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CONSTENTS

Critical infrastructure at sea and the energy security of the Republic of Poland

Przemysław Niewiński

Abstract: In this article, the author will present issues directly related to the security of critical infrastructure, which includes, inter alia, infrastructure ensuring energy security of our country. In view of the geopolitical events that we have witnessed recently, this is one of the key problems to be solved in the legislative and systemic spheres. The problem of legislative, competence and equipment shortages in securing the critical infrastructure of the Republic of Poland at sea has been repeatedly signaled, but very often it was met with some leniency, as no one assumed that a conflict that was so brutal and "classic" in its shape could occur. Russia's aggression against Ukraine has arisen. Critical infrastructure includes not only future offshore wind farms, but also, inter alia, ports, refineries, power plants, mining platforms, etc., the protection of which would require serious revision. In this publication, however, the author will focus primarily on issues related to offshore wind energy and possible investments related to the production of hydrogen in Polish maritime areas.
Key words: critical infrastructure, energy policy, maritime policy, maritime law

Introduction

The dynamics of development of offshore wind energy places it as one of the most dynamically developing energy technologies in Europe. The European Commission recognizes the advantages of offshore wind energy promoting its development and use in the Member States. European authorities are aware that the development of this sector may not only support Europe's achievement of its goals - the use of renewable energy and reduction of greenhouse gas emissions, but also be a factor stimulating economic growth, for example by increasing innovation or creating new jobs [Drożdż, Mróz 2017: 151-152].

The current work related to offshore wind energy in Polish maritime areas is in line with the policy of decarbonisation of electricity sources carried out by the Member States of the European Union, included, inter alia, in the Communication from the Commission to the European Parliament, the European Council, the Council, the Economic and Social Committee and Committee of the Regions of 11 December 2019, known as the "European Green Deal" (COM (2019) 640), as well as the National Security Strategy of the Republic of Poland. Well, in the document approved on May 12, 2020 by the President of the Republic of Poland, at the request of the Prime Minister, the document indicated that in order to ensure the energy security of the state, conditions should be created for the development of alternative energy sources, e.g. by:

– expanding and modernizing the generation capacity as well as electricity transmission and distribution networks in order to ensure continuity of supplies, including the prevention of unexpected interruptions in supplies. Development of dispersed sources of electricity in a sustainable manner, with the adaptation of the National Power System to the characteristics of the operation of these sources;

- with greater diversification of crude oil and natural gas supply sources. Expanding the existing natural gas import capacity (including increasing the receiving capacity of the LNG terminal in Świnoujście) and building new entry points to the Polish transmission system (construction of the Baltic Pipe gas pipeline, construction of the LNG terminal in Gdańsk Bay). Continuation of work on projects diversifying gas fuel supplies to the countries of the region, including the Three Seas Initiative. Continuation of works related to the expansion of the natural gas transmission and storage systems, including the completion of the construction of the North-South route, enabling the creation of the basis for the operation of a gas hub in Poland;
- continuing diplomatic, legal and administrative actions to stop the construction of transmission infrastructure increasing the dependence of the Central European region on gas supplies from the Russian Federation, strengthening the region's resilience to the risk of using gas supplies as an instrument of political pressure (SBNRP 2020).

The last point is especially important in the geopolitical situation that surrounds us.

However, it should be borne in mind that the construction of offshore wind farms is only one of the elements of a series of investments aimed at increasing the volume of energy produced from renewable sources in Poland. The issues directly related to the investment in OWF in Polish maritime areas are:

- expansion of the power grid in the northern part of Poland, necessary in the event of a reversal of energy supply and further distribution along the Polish coast;
- increasing the energy storage capacity;
- systemic replenishment of energy deficits in the event of unfavorable hydrometeorological conditions;
- developing international cooperation in the areas of acquiring the necessary technologies, exchanging experiences or connecting energy systems [Miętkiewicz 2019: 100 - 102].

Regulations concerning the location of renewable energy sources in sea areas

When starting to consider the legal status of facilities intended for the production of electricity or hydrogen, in Polish sea areas and what is hidden behind it, first of all, one should look at the provisions regulating the maritime area, in which the Republic of Poland is entitled to implement investments related to the construction of maritime wind farms and possible investments related to the production of hydrogen.

First, Art. 22 sec. 1 of the Act on the sea areas of the Republic of Poland and the maritime administration indicates that the Republic of Poland has the exclusive right to erect, grant permits for the construction and use in the exclusive economic zone of artificial islands, all kinds of structures and devices intended for scientific research, exploration or exploitation of resources, as well as with regard to other projects in the field of economic research and exploitation of the exclusive economic zone, in particular the use of water, sea currents and wind for energy purposes. This is a positive premise that determines the location of offshore wind farms. Art. 23 sec. 1a, however, indicates a negative premise concerning the location of this type of investment. At his disposal, it talks about the prohibition of erecting and using offshore wind farms in internal sea waters and territorial sea (Journal of Laws of 2022, item 457). The provisions of the Act on the sea areas of the Republic of Poland and maritime administration regarding the location of offshore wind farms are a consequence of the standards contained in the United Nations Convention on the Law of the Sea, drawn up in Montego Bay on December 10, 1982. Offshore wind farms say that the coastal state has the exclusive right in the exclusive economic zone to build and issue permits and regulations for the construction, operation and use of installations and structures intended for the economic study and operation of the zone, such as generating energy through the use of water, currents and winds (Journal of Laws of 2002, No. 59, item 543: article 33).

Another regulation that needs to be looked at is that contained in Art. 22 sec. 2 of the Act on the maritime areas of the Republic of Poland and maritime administration, stating at its disposal that devices intended for the economic exploitation of the exclusive economic zone in order to use water, sea currents and wind for energy purposes, are subject to Polish law. Analyzing this provision, and bearing in mind the provisions of the Montego Bay Convention, we come to the conclusion that Poland has exclusive jurisdiction over offshore wind farms in Polish sea areas, including the jurisdiction to issue laws and other legal provisions in customs, fiscal and sanitary matters. and immigration, as well as in security matters. However, it should be remembered that, according to the Convention on the Law of the Sea, such installations do not have the status of islands. They do not have their own territorial sea, and their presence does not affect the delimitation of the territorial sea or the exclusive economic zone of the Republic of Poland (Journal of Laws of 2002, No. 59, item 543: article 60 sec. 8). Around offshore wind farms, the competent director of the maritime office may, however, establish, in accordance with Art. 24 of the Act on maritime areas of the Republic of Poland and maritime administration, security zone. The width of this zone has been regulated in the cited provision, which is an implementation to the Polish legal system, of the provisions regarding the safety zone around, inter alia, offshore wind farms included in the Montego Bay Convention. According to these standards, the width of the safety zone around the set of offshore windmills that make up the wind farm is 500 m from each point of their outer edge. The prerequisite is that the distance between the individual windmills included in the offshore wind farm does not exceed 1000 m. According to the applicable standards, these distances, in the case of Polish offshore wind farms, will vary between 400 - 640 m. Taking these premises into account, the entire area inside the offshore wind farm and within 500 m from the outer edges of the extreme offshore wind turbines can be considered a safety zone. In this area, the director of the maritime office determines the conditions of movement in the safety zone, in particular, he may impose restrictions on shipping, fishing, practicing water or diving sports or underwater works (Act of 21 March 1991 on the maritime areas of the Republic of Poland and maritime administration, Journal of Laws of 2022, item 457: article 24).

The last of the documents to be described is undoubtedly the Inner Sea, Territorial Sea and Exclusive Economic Zone Spatial Development Plan on a scale of 1: 200,000.

- the growing number of spatial conflicts at sea related to the intensification of maritime navigation, the emergence of new forms of use, and opening up to new opportunities;
- the process of redefining ways to benefit from the sea: decline in some traditional maritime industries, emergence of new ways of using the sea;

– the growing scale of land-sea spatial interactions (underwater transmission infrastructure, changes in the coastal landscape by structures erected in sea areas) [Matczak, Pardus, Pankau 2019: 7-8]

In 2016, the Directors of Maritime Offices started developing one, coherent draft plan for the spatial development of Polish sea areas, in the part relating to the EEZ, the territorial sea and the internal sea waters (including the Gulf of Gdańsk). This plan aims to support sustainable development in maritime areas, including by indicating areas and determining the ways of co-existence of various forms of spatial development of sea areas in order to shape the spatial order of these areas. It should be remembered that the spatial development plan of Polish sea areas is the basis for issuing decisions in sea areas relating to the use and development of sea areas, and thus also investments related to offshore wind energy in Polish sea areas [Matczak, Pardus, Pankau 2019: 12-13].

Legal status of offshore wind farms

Taking into account the above-mentioned provisions, it is obvious that the Republic of Poland will enjoy immunity from jurisdiction in relation to offshore wind farms, and the provisions in force in the area of these installations will be the provisions of Polish law. Art. 24 of the Act on maritime areas of the Republic of Poland and maritime administration speaks of the optional entitlement of the director of a maritime office to establish offshore wind farms in Polish maritime areas, but there is a real need to issue an ordinance in the future, establishing zones with restricted navigation rights and other activities around offshore wind farms related to the economic or recreational use of these sea areas.

The argument supporting this position is the fact that, first of all, pursuant to Art. 3 point 2 of the Act on Crisis Management of April 26, 2007, the offshore wind farms will belong to the critical infrastructure as equipment and installations included in the electricity supply system. Such services, in accordance with the above-mentioned legal act, are recognized as crucial for the security of the state and its citizens and used to ensure the efficient functioning of public administration bodies, as well as institutions and entrepreneurs (Journal U. of 2022, item 261, as amended). Secondly, we currently have, in the Polish legal system, nine binding orders of the director of the Maritime Office in Gdynia, establishing safety zones, including:

– in Polish sea areas, along the entire route of the offshore gas pipeline, the "B-8" field - Władysławowo to ensure proper protection of this installation [ORDER No. 9 OF THE DIRECTOR OF THE MARITIME OFFICE IN GDYNIA of November 8, 2017 on the establishment of a security zone for the deposit gas pipeline " B-8 "- Władysławowo];
– in the waters of the Gulf of Gdańsk along the DN 1600 deep-water pipeline and the sea end of the pipeline [ORDER No. 1 OF THE DIRECTOR OF THE MARITIME OFFICE IN GDYNIA of 27 February 2017 on the establishment of a safety zone around the equipment of the deep-water pipeline DN 1600 and the sea end of the pipeline];
– in the Polish economic zone around the "LOTOS PETROBALTIC" drilling platform located at point B-8 at the position φ = 55 ° 24'01 "N and λ = 018 ° 43'19" E [ORDINANCE No. 14 of the DIRECTOR OF THE MARITIME OFFICE IN GDYNIA of 5 October 2015 on the establishment of safety zones around the "LOTOS PETROBALTIC" drilling platform and around the CALM buoy based on the B-8 field],

thus objects belonging to the critical infrastructure.

