisation of thermal waters, which is not only a practical solution, but it is also far economically justified (Gunnlaugsson 2004). The total area covered by the geothermal de-icing system is over 1,200,000 m^2, of which nearly 725,000 m^2 belong to the capital (Björnsson (Ed.) 2010). Annual energy consumption depends on atmospheric conditions, the length of the winter period and amounts on average to 430 kWh/m^2. It is worth to be highlighted that an important and strategic element of the geothermal de-icing system in the country's security context is maintaining a good state of the road connecting the capital with the International Airport in Keflavik (once the centre of the American air base).

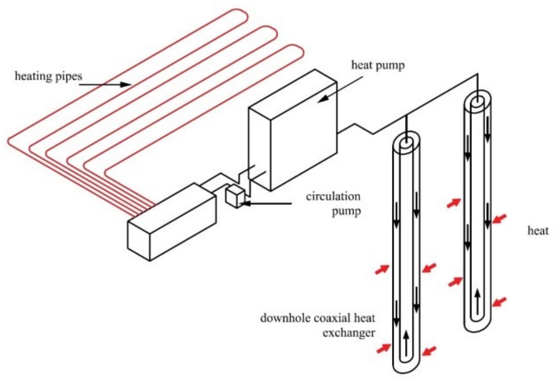

Figure 3: Simplified diagram of the road de-icing system in Ninohe, Japan (Morita and Tago 2000).

In turn, the first de-icing/snow-melting system in **Japan** was installed in Ninohe, a city located 500km north of Tokyo and has been operating continuously since 1995 (Morita and Tago 2000). The system uses three coaxial heat exchangers with a depth of 150 meters (sandy deposits; ground temperature 22.5˚C) and the 15kW heat pump (Fig. 3). In winter, heat extracted from the ground through heat exchangers is transferred to the heat pump, where the temperature is raised and thermal energy is transferred to the working fluid circulating in the pipe network placed directly in the asphalt (at a depth of 10cm; with intervals of 20cm). The system was installed on a winding road section with the slope of 9%, in order to increase the safety of driving in winter and to prevent collisions and various road accidents. The total area covered with the system is 266m^2 – a section of a road with a width of 4m and a length of 65m. The de-icing system works fully automatically using information from the temperature sensor and two water detectors placed on the road surface – it starts to operate when the temperature drops below a certain value or the detectors descry the presence of water/ice (Morita and Tago 2000). Moreover, during the summer the system works like a heat store. The sun's radiation heats the road surface in which heating pipes with working fluid are placed, raising its temperature up to 50˚C. Then, through a coaxial heat exchanger, the heat is transferred to the ground and "stored" for the winter period (Morita and Tago 2000).

The utilization of shallow geothermal potential to remove snow cover and ice was proposed by scientists from **North Dakota (USA)** (Ho and Dickson 2017). Considering the specific weather conditions of the eastern part of North Dakota from the period of 15 years (2000-2015) and analyzing the local geothermal potential (low temperature resources), they considered a snow removal system consisting of two basic elements – a ground heat pump (4kW power) with a horizontal collector and network of tubes located under the surface (Fig. 4). The horizontal collector is placed in a thermally stable zone of the ground (in this case at the depth of 6m), where the temperature presents higher values than on the surface (Ho and Dickson 2017). As a result of the modeling, the authors proved that the system based on the implementation of a ground-source heat pump is technically feasible and effective. Nevertheless, they also emphasized that the possibility of direct use of geothermal waters (deep geothermal resources) could in effect significantly increase the efficiency of the system (Ho and Dickson 2017).

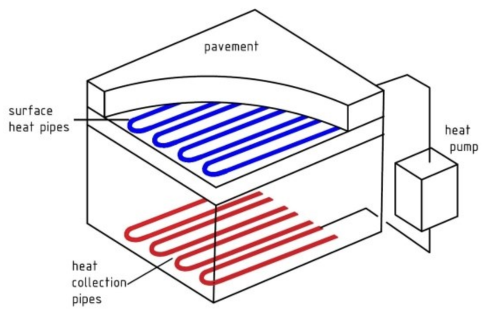

Figure 4: An exemplary de-icing system – schematic diagram of heat pump utilization (Ho and Dickson 2017).

5. CONCLUSIONS

Geothermal resources are the natural wealth of a particular country and their effective utilization brings many multifarious benefits. The aspect of improving energy security, both on a global and local level, is particularly important. In recent years, Poland has been taking measures to increase the share of geothermal energy in the use of renewable energy sources, as well as in the total energy mix of the country. This is reflected in several governmental documents and financial support dedicated mainly to new geothermal investments. Geothermal energy is an ecological and renewable source of energy that can be an alternative source of energy to fossil fuels constantly used in the Polish energy sector, mainly in the area of heat supply and hot water preparation. On a local scale, geothermal energy can be also used for other purposes, e.g. maintaining good condition of communication routes (access roads, pavements, etc.), airport plates or landing fields in the winter months. The experience of countries using the geothermal potential, not only for civilian objects, but also for military or public entities, constitutes a perfect example of solutions that in Poland are primarily in different conceptual phases. However, it is extremely important for geothermal energy sector to be seen as potential and beneficial, by various professions, including military ones. The implementation of geothermal technologies (deep wells, borehole heat exchangers, heat pumps) in civilian and military institutions and/or buildings can bring profitable effects in the context of our country's energy, social or military security.

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