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Energy security in the context of nuclear energy - threat analysis with the use of the GIS tools

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ABSTRACT

This article presents Poland's approach to energy security in legal acts, possible threats for the environment posed by construction and exploitation of a nuclear power plant, and threats posed by human's direct activity, to which a separate chapter is devoted. This article also shows the potential of the Geographic Information System (GIS) tools, which enable not only gathering spatial data, but also processing and visualising it. The aim of the geoinformation systems is data analysis, which eases decision-making.

***Keywords*:** energy security, nuclear power plant, energy policy

1. INTRODUCTION

It is the country's task to provide security, in every understanding. The term "security" evolves and is developed in new areas all the time. One of the newest, recently defined national security area is energy security. It is included into the category of economic security. Recently it gained in significance i.a. because of the concern for the possibility of exhausting in the future such energy sources as coal or crude oil. It constitutes one of the main factors influencing the functioning of a country, economy, and society.

The greatest controversy concerning energy security causes the topic of nuclear energy. It has high significance for the future energy security and this is why much attention is paid to it in the Poland's energy policy for the period to the year 2030. The validity of the development of the nuclear sector in Poland should be concerned mainly from the point of view of threats and changes in the environment, connected with the nuclear power plant functioning. Spatial analyses conducted with the use of the GIS (Geographic Information System) tools are extremely helpful in the visualisation of environmental risk posed by this type of energy. This is why exemplary analyses, enabling the visualisation of i.a. radiological protection zones, were conducted and described.

2. TERMS "ENERGY SECURITY" AND "NUCLEAR ENERGY"

There are many definitions of energy security. One of them defines it as availability of energy at all times, in various forms, in sufficient amount and for affordable price [1]. Energy security, according to International Energy Agency (IEA), can be divided into short term and long term. Long term concerns investments in planning and in realisation which are supposed to make the process of energy delivery more efficient, taking economic development and environmental needs into account. Short term indicates the speed of energy system reaction to the changes in the demand for energy [2]. Another definition describes energy security as an optimal state connected with the realisation of three elements: providing continuity in energy delivery, liberalised and competitive energy market, and fulfilling the environment protection requirements [3]. In simple words, it can be described as absence of the state of emergency connected with a break in fuel and energy delivery [4]. However, universal understanding of energy security focuses on providing energy resources sufficient and adequate to the needs in a given country.

Another important term worth defining is nuclear energetics. Nuclear energy is produced in a nuclear reactor, in which a controlled reaction takes place thanks to the splitting of the proper amount of nuclei [5]. Nuclear energetics gained in significance in the 1980's and the main reason for its development was, and still is, looking for "clean energy sources" - so the ones which do not pollute the environment [6]. Many advantages of nuclear energetics can be enumerated. As mentioned above, it is environmentally friendly. It does not produce any dusts of fumes harmful for the environment and the radioactive substances, produced during reactor's work, constitute a relatively small percentage of all radioactive elements present in the environment [6]. Another advantage concerns the financial issue. Nuclear energy is ten times cheaper than the energy obtained from natural gas and a hundred times cheaper than obtained from coal [6]. The main disadvantages focus around the society's negative perception of nuclear power plants because of i.e. Chernobyl disaster. However, a nuclear reactor will never turn into an atomic bomb. Another disadvantage are nuclear power plant's high building costs. The radioactive waste storage is also a controversial issue [7].

3. NUCLEAR ENERGY IN POLAND

Poland has four possible ways to provide energy security: solid fuel, gas, renewable energy sources (RES), and nuclear energy. Taking the EU's environmental requirements into

consideration, it is impossible to imagine providing energy security without going towards the investment in nuclear power plants. It is worth-noticing how in the Polish legislation and strategic documents the issue of energy security and nuclear energetics in particular is treated. The most important legal act in the field, namely the act Energy law, already in the paragraph one points to the aim of the regulation, which is providing energy security, thereafter defined as "the state of economy enabling the coverage of current and prospective demand of the receivers for fuels and energy in technically and economically justified way, while preserving the environment protection requirements" [8]. Energy security was highlighted as part of the national security in the National Security Strategy of 2014, being currently in force. According to the energy policy presented in the Strategy, its aim is to provide the development of generative, industrial, and storage infrastructure, as well as modern investments and economical technologies [9]. A sector strategy was also developed - Poland's energy policy for the period to the year 2030, in which this issue is thoroughly described. A whole chapter entitled "diversification of the structure of electric energy production through the introduction of nuclear energetics" was devoted in this document to the issues concerning nuclear energetics [10]. The willingness to introduce nuclear energetics in Poland was presented there, pointing to its advantages, such as lack of emission of carbon dioxide, harmful for the environment. The estimated date of the first nuclear power plant activation is the year 2020 [10]. Therefore, the goal of energy policy is to prepare the proper infrastructure for the nuclear energetics and provide proper conditions for its functioning, including the appropriate legal conditions.