Ensuring the security of critical infrastructure

The consequences of including offshore wind farms in Polish sea areas in the critical infrastructure of the State are of a dual nature. Firstly, according to the Act on Crisis Management, the owner and independent and dependent owners are obliged to ensure adequate protection of the critical infrastructure systems. It is carried out in particular through the preparation and implementation, according to the anticipated threats, plans for the protection of critical infrastructure and the maintenance of own backup systems ensuring security and maintaining the functioning of this infrastructure, until it is fully restored (Journal of Laws of 2022, item 261, as amended: article 6 sec. 5).

Offshore wind farms, as critical infrastructure, should be included in:

- the National Critical Infrastructure Protection Program adopted by the Council of Ministers, the aim of which is to create conditions for improving the security of this infrastructure;
- issued under Art. 6 of the Act of 5 July 2018 on the national cybersecurity system (Journal of Laws of 2020, item 1369, as amended), Regulation of the Council of Ministers on the list of key services and thresholds of significance of the disruptive effect of an incident for the provision of services key.

Additionally, it should be taken into account whether, pursuant to § 2 point 23 and 24 of the Regulation of the Council of Ministers of June 24, 2003 on facilities of particular importance for state security and defense and their special protection (Journal of Laws No. 116, item 1090, as amended), investments related to offshore wind energy and possible production of hydrogen should not be subject to special protection, as objects of particular importance for the security and defense of the state. This would be of key importance at the time of a threat to state security and in time of war. Well, under paragraph. 1 of Decision No. 443 / MON of the Minister of National Defense , the Armed Forces of the Republic of Poland in conditions of a threat to state security and during war, take part in special protection of category I facilities recognized by the Council of Ministers as particularly important for state security and defense (Journal of Laws of the Ministry of National Defense of 2013, item 396).

According to the National Critical Infrastructure Protection Program, the minister responsible for state assets, the minister responsible for energy and the minister responsible for the management of mineral deposits are responsible for the energy supply system, energy raw materials and fuels. Actions taken in the area of this responsibility include, inter alia, assessing the risk of possible system disruptions and periodic analyzes of their protection, cooperation with other authorities that, under the Acts, have authority over a given fragment of the system, supporting the organization of exercises and system training to improve the efficiency of system protection in terms of organizational, technical and formal - legal (NPOIK 2015: 17 – 21), as well as agreeing system protection plans, which results from § 4 sec. 1 point 2 of the Regulation of the Council of Ministers of 30 April 2010 on critical infrastructure protection plans. This implementing act specifies in detail the method of creating, updating and the structure of critical infrastructure protection plans prepared by owners and holders of self-contained and dependent facilities, installations or devices of critical infrastructure and the conditions and procedure for recognizing compliance with the obligation to have a plan that meets the requirements of the critical infrastructure protection plan. At the same time, the scope of the ministers' responsibility for individual systems of critical infrastructure is taken into account in the activities of their subordinate or subordinate bodies (Journal of Laws No. 83, item 542) .

Threats to critical infrastructure

Another legal act, through the prism of which it is necessary to look at offshore wind energy and installations used to generate hydrogen as elements of the state's critical infrastructure, is the Anti-Terrorist Activities Act of 10 June 2016. issues related to securing critical infrastructure in the context of preparation for taking control over terrorist events.

Firstly, in the event of a threat of a terrorist event or in the event of such an event, the Prime Minister, after consulting the minister competent for internal affairs and the Head of the Internal Security Agency, may introduce one of the four alert levels:

- first alert stage (ALFA stage);
- second alert stage (BRAVO stage);
- third alert stage (CHARLIE stage);
- fourth alert level (DELTA level) (Journal of Laws of 2021, item 2234, as amended: article 15).

Pursuant to the provisions of this Act, in the event of ordering at least the second level of emergency, i.e. a situation of an increased and predictable threat of a terrorist event, without an identified specific target of the attack, the Police is obliged to check the security of critical infrastructure facilities, and in relation to selected of them, taking into account the type of threat, enables the Head of the Internal Security Agency, in agreement with the minister competent for internal affairs, to issue the Police with a recommendation to protect them in particular (Journal of Laws of 2021, item 2234, as amended: article 12). In the Regulation of the Prime Minister on the scope of projects carried out in individual alert levels and alert levels of CRP of July 25, 2016, which is an executive act to this act, issued on the basis of the statutory delegation contained in Art. 16 sec. 5 of the Act on anti-terrorist activities, we find a provision authorizing the Police Commander in Chief, the Border Guard Commander in Chief or the Commander-in-Chief of the Military Police to introduce the obligation to wear long weapons and bulletproof vests by uniformed officers or soldiers directly carrying out tasks related to securing places and facilities that may potentially become become the target of a terrorist event, in the case of introducing at least the second level of alarm (Journal of Laws, item 1101, as amended).

In the Strategic Concept of Maritime Security for the Republic of Poland published in 2017, the authors of this study indicated that the main threats related to the Baltic region in particular include:

- militarization of the Baltic region, related mainly to the development of Russian military potential, especially anti-access capabilities (Anti Access / Area Denial, A2 / AD) in the Kaliningrad Oblast, which leads to an increase in the importance of the armed forces as an instrument used in international relations in the region ;
- Russia's monopoly position in the area of energy supplies - some countries are too heavily dependent on imports of energy resources from the Russian Federation, as well as on the Russian transport infrastructure;
- potential small-scale local conflict (incidents without and with the use of weapons; hybrid or asymmetric war; connectivity wars), including the so-called geoeconomic battlefield;

- unregulated demarcation of the exclusive economic zones of the Baltic states and restrictions on access to certain types of straits used for international navigation;
- forcing coastal and maritime investments by a state or a group of states that limit the economic undertakings of other states in the region [Brysiewicz, Gwizdała, Makowski 2017: 11-12].

How much of a current and new dimension are these sources of threats gaining, which also have a direct impact on the critical infrastructure facilities at sea, in the light of the currently ongoing military attack by the Russian Federation on Ukraine. Therefore, it will not be revealing that due to the purpose of offshore wind energy combined with the extended response time of relevant services responsible for state security, which is influenced by the location of offshore wind farms in Polish sea areas, these investments may become of the Polish energy sector as a target of acts of a terrorist nature.

Polish Naval Forces in Polish sea areas

The professional nomenclature called the components of the Polish Naval Forces are directly related to ensuring safety in the maritime areas of our country:

- The Polish Navy, which is intended to pursue the interests of the state in maritime areas, defend the territory of Poland, and participate in the joint defense of NATO countries as well as strengthening the allied deterrence system;
- Sea special operations units, whose task in the marine environment is, inter alia, sea area control including shipping control, protection of sea communication corridors etc;
- Border Guard - a police formation that, through its Maritime Branch, carries out, inter alia, supervision over the exploitation of Polish sea areas and compliance by ships with applicable regulations and the prosecution of infringers, protection of the marine environment and cooperation with other services and national administration in sea areas;
- Local maritime administration bodies, the functions of which are performed by two directors of the Maritime Offices in Szczecin and Gdynia. These authorities have been equipped with competences to, inter alia, conducting controls and inspections as well as imposing sanctions in the form of administrative fines and fines for violating legal provisions, which belong to the competence of these authorities;
- Chief Inspector of Sea Fisheries, as the central body of government administration. His main tasks include supervising compliance with the provisions on sea fishing and the organization of the fish market, and imposing fines for violating these provisions;
- Maritime Search and Rescue Service (SAR), whose tasks include searching and rescuing every person in danger at sea and combating oil and chemical threats and pollution of the marine environment;
- The Customs and Tax Service, which is a uniformed service, separated within the National Tax Administration, subordinate to the Minister of Finance. Its main tasks, in the maritime environment, are the detection of tax and fiscal crimes in areas subject to Polish jurisdiction and in sea ports, and the prosecution of their perpetrators;
- Water Police (a unit of the Police Preventive Service), which in the maritime environment performs tasks related to the protection of the safety of people and property and to

maintaining public safety and order in waters intended for general use (in the territorial sea and internal waters).

The authorities presented above, which are part of the Polish Navy, are an important element of the national security system and the defense of the state's interests at every level [Brysiewicz, Gwizdała, Makowski 2017: 21-25].

As can be seen in the diagram of the organs that make up the Polish Naval Force component, there is one rather disturbing feature. Well, significant fragmentation of the authorities responsible for ensuring safety in Polish maritime areas. It is from this fragmentation and sometimes overlapping competences that sometimes very important problems arise, as well as competency disputes between individual representatives of the maritime administration. The result of such a multitude of organs seems to be, inter alia, operation of maritime administration bodies on various, incompatible systems, whether it is the supervision and imaging of Polish sea areas or the exchange of information between individual institutions.

The author, based on his own professional experience, noticed that the real problem seems to be the lack of detailed procedures defining the principles of joint action and cooperation in situations that require it, and of a single center coordinating such joint activities of individual components of the Polish Naval Forces. This could lead to two extreme situations, both very dangerous from the point of view of maritime safety. The first is a situation where, when the competences of two different authorities overlap, with the simultaneous lack of procedures regulating the principles of cooperation, causing no response from the authorities and, colloquially speaking, "waiting" for which authority will take over action in a given situation. The second fact, equally dangerous, may lead, especially in the reporting periods of individual institutions, in which various types of statistics are prepared, that it may lead to a situation where one event will start servicing several institutions, precisely in order to demonstrate activity in a given area. Such a situation is also very undesirable, firstly for economic reasons, and secondly, such a state involves excessive naval forces in one event.

The second result, resulting, inter alia, from out of the multitude of organs, there is a lack of modern vessels in the individual components of the Polish Law Enforcement Naval Forces component, especially those with 24-hour autonomy and bravery allowing for real performance of tasks in difficult weather conditions. Both Polish Navy and Border Guard units are age units in really negligible numbers. The Water Police Station in Gdańsk, as well as units subordinate to the Customs and Tax Offices, have at their disposal small vessels, unsuitable for longer operations on the high seas, especially in difficult hydro-meteorological conditions. The units subordinate to the Chief Sea Fisheries Inspectorate do not have any vessels in their equipment, therefore they are usually inspected in the port.

