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MANAGEMENT OF ENERGY DEVELOPMENT IN GERMANY IN THE CONTEXT OF DECARBONIZATION

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МЕНЕДЖМЕНТ РОЗВИТКУ ЕНЕРГЕТИКИ НІМЕЧЧИНИ В КОНТЕКСТІ ДЕКАРБОНІЗАЦІЇ

Various issues of energy management in Germany are analyzed, including the most important trends in the development of the world economy. The question of Germany's refusal reasons to use atomic energy and the history of such a decision is considered. It is indicated that the decisive impetus to the processes was given by the accident at the Fukushima nuclear power plant in Japan, which is geographically very far from Germany, in significantly different natural and geological conditions, in a zone of high seismic activity, which is not typical for Europe. It is shown that the accident in Japan was not caused by improper operation of the station or any technical reasons, but was the result of the largest earthquake and the next giant tsunami in intensity, which are extremely rare and impossible for the conditions in Germany. An analysis of the development of atomic energy in countries geographically close to Germany was carried out. The exceptionally high role of nuclear power plants in the energy sector of France, which historically has been the world leader for a long time in terms of their specific weight in the country's overall energy balance, is shown. Plans of France to preserve existing nuclear power plants and build new ones were considered. The development of small modular reactors will be an important direction in the development of nuclear energy. The aspiration of a country that previously did not have nuclear energy to build nuclear power plants and develop this energy sector for economic and environmental reasons is also shown. The analysis of various aspects of the management of energy development in Germany was carried out, taking into account the conditions that have prevailed up to now. An assessment of the importance of the existing elements of the country's electricity supply - wind and solar power plants, thermal plants on lignite and hard coal, natural gas, nuclear power plants - is given. It is shown that the main direction of energy development, which meets the imperative of decarbonization, is the most intensive transition to ecological types of energy, primarily wind and solar energy, the use of hydrogen produced in an ecological way. For some transitional period, it is possible to use existing nuclear power plants in Germany, and in the future - small modular reactors, which requires public consent, legislative changes and explanatory work. The importance of international cooperation in the field of energy was emphasized. The importance of making optimal management decisions and their implementation is shown.

Аналізуються різні питання менеджменту енергетики Німеччини з урахуванням найважливіших тенденцій розвитку світової економіки. Розглянуто питання про причини відмови Німеччини від використання атомної енергії та історія прийняття такого рішення. Вказано, що вирішальний імпульс процесам надала аварія на атомній електростанції Фукусіма в Японії, яка географічно знаходиться дуже далеко від ФРН, в природних, геологічних умовах, що істотно відрізняються, в зоні високої сейсмічної активності, що не характерно для Європи. Показано, що аварія в Японії не була спричинена неправильною експлуатацією станції або будь-якими технічними причинами, а стала результатом найбільшого землетрусу та наступного гігантського за інтенсивністю цунамі, які зустрічаються надзвичайно рідко та неможливі для умов Німеччини. Виконано аналіз розвитку атомної енергетики географічно близьких до ФРН країн. Показано винятково високу роль атомних електростанцій в енергетиці Франції, яка історично тривалий час є світовим лідером за їхньою питомою вагою у загальному балансі енергії країни. Розглянуто плани Франції щодо збереження існуючих атомних електростанцій та будівництва нових. Важливим напрямом розвитку атомної енергетики буде розвиток малих модульних реакторів. Показано також прагнення країни, яка раніше не мала атомної енергетики, будувати атомні електростанції та розвивати цю галузь енергетики з економічних та екологічних причин. Виконано аналіз різних аспектів управління розвитком енергетики Німеччини з урахуванням умов, що склалися до теперішнього часу. Дано оцінку значимості існуючих елементів забезпечення країни електроенергією – вітрових та сонячних електростанцій, теплових станцій на бурому та кам'яному вугіллі, природному газі, атомних електростанцій. Показано, що магістральним напрямом розвитку енергетики, які відповідають імперативу декарбонізації, є максимально інтенсивний перехід на екологічні види енергії, насамперед енергію вітру та сонця, використання водню, що виробляється екологічним способом. На деякий перехідний період можливе використання існуючих у Німеччині атомних електростанцій, а в майбутньому – малих модульних реакторів, що потребує суспільної згоди, законодавчих змін та роз'яснювальної роботи. Наголошено на важливості міжнародного співробітництва у сфері енергетики. Показано значущість прийняття оптимальних управлінських рішень та їх втілення у життя.