Most of the mentioned documents point not only to taking up appropriate legal and investment actions, but also to creating social acceptance in the field and to the issues of environment protection and influence of the planned investment on the environment. In the context of nuclear energetics, one of the assumptions of Poland's energy policy is the diversification of the structure of electric energy production through the introduction of nuclear energetics [12].

4. NUCLEAR POWER PLANT AND ITS INFLUENCE ON THE ENVIRONMENT

Energy is a very important and necessary for living element for the society. The need for it is still growing together with the civilisational advance and the development of various sectors, i.e. economic. The more complex a society is and the more goods it produces, the more energy it needs [13]. There are prognoses that to the year 2050 the energy consumption will multiply up to three times in comparison to the year 2010 [14]. A nuclear power plant will definitely improve Poland's electro-energetic system stability [15].

However, there are threats and environmental changes connected with the functioning of a nuclear power plant. During a nuclear power plant's operation various wastes are produced, which have to be isolated from the environment inhabited by people [16]. The wastes have to be stored even for thousands of years in appropriate vessels or mining pits, constituting a barrier from the inhabited environment [17].

One of the environmental effects of Nuclear power plant functioning is radioactivity. The characteristic feature of the elements from the cycle of producing energy in a nuclear power plant is radiation. The amount and power of the radiation depends on the type and power of a reactor. A nuclear reactor is not the only source of radiation. The pools for storing

the burnt out fuel and radioactive waste storages, the amount of which increases together with the years of exploitation of a nuclear power plant, should be mentioned here [18].

The guidelines of the International Atomic Energy Agency point to the obligation of creating usually three zones around nuclear power plants in case of the reactor's failure. The first zone to 1000 m from the centre of a nuclear power plant has the most limitations. Land development in this area is only submissioned to producing energy and should take into consideration the ecological threat created by maximal project failure. The second zone spreads between 1000 m and 5000 m from the centre of a nuclear power plant. In this zone permanent and temporary stay of people and any form of land development undergo a strict supervision. The third zone is between 5000 m and 20000 m from the centre of a nuclear power plant [19]. No changes in land development or limitations in population are provided for this area. However, for this area action plans in case of emergency are prepared. The plans concern directly the safety of people inhabiting the area and the instructions for local authorities in case of any radiological threat [17]. Fig. 1. presents the three radiological protection zones for the planned nuclear power plant in Żarnowiec in the Pomorskie Voivodeship. All three zones cover the area of aprox. 1200 km^2. It is worth-noticing that in the second zone there will be local smaller towns (Nadole, Czymanowo, Sobieńczyce), which is precisely presented by Fig. 2., in which there are two radiological protection zones.

