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Polityka energetyczna a energia przyszłości

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Small modular reactors in Polish-American energy cooperation

Małe reaktory modułowe w polsko-amerykańskiej współpracy energetycznej

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Małe reaktory modułowe w polsko-amerykańskiej współpracy energetycznej

Artykuł dotyczy znaczenia małych reaktorów modułowych w polsko-amerykańskiej współpracy na rzecz realizacji cywilnego programu jądrowego w Polsce. Aby zapewnić bezpieczeństwo energetyczne i spełnić wymagania europejskie w zakresie ochrony środowiska, polskie władze zdecydowały się na realizacje cywilnego programu jądrowego. Za decyzją tą przemawia wiele argumentów technologicznych, środowiskowych i geopolitycznych, a ponadto ma ona poparcie społeczne. Jak dotąd w realizacji cywilnego programu jądrowego szczególną rolę odgrywają Stany Zjednoczone, które gotowe są na transfer technologii jądrowej do Polski. Dotyczy to zarówno tradycyjnych elektrowni jądrowych, jak i małych reaktorów modułowych. Technologia SMR jest nowa, a przedsiębiorstwa amerykańskie wiodą prymat w jej rozwoju. Ponieważ pierwsze wiarygodne dane dotyczące efektywności i funkcjonalności SMR pojawią się dopiero za około dekady, Polska nie zdecydowała się na wykorzystanie tych systemów jako podstawowej technologii w programie rozwoju energetyki jądrowej. Mają one jednak pełnić funkcję subsydiarną w postaci źródeł zasilania dla dużych polskich przedsiębiorstw. Jeśli w przyszłości dowiodą swojej wartości, to nie wykluczone, że będą wykorzystywane również w masowej produkcji energii dla społeczeństwa.

Small modular reactors in Polish-American energy cooperation

The paper concerns the importance of small modular reactors in Polish-American cooperation for the implementation of the civil nuclear program in Poland. To ensure energy security and meet European environmental requirements, the Polish authorities decided to implement a civil nuclear program. There are many technological, environmental and geopolitical arguments for this decision, and it has public support. So far, the United States has played a special role in the implementation of the civil nuclear program, as it is ready to transfer nuclear technology to Poland. This applies to both traditional nuclear power plants and small modular reactors. The SMR technology is new and American companies are at the forefront of its development. Since the first reliable data on the efficiency and functionality of SMRs will not appear until about a decade, Poland has not decided to use these systems as a core technology in the nuclear power development program. However, they are to play a subsidiary role in the form of power sources for large Polish enterprises. If they prove their worth in the future, it is possible that they will also be used in the mass production of energy for society.

Introduction

The first plans to build nuclear reactors in Poland were made at the turn of the 1950s and 1960s. So far, the only nuclear projects that have been successfully implemented in Poland are the research reactor "Ewa" operated in the years 1958–1995 and the research reactor "Maria", launched in 1974 and still operating at the Institute of Atomic Energy in Świerk. The nuclear disaster in Chernobyl in April 1986 and the economic crisis in Poland prevented the completion of the construction of the nuclear power plant near Żarnowiec. For two decades, however, the concept of building nuclear power plants in Poland has been developed, and it has been accelerated in recent years. The reason for this is primarily the increasing environmental requirements of the European Union regarding the reduction of greenhouse gas emissions to the atmosphere. When moving away from coal as the main source of energy, the state must ensure safe, diversified energy sources, delivered at an acceptable price[1]. Nuclear energy is to be the main tool for reducing greenhouse gas emissions. The turmoil in the markets for traditional energy resources, caused, inter alia, by the policy of blackmail carried out by Russia in the context of the certification of the Nord Stream II gas pipeline, and later military aggression against Ukraine, make alternative energy sources, including nuclear energy, even more needed than before.

Social support for the construction of nuclear power plants is growing rapidly in Poland, which is confirmed by public opinion polls commissioned by the Ministry of Climate and Environment. In 2020, the support ranged from 57 to 62.5%[2], and in November 2021, the support peaked at 74%, of which 58% of respondents would agree to locate a nuclear power plant in the immediate vicinity of their place of residence[3].

1 W. Wątor, *Stan i perspektywy energetyki jądrowej w Polsce,* [in:] *Wokół teoretycznych i praktycznych aspektów stosunków międzynarodowych,* eds. T. Kubin, J. Łapaj-Kucharska, T. Okraska, Wydawnictwo Uniwersytetu Śląskiego, Katowice 2020, p. 494.