Does such a state of affairs translate into investments related to offshore wind farms or installations for the production of hydrogen in Polish sea areas? According to the author of this publication, it is very fundamental. As already mentioned in the first part of this article, after including offshore wind farms into the Polish power grid, they will become a critical infrastructure. Therefore, it will become necessary to designate, first of all, in the construction phase, zones that are dangerous to shipping and fishing, including water areas where works related to the construction and connection processes of offshore wind farms will be carried out. Of course, a number of exceptions will be necessary, allowing navigation in this area, e.g. units performing activities and services related to the operation of offshore wind energy infrastructure, Navy ships, Border Guard vessels or maritime administration, as well as conducting activities to save lives or combat threats or pollution at sea.

If the ship enters the designated safety zone, the captain may face an administrative tort joke. 56 point 9 of the Act on the maritime areas of the Republic of Poland and maritime administration. The sanction for this offense is a fine up to the amount not exceeding twenty times the average monthly salary in the national economy for the previous year, announced by the President of the Central Statistical Office. It is imposed by way of an administrative decision by the director of the maritime office. The structure and the imperative nature of this provision do not allow the authority competent to impose the above fine to refrain from issuing a decision imposing a financial penalty for an administrative tort committed. Therefore, it is enough to find a violation of the security zone for the fine to be imposed on the person committing the above-mentioned offense. The only thing that remains for the decision of the office director is the amount of the fine, which takes into account the scope of the breach, the repeatability of the breach or the financial benefit obtained for the breach. Moreover, such a decision is immediately enforceable.

Well, this finding, identification and detection of a specific individual as the perpetrator of this violation can be very problematic in practice. At this point, it is necessary to return in our considerations to the incompatibility of the surveillance systems and the visualization of Polish sea areas, the lack of cooperation procedures and, for example, the coordination center for these activities, and the shortages in the equipment of individual components of the Polish Naval Forces. Let us analyze a very common and simple situation where such a vessel enters the no-navigation zone. Ideally, the ship has the Automatic Identification System (AIS) turned on and the relevant authorities that detected the incident, using simple tools available in supported IT systems, are able to prove the violation. But what if such a unit does not have the AIS system enabled or is simply not equipped with it in accordance with applicable regulations. At that time, the organs of the Polish Naval Forces component had only radar imaging, which allows them to observe that an object has entered the designated security zone. In such a situation, they are left with an attempt to establish contact with such a unit by radio in order to recognize it, or an attempt to establish contact with nearby units in order to establish the details of the vessel violating the safety zone around offshore wind farms. If such actions do not bring the expected result, the only solution is to send subordinate vessels or aircraft to this area in order to identify the unit responsible for the violation of the regulations. This is, of course, associated with an extended response time, and hence the risk of not finding the culprit, as well as with a significant financial burden for a given organizational unit, incurred in connection with the operation of a subordinate vessel or aircraft. The matter becomes more complicated when the violation of the safety zone around offshore wind farms in Polish sea areas results in damage or rendering unusable elements or the entire offshore wind farm. We are already dealing here with a criminal tort, so the perpetrator commits a crime stipulated in the penal code. In the doctrine, a failure is defined as a condition in which an element has been deprived of any functional features, preventing or impeding its functioning in a line or network. Making unusable, on the other hand, consists in subjecting a component of the entire line or network to such an action which does not affect its physical substance, but causes that this element no longer fulfills its function. Thus, rendering unusable will be, for example, demagnetization or irradiation of the components of an offshore wind farm, leading to disruption of its proper operation [Lach 2020: 1210].

Such actions meet the criteria of an act specified in Art. 254a cumulatively with Art. 288 and art. 294 § 1 of the Penal Code and is subject to the penalty of deprivation of liberty for a period from one to ten years (Penal Code).

So, as you can see from this very simple situation, which is not a rare event in Polish maritime areas, the infrastructure related to offshore wind farms and hydrogen production will become extremely sensitive and particularly exposed to all kinds of sabotage attempts, or even attempts to check the effectiveness of the system security of the Republic of Poland.

In order to prevent, in the near future, situations leading to the exposure of offshore wind farms to possible disruptions or destruction, a number of solutions should be introduced to protect this infrastructure.

Firstly, as an alternative solution to the increasingly newer and more costly various systems of supervision and visualization of Polish sea areas intended for individual authorities, a single system of supervision of sea areas under the jurisdiction of our country should be introduced. Such a system, common to all institutions that make up the chain of the maritime security system of the Republic of Poland, would, firstly, be more economically advantageous, and secondly, it would significantly improve the daily supervision over the security of Polish maritime areas. Of course, apart from the main system, a backup system should also be introduced, ensuring the continuity of supervision in the event of a failure or service work of the main system. The natural consequence of implementing such a system would be the establishment, at the beginning, of a center for coordinating the activities of individual components of the Polish Naval Forces, in the scope of which would be to direct appropriate forces and resources to events affecting the security of Polish maritime areas. The financing of such a center would have to be shared jointly and severally by government administration bodies, which are responsible for the activities of individual bodies forming the network, broadly understood, of maritime administration.

Secondly, the penalties for violating, by a vessel, the safety zone designated around the offshore wind farm, must be adequate to the costs, at least purely operational, incurred by the administrative authority in connection with sending the vessel or aircraft to a given area. These penalties would, of course, support the State Treasury, and thus the administrative body that incurred such costs. In addition, institutions directly interested in ensuring the safety of investments related to offshore wind energy should provide in their budgets for participation in at least part of the costs of operations related to ensuring the safety of this infrastructure, incurred by components of the Polish Maritime Force, directly involved in these operations. Only such solutions seem to be able to realistically ensure an efficient and quick reaction of the services to the violation of the zone and will certainly act as a deterrent against committing the violation of the law in question.

Thirdly, the areas of offshore wind farms, as objects of critical maritime infrastructure, should be under constant supervision of vessels, individual components of the Polish Maritime Force. Of course, when designating surveillance zones, a number of factors should be taken into account, e.g. hydro-meteorological conditions prevailing in a given region and period, and thus the appropriate selection of units, introducing rotation of such supervision by individual links in the chain forming the maritime safety system of the Republic of Poland. Here we come back to the legitimacy of establishing, for a good start, a coordination center of activities and the legitimacy of financing such activities by the government administration bodies concerned.

Consideration should also be given to the use of autonomous vessels in the near future in order to ensure the safety of offshore wind farms in Polish sea areas. However, such a solution will only be possible when the appropriate legal framework is created, both for the establishment of the statute of such an entity and its potential operator.

Summary

When analyzing the issues presented in this article, it should be very seriously emphasized that in the current legal status and the state of equipment of individual administrative bodies responsible for supervision and enforcement of regulations directly affecting the maritime safety of our country, offshore wind farms as elements of critical infrastructure in Polish maritime areas will become objects without proper protection of their safety. Of course, there are many voices that it is the role of the private sector to ensure the protection of the offshore wind farms in Polish maritime areas. This position seems to be a consequence of a misunderstanding of two completely separate concepts, i.e. current protection of the facility and reaction to the actual threat, directly related to the energy security of our country. It is necessary to urgently provide, through a series of legislative measures, appropriate tools to the authorities creating the security chain of Polish maritime areas, so that the provisions relating to the safety of the OWF are not just dead records, impossible moments to be implemented. At the beginning, the creation of a single system to supervise Polish maritime areas, the headquarters of which would be in the newly created center of coordination of activities, would be a good start and perhaps a spark for the creation of a single service in the future, gathering in the scope of its tasks the maritime administration of our country, so fragmented today. Only providing the relevant services responsible for state security with adequate system tools will guarantee the efficient and safe operation of these investments, which have an undoubted benefit for the diversification of our country's energy sources, which is a priority in the current geopolitical situation. In today's realities, it is not difficult to accept a scenario in which Polish critical infrastructure may become the object of a conventional or cyberattack by a hostile state. Unfortunately, we are currently not sufficiently prepared for such an attack.

Bibliography

1. Communication from the Commission to the European Parliament, the European Council, the Council, the Economic and Social Committee and Committee of the Re-gions of 11 December 2019, known as the "European Green Deal", (COM (2019) 640).
2. SBNRP 2020 – Strategia Bezpieczeństwa Narodowego Rzeczypospolitej Polskiej, Warszawa 2020.
3. Ustawa z dnia 21 marca 1991 r. o obszarach morskich Rzeczypospolitej Polskiej i ad-ministracji morskiej (t.j. Dz. U. z 2022 r. poz. 457).
4. Konwencja Narodów Zjednoczonych o prawie morza, sporządzona w Montego Bay dnia 10 grudnia 1982 r. (Dz. U. z 2002 r. Nr 59, poz. 543).
5. Ustawa z dnia 26 kwietnia 2007 r. o zarządzaniu kryzysowym (t.j. Dz. U. z 2022 r. poz. 261 z późn. zm.).
6. Ustawa z dnia 5 lipca 2018 r. o krajowym systemie cyberbezpieczeństwa (t.j. Dz. U. z 2020 r. poz. 1369 z późn. zm.).