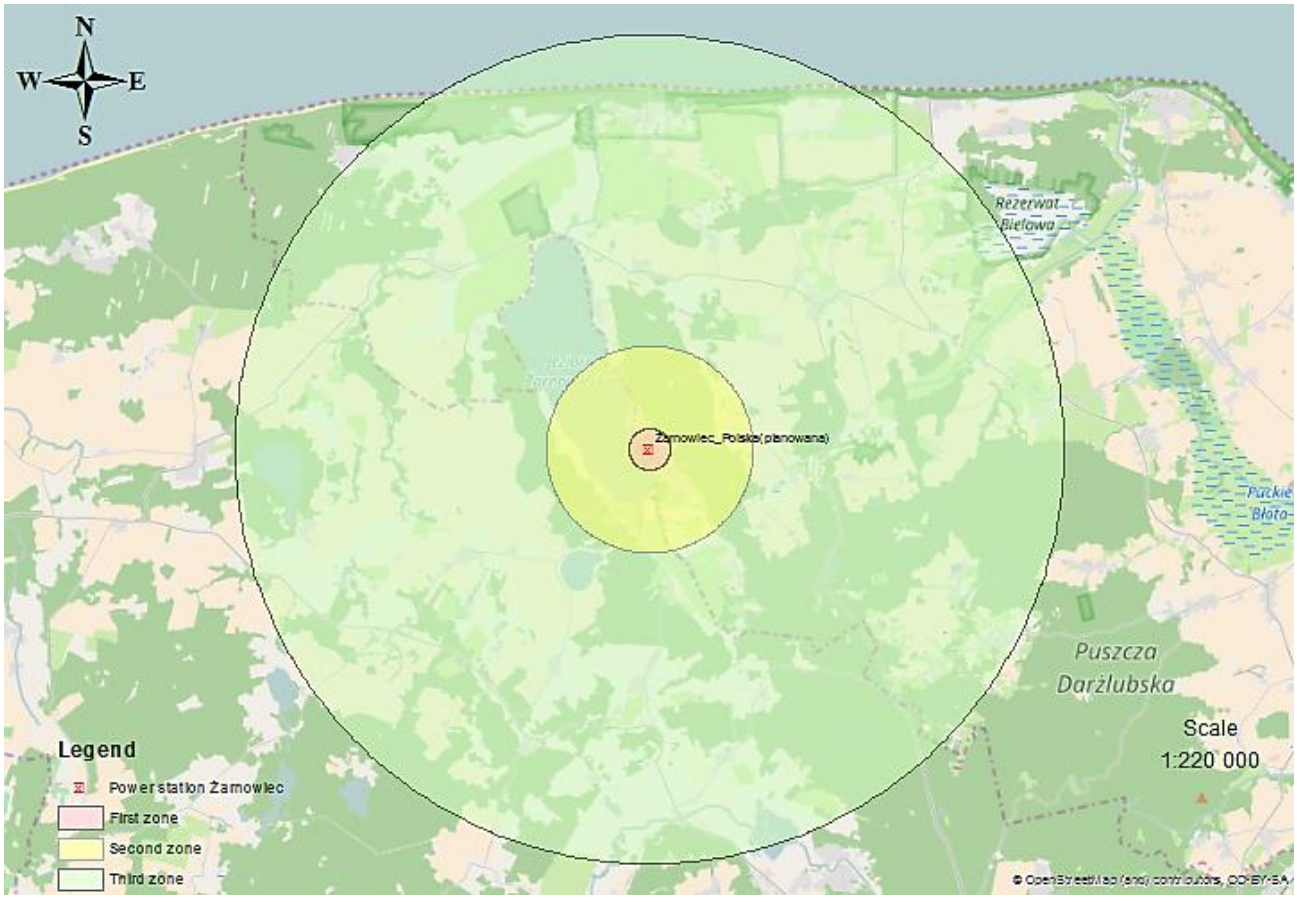

Fig. 1. Radiological protection zones for the planned nuclear power plant in Żarnowiec
Source: own elaboration

Another factor which can influence the closest surrounding of a nuclear power plant is the emission of heat into the natural environment during the production of energy. It is caused by a characteristic feature of this kind of acquiring energy, namely cooling down the turbines with water. It causes the change in local ecosystem, such as increased precipitation or occurrence of fog. While planning a nuclear power plant a proper road infrastructure is something to take into consideration, for the building of the investment as well as for the supplying of uranium as the fuel for the reactor. Additionally, transportation of the elements of the nuclear fuel cycle causes the problems connected with radiation of these elements. However, the use of specialist vessels limits the scattering of radioactive material to minimum, even in extreme conditions.