2 *Poparcie społeczne dla budowy elektrowni jądrowej w Polsce – badania z listopada 2020 r.,* „Gov.pl" [online], XI 2020, [access: 28 II 2022]: <https://www.gov.pl/web/polski-atom/poparcie-spoleczne-dla-budowy-elektrowni-jadrowej-w-polsce---badania-z-listopada-2020-r-625-polakow-popiera-budowe-elektrowni-jadrowych-w-polsce>.

3 *74% Polaków popiera budowę elektrowni jądrowych w Polsce,* „Gov.pl" [online], 15 XII 2021, [access: 28 II 2022]: <https://www.gov.pl/web/klimat/74-polakow-popiera-budowe-elektrowni-jadrowych-w-polsce>.

This is the result of both the government's information policy, growing environmental awareness and perception of geopolitical instability and its impact on the European energy resources market.

The aim of the paper is to define the importance of small modular reactors in Polish-American cooperation for the implementation of the civil nuclear program in Poland. The main research problem is the question of whether the SMRs can play a significant role in this bilateral cooperation to ensure Poland's energy security. The main thesis assumes that Polish-American cooperation in the field of small modular reactors has great development potential. A few projects have been launched already to supply large Polish enterprises, including those owned by the state treasury, with these reactors. If the technology turns out to be in line with the optimistic projections of manufacturers, the SMRs will become a serious competition to traditional, large nuclear power plants.

The legitimacy of developing a civil nuclear program and building small modular reactors

The nuclear reactor accident at Fukushima Daiichi in Japan in March 2011 resulted in a partial departure from nuclear power in some Western countries, including Japan, South Korea, Taiwan, Germany and Italy. At the end of 2020 there were 441 operable nuclear reactors, with a combined capacity of 392 GWe. Between 2018 and 2020 there have been 26 reactors permanently shutdown, but 20 new reactors started working. Due to the greater power of the reactors being launched, the total capacity increased by 0.5 GWe[4]. This means that the production capacity in the world remains at a similar level. Currently, 52 nuclear reactors are under construction, 10 of which in Central and Eastern Europe[5]. In the high case scenario International Atomic Energy Agency (IAEA) expects world nuclear generating capacity to more than double to 792 GWe

4 *World NuclearPerformance Report 2021,* World Nuclear Association, London, IX 2021, <https://world-nuclear.org/getmedia/891c0cd8-2beb-4acf-bb4b-552da1696695/world-nuclear-performance-report-2021.pdf.aspx> [access: 12 II 2022].

5 *The Database on Nuclear Power Reactors,* „International Atomic Energy Agency" [online], [access: 28 II 2022]: <https://pris.iaea.org/pris/>.

by 2050[6]. However, the nuclear energy's share of global gross electricity generation is gradually decreasing from a peak of 17.5% in 1996 to 10.1% in 2020[7]. This is due, inter alia, to the increase in the share of renewable sources in the energy mix of some countries.

The following arguments support the concept of building nuclear power plants in Poland[8]: stability of high-power energy supplies; providing low-carbon power for industry and the population; guarantee of stability of energy production; independence of energy supply from weather conditions; relatively low price of energy generation; the possibility of diversifying energy sources in the country's energy balance; the ability to meet the increasing demand for energy; reducing dependence on imports of traditional, depleted fossil fuels; reducing the risk of significant fluctuations in fossil fuel prices; the possibility of using nuclear reactors for various civilian purposes; the possibility of cogeneration, i.e. heat transfer to urban complexes; reduction of costs of purchasing CO_2 emission permits; transfer of modern technologies and new research and development opportunities; improving the health of residents; creating new work places; increasing the level of security of energy generation; the operation of nuclear power plants in neighboring countries.

The main disadvantages of nuclear power plants include: the high cost of building and dismantling a nuclear power plant, especially large nuclear reactors; the risk of a significant increase in the construction cost during the project implementation; the risk of extending the project implementation time; problem with the disposal of radioactive waste; the possibility of a radiation emergency; in the event of a major accident, the risk of radioactive contamination; exposure to a deliberate catastrophe, for example by a terrorist attack or hostilities; potential aspirations for the implementation of a military nuclear project. The most serious risk relates to the possible failure of the reactor and, consequently, contamination

6 *Energy, Electricity and Nuclear Power Estimates for the Period up to 2050,* International Atomic Energy Agency, Vienna 2021, p. 3. <https://www-pub.iaea.org/MTCD/Publications/PDF/RDS-1-41_web.pdf> [access: 12 II 2022].

7 M. Schneider [et. al.], *The World Nuclear Industry Status Report 2021,* Paris, IX 2021, p. 17: <https://www.worldnuclearreport.org/IMG/pdf/wnisr2021-lr.pdf>.