Keywords: *Management, energy, economic efficiency, logistics, ecology, power plants, prospects, solar power plants, small modular reactors, offshore wind farms.*

Ключові слова: *Управління, енергетика, економічна ефективність, логістика, екологія, електростанції, перспективи, сонячні електростанції, малі модульні реактори, морські вітропарки.*

Statement of the problem in a general form and its connection with important scientific or practical tasks. The development of the world economy in recent decades is associated with the increasingly important role of innovation. Innovation ensures the intensity of economic progress. Innovation in the energy sector is especially important. This is due to major environmental problems. Solving these problems is critical to the future of human civilization. It is necessary to consider issues of effective management of the energy sector using the example of the largest economy in Europe – the German economy. This can serve as an example for other countries in the world.

Analysis of the latest research and publications, in which the solution to this problem was initiated and on which the author relies, selection of previously unsolved parts of the general problem, to which the article is devoted. Recently, many publications of famous scientists have been devoted to the issues of management of various spheres of the economy and innovation management. These issues are given attention in articles, in particular, by such authors as O.V. Bozhanova, S.M. Illyashenko, V.M. Heyets, O.P. Prosovych, V.V. Prokhorova, as well as many others. However, the issues of effective management of the energy industry and innovation in this area, especially on the example of countries with developed energy industries, have not yet been fully studied.

Formulation of the goals of the article (statement of the task). The purpose of the article is to formulate a model for the development of the German energy complex with a distinction between immediate development tasks and later and future tasks, taking into account environmental factors.

Results. Today, Germany is the leading economic country in Europe, one of the most significant economies of the planet. Germany consumes large energy resources, which are becoming more and more difficult to obtain every year. At the same time, energy production has probably the greatest negative impact on the planet's climate, which is already very noticeable, and is increasingly causing natural disasters and large economic losses.

In this regard, it is interesting to develop and implement such an energy model that would ensure the achieved high potential of economic development in Germany, a traditionally formed decent standard of living in the country and environmental protection, a careful attitude to nature, which is considered the key features of modern development civilization

An analysis of the main sources of electricity production in the Federal Republic of Germany in 2021 (Fig. 1) showed the following [1]. The dominant position is occupied by wind energy, the specific weight of which is 23.1% with the production of 113.51 TW·h, which reflects the long-term process of decarbonization. The second position of brown coal power plants is quite clear - 20.2% and 99.05 TW·h, which is due to the use of huge, easily accessible domestic deposits of this raw material with a low cost.

Nuclear power plants continued to play a significant role in the energy industry (13.3% and 65.37 TW·h), their replacement by any others in a short period of time appears to be extremely difficult, and in the conditions of rising world prices for hydrocarbon raw materials, it is economically unjustified.

Thermal power plants operating on natural gas (10.4% and 51.17 TW·h) were designed for cheap and affordable fuel, which does not reflect today's realities, although from an ecological point of view such plants are relatively acceptable.