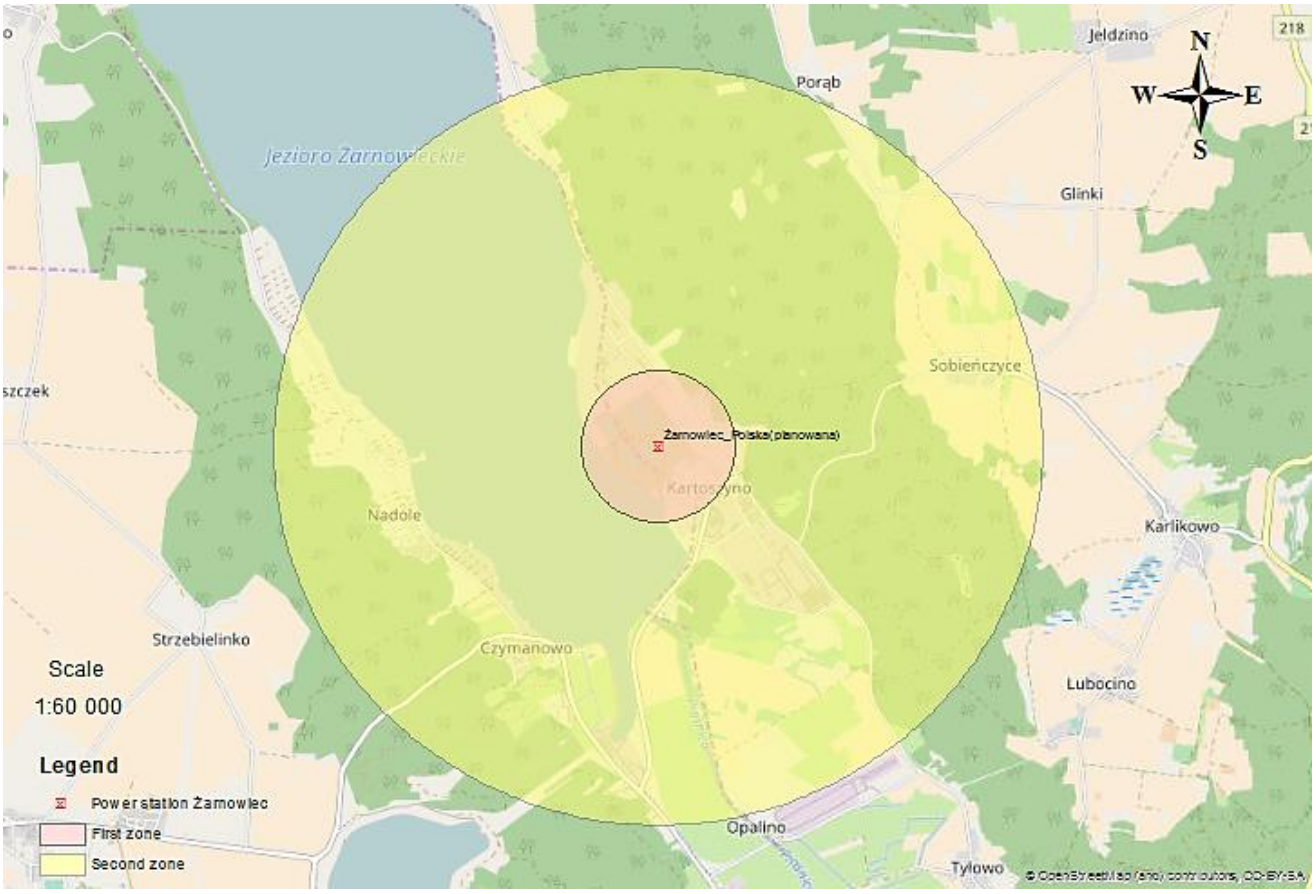

Fig. 2. The first and the second radiological protection zone for the planned nuclear power plant in Żarnowiec
Source: own elaboration.

5. THREATS CAUSED DIRECTLY BY HUMAN ACTIVITY

Nuclear energetics is a stable source of energy which is safe for people and for the environment. However, last decades have shown that this technology undergoes failures, too [20].

Threats caused directly by humans can be divided into three groups:

- terrorist threats,
- criminal threats,
- threats caused by employee's mistakes.

Terrorist threats, as the events of the last years show, are more and more likely and need to be reckoned with. The backgrounds of terrorist attacks are political or ideological (religious), but in both cases a terrorist cares about publicity and general fear after an attack. One of the most common types of terrorist attacks is to highjack a plane and crash it into a chosen facility (World Trade Center in 2001). There is a possibility that a hijacked plane will be aimed at a nuclear power plant. However, as the report of the Aircraft Owners and Pilots Association claims, even a crash of the Boeing 747 should do no harm to a typical reactor. Terrorists can also make attempts of attacks on nuclear power plants with the use of missiles, the range of which is up to a few kilometres. Such an attack has many advantages for a terrorist, as it is a surprise attack and he does not have to force through any protection zones to reach the close proximity of a reactor. This can damage a reactor leading to the risk of radioactive substances spreading. Another possible scenario is planting explosives inside the construction elements of a nuclear power plant by a terrorist. Because of this all components of a power plant should be closely examined and construction crews should be thoroughly monitored on the premises of the investment.