8 T. Młynarski, M. Tarnawski, *Źródła energii i ich znaczenie dla bezpieczeństwa energetycznego w XXI wieku,* Difin, Warszawa 2016, p. 182.

with radioactive radiation. However, practice shows that in the world many more technical failures concern the operation of other types of power plants, mainly coal-fired and gas-fired. They, too, have resulted in many more victims[9]. The balance of profits and losses clearly supports the idea of developing a civil nuclear program in Poland[10].

Small modular reactors provide additional opportunities to reduce or even eliminate the disadvantages and risks associated with the use of traditional nuclear reactors. The SMRs are advanced nuclear reactors that have a power capacity of up to 300 MWe per unit. This is about one-third of the generating capacity of traditional nuclear power reactors. SMRs are much smaller than traditional reactors and their modular nature makes it possible for systems and components to be factory-assembled and transported as a unit to a power plant location[11]. The modular nature of SMRs means that they can be combined with each other in order to build a large nuclear power plant[12].

The main potential advantages of the SMR are[13]: small size and modularity allow the module to be almost completely built in the factory; designs are generally simpler; they can be located in places unsuitable for the construction of large reactors; there is no need to adapt the design to a specific location, which reduces costs; reduced capital investment; modular nature allows for an easier formula for financing the project; lower risk

9 K. W. Fornalski, *Energetyka jądrowa a bezpieczeństwo energetyczne,* [in:] *Geopolityka współczesnego bezpieczeństwa energetycznego. Wybrane aspekty,* eds. M. Ilnicki, Ł. Nowakowski, I. Protasowicki, Towarzystwo Naukowe Powszechne, Warszawa 2017, p. 163–164.

10 B. Bojarczyk, J. Olchowski, *Energetyka jądrowa w kontekście bezpieczeństwa energetycznego Polski,* „Teka Komisji Politologii i Stosunków Międzynarodowych" 2014, vol 9, p. 31.

11 J. Liou, *What are Small Modular Reactors (SMRs)?,* „International Atomic Energy Agency" [online], 4 XI 2021 [access: 28 II 2022]: <https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs>.

12 *Small Nuclear Power Reactors,* „World-Nuclear" [online], XII 2021, [access: 28 II 2022]: <https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx>.

13 CORDEL Working Group of the World Nuclear Association, *Facilitating International Licensing of Small Modular Reactors,* London, VII 2015, p. 3, 6: <https://world-nuclear.org/uploadedFiles/org/WNA/Publications/Working_Group_Reports/REPORT_Facilitating_Intl_Licensing_of_SMRs.pdf> [access: 28 II 2022]; J. Liou, *op. cit.*

of extending the production time of the reactor and increasing its costs during the implementation of the investment; economies of series production for a specific SMR design can further reduce the investment cost; modules can be added to each other, increasing the quality and efficiency of the installation; can be constructed in 24–36 months; ability to add modules incrementally to match increasing energy demand; the ability to adjust the power to the capacity of the power grid; can be installed into an existing grid or remotely off-grid, as a function of its smaller electrical output; can serve as a backup power supply in emergency situations, which especially concerns microreactors; the specificity of production enables the introduction of higher quality standards; lower power leading to reduction of the source term and smaller radioactive inventory in a reactor; the possibility of underground or underwater location of the reactor unit gives greater resistance to natural hazards and threats caused by human activity; rely more on passive systems and inherent safety characteristics, such as low power and operating pressure; passive systems increase safety margins, significantly reducing the possibility of radioactive contamination in the case of an accident; passive systems enable reactor shutdown without human intervention or external power; less reliance on active safety systems and additional pumps, as well as AC power for accident mitigation; they can be used by countries and entities with little experience in the field of nuclear energy; lower requirement for access to cooling water; less frequent refueling, average every 3 to 7 years, in comparison to between 1 and 2 years for regular atomic plants; possibility to remove reactor module or in-situ decommissioning at the end of the lifetime.

However, SMRs are not completely free from disadvantages and risks, and the most serious ones include[14]: lack of certain data on the actual costs of building and operating; a departure from economies of scale runs the risk of a higher energy production price; uncertainty whether factory manufacturing of modules will prevent the large cost and time overruns as well as quality problems; investment risk related to the construction of production lines and ordering more reactors, which may turn out to be unprofitable; adding successive modules at long intervals can cause

14 M. V. Ramana, S. Thomas, *Small modular reactors offer no hope for nuclear energy,* „Advanced Science News" [online], 14 I 2022, [access: 28 II 2022]: <https://www.advancedsciencenews.com/small-modular-reactors-offer-no-hope-for-nuclear-energy/>.

operational problems and high maintenance cost; uncertainty about the amount of radioactive waste produced; risks related to the potential dispersion of nuclear reactors in the territory of the country.