7. NPOIK - Narodowy Program Ochrony Infrastruktury Krytycznej, przyjęty Uchwałą nr 210/2015 Rady Ministrów z dnia 2 listopada 2015 r.
8. Rozporządzenie Rady Ministrów z dnia 11 września 2018 r. w sprawie wykazu usług kluczowych oraz progów istotności skutku zakłócającego incydentu dla świadczenia usług kluczowych (Dz. U. poz. 1806).
9. Rozporządzenie Rady Ministrów z dnia 24 czerwca 2003 r. w sprawie obiektów szczególnie ważnych dla bezpieczeństwa i obronności państwa oraz ich szczególnej ochrony (Dz. U. Nr 116, poz. 1090 z późn. zm.).
10. Decyzja Nr 443/MON Ministra Obrony Narodowej z dnia 24 grudnia 2013 r. w spra-wie udziału Sił Zbrojnych Rzeczypospolitej Polskiej w szczególnej ochronie obiektów (Dz. Urz. MON z 2013 r. poz. 396).
11. Rozporządzenie Rady Ministrów z dnia 30 kwietnia 2010 r. w sprawie planów ochro-ny infrastruktury krytycznej (Dz. U. Nr 83, poz. 542).
12. Rozporządzenie Prezesa Rady Ministrów z dnia 25 lipca 2016 r. w sprawie zakresu przedsięwzięć wykonywanych w poszczególnych stopniach alarmowych i stopniach alarmowych CRP (Dz. U. poz. 1101 z późn. zm.).
13. Strategiczna Koncepcji Bezpieczeństwa Morskiego Rzeczypospolitej Polskiej, Brysie-wicz J., Gwizdała D., Makowski A., Biuro Bezpieczeństwa Narodowego, Warszawa-Gdynia 2017.
14. Morska energetyka wiatrowa jako istotny potencjał rozwoju polskiej gospodarki mor-skiej, Drożdż W., Mróz-Malik O., [w:] Problemy Transportu i Logistyki 1/2017 (37), Wydawnictwo Naukowe Uniwersytetu Szczecińskiego, Szczecin 2017, s. 151-159.
15. Plan zagospodarowania przestrzennego morskich wód wewnętrznych, morza teryto-rialnego i wyłącznej strefy ekonomicznej w skali 1: 200 000, Matczak M., Pardus J., Pankau F., [w:] Biuletyn Komitetu Przestrzennego Zagospodarowania Kraju PAN Ze-szyt 276, Polska Akademia Nauk, Komitet Przestrzennego Zagospodarowania Kraju, Warszawa 2019, s. 6-30.
16. Morskie farmy wiatrowe a bezpieczeństwo morskie państwa, Miętkiewicz R., [w:] Sprawy Miedzynarodowe Tom 72 Nr 1 (2019): Jak uczyć o stosunkach międzynarodowych? Instytut Studiów Politycznych PAN, Warszawa 2020, s. 97-112.
17. Lach A. Rozdział XXXII. Przestępstwa przeciwko porządkowi publicznemu, [w:] Ko-deks Karny – Komentarz, Konarska-Wrzosek V., Wolters Kluwer, Warszawa 2020.
18. Penal Code - Ustawa z dnia 6 czerwca 1997 r. Kodeks karny (t.j. Dz. U. z 2021 r. poz. 2345 z późn. zm.).

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Energy security – the case of Polish National Power System facing energy transition's challenges

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Abstract: Energy security plays a key role in energy and economic policy. The importance of energy security has been highlighted by the energy and geopolitical crisis. The aim of this article is to present the crucial threats and challenges facing Polish National Power System, as well as to provide solutions to ensure Poland's energy security over the next 10 years. Article verify the hypothesis that security of electricity supply in Poland may be endangered in the coming years due to, among others, investment gap, coal power plants phase-out and undiversified energy mix. Therefore, it is a necessity to accelerate the investment processes in new generation capacity, especially in nuclear energy. Energy transition plans and energy policy need to be revised in light of the current energy and geopolitical crisis. Rapid growth of photovoltaics improves the energy security, mainly in the summer period, nevertheless, there is still insufficient development of investment in renewable energy sources, particularly in wind energy. In the Polish National Power System there are a lot of constraints such as investment gap, low capacity of transmission and distribution grids and high exposure to climate risk, thus it is necessary to take comprehensive investments to improve energy security in both the short and long term.
Key words: Energy security, energy transition, energy crisis, decarbonisation, coal phase-out, energy policy

1. Introduction

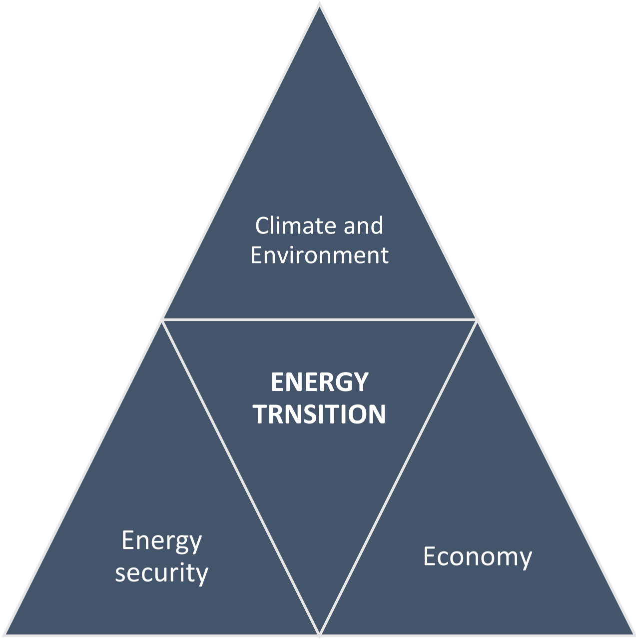
One of the most important objectives of energy policy is to ensure energy security in the form of stable energy supplies in a technically and economically viable manner. The issue of energy security has taken on particular importance in view of the energy crisis in Europe, triggered, inter alia, by Russia's invasion in Ukraine. Almost overnight, Europe faced a threat to the security of supply of strategic energy resources. This situation made Europeans realise the importance of a rational approach to energy policy and energy security.

Poland is facing the challenge of energy transition. The overall effort to decarbonise and diversify Poland's energy mix brings to centre stage issues of energy security, which have been further emphasised by the energy and geopolitical crisis consuming Europe. For this reason, it is so important to analyse the factors that make up Polish energy security and aim to maintain it at the highest possible level.

Energy security plays crucial role in not only the energy sector but also in the whole economy. However, there is a lack of a widely accepted definition of energy security – among researchers this concept is blurred (Winzer, 2012, p. 36). There are a lot of papers tackling with the energy security definition, nevertheless there is no consensus on a common accepted definition (Ang et al., 2015, p. 1078-1081). Energy security is highly context-dependent concept, related to the individual country's circumstances, geopolitical issues and development of economy and energy sector (Ibidem). Among the literature, researchers focus on multidimensional nature of energy security concept, emphasising i.e. security of supply, energy availability and energy prices (Spanjer, 2007), (Jamasb, Pollitt, 2008), (Ang et al., 2015), technology, environment, energy policy and cyber security (Azzuni, Breyer, 2018). Both definition as well as dimensions of energy security are a subject to change as a geopolitical, economic and energy circumstances are dynamically evolving over time (Ang et al., 2015, p. 1078). Definition of energy security is also provided in legal acts. Polish Energy Act defines energy security as "the state of the economy that makes it possible to meet customers' current and future fuel and energy demand in a technically and economically reasonable manner, while complying with the requirements of environmental protection". Thus, it presents the multidimensional nature of energy security concept.

Energy security is a key element of the transition, as highlighted by the Energy Trilemma concept (Heffron et al., 2015). The energy transition encompasses in its scope three key areas: Climate and environment, Economy and Energy Security (Figure 1). Therefore, it is impossible to consider it without taking into account energy security challenges.

Fig. 1. The concept of Energy Trilemma.



Source: Own labour based on the concept of Energy Trilemma
Balanced Energy Trilemma is crucial factor for performing the Energy Transition towards sustainable energy system (Khan et al., 2021, p. 1)

The aim of this article is to present the crucial threats and challenges facing Poland's National Power System, as well as to provide solutions to ensure Poland's energy security over the next 10 years. The research methods used in this article are literature review and data analysis. Article verify the hypothesis that security of electricity supply in Poland may be endangered in the coming years due to, among others, investment gap, coal power plants phase-out and undiversified energy mix.

2. Snapshot of energy security issues in Polish National Power System

The energy security of Poland is the result of the functioning of many interconnected systems. In the context of security of electricity supply, it results from the operation of the generation, transmission and distribution sectors, but also depends on the energy policy pursued. In recent years, the words "energy security" and "blackout" have been heard more and more frequently in the Polish media. This has to do with the real threat posed by a shortage of generation capacity, which has occurred during periods of heat waves over recent years. The most serious such event occurred in August 2015, when power stages had to be introduced to relieve pressure on the electricity system (Rzeczpospolita, 2015). The current very dynamic development of prosumer photovoltaic installations has to some extent dismissed this threat, however, the stability of the National Electricity System is still dependent on the ability to import energy at critical moments.

Energy security can be threatened in the event of a major failure of a large generation facility or an important component of the transmission network, which may lead to Common Cause Failure (CCF) being a failure of multiple components of a system due to one common cause (Bukowski et al., 2022, p. 10). Such an event occurred on 17 May 2021 when, as a result of a failure at the Rogowiec substation serving the power output of 10 of the 11 units of the Bełchatów power plant, these units had to be switched off and the power system suddenly lost 3900 MW (PSE, 2022). Despite such a serious failure, there was no energy security emergency - the power system operated smoothly mainly due to energy imports from Germany, the Czech Republic and Slovakia, the activation of the spinning thermal reserve in operating coal-fired power plants and the use of pumped storage power plants. It should be borne in mind, however, that the occurrence of such a situation during a heat wave and drought, as well as with a simultaneous shortfall in available generation capacity, such an event could necessitate the introduction of power supply steps and affect the demand side.

The importance of security of electricity supply, which is one of the key elements of national energy security, is reflected in legislation at EU level. The EU, in one of its regulations, created the concept of an *electricity crisis*, which denotes an existing or unavoidable situation of a significant shortage of electricity (European Union, 2019).

The energy transition, which is already happening, is undoubtedly the biggest challenge facing the energy sector in Poland. Moving away from coal, the dynamic development of renewable energy sources and the construction of new gas-fired and potential nuclear power plants is a major challenge, the cornerstone of which is ensuring energy security. A key aspect of the energy transition will be to plan it precisely so that no temporary power shortages arise in the system. In addition, the change in the structure of electricity generation will bring new challenges, such as the need to balance generation from RES or the expansion of the gas transmission pipeline system and the increase in demand for natural gas.

Energy security is also about the supply of fuels and energy resources. A diversified structure of both the energy mix (not allowing a situation of dependence on a single type of energy source) together with diversified sources of supply of fuels and energy raw materials are a critical element of energy security at both national and European level. The current energy and geopolitical crisis has underlined this emphatically (von Homeyer et al., 2022).