Other threats caused by humans are criminal in nature and may concern stealing radioactive materials or nuclear waste. Radioactive materials are not only the side effects of the nuclear fuel cycle, but also equipment (aprons, test tubes, substances) coming from radiological centres or universities, where experiments were conducted. Such materials, in the wrong hands, can lead to the contamination of drinking water or enable the construction of radiological bombs. Actions connected with conveying information about nuclear power plant functioning are also included in the criminal threats. These concern soft spots in security systems, security guards' work organisation and equipment, data about employees, especially about their private life and addictions. Such information enable the planning of an attack. Because of this, the choice of the staff, especially the people working directly with a reactor, is extremely important.

The third kind of threats is caused by the mistakes of working staff wile a nuclear power plant operates. The greatest catastrophes in history were connected with human mistakes. The explosion of the power plant in Chernobyl should be mentioned here, but also the failures of such power plants as the Three Mile Island in the USA, the Chalk River in Canada or the Tokaimura in Japan.

The nuclear power plant catastrophe in Chernobyl on the 26th of April in 1986 is considered to be the greatest ecological disaster caused by a human error. The power plant's reactors (RBMK-1000) had a flaw - instability during low-power work. In order to avoid the instability of the reactor, most of the automatic security was disabled. When the situation got out of control, it had been already too late to switch on the securities, the reactor was working with the power a hundred times higher than standard and the core's temperature was reaching 2000 °C, which lead to two explosions and caused releasing the radioactive substances into the atmosphere.

A cloud of radioactive elements was moving in the dominant wind direction. Firstly, it flew over Sweden and Finland, then over Central Europe and farther west, reaching the

Benelux countries, France, Great Britain. After few days the radioactive contamination reached such distant countries like the United States, Canada, or Japan. The UN and the UNICEF estimated that only on the premises of Russia, Belarus, and Ukraine over 7 million people suffered because of the nuclear power plant catastrophe in Chernobyl According to the UNSCEAR 2000 report, the activity measurement of 137Cs (caesium isotope) showed over 3,7 MBq/m^2 (where 3,7 MBq is the acceptable orally absorbed annual dose for man). It is the area of the surface of about 146 000 km^2, inhabited by over 6 million people. The Chernobyl catastrophe caused long-term environment contamination of the areas in the closest proximity to the power plant, but also of those hundreds and thousands kilometres away. The effects of the failure influenced the health state of the people living in the contaminated area and the future generations.

The effects of the design basis accident for the planed power plant in Żarnowiec are presented by the figure 3, in which spreading of the radioactive substances has been shown, including dominant wind in Poland. In the case in which the wind blows with the speed of 10 km/h, the speed is enough for the radioactive particles to get to the Trójmiasto (population over 700 000) in 12 hours, and in 24 hours to fold a large part of the Warmian-Mazurian Voivodeship.