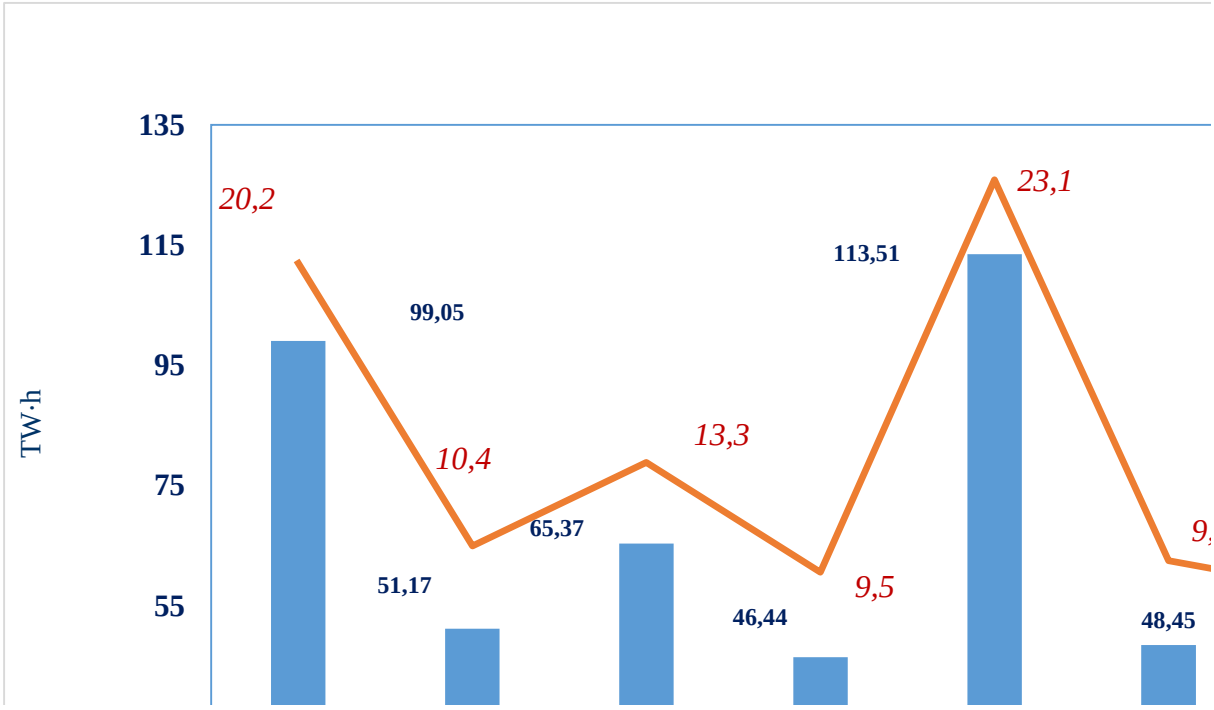

Figure 1. Electricity production in Germany in 2021 by types of sources
Source: based on [1].

Solar energy is becoming increasingly important (9.9% and 48 TW·h), which is already somewhat ahead of coal-fired power generation (9.5% and 46.44 TW·h).

Other sources make a minor contribution to the country's energy balance and their role is unlikely to increase in the future.

It is obvious that wind and solar energy today provide a third of Germany's electricity generation, which is already significant, but still not enough and much less than it could be with the imperative desire for decarbonization and building the economy of the future.

The future of the country's nuclear energy is a difficult problem for Germany, which goes beyond the economy, and is also the most important social problem. The question arises: how does the state of the German nuclear power industry and the direction of winding down the operation of the country's nuclear power plants correlate with the development of this industry in a number of other countries of the world, and especially in Europe, where similar plants play a prominent role.

As can be seen from Table 1 [2], according to the International Atomic Energy Agency (IAEA), in 2021, the world leader in terms of the total capacity of nuclear power plants (96,553 MW) and the annual production of electricity using them (771,637,57 GW·h) is the USA, where 94 nuclear reactors of various capacities operate, while the share of nuclear energy in the total amount of electricity was 19.6%.

Table 1. The share of nuclear energy in electricity production in 2021

Country	General useful electric power, MW	Active reactors number	Production of nuclear electricity, GW·h	The share of nuclear energy in the total volume, %
Argentina	1641	3	10169.72	7.2
Belgium	5942	7	47962.47	50.8
Brazil	1884	2	13858.44	2.4
Bulgaria	2006	2	15798.89	34.6
Canada	13624	19	86780.11	14.3
China	50034	53	383205.32	5.0
Czech Republic	3934	6	29043.75	36.6
Finland	2794	4	22645.97	32.8
France	61370	56	363394.15	69.0
India	6795	22	39757.85	3.2
Japan	18184	19	61304.12	7.2
Republic of Korea	23091	24	150456.38	28.0
Netherlands	482	1	3614.16	3.1
Romania	1300	2	10401.16	18.5
Slovakia	1868	4	14645.84	52.3
Slovenia	688	1	5418.64	36.9
Spain	7121	7	54218.18	20.8
Sweden	6882	6	51426.36	30.8
Switzerland	2960	4	18593.20	28.8
Ukraine	13107	15	81125.58	55.0
UK	8923	15	41788.50	14.8
USA	96553	94	771637.57	19.6

Source: based on [2].

France occupies a unique place in the world of nuclear energy, having for many decades been the country with the largest share of nuclear power plants in the production of electricity, which, despite its decline, still reaches 69%. The capacity of 56 French nuclear units is 61,370 MW, which made it possible to produce 363,394.15 GW·h of electricity in 2021.

Ukrainian nuclear energy plays an important, unique role in the country's economy, providing 55% of all electricity in 2021. At the same time, the country's nuclear plants cannot be replaced by others. For example, thermal power plants operating on hard coal are difficult to provide with the necessary raw materials both in terms of volume and quality.

Nuclear power plants are important for the energy industry of Slovakia, Belgium, Bulgaria, the Czech Republic, Finland, Sweden, Switzerland, South Korea, Spain, and Romania (Table 1). The role of atomic energy in the United Kingdom and Canada is not so significant, but it is noticeable.