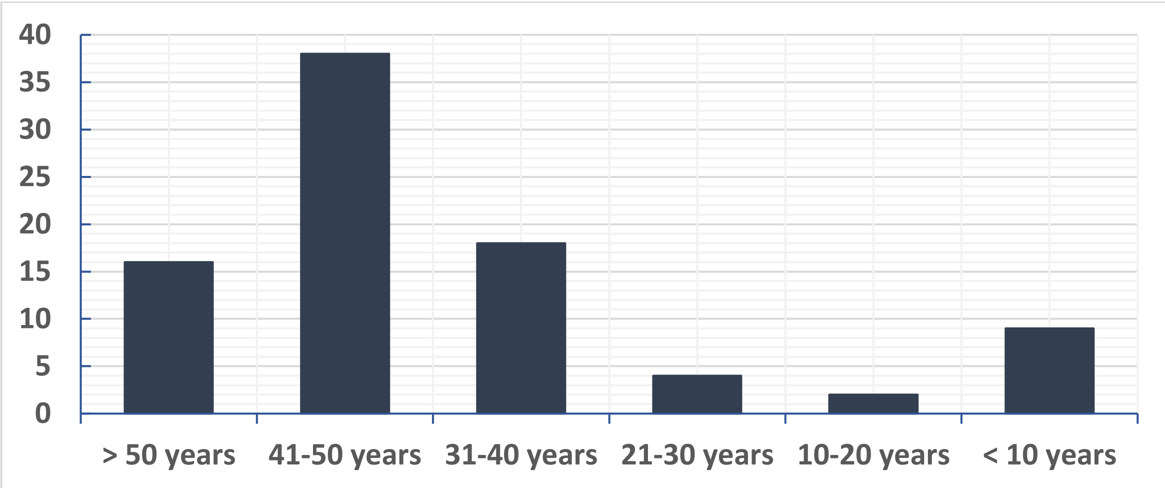
In the following part of this article, the concept of energy security will be largely narrowed down to issues related to the electricity sector only.

3. The characteristics of the biggest challenges facing the electric power system

3.1. Investment gap

The operation of electricity generation assets is largely based on power plants built in the 1960s, 1970s and 1980s. The turn of the century was characterised by an almost disappearance of investments in generation sources. Reasons for this include the privatisation of the energy sector or the political transformation and the economic downturn that followed. This led to a so-called investment gap in the area of generation assets (Krupiński et al., 2019). In fig. 2 shows the age structure of coal units in Poland.

Fig. 2. Age structure of coal-fired units in Poland - the number of coal-fired units commissioned over a specific time period.



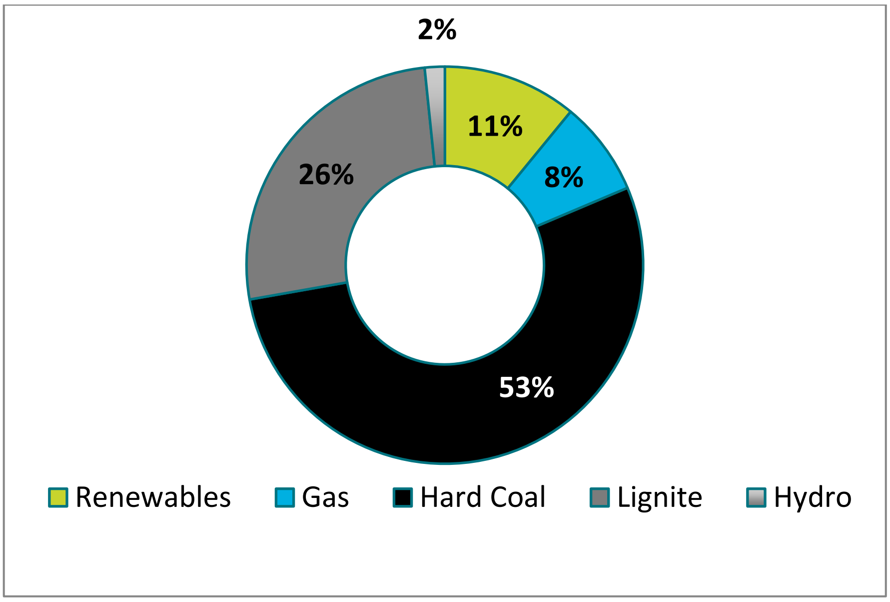
Source: Own labour based on the Energy utilities' data

One of the fundamental goals of the energy transition is to fill this gap - that is, to replace the oldest, inefficient and environmentally unfriendly coal-fired units with new, highly efficient combined cycle gas turbine (CCGT) units, nuclear power plants or renewable energy sources (RES). The investment gap means that the Polish energy mix is still based on coal and is unable to be competitive with the energy sectors of most EU countries. The lack of a clear strategy for Poland's energy transition, the insufficient number of investment projects under way, as well as the lack of a precise plan for replacing phased-out coal-fired capacity, make the issue of the investment gap in the area of power generation assets significant.

3.2. Replacement of phased-out coal capacity

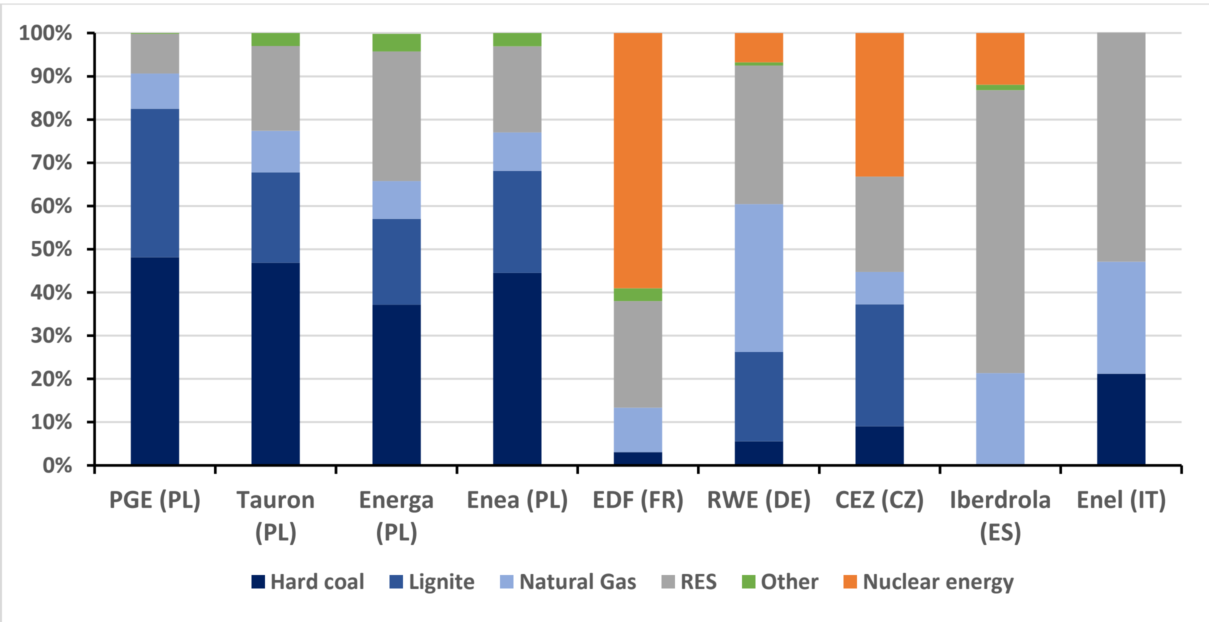
Filling the investment gap resulting from the energy transition already underway, however, poses another challenge for the National Power System (NPS) in terms of replacing capacity from obsolete coal units. In view of the withdrawal of such large volumes of installed capacity from the NPS, it is planned to take into operation the units currently under construction, but in the long term there is a real risk of domestic generation not covering the demand for electricity, as alarmed by the Supreme Audit Office (Najwyższa Izba Kontroli, 2019). The threat of domestic generation units failing to cover the demand of electricity consumers is likely to be exacerbated during hot periods, which is related to the high sensitivity of thermal power plants to meteorological and hydrological factors characteristic of heat waves, as was the case in August 2015 when, among other things, the security of electricity supply was threatened. One way to counter this threat was to create a capacity market to provide a financial incentive to undertake much-needed investment in electricity generation assets. It is also crucial to develop a timetable of investments and retirements of obsolete coal-fired capacity so that the system's capacity is not reduced below the minimum values set by electricity demand. The scale of the problem of Poland's generation sector's dependence on coal assets is shown in fig. 3 and fig. 4.

Fig. 3. Polish Energy mix (electricity production in %) as for 2021.



Data source: PSE

Fig. 4. Energy mixes of certain European and Polish energy companies.



Data source: Energy utilities' reports

Electricity production in Poland is based on coal in 79% as in 2021 (fig. 3). The almost total dependence of the power generation sector on coal is highly undesirable, especially from the point of view of energy security as well as exposure to climate risk.

The overwhelming dominance of coal in the Polish energy mix is also reflected in the electricity generation structure of Polish energy companies. The dependence of them on coal ranges from around 65% to as much as over 80% of total installed capacity (fig. 4). This is in stark contrast to companies from other European countries. For example, foreign companies that are characterised by having coal in their energy mix are already at a different stage of the energy transition than Polish companies, and their dependence on coal is much lower. Germany's RWE is about 25% dependent on coal, and the Czech CEZ is less than 40%. In contrast, France's EDF is dominated by nuclear power and Italy's Enel and Spain's Iberdrola by renewable energy. It is therefore crucial to develop a rational decarbonisation timetable that allows for the substitution of decommissioned coal units to ensure energy security. The development of gas-fired power generation to replace decommissioned coal units has been called into question by Russia's invasion of Ukraine and the energy and geopolitical crisis in Europe. This situation has had a not inconsiderable impact on the design of the energy transition in Poland and will be discussed in more detail later in this publication.

An undiversified energy mix based on coal and lignite is undesirable from the point of view of energy security, especially given the problem of obsolete coal assets and the need to phase out the oldest units, as outlined earlier. The situation becomes more complicated especially when there is a sequence of unfavourable conditions affecting coal-fired generating units, which may be emergency stoppages and losses due to meteorological situations (this issue will be further discussed in chapter 3.3). Other risks could be problems with hard coal supply, as well as lignite deposits running out. The first problem became apparent in 2022, after Poland imposed a ban on hard coal imports from Russia, and the second problem will soon become visible in connection with, inter alia, the depletion of lignite deposits supplying Poland's largest power plant in Bełchatów (the expiry date of the mining concession for the Bełchatów Field expires in 2026, and for the Szczerców Field in 2038) (Naworyta, Zajączkowski, 2018, p. 94).

Concluding, the issue of highest priority for the Polish NPS, faced with the threat of a generation capacity gap, is to ensure security of electricity supply and maintain generation capacity at an appropriate level (Ślęzak, 2016).