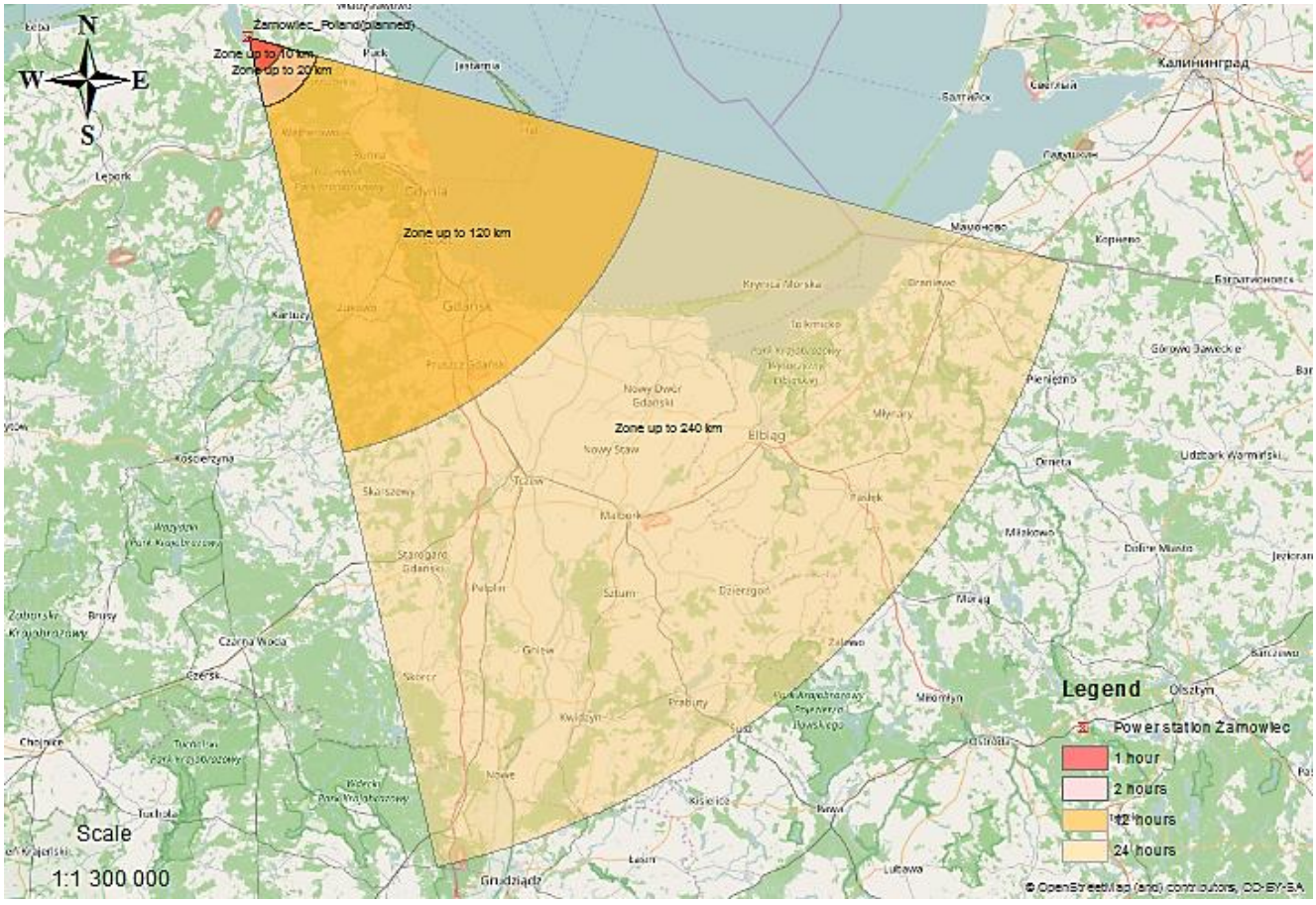

Fig. 3. The probability of propagation of radioactive substances at 10 km/h
Source: Own elaboration.

This kind of analysis (Figs. 1, 2, 3), conducted with the GIS tools, may serve as an appendix to the strategic documents related to the country's energy security. It is worth mentioning, that using real meteorological parameters very thorough apportion of the real spreading of the radioactive substances is possible. Such strategies are defined as future actions concepts, aimed at preventing threats for national businesses in the energy security sector and actions connected with the elimination of the already existing threats. Generalizing, the strategy is bound to describe potential threats and ways of their elimination. The main goal of the actions taken up, is then to provide a stable functioning of the country's energetic system, in this context also a proper security level. The described analysis with the use of the GIS tools clearly depicts the most probable direction of the radioactive substances spreading, thanks to which in case of the occurrence of the threat like reactor failure, prompter taking up the right measures is possible in order to eliminate negative effects (e.g. evacuation from endangered areas, for such analysis shows which areas to evacuate in the first instance).