Development of SMRs in the United States

SMR technology was first introduced to commercial operation in May 2020. It was Russia's Lomonosov Dormitory floating nuclear power plant which is producing energy from two 35 MWe SMRs. Over 70 commercial SMR designs are developed in various countries, including Argentina, Canada, China, Russia, South Korea, United Kingdom and the USA. Those reactors are in the licensing or construction phase. The individual models are expected to have different power levels and different applications, including electricity, hybrid energy systems, heating, water desalinization and steam for industrial applications[15].

In the United States, various SMR projects are implemented, with varying powers and applications. Various cooling methods are also used, including both light water and gas, liquid metal, or molten salt. So far, the U.S. Departament of Energy (DoE) has provided substantial support to the development of light water-cooled SMRs. Most of them are still under licensing review by the Nuclear Regulatory Commission (NRC) and will likely be deployed in the late 2020s to early 2030s. However, DoE is also considering supporting projects with non-light water coolants, due to possible additional economic, operational and safety benefits[16]. DoE provides funding from the very beginning of work on the SMR technology. However, since April 2018, the possibility of obtaining large development grants has significantly increased with the introduction of *the Advanced Nuclear Industry Funding Opportunity* program[17].

15 J. Liou, *op. cit.*

16 *Advanced Small Modular Reactors (SMRs),* „Office of Nuclear Energy" [online], 22 XII 2021 [access: 26 II 2022]: <https://www.energy.gov/ne/advanced-small-modular-reactors-smrs>.

17 *Advanced Nuclear Industry Funding Opportunity (iFOA-1817),* „U.S. Department of Energy" [online], [access: 22 II 2022]: <https://gain.inl.gov/SitePages/DE-FOA-0001817.aspx>.

The largest project of the small modular reactor power plant in which the DoE is involved is the one carried out jointly with NuScale Power and Utah Associated Municipal Power Systems (UAMPS). The Carbon Free Power Project (CFPP) has been launched at the Idaho National Laboratory in Idaho Falls since 2014. During the first seven years of development, the project was co-financed by the DoE in the amount of over 400 million USD. In August 2020 NuScale light water reactor received, as the first SMR, design approval from the NRC. After receiving the license, in October 2020, the DoE approved a 1.355 billion USD multi-year cost-share award. The first NuScale SMR power plant is to be launched in 2030[18]. NuScale Power Module (NPM) uses pressurized water reactor technology with passive safety systems, and its power is 77 MWe of electricity. A single module is enclosed in a tank 23 meters high and up to 4.5 meters in diameter. NuScale's power plants can house up to four, six, or 12 individual power modules. In recent years, NuScale has signed contracts for the implementation of SMR projects with the countries of Central and Eastern Europe,including Bulgaria, the Czech Republic, Poland, Romania and Ukraine, but also with Great Britain, Canada and Jordan. In 2019, an agreement was also signed with the South Korean Doosan Heavy Industries and Construction Co., the purpose of which is deployment of the NPM worldwide.

The second major American undertaking is the General Electric Hitachi Nuclear Energy (GEH) project – SMR BWRX-300. This is a 300 MWe water-cooled, natural circulation small modular reactor with passive safety systems. GEH wants the BWRX-300 to be the lowest-risk, most cost-competitive and quickest to market SMR. The project is implemented in a technological partnership with the Ontario Power Generation (OPG), as part of the Darlington New Nuclear Project, the result of which is to be the construction of the first reactor in 2028 in Darlington site in Canada. The BWRX-300 design is based on a 1500 MWe NRC licensed ESBWR reactor and is its simplified version. Currently it is undergoing a Canadian Nuclear Safety Commission pre-licensing vendor design review. GEH has also entered into partnerships with companies from the United

18 *The Carbon Free Power Project*, „Nuscale Power" [online], [access: 20 II 2022]: <https://www.nuscalepower.com/projects/carbon-free-power-project>.

States, Poland, Estonia and the Czech Republic[19], and also received UK Government funding of around 30 million GBP. An independent report by PricewaterhouseCoopers (PwC) Canada, estimated that the construction of the first BWRX-300 in Ontario would generate about 1.9 billion USD in GDP, 1.6 billion USD in labor income and about 500 million USD in federal, provincial and municipal tax revenue[20].