3.3. Security of electricity supply during heat waves

As already indicated in this chapter, over the last few years, during periods of heat waves (i.e. the occurrence of maximum daily air temperatures above 30°C), there have been situations of threat to the security of electricity supply throughout the country (particularly in August 2015) or in the regions (late July and early August 2018). These resulted from a significant reduction in generation capacity through losses caused by hydrological (low water levels, increased water temperatures in rivers and reservoirs) and meteorological (high air temperature and lack of wind) situations. In addition, at the same time, record summer power demand was recorded, caused mainly by the increasing use of air-conditioning units during summer periods. In addition to the expansion of cross-border interconnections, one important way to address this problem is the dynamic development of photovoltaics, both at the level of prosumer installations and photovoltaic farms. Currently, the installed capacity of photovoltaics in Poland exceeds 10 GW (fig. 5 in chapter 5). This makes it possible to balance the increase in power demand during midday hours on hot days, improving the operation of the entire NPS. Therefore, the risk of a threat to the security of electricity supply during midday peaks on hot days has now been reduced.

The problem, however, can occur in winter with daily demand peaks on days with unfavourable meteorological conditions for RES generation (cloudy and windless). The spread of heat pumps may lead to further significant increases in electricity demand in winter, which, in the event of a failure in coal-fired power plants, may cause problems in meeting the energy demand of the NPS.

3.4. Capacity of transmission and distribution grids

The problem of insufficient capacity of transmission networks is related to the insufficient number of transmission networks in operation in Poland, especially in the north-south axis. The energy transformation, and consequently the construction of new generation facilities, will require the construction of new transmission lines to take power out of generation facilities and to improve the capacity of energy flow in the NPS. In addition, the expansion of cross-border connections is crucial in terms of increasing import capacity, which in extreme situations is the last resort in stabilising the operation of the NPS in the event of widespread outages. An example of such a situation could be the already mentioned disconnection of 10 units of the Belchatow power plant from the grid on 17 May 2021. The expansion of distribution networks is expected to improve their operating conditions in connection with the growing trend of prosumer energy, electromobility and the development of smart grids. The distribution networks are currently a narrow bottleneck that significantly constrains the possibilities for further RES development, especially prosumer PV installations.

3.5. Energy import as a key element in ensuring security of electricity supply

The planning of the energy transition as well as the country's entire energy policy must be based on ensuring a sufficient level of generating capacity capable of covering the power demand in its totality. Basing the security of electricity supply on energy imports may then lead to a serious threat to the security of electricity supply and, in an extreme case, even to a blackout, as energy imports may not be sufficient in the event of problems in neighbouring countries or if there is a significant drop in capacity on cross-border connections. In the August 2015 in question, the phenomenon of so-called circular flows occurred, which clearly reduced the import capacity in the NPS. A surplus of energy produced in RES installations in Germany flowed through the Polish power system and outflowed towards the Czech Republic and Slovakia. However, investments have now been made in so-called phase shifters on cross-border connections in order to reduce the scale of this phenomenon in the future. Basing the energy mix on hard coal, as presented in the earlier chapters, in the realities of Poland means the necessity of importing hard coal due to insufficient mining in domestic mines. This leads to a certain dependence of energy security on imports of this raw material. Problems with the supply or distribution of this fuel may have serious consequences for the NPS. The shortage of coal on the Polish market that followed the embargo on coal imports from Russia in 2022 proved the necessity to pursue decarbonisation and move away from a coal-based energy monoculture.

3.6. Exposure to climate risk

Climate risk is one of the biggest challenges now facing the energy sector (Kouloukoui et al., 2019, p. 1-2). The Polish power generation sector's dependence on coal means exposure to climate risk. Insufficient diversification of the energy mix and the need for decarbonisation result in high exposure of Polish energy entities to climate risk, which manifests itself in the materialisation of a number of new risks, mostly financial risks. The energy sector is a sector particularly exposed to climate change risks (Burchard-Dziubińska, 2020, p. 161). The new regulations, which are a result of energy and climate policy at both national and European level, aim to phase out energy sources using fossil fuels and develop pro-environmental energy sources. The introduction of the EU ETS CO_2 emissions trading scheme exposes Polish energy companies, which are heavily reliant on coal (fig. 4), to financial risks associated with increases in the price of these allowances. On top of this, entities with coal-fired generation assets in their portfolio, as well as coal and lignite mines, are less well perceived by the market and consumers - in contrast to companies considered 'green', which are more oriented towards sustainable energy development. Climate risk also means the practical impossibility of financing coal power development from international financial institutions or corporate sources of capital due to the aversion of the financial sector to finance coal investments in the era of decarbonisation. The failure to complete the financial assembly and guarantee the investment funds was the reason for the collapse of the project to build the last coal-fired power plant in the EU at Ostrołęka in Poland. Therefore, ignoring climate risk has led to investment failure. Climate risk is the biggest threat to entities that ignore it and do not adapt their strategy to current market reality. (Henderson et al., 2018, p. 10).

4. Poland's energy security in the face of the geopolitical and energy crisis

Russia's invasion of Ukraine on 24 February 2022 created a geopolitical crisis in Europe and clearly intensified the emerging energy crisis (von Homeyer et al., 2022). As a neighbouring country of Ukraine, Poland faced a difficult geopolitical situation due to the ongoing war across its eastern border, as well as a result of its neighbourhood with the Kaliningrad Oblast and Belarus. However, defence-related aspects aside, this situation has had a significant impact on the energy security of both Poland and the majority of European Union countries, mainly due to the previous dependence on imports of energy resources from Russia (Wang et al., 2022). This problem has particularly affected natural gas and hard coal. Poland's energy security after the cut-off of gas supplies from Russia in April 2022 has not been compromised due to a sufficiently diversified structure of gas supplies to Poland, which has been made possible by many years of efforts to become independent from Russian gas, as well as a filling gas storage facilities. The interruption of Russian gas supply to Germany via the Nord Stream pipelines has caused a real threat to the security of gas supply in Germany and has clearly exacerbated the energy crisis in the area of natural gas supply in a significant part of Europe (Bukowski et al., 2022).

A consequence of this situation is also the uncertainty about the further development plans for gas-fired power generation in Poland, which was to fulfil the key role of a so-called transition technology in the energy transition. As an intermediary technology between coal and RES, it was to increase the pace of decarbonisation of the Polish energy sector. However, both the difficulties in meeting the increased demand for gas and the unprecedented increase in natural gas prices have led to a situation where the further development of gas-fired power generation may be considered unprofitable and unfavourable, both from an economic and energy security perspective.

The energy crisis, also driven by the high inflation, is also manifesting itself in very high electricity prices, especially for industrial consumers and businesses. Among the reasons for this are not only rising prices for energy commodities and fuels, but also a general increase in labour costs or increasing margins by energy companies. This further complicates the energy transition plans and negatively affects the functioning of the whole economy, as well as the pauperisation of the poorest social strata by increasing the problem of energy poverty.

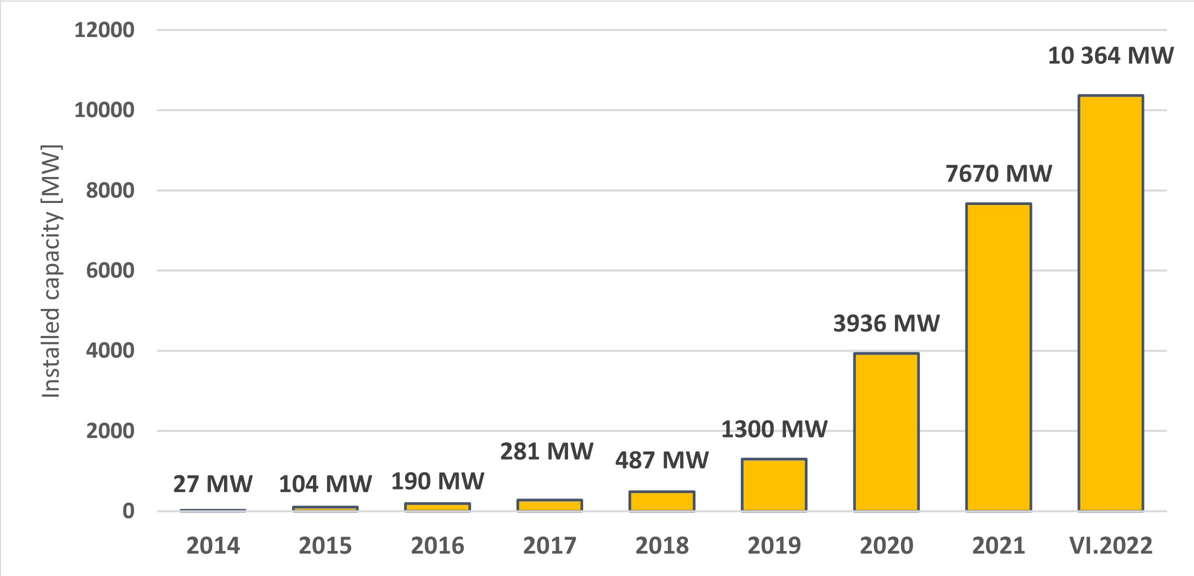
The energy and geopolitical crisis triggered by Russia's invasion of Ukraine has made it clear how crucial energy security is to the economy, and its threat impacts industrial consumers, businesses and individual consumers. Examples include announcements of planned reductions in natural gas supplies in some European countries or orders to reduce indoor temperatures during the heating season. The crisis also forces the question of the state of Poland's energy security in the face of current economic and geopolitical challenges. Furthermore, crisis underlines the necessity of energy transition towards sustainability in Poland (Bukowski et al., 2022).

5. How to ensure Poland's energy security over the next 10 years?

The essential objective of energy policy is to improve energy security (Von Hippel et al., 2011, p. 6727). Over the next 10 years, energy security is to be improved by investment in new electricity generation assets. The construction of new generation facilities is intended to replace outdated coal-fired power plants, whose electricity generation costs make them an economically irrational technology, especially based on the current price of CO_2 emission allowances. The dynamic development of RES (especially onshore and offshore wind power plants and photovoltaics) is expected to ensure the decarbonisation of the Polish energy sector and improve the competitiveness of Polish energy companies through better economic efficiency of these sources. Gas-fired power plants were to be an important element of Poland's energy transition. Natural gas, treated as a transitional fuel, was to facilitate the transition away from coal-fired sources. However, the energy and geopolitical crisis has clearly shaken this concept. Gas-fired power plants were planned to operate mainly as sub-peak and peak load power plants, and their key role was to be balancing a system based on uncontrollable RES. However, from the perspective of both the economic situation and energy security, in the realities of the energy and geopolitical crisis, the approach is characterised by a relatively high level of risk and the need to upgrade some coal-fired units to enable them to extend their operating hours is not excluded. A key element in maintaining energy security, as well as reducing the investment gap and enabling the replacement of phased-out coal units, is investment in nuclear power. Poland needs base load capacity using fuel other than hard coal or lignite covered by the EU ETS. Marginalising the role of natural gas in Poland's energy transition may lead to even greater nuclear investment needs.