6. CONCLUSIONS

Many pros and cons are connected with nuclear energetics as the element of energy security. Threats and environmental changes caused by functioning of nuclear power plants need to be taken into consideration. The advantages coming from nuclear power plants are obtaining great amounts of energy out of small amount of fuel and lack of wastes getting into the environment during direct exploitation. Competitive electric energy prices, small amount of fumes emitted into the atmosphere, and reliability of energy supplies, which influences the energy security of a country, should also be mentioned among advantages. The disadvantages of this way of obtaining electric energy are the possibility of getting radioactive elements into the environment, the wastes from the power generation cycle storage (burnt out fuel and other wastes storage), but also high costs of building and demolishing after finishing its exploitation. Wherefore, the construction and functioning of power plants and the threats connected with this should be thoroughly analysed. The GIS tools prove to be useable in this activity, as with their help useful visualisations can be conducted.

References

[1] Adam Corner, Dan Venables, Alexa Spence, Wouter Poortinga, Christina Demski, Nick Pidgeon, Nuclear power, climate change and energy security: Exploring British public attitudes. *Energy Policy*, Volume 39, Issue 9, 2011, Pages 4823-4833, https://doi.org/10.1016/j.enpol.2011.06.037

[2] Hoseok Kim, Eui-soon Shin, Woo-jin Chung, Energy demand and supply, energy policies, and energy security in the Republic of Korea. *Energy Policy,* Volume 39, Issue 11, 2011, Pages 6882-6897, https://doi.org/10.1016/j.enpol.2011.07.056

[3] Masatsugu Hayashi, Larry Hughes, The Fukushima nuclear accident and its effect on global energy security. *Energy Policy*, Volume 59, 2013, Pages 102-111, https://doi.org/10.1016/j.enpol.2012.11.046

[4] Mathews, J., Tan, H. Economics: Manufacture renewables to build energy security. *Nature* 513, 166–168 (2014). https://doi.org/10.1038/513166a

[5] Morgan Bazilian, Benjamin F. Hobbs, Will Blyth, Iain MacGill, Mark Howells, Interactions between energy security and climate change: A focus on developing countries. *Energy Policy*, Volume 39, Issue 6, 2011, Pages 3750-3756, https://doi.org/10.1016/j.enpol.2011.04.003

[6] Benjamin K. Sovacool, Ishani Mukherjee, Conceptualizing and measuring energy security: A synthesized approach. *Energy*, Volume 36, Issue 8, 2011, Pages 5343-5355, https://doi.org/10.1016/j.energy.2011.06.043

[7] M. A. Pilinskaya, Cytogenetic effects in human as the result of the Chernobyl accident. *World News of Natural Sciences* 1 (2015) 18-22

[8] P. A. Fedirko, I. Kadoshnikova, Risks of eye pathology with the victims of the Chernobyl catastrophe. *World News of Natural Sciences* 3 (2016) 12-18

[9] Lynne Chester, Conceptualising energy security and making explicit its polysemic nature. *Energy Policy*, Volume 38, Issue 2, 2010, Pages 887-895, https://doi.org/10.1016/j.enpol.2009.10.039

[10] Zha Daojiong (2006) China's energy security: Domestic and international issues, Survival, 48:1, 179-190, DOI: 10.1080/00396330600594322

[11] Benjamin K. Sovacool, Harry Saunders, Competing policy packages and the complexity of energy security. *Energy*, Volume 67, 2014, Pages 641-651, https://doi.org/10.1016/j.energy.2014.01.039

[12] Jessica Jewell, Aleh Cherp, Keywan Riahi, Energy security under de-carbonization scenarios: An assessment framework and evaluation under different technology and policy choices. *Energy Policy*, Volume 65, 2014, Pages 743-760, https://doi.org/10.1016/j.enpol.2013.10.051

[13] Benjamin K. Sovacool, An international assessment of energy security performance. *Ecological Economics*, Volume 88, 2013, Pages 148-158, https://doi.org/10.1016/j.ecolecon.2013.01.019

[14] Lee S, Yoon B, Shin J. Effects of Nuclear Energy on Sustainable Development and Energy Security: Sodium-Cooled Fast Reactor Case. *Sustainability* 2016; 8(10): 979. https://doi.org/10.3390/su8100979

[15] Jingzheng Ren, Benjamin K. Sovacool, Prioritizing low-carbon energy sources to enhance China's energy security. *Energy Conversion and Management*, Volume 92, 2015, Pages 129-136, https://doi.org/10.1016/j.enconman.2014.12.044

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