SMRs in the strategy of the development of nuclear energy sector in Poland

The main assumptions for the development of the Polish nuclear energy sector are contained in the strategic documents – the *Polish Nuclear Power Program* (PNPP)[21] in the last version of October 2, 2020 and *the Energy Policy of Poland until 2040* (EPP)[22]. According to them, by 2030, there supposed to be a reduction in greenhouse gas (GHG) emissions of about 30% compared to 1990, and by 2040 more than half of the installed capacity is to be non-emission sources. One of the key ways to achieve this ceiling is the implementation of the nuclear program. It assumes the construction of nuclear power plants with large-scale, Generation III (+) pressurized water reactors (PWR). The objective is construction and commissioning between 2026 and 2043 of two nuclear power plants with six nuclear power units, where the installed nuclear capacity is to be approx. from 6 to 9 GWe. After this project is completed, the share of nuclear energy in the energy mix of Poland is to be at approx. up to 20%. The first power plant is to be built in Lubiatowo-Kopalino in the Choczewo commune in Pomerania.

19 *The BWRX-300 Small Modular Reactor,* „GE Hitachi" [online], 22 XII 2021 [access: 26 II 2022]: <https://nuclear.gepower.com/build-a-plant/products/nuclear-power-plants-overview/bwrx-300>.

20 *BWRX-300 deployment and commercialisation MoU signed,* „World Nuclear News" [online], 7 VII 2021 [access: 26 II 2022]: <https://www.world-nuclear-news.org/Articles/Companies-sign-MoU-on-deployment-and-commercialisa>.

21 *Program Polskiej Energetyki Jądrowej,* Rada Ministrów, Warszawa, 2 X 2020: <https://www.gov.pl/web/polski-atom/program-polskiej-energetyki-jadrowej-2020-r> [access: 18 II 2022].

22 *Polityka energetyczna Polski do 2040 r.,* Ministerstwo Klimatu i Środowiska, Warszawa, 2 II 2021, <https://www.gov.pl/web/klimat/polityka-energetyczna-polski> [access: 18 II 2022].

The investor is the Polish Nuclear Power Plants, while the technology is to be provided by one of the foreign entities with extensive experience in the construction of reactors. Companies from the United States – the Westinghouse Electric Company (WEC), France – the Électricité de France (EDF) and South Korea – the Korea Hydro & Nuclear Power (KHNP) compete for this investment. The EDF was the first to submit a proposal by offering the European Pressurized Reactor (EPR). The construction of 4 to 6 nuclear units is to cost from PLN 150 to 220 billion. Concerns from the USA and South Korea are to present their proposals in 2022, and the Koreans have assured that their offer would be about 30% cheaper than the French one. WEC will propose the Advanced Passive 1000 (AP1000) reactor, while the KHNP the Advanced Power Reactor 1400 MWe (APR 1400). All of the above systems are pressurized water reactors and all of the competing countries provide for participation in financing the project[23].

The PNPP refers to the development of small modular reactors technology, indicating that their commercial implementation in the world may take place around 2040. It is noted that there is no design or execution documentation, on the basis of which it would be possible to reliably assess the efficiency and cost of using such systems. The document states that the SMRs, both an integrated design and an „add-on" design that allows the addition of successive modules at intervals of several years, can cause operational problems and high maintenance cost. It is also found that SMRs do not have any advantages over traditional reactors, and they are inferior to them in many respects, e.g. in terms of thermodynamic efficiency, which means generating more radioactive waste. Moreover, the high unit cost of the installed capacity and the possible dispersion of nuclear installations within the territory of the country are indicated. The limited possibility for domestic enterprises to participate in the production process due to the production of reactor modules in the designer's plants is also indicated. The main factor that excludes the possibility of basing the civil nuclear energy program in Poland on SMRs is a long, about 20-year time

23 *Lokalizacja elektrowni atomowej już jest. Kiedy ma powstać? Wyjaśniamy,* „Business Insider" [online], 22 XII 2021 [access: 26 II 2022]: <https://businessinsider.com.pl/technologie/lokalizacja-elektrowni-atomowej-juz-jest-kiedy-powstanie-wyjasniamy/e8xy866>.

perspective for the operational experience, which could constitute the basis for a possible decision to use this type of technology. However, the government ensures the observation of the development of the SMR technology and if the experience with its use is positive, it will consider their use in district heating in the future[24]. While the many unknowns do hold back the SMR-based nuclear program, the strategy overlooks many of the potential benefits that these reactors may bring in the future.