An increasingly important source in the Polish energy mix is photovoltaics, which has developed rapidly in recent years (fig. 5).

Fig. 5. Photovoltaics' installed capacity in Poland in years 2014-VI.2022 [MW].



Source: Own labour based on the data: SBF Polska PV, PSE, ARE

Prosumer installations dominate among photovoltaic installations in Poland, mainly due to the 'Mój prąd' support programmes (Krawczak, 2020, p. 14). Such a rapid development of photovoltaics allows the stabilisation of the NPS operation during summer periods and, from the point of view of the users of such investments, is financially advantageous due to the increase in electricity prices. Photovoltaics also have a positive impact on improving energy security on hot days thanks to the high electricity production during midday hours, which balances the increased demand by the increasing number of air conditioners and makes the electricity supply security threat scenarios of 2015 and 2018 much less likely.

Mitigating climate risk will have a significant impact on Poland's energy security over the next 10 years. The risks arising from climate change, as well as the significant pressure from the financial sector on energy companies due to the EU's energy and climate policy, result in coal assets being treated as ballast in Polish energy companies. Energy transition is expected to reduce the risks arising from the negative assessment of companies by external financial institutions and is expected to improve their competitive position in the European market. Decarbonisation in the reality of the energy and geopolitical crisis and high inflation will be a particularly difficult task, taking into account the economic situation as well as Poland's energy security. However, failure to continue the energy transition will result in a lost opportunity for the development and modernisation of the power sector, facing an investment gap in the area of power generation assets (Krupiński et al., 2019).

6. Summary

Poland's energy security, being a multi-component jigsaw that consists of many elements, requires that it be given the utmost attention and treated as one of the strategic elements of both energy policy and overall economic and national security policy. Security of electricity supply in Poland may be endangered in the coming years due to, among others, investment gap, coal power plants phase-out and undiversified energy mix. The issue of highest priority for the Polish NPS, faced with the threat of a generation capacity gap, is to ensure security of electricity supply and maintain generation capacity at an appropriate level. The energy and geopolitical crisis associated with Russia's invasion of Ukraine has clearly highlighted how crucial it is for the economy to take care of energy security. Energy transition plans and Poland's energy policy need to be revised in the light of the current crisis. Investment in nuclear energy is becoming a necessity in order to cover the investment gap and to ensure the replacement of decommissioned coal-fired power blocks in the face of the serious problems affecting the gas-fired power generation sector. In addition, the challenges associated with the work of the NPS point to the necessity to further expand RES capacity and to continue the process of decarbonisation of the Polish energy sector, which is still strongly dependent on coal. The need to mitigate climate risk is currently one of the biggest challenges facing the energy sector in Poland. According to the Energy Trilemma concept, the energy transition should address energy security and economy aspects as well as climate and environment issues.

Bibliography

1. Ang, B. W., Choong, W. L., Ng, T. S, *Energy security: Definitions, dimensions and indexes*. "Renewable and Sustainable Energy Reviews", *42*, 2015, pp. 1077–1093. https://doi.org/10.1016/j.rser.2014.10.064.
2. Azzuni, A., Breyer, C., *Definitions and dimensions of energy security: a literature review*. "Wiley Interdisciplinary Reviews: Energy and Environment", *7*(1), 2018, pp. 1–34. https://doi.org/10.1002/wene.268.
3. Bukowski, M., Kobyłka, K., Sobkiewicz, M. (2022). *Nowy paradygmat. Dlaczego energetyka potrzebuje konkurencji?*, Fundacja Warszawski Instytut Studiów Ekonomicznych i Europejskich Wise Europa, Warszawa, 2022.
4. Burchard-Dziubińska, M., *Systemy społeczno-gospodarcze w Polsce wobec ryzyka związanego ze zmianą klimatu*. [in]: Zmiana klimatu - skutki dla polskiego społeczeństwa i gospodarki, 2020, pp. 159–174. https://doi.org/10.24425/137391.
5. Heffron, R. J., McCauley, D., Sovacool, B. K., *Resolving society's energy trilemma through the Energy Justice Metric*. Energy Policy, *87*, 2015, pp. 168–176. https://doi.org/10.1016/j.enpol.2015.08.033.
6. Henderson, R. M., Reinert, S. A., Dekhtyar, P., Migdal, A. *Climate Change in 2018: Implications for Business*. Harvard Business School, 2018, pp. 1–39. www.hbsp.harvard.edu.
7. Jamasb, T., Pollitt, M., *Security of supply and regulation of energy networks*. Energy Policy, *36* (12), 2008, pp. 4584–4589. https://doi.org/10.1016/j.enpol.2008.09.007.
8. Khan, I., Hou, F., Irfan, M., Zakari, A., Le, H. P., *Does energy trilemma a driver of economic growth? The roles of energy use, population growth, and financial development.* Renewable and Sustainable Energy Reviews, *146*, February 2021, https://doi.org/10.1016/j.rser.2021.111157.
9. Kouloukoui, D., Marinho, M. M. de O., Gomes, S. M. da S., Kiperstok, A., Torres, E. A., *Corporate climate risk management and the implementation of climate projects by the world's largest emitters*. Journal of Cleaner Production, *238*, 2019. https://doi.org/10.1016/j.jclepro.2019.117935.

10. Krawczak, E., *Dynamiczny rozwój instalacji fotowoltaicznych w Polsce*. [in]: R. Dzierżak, Ż. M. Grądz (Ed.), Prace doktorantów Politechniki Lubelskiej – 2020, 2020, pp. 7–17. Wydawnictwo Politechniki Lubelskiej.
11. Krupiński, S., Kuszewski, P., Paska, J., *Efektywność finansowa bloku węglowego klasy 1000 MW na przykładzie elektrowni Ostrołęka C*. Przeglad Elektrotechniczny, *95*(10), 2019, pp. 72–77. https://doi.org/10.15199/48.2019.10.15.
12. Najwyższa Izba Kontroli. *Inwestycje w moce wytwórcze energii elektrycznej w latach 2012-2018 - informacje o wynikach kontroli*, 2019. https://www.nik.gov.pl/plik/id,21644,vp,24294.pdf.
13. Naworyta, W., Zajączkowski, M., *Ocena możliwości eksploatacji zasobów złoża węgla brunatnego Bełchatów - Pole Kamieńsk*. Biuletyn - Panstwowego Instytutu Geologicznego, *472*, 2018, pp. 93–104. https://doi.org/10.5604/01.3001.0012.7114.
14. Ślęzak, K., *Rola operatora systemu przesyłowego w zapewnieniu krajowego bezpieczeństwa dostaw energii energetycznej w polskim prawie w obliczu zagrożenia*. Acta Scientifica Academiae Ostroviensis. Sectio A, Nauki Humanistyczne, Społeczne i Techniczne, *7*(1), 2016, pp. 414–427.
15. Spanjer, A., *Russian gas price reform and the EU-Russia gas relationship: Incentives, consequences and European security of supply*. Energy Policy, *35*(5), 2007, pp. 2889–2898. https://doi.org/10.1016/j.enpol.2006.10.019.
16. Von Hippel, D., Suzuki, T., Williams, J. H., Savage, T., Hayes, P., *Energy security and sustainability in Northeast Asia*. Energy Policy, *39* (11), 2011, pp. 6719–6730. https://doi.org/10.1016/j.enpol.2009.07.001.
17. Von Homeyer, I., Oberthür, S., Dupont, C., *Implementing the European Green Deal during the Evolving Energy Crisis*. Journal of Common Market Studies, 2022, pp. 1–12. https://doi.org/10.1111/jcms.13397.
18. Wang, Y., Bouri, E., Fareed, Z., Dai, Y. *Geopolitical risk and the systemic risk in the commodity markets under the war in Ukraine*. Finance Research Letters, *49* (June), 2022. https://doi.org/10.1016/j.frl.2022.103066.
19. Winzer, C., *Conceptualizing energy security*. Energy Policy, 46, 2012, pp. 36–48. https://doi.org/10.1016/j.enpol.2012.02.067.

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The DSO network development with the increase of distributed energy resources number and their capacity

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Abstract: Energy transition is a continuous process, involving all elements of the energy sector. For Distribution System Operators the ability to cope with new challenges resulting from the energy transition (i.a. digitalisation, EV, PV, energy storage, distributed energy, energy communities, microgrids, energy sharing, geopolitical changes) is one of the most significant elements of this process. To meet the challenges of the transformation, it is necessary to develop new solutions adapted to the needs of all market participants, redefine priorities, establish new rules of cooperation in order to ensure security and stability of the power system at economically justified costs. The article describes network flexibility as a tool allowing DSOs meet needs of energy sector transformation process based on *flow-circle concept.* The idea of it is to use continuous observation tools (captured in the observability of the network), making predictions over different time horizons, across different areas, with varying observation granularity. The result of the calculations allows to identify constraints in the system, e.g., overloads, risk of failure or shortage of power or energy, and to select countermeasures commensurate with the threat and available at the selected time horizon.
Key words: DSO, network management, flexibility, local balancing, flow-circle concept

Introduction

The main objective of the energy market transformation is to accelerate the decarbonisation process of the European economy. One of the main factors contributing to the acceleration of this process in the energy sector is the decentralisation of generation through activation of consumers. Local energy balancing areas are also gaining in importance, especially in the context of their pursuit of self-sufficiency. At the same time, the increasing availability of new technologies and market incentives makes it possible to further accelerate these processes. This trend creates several opportunities for market participants, such as energy contracts based on dynamic electricity prices, providing demand response services both individually and through aggregation, production, and sale of electricity by the customer without the need of having a license, or creating self-balancing areas based on stakeholder cooperation. In addition, the changing geopolitical environment, which brings a new dimension to the concept of power system stability, creates the need to accelerate the energy transformation towards gaining independence from external sources of energy, which in turn means that rapid development of energy sources at the local level should be expected.