Germany's refusal to develop nuclear energy in the future and the gradual closure of nuclear power plants already existing in the country at that time has several components.

Initially, the complete abandonment of such stations did not find support from the authorities, but was actively promoted by environmental organizations and individual political forces. A significant change in the situation came after the accident in March 2011 at the Japanese nuclear power plant "Fukushima-1", the cause of which was an earthquake in Japan, one of the strongest in the history of mankind, which caused a tsunami in the Pacific Ocean. In June 2011, the German government made a radical decision to completely abandon nuclear energy by the end of 2022. Now this decision has been postponed until the spring of 2023.

An analysis of the essence of the problem and the development of events that took place around it over the past years showed the following. The decision to completely abandon nuclear energy was probably more emotional and psychological than rational, which is supported by a number of arguments.

The key factor that directly caused such a decision was the largest earthquake in Japan. It should be noted that earthquakes of similar intensity are quite rare there, the destruction of the station was not caused by the earthquake itself, but by the tsunami due to the location of the station directly on the coast. Although Japan has many nuclear power plants, they were not affected by this earthquake. Northern Europe and Germany are generally not characterized by any significant earthquakes capable of damaging such objects.

The accident at the Fukushima-1 nuclear power plant did not lead to the abandonment of nuclear energy in Japan itself. Currently, 19 nuclear reactors with a capacity of 18,184 MW are operating in the country. There are no known plans to abandon nuclear power in Japan today or in the future.

The question arises: how does the elimination of nuclear power plants in Germany and the problem of radiation safety correlate with the existence of many nuclear power units near the country in neighboring countries, where there are many times more of them than in the country itself? Only France, Switzerland, Belgium, the Netherlands, and the Czech Republic, which directly border Germany, have a total of 74 nuclear reactors as of 2021.

The abandonment of nuclear energy was to be accompanied by an increase in energy production with the help of wind and solar power plants. Such an increase, even a very noticeable one, took place in recent years, but it is far from sufficient to replace the energy of not only nuclear, but also coal and gas power plants.

There have long been no insurmountable technical or economic obstacles to a radical increase in electricity production using offshore wind farms, but it has not been done. Only now has it become known about the plans to build really large offshore wind farms as part of international cooperation projects capable of providing Europe with energy. But the implementation of such projects will take a long time.

Germany did not have any liquefied natural gas (LNG) terminal, relying on overseas pipeline gas supplies, although such terminals existed in many

neighboring European countries. Only recently, the current government of Germany is making intensive efforts to build six marine terminals, which in the future will also be able to receive liquefied hydrogen.

The rejection of nuclear power plants did not take into account the significant increase in world prices for oil and natural gas, which has been happening recently, and the problems of their delivery, which are worsening.

It was not taken into account that the nuclear power plants that existed in Germany were complex, technically perfect objects of high reliability, managed by highly qualified specialists. A lot of money and time was spent on the construction of such stations and the training of specialists. The operation of nuclear power plants was economically efficient. In the case of a constant increase in global energy prices, the importance of this factor increases.

It is also very remarkable that countries that are extremely scrupulous about environmental protection, have an exceptionally picturesque nature, such as France (the world leader in the number of foreign tourists) and Switzerland are not going to give up nuclear energy, but are also devoted to the ideas of developing ecological types of energy. According to the Reuters agency, in November 2021, French President Emmanuel Macron, in particular, said: "We are going to resume the construction of nuclear reactors in our country for the first time in several decades and continue the development of renewable energy sources" [3]. Such a decision is dictated by the desire to reduce dependence on imported energy sources and prevent a sharp rise in electricity prices [4].

In addition, France supports the idea of developing small modular reactors. "We have a decisive advantage - our historical model: we already have nuclear power plants," said Macron, presenting France's development strategy until 2030 at the Elysee Palace [5]. According to the document, 8 billion out of 30 billion euros will be sent to the energy sector, of which 1 billion will be spent on the development of so-called mini-reactors [5].

While Germany is about to completely abandon nuclear power, Poland, which still does not have a single nuclear power plant, has decided to build its first

nuclear power plant in November 2022. As reported [6], it will be created on the basis of American AP1000 reactor technology. It is indicated that construction will begin in 2026, and in 2033 the first unit will be put into operation.

The following changes in the German energy industry must take into account the existing system, which has been in place for many decades and cannot be changed in a short time. At the same time, the functioning of the energy industry must follow the imperative of decarbonization and high efficiency. Taking this into account, it is possible to propose the following development model in the most general terms, which needs to be divided into phases of the immediate and distant perspective.