Polish-American partnerships for the development of SMRs

In recent years, Poland has significantly increased cooperation with the United States in the field of energy security. Cooperation in the area of American liquefied natural gas imports via the gas terminal in Świnoujście is of primary importance. The states cooperate under the Three Seas Initiative (TSI) to make Central and Eastern Europe independent of gas imports from Russia[25]. For this reason, with the support of the US, the Polish authorities tried to stop the implementation of the German-Russian Nord Stream II project[26]. Poland wants to become the main hub for LNG imported from the USA, competitive to Germany, which is the hub of Russian gas[27]. Although the countries associated with the TSI have adopted different directions for the development of their own energy sectors[28], the vast majority of them understand the need to reduce energy dependence on Russia[29]. After the Russian aggression against

24 *Program Polskiej Energetyki..., op. cit.,* p. 14.

25 A. Lanoszka, *Poland in a time of geopolitical flux,* „Contemporary Politics" 2020, vol. 26, no 4, p. 468.

26 V. Jančošekovà, *Regional cooperation in Central and Eastern Europe and its implications for the EU,* „European View" 2017, vol. 16, p. 235.

27 D. Michalik, *Współpraca energetyczna w Grupie Wyszehradzkiej – szanse i zagrożenia,* [in:] *Bezpieczeństwo energetyczne Polski i Europy: Uwarunkowania – wyzwania – innowacje,* eds. M. Ruszel, S. Podmiotko, Instytut Polityki Energetycznej im. I. Łukasiewicza, Rzeszów 2019, p. 144.

28 V. Anghel, *Together or Apart? The European Union's East–West Divide,* „Survival. Global Politics and Strategy" 2020, vol. 62, no 3, p. 193.

29 P. M. Silva II, Z. Selden, *Economic interdependence and economic sanctions: a case study of European Union sanctions on Russia,* „Cambridge Review of International Affairs" 2020, vol. 33 no 2, p. 236.

Ukraine in February 2022, the negative attitude of the West towards Russia increased dramatically. Along with this, countries immediately began to cut off the import of energy resources from Russia. Civil nuclear technology has become another important area of Polish-American cooperation for the energy security of Poland and CEE. In view of the consequences of the Russian-Ukrainian war for the energy market, cooperation in the area has become even more important than before.

On November 8, 2018 in Warsaw, Minister of Energy Krzysztof Tchórzewski and Secretary of Energy Richard (Rick) Perry signed *a Joint Declaration Concerning Enhanced Cooperation on Energy Security*[30]. It declared the strengttheening of cooperation in all energy areas, including nuclear energy. Within its framework, the parties announced cooperation in the following areas: construction of nuclear power plants; infrastructure development and maintenance; service and supply chain development; joint nuclear projects; research; safety regulation; efficiency and environmental friendliness; and best practices and funding mechanisms. A day later in Warsaw, the government plenipotentiary for strategic energy infrastructure – Piotr Naimski and Rick Perry signed *a Memorandum of Understanding on a Poland – U.S. Strategic Dialogue on Energy*[31]. According to it, nuclear energy was to become one of the four main areas of strategic dialogue, alongside cybersecurity, fossil energy, and energy infrastructure.

On the day of the meeting of Presidents Donald Trump and Andrzej Duda in Washington on June 12, 2019, accompanying ministers Naimski and Perry signed *a Memorandum of Understanding between Poland and the U.S. Concerning Strategic Civil Nuclear Cooperation*[32]. According

30 *Joint Declaration Between the United States Department of Energy and the Ministry of Energy of the Republic of Poland Concerning Enhanced Cooperation on Energy Security,* Warsaw, 8 XI 2018, <gov.pl, file:///C:/Users/UKW/Desktop/Deklaracja_DOE-ME_eng.pdf> [access: 20 II 2022].

31 *Memorandum of Understanding between the Republic of Poland and the United States of America on a Poland – U.S. Strategic Dialogue on Energy,* Warsaw, 9 XI 2018, <https://www.energy.gov/sites/default/files/pi_iec/098b7ef9801426fc.pdf> [access: 20 II 2022].