The directions of energy development in Germany should be divided into measures of the near future and measures of a later perspective.

Directions of development for the nearest future.

1. Thermal power plants on brown coal. Lignite is found in very large quantities in the bowels of the country and has historically been mined using high-performance equipment. Thus, the existing capacities of mining and thermal stations, logistical advantages and low cost of lignite with noticeable disadvantages determined its significant specific weight in the energy industry. Existing brown coal thermal power plants need to be maintained, modernized and reconstructed.

2. Nuclear power plants. It is recommended to continue the operation of the nuclear plants already existing in the country, which will require a change in legislation and extensive outreach work in German society.

3. Thermal stations on natural gas. The operation of such relatively efficient stations for the use of liquefied gas and hydrogen should be supported.

4. Thermal stations on hard coal. In this case, imported raw materials are used, which creates logistical problems and increases the cost. Such stations should exist for some time, until they are replaced by more progressive ones.

5. Solar power plants. In 2021, 10% of electricity was produced with the help of such stations. Solar power plants meet the imperative of decarbonization and must be expanded to the greatest extent.

6. Wind power stations. In 2021, 23% of electricity was produced with the help of such stations. They have a higher utilization rate of installed capacity than solar ones. To the greatest extent, they correspond to the imperative of decarbonization and they must be expanded as actively as possible.

In the longer term, the development of Germany's energy industry will fully meet the imperative of decarbonization. The basis of it can be the following types of stations.

1. Thermal power plants on water. Hydrogen will be produced in places of excess electricity and delivered to Germany mainly in liquefied form by sea.

2. Solar power plants. They will play one of the most important roles in energy, second only to wind power.

3. Wind power stations. Such stations will become the main ones in world energy. Most of them will probably be located in the seas, from where the energy will be transferred to places of consumption.

4. Nuclear power plants. Mostly small modular reactors. The issue requires public approval and legislative changes.

It seems to be extremely important, which will determine success, to thoroughly inform the broad circles of the German public about rational measures that correspond to the complexity of the current situation of the country's energy development.

Germany has recently, in cooperation with other countries, taken energetic steps towards the development of more effective global "green energy". Following the visit of German Chancellor Olaf Scholz to Canada at the end of August 2022, an agreement was signed to start the export of hydrogen from Canada to Germany from 2025 [7]. In Canada, the hydrogen will be produced by wind farms on the island of Newfoundland, in the Atlantic, which has windy weather and many hills that favor efficient energy production. According to the same reports [7], Canada is also able to supply liquefied natural gas. Six floating terminals for receiving LNG, which are being built in German seaports, were also designed for hydrogen from

the very beginning, which opens up a wide range of opportunities for obtaining ecological fuels.

According to Deutsche Welle [8], in September 2022, the energy ministers of the European Union members Belgium, Denmark, Germany, Ireland, Luxembourg, the Netherlands, France and Sweden, as well as Norway, agreed on an extremely large-scale investment plan, which provides for the joint construction and further use of wind farms. He assumes that already in 2030, their capacity in the North Sea (Table 2) will increase 4 times - to 76 GW, by 2040 it will be 138 GW, and by 2050, when the European Union wants to achieve climate neutrality, it should reach 260 GW

As further reported by Deutsche Welle [8], even earlier, at the end of August 2022, in Copenhagen, high representatives of the coastal countries of the Baltic Sea, namely: Germany, Denmark, Latvia, Lithuania, Poland, Finland, Sweden and Estonia, reached an agreement by 2030 to increase the available capacities of offshore wind power plants by 7 times and bring them up to (Table 2) 20 GW. By 2050, this indicator should increase to 93 GW.

Table 2. Dynamics of development of offshore wind farms in Northern

Period (years)	Power, GW	
	North Sea	Baltic Sea
2030	76	20
2040	138	н.д.
2050	260	93

Source: based on [8].

The construction of giant-scale offshore European wind farms is the most important, major direction of energy development within the framework of the imperative of decarbonization and indicates the path to a global solution to humanity's energy problem and preservation of the planet's climate.

Conclusions. Thus, the analysis of the functioning of the energy industry in Germany in combination with the dominant global trends, existing problems and contradictions, as well as key elements of the proposed model of its development allowed to establish the following.

Currently, the main part of the country's electricity is produced with the help of wind, lignite thermal, solar, nuclear plants, as well as natural gas and hard coal plants.

The production of energy using lignite, despite all the disadvantages of this type of fuel, relies on large deposits that are developed inside the country in an efficient open way with the help of high-performance equipment, which eliminates the import of this raw material and many logistical problems, and may be acceptable for some perspective.

Germany envisages abandoning the use of nuclear energy, which is markedly different from the existing practice and plans for changes in the energy sector of the world's leading countries.

A model of the development of the electricity industry of the Federal Republic of Germany is proposed, calculated for the near and distant perspective, the basis of which will be the use of wind and solar energy, ecological hydrogen within the framework of the imperative of decarbonization.

The key element of the energy industry of Germany and Northern Europe will be giant wind farms being built in the North and Baltic Seas as part of international cooperation projects, the total capacity of which may reach 353 GW by 2050.

Achieving the goals of climate protection on the planet requires close attention to this most important problem, scientific research, adoption of appropriate management decisions, and their consistent implementation in the interests of all humanity.

Література

1. Öffentliche Nettostromerzeugung in Deutschland im Jahr 2021. URL: https://www.energy-charts.info/downloads/Stromerzeugung_2021.pdf_(Zugriff am 4 September 2023).

2. In Operation & Suspended Operation. URL: https://pris.iaea.org/PRIS/WorldStatistics/OperationalReactorsByCountry.aspx (Accessed 6 September 2023).

3. Macron says France will build new nuclear energy reactors. URL: https://www.reuters.com/business/energy/macron-says-france-will-build-more-nuclear-energy-reactors-2021-11-09/ (Accessed 9 November 2021).

4. Франція відновлює будівництво атомних реакторів. URL: https://korrespondent.net/world/4415714-frantsyia-vozobnovliaet-stroytelstvo-atomnykh-reaktorov (дата звернення: 11 вересня 2023).

5. Инвестиции в атомную энергетику: зачем Франции мини-реакторы. URL: https://p.dw.com/p/424F2 (дата звернення: 15 вересня 2023).

6. Rząd potwierdza strategiczne partnerstwo z USA przy budowie pierwszej elektrowni jądrowej w Polsce. URL: https://www.gov.pl/web/klimat/rzad-potwierdza-strategiczne-partnerstwo-z-usa-przy-budowie-pierwszej-elektrowni-jadrowej-w-polsce (data złożenia wniosku: 7 września 2023 r.).

7. Канада будет поставлять в ФРГ водородное топливо с 2025 года. URL: hhttps://p.dw.com/p/4Fwb6 (дата звернення: 4 вересня 2023.).

8. Морские ветропарки станут основой электроэнергетики Европы. URL: https://p.dw.com/p/4Gvde (дата звернення: 6 вересня 2023.).

References

1. Fraunhofer Institute for Solar Energy Systems ISE (2022), “Net public electricity generation in Germany in 2021”, available at: https://www.energy-charts.info/downloads/Stromerzeugung_2021.pdf (Accessed 4 September 2023).

2. International Atomic Energy Agency (2022), “In Operation & Suspended Operation”, available at: https://pris.iaea.org/PRIS/WorldStatistics/OperationalReactorsByCountry.aspx (Accessed 6 September 2023).

3. Reuters (2021), “Macron says France will build new nuclear energy reactors”, available at: https://www.reuters.com/business/energy/macron-says-

france-will-build-more-nuclear-energy-reactors-2021-11-09/ (Accessed 9 November 2021).

4. Korrespondent.net (2021), “France resumes construction of nuclear reactors”, available at: https://korrespondent.net/world/4415714-frantsyia-vozobnovliaet-stroytelstvo-atomnykh-reaktorov (Accessed 11 September 2023).

5. Deutsche Welle (2021), “Investments in nuclear energy: why France needs mini-reactors”, available at: https://p.dw.com/p/424F2 (Accessed 15 September 2023).

6. Ministerstwo Klimatu i Środowiska (2021), “The government confirms its strategic partnership with the USA in the construction of the first nuclear power plant in Poland”, available at: https://www.gov.pl/web/klimat/rzad-potwierdza-strategiczne-partnerstwo-z-usa-przy-budowie-pierwszej-elektrowni-jadrowej-w-polsce (Accessed 7 September 2023).

7. Deutsche Welle (2022), “Canada will supply hydrogen fuel to Germany from 2025”, available at: hhttps://p.dw.com/p/4Fwb6 (Accessed 4 September 2023).

8. Deutsche Welle (2022), “Offshore wind farms will become the backbone of Europe's power industry”, available at: https://p.dw.com/p/4Gvde. (Accessed 6 September 2023).

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