32 *Memorandum of Understanding between the Government of the Republic of Poland and the Government of the United States of America Concerning Strategic Civil Nuclear Cooperation,* Washington D.C, 12 VI 2019, <https://www.gov.pl/attachment/c4e73ba4-c9fb-4490-b3a8-64440496d532> [access: 20 II 2022].

to the agreement, cooperation at the governmental, expert, scientific and business levels was to ensure the development of an optimal program for the development of nuclear infrastructure in Poland, while maintaining the highest safety standards and with full respect for the international regime in the field of non-proliferation of nuclear weapons. It covered the entire spectrum of current and future American technologies, reactors, fuels, equipment, and services. In turn, on the occasion of the 5th summit of the Three Seas Initiative, on October 19, 2020, *an Agreement Between the USA and Poland on Nuclear Energy*[33] was signed in Washington by Secretary of Energy, Dan Brouillette, and in Warsaw by minister Naimski. The agreement concerns the parties' actions for possible cooperation in the construction of large nuclear power plants in Poland by American companies. Although it does not refer directly to SMRs, it assumes the deepening of multifaceted cooperation in the field of civil nuclear energy technology.

The most important Polish-American undertaking in the field of small modular reactors is the cooperation of KGHM Polska Miedź S. A. with NuScale Power. KGHM deals with the mining and processing of valuable natural resources, mainly copper and silver, by implementing investments in Europe and the Americas. It is one of the largest state-owned Polish companies, therefore its energy demand is high. In September 2021, the companies signed a memorandum of understanding, and on February 14, 2022, a landmark agreement to initiate work towards implementing advanced SMRs in Poland. According to the agreements, the carbon-free NuScale VOYGR power plant is to be built in Poland in 2029. The VOYGR plant is a scalable power plant that can be offered in four-module VOYGR-4 (308 MWe), six-module VOYGR-6 (462 MWe) or 12-module VOYGR-12 (924 MWe) configurations. The contract covers the construction of a power plant in Poland with six modules, but with the possibility of its long-term development up to 12 modules. It is worth mentioning that support for all 12 modules can create up to 270 permanent jobs for its operations[34].

33 *Agreement Between the United States of America and Poland on Nuclear Energy,* 19/22 XI 2020, <https://www.state.gov/wp-content/uploads/2021/05/21-224-Poland-Nuclear-Energy.pdf> [access: 20 II 2022].

34 *NuScale to Announce Historic Agreement with KGHM to Initiate the Deployment of the First Small Modular Reactor in Poland,* „Nuscale Power" [online], 15 II

The agreement is a consequence of the new Climate Policy of KGHM Polska Miedź and the choice of the energy sector as the new direction of the company's strategic development. The construction of SMR is to enable KGHM to reduce CO2 emissions by 8m tonnes annually. SMR technology is also expected to increase the company's cost efficiency and transform the Polish energy sector, representing a milestone towards the commercialization and development of clean, reliable and affordable energy. Minister for State Assets, Deputy Prime Minister Jacek Sasin, participating in the delegation from Poland, said during the ceremony of signing the contract: "we are working on such a concept in the replacement of coal-fired units with small nuclear reactors, because it would allow for a much cheaper energy transformation and would not require – as it is today – de facto rebuilding power plants only to use all the infrastructure that is already there."[35] As noted by the minister, three 300 MWe SMRs could replace one traditional coal-fired power plant with a capacity of 1 GWe, and the existing network infrastructure would allow for the distribution of this energy throughout the country. However, he explained that SMR power plants are to be used by Polish large companies and just complement the project of building two large nuclear power plants. At the moment, the government does not envisage replacing traditional nuclear power plants with SMR systems. The situation changed with the change of government in Poland and the replacement of KGHM management in 2024. The new President of KGHM, Andrzej Szydło, stated in mid-June 2024: „I am a big supporter of SMR, but not in the form of sponsoring the development of early stage technologies."[36] KGHM's participation in the development of SMR technology is therefore in question.

2022 [access: 20 II 2022]: <https://newsroom.nuscalepower.com/press-releases/news-details/2022/ADDING-MULTIMEDIA-NuScale-to-Announce-Historic-Agreement-with-KGHM-to-Initiate-the-Deployment-of-the-First-Small-Modular-Reactor-in-Poland/default.aspx?utm_source=nuscalepower&utm_medium=web&utm_campaign=default-hero-1>.

35 *Energetyka jądrowa w Polsce staje się faktem. KGHM podpisał z NuScale umowę na budowę reaktorów SMR,* „Polska Agencja Prasowa" [online], 14 II 2022 [access: 20 II 2022]: <https://www.pap.pl/aktualnosci/news%2C1079535%2Cenergetyka-jadrowa-w-polsce-staje-sie-faktem-kghm-podpisal-z-nuscale-umowe>.

36 *KGHM nie chce być sponsorem rozwoju małego atomu,* „Biznes Alert" [online], 12 VI 2024 [access:15 VI 2024]: <https://biznesalert.pl/finansowanie-smr-kghm-male-reaktory-jadrowe-atom/>.

Another partnership for the construction of SMR in Poland was established on October 22, 2019 between the Polish chemical company Synthos owned by Michał Sołowow and GE Hitachi, for the development and construction of the BWRX-300. According to the agreement, the construction of the reactor in Poland would be completed within a decade[37]. In the same month, the Polish Ministry of Investment and Development and the American conglomerate General Electric signed a letter of intent on obtaining energy from modern sources, including renewable ones[38]. In December 2021, Synthos Green Energy and PKN Orlen have establish the Orlen Synthos Green Energy (OSGE) joint venture to commercialise SMR and micro modular reactor (MMR) technology, in particular GEH BWRX-300. PKN Orlen and Synthos Green Energy each hold 50% of shares and voting rights. The participation of the state-owned fuel giant – PKN Orlen in the project is due to the need to reduce carbon dioxide emissions.

In September 2021, Michał Sołowow and Zygmunt Solorz, the owner of Polsat Group and many other companies, established a partnership for the construction of SMR. On the basis of some of the assets of the Solorz's energy company – ZE PAK, they founded an enterprise which wants to invest in building in Pątnów 4 to 6 SMR-type reactors with a capacity of 300 MWe each. It is worth mentioning that Pątnów is the location indicated in the government's Polish Nuclear Power Program. However, as the initiators of the project reserve, it is not intended to compete with the national program for the construction of large nuclear power plants, but only to supplement it[39]. That same month, Synthos also concluded a letter of intent regarding the cooperation in the use of SMR with a chemical enterprise CIECH owned by Sebastian Kulczyk. The main goal of these

37 *Synthos zakończył prace nad studium wykonalności dla reaktora BWRX-300,* „Nuclear.pl" [online], 15 XII 2020 [access: 28 II 2022]: <https://nuclear.pl/wiadomosci,news,20121501,0,0.html>.

38 Ministerstwo Klimatu, *Polska liczy na współpracę z USA w energetyce jądrowej,* „Biznes Alert" [online], 14 II 2020 [access: 28 II 2022]: <https://biznesalert.pl/polska-usa-wspolpraca-atom-lng-oze-energetyka/>.

39 *Poland's two largest private entrepreneurs to build a nuclear power plant in Pątnów,* „Ceenergy News" [online], 7 IX 2021 [access: 28 II 2022]: <https://ceenergynews.com/nuclear/polands-two-largest-private-entrepreneurs-to-build-a-nuclear-power-plant-in-patnow/>.

companies is to move away from coal-based power generation in favor of non-carbon sources[40].

Unlike KGHM, OSGE is not abandoning the SMR project. On July 1, 2024, OSGE is starting environmental studies at Stawy Monowskie, where the first of the planned SMRs is to be built. Work will soon begin on the Preliminary Safety Analysis Report (PSAR), which will be the basis for the BWRX-300 licensing process in Poland. It should be noted that other Polish companies are cooperating with partners from countries other than the USA to build SMRs. An example is the Świętokrzyskie Industrial Group „Industria", which is at an advanced stage of implementing the SMR project based on British Rolls-Royce technology.

Conclusion

Military security issues have played a key role in Polish-American cooperation since the end of the Cold War. In recent years, however, cooperation in the area of energy security has been intensified, mainly to reduce dependence on the import of energy resources from Russia. The consequences of the Russian invasion of Ukraine significantly increased the urgency of the need to strengthen Polish energy cooperation with other countries, including the USA. So far, the main area of Polish-American energy cooperation has been the gas sector, but the nuclear energy sector might play an increasingly important role. Although there are many indications, the Polish government has not yet decided whether American companies will build traditional large nuclear power plants in the country. In recent years, there has also been an opportunity for Polish-American cooperation to build small modular reactors. Although this technology is only in the development phase, more and more Polish companies are signing agreements with American producers of these systems. Due to the lack of data on the efficiency, cost, operation and safety of SMRs, the Polish authorities did not choose this technology as the main element of the national nuclear program. SMRs are to play a supplementary role

40 *CIECH and Synthos Green Energy will be cooperating in the use of nuclear energy,* „Ciech Group" [online], 8 IX 2021 [access: 28 II 2022]: <https://ciechgroup.com/en/ciech-group/news/news/ciech-and-synthos-green-energy-will-be-cooperating-in-the-use-of-nuclear-energy/>.

to traditional reactors, being a source of energy for large enterprises. If in the future SMRs meet the expectations of users, it cannot be ruled out that they will be used in general energy production, also for individual consumers. Given the close Polish-American relations and the US domination in the development of this technology, companies from across the Atlantic will probably be key partners.

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