The article describes network flexibility as a tool allowing DSOs meet needs of energy sector transformation process based on *flow-circle concept.* The concept has been developed based on the authors' years of experience and operational knowledge of DSOs. The research method used in the article is an analysis of the experience of DSOs operation supplemented by knowledge available in selected literature on the subject. On the basis of the analysis made and the authors' own observations of the direction of the sector transformation, the general approach of DSOs to grid management taking into account the rapid development of distributed energy sources has been characterized.

Determinants of DSO operations with respect to trends resulting from energy market transformation

The main challenges for distribution system operators (DSOs) resulting from changes in the market environment can be grouped into six areas:

- Grid maintenance and development,
- Data management,
- Local balancing,
- DSO-TSO coordination in relation to services procurement,
- Electromobility and energy storage development,
- New services for customers.

One of the changes will consist in the development of power system at local energy balancing areas as a consequence of changes in the direction of energy flows from distributed generation[1] connected to the LV grid towards higher voltages. Local initiatives with the ability to maintain partial energy independence will be developed. At the same time DSOs will identify and manage the possibilities of flexibility resources connected to the grids (DSR, energy storage, EVs). The rapid development of distributed energy resources (DER), together with new technologies, including IT/ICT, will enable new solutions for DSOs to support network management (e.g., flexibility services platform, flexibility sources register).

Such a wide range of many variable factors in the DSO environment has a significant impact on the network infrastructure management methods related to network maintenance and development. Grid observability, the ability to access and process current information about the status of network elements, its topology and flows, are all becoming highly important. The increasing number of distributed generation will result in difficulties in forecasting bi-directional energy flows in the grid. This implies the need for DSOs to adapt the currently functioning technical and organisational solutions to new challenges. The future role of the grid operator will be to manage the grid in such a way as to enable the connected entities to use the power system (to withdraw or return energy and to ensure security of supply) while minimizing constraints, e.g., related to the capacity of grid components or the quality of energy itself (such as voltage level).

The power system consists of interdependent and closely interconnected elements, therefore, the coordination of services between key network operators (TSO and DSO) is of crucial importance. In that regard it is necessary to develop a new understanding of this cooperation in the context of balancing the operators' needs considering the role of equal footing. The detailed definition and appropriate (active) management of flexibility resources will provide DSOs with support for the National Power System and the ability to counteract network congestion or system failures when necessary. The use of flexibility resources by DSOs shall also allow for greater influence on the shaping of peak demand for energy and planning of the transmission grid development. At the operational level of DSOs, network flexibility is an issue of high

[1] Directive UE 2019/944, art 2 (32) ‘distributed generation’ means generating installations connected to the distribution system.

importance for the future operations of the DSO area, due to the upcoming acceleration of decarbonisation indicated in the REPowerUE[2]. This will require a new approach to network management in which an important role will be assigned to the network at the LV level, saturated with DER installations and characterised by a high variability of customer behaviour.

The new market conditions and the new role of DSOs also translate into changes in customer service. This will particularly concern the area of customer relationship management, both in the field of concession business and product development, as well as sales and services related to new, non-tariff products. This means that DSOs should have an efficient service and sales mechanism with directional competences and appropriate tools to effectively carry out all the necessary activities (IT, procedures, teams). It is important for DSOs to ensure that consumers can benefit from the offers available on the energy market without unnecessary barriers and at the same time to guarantee the possibility of providing additional services to other market players. The introduction of appropriate support in the form of regulation and the availability of technologies that provide financial benefits is key to achieving consumer involvement.

The amount of data in the distribution network is growing and will continue to grow; therefore, it is important to implement an appropriate model for managing such a large amount of data, for its collection, processing and sharing. Due to decentralisation processes and the use of data in the day-to-day operation of the DSO network and in planning its development, institutional supervision over information and data flow should be built based on "regional" entities, such as distribution companies which receive more than 90% of metering data. This data is collected, stored, and managed for the purposes of planning, operation, and management of the grid, and will ensure proper use of available flexibility resources in the future.

In terms of flexibility sources, the issue of EVs and energy storage needs more attention due to its dynamics of development. Energy storage facilities available to DSOs will be significant, both in the operational area and in development planning. Also, the development of electromobility means for DSOs the need to take additional measures related to adapting the network to support charging processes and support for the construction of charging points. In this context DSOs should prepare for the challenges ahead, as well as take advantage of the opportunities that arise (methodology for low-cost locating of charging points, feeding energy back into the grid from storage facilities, and tools for influencing charging periods and possible feeding of energy back into the grid by EVs) [3].

Distribution system – general, technical view

Large power distribution systems in Poland are part of the National Power System based on the alternating current (AC) transmission grid owned by the TSO. These systems generally consist of EHV lines and equipment to transmit energy to distribution grids consisting of three voltage levels - high, medium, and low (HV, MV, LV). Distribution grids provide the connected

[2] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, EU Solar Energy Strategy, Brussels, 18.5.2022, COM(2022) 221 final: *As part of the REPowerEU plan, this strategy aims to bring online over 320 GW of solar photovoltaic by 2025 (more than doubling compared to 2020) and almost 600 GW by 2030. These frontloaded additional capacities displace the consumption of 9 bcm of natural gas annually by 2027. Solar photovoltaics (PV) and solar thermal technologies can be rolled-out rapidly and reward citizens and businesses with benefits for the climate and their purses. To reach the EU 2030 targets, energy demand covered by solar heat and geothermal should at least triple*.

[3] According to EC announcements, the production of conventional petrol and diesel cars will be banned by 2035.

customers with energy of a specified quality and technical parameters. In addition, the distribution grids enable the reception and distribution of energy generated from local resources. A significant part of the grid was designed to distribute energy in the central source - energy reception model, which determines it to be a unidirectional network. The connection of distributed resources causes flows in the network that are inconsistent with this general principle, disrupting network operation and leading to a number of technical problems. It is important for DSOs to effectively identify and mitigate these problems, therefore, the network must be observable and controllable at a sufficient level in order to increase its potential for connecting new load and generation installations.

Moreover, the development of high shares of PV and wind installations has an impact on the way the electricity grid is managed. As solar energy is produced in direct current (DC), conversion to alternating current (AC) to feed into the grid and then converting back to DC, e.g., to store energy, leads to energy losses. Such conversion losses are currently growing due to the fact that more devices and systems, such as batteries, heat-pumps, data centres, electric vehicles or appliances, operate in DC. Increasing the use of DC technologies could thus be beneficial to the electricity system[4].

The characteristics of each network area by operating voltage, illustrating the observability of the network and its users are presented below[5].

The distribution network at the HV is controllable and characterised by a high level of observability. Its topology is mapped in the dispatching systems of individual distribution system operators. As regards metering, measurements of the basic values (power, energy, voltages, currents) are taken in practically all network elements (lines, equipment) and the connected consumers and generators are fully metered by means of remotely read meters. Moreover, most of the generation sources have the ability to remotely control active and reactive power, which creates certain opportunities to use their regulation potential (important in the context of flexibility and system services) for network management in the broad sense. The necessity of having network observability at the HV is one of the important elements for the proper determination of the balancing level of individual areas of National Power System through the Balancing Market.

The distribution network at the MV is not entirely observable and controllable, which in its current condition may cause difficulties in its management, among others, due to uneven saturation with remotely controlled switching devices. As regards metering, measurements of the basic values (power, energy, voltages, currents) are taken in some network elements (mainly lines connected directly to primary stations and secondary substations), and the connected consumers as well as producers are fully metered owing to remote access to the data. The number of available metering points varies across the network, which affects the overall assessment of observability. An additional element that influences the level of network observability at the MV is the remote reading of balancing meters installed at secondary substations. Data collected from such meters and reflected in SCADA systems will be an important element of the new

[4] *The European Commision is investigating how low-voltage DC technologies can enhance the clean energy transition. Based on the conclusions drawn from this process, it will engage with European and international standardisation bodies for the establishment of the necessary standards and protocols*. EU Solar Energy Strategy, Brussels, 18.5.2022, COM(2022) 221 final.

[5] Based on own experience and observations.

model of managing network operation with many distributed resources. Generating installations on the MV, mainly due to the nature of primary energy (RES), are controllable to a certain extent, yet mostly unidirectional through power reduction.

The LV grid has the lowest level of observability and controllability, mainly due to the lack of metering of both network elements and consumers with remote access to meter reading. The situation will be improved significantly after the implementation of a national program of smart meters installation. Nevertheless, the metering of all customers will necessitate the implementation of systems and algorithms that will be able to manage the large amount of metering data for its effective use for the purposes of network observability and management processes.

Bearing in mind the information outlined above, it may be concluded that the distribution grids, depending on voltage level, are prepared to a different extent for the changes related to energy transformation (transition from central generation to distributed generation and customer activation). For high-voltage grids, the situation seems to be under control. However, problems arise at other voltage levels where the existing grid will be challenged to serve new types of entities (distributed energy resources, prosumers, local energy communities, virtual prosumers, EV chargers) connected to the existing grid infrastructure.

Currently, distributed generation forecasted to be connected faces a large number of connection conditions refusals. In the future, if the rules for the connection of distributed resources are not changed, it will be virtually impossible to make new connections without significant development of the distribution network and its connections to the transmission grid. At present the most common reasons for refusal are the voltage criterion and the criterion of power reserve in the primary station node. The remaining criteria are currently of much lesser importance (overload, short-circuit and quality criteria). Furthermore, it has to be underlined that at the LV, RES installations are not obliged to apply for connection conditions, which means that there is no possibility for DSOs to analyse whether the number of connected resources in a given area (circuit) guarantees their stable operation while ensuring network operation security in this area.

Connection of distributed, intermittent, and unpredictable energy resources poses challenges for DSOs in terms of performing basic operator's duties, i.e., network management and ensuring its stability, but at the same time provides opportunities to use these resources in DSO network management and development planning. Therefore, it seems to be necessary to develop:

- additional, standardised IT tools to facilitate the forecasting of distributed generation resources (including consumer behaviour),
- regulatory-supported products that will ensure the use of the available potential of active customers, and
- competences and organisational structures facilitating efficient use of potential of connected resources (including development planning).

Assessment of the quality and stability of electricity supply carried out by DSOs currently considers the objectives and tasks resulting from the quality regulation defined by the NRA[6].

[6] Regulacja jakościowa w latach 2018-2025 dla Operatorów Systemów Dystrybucyjnych; URE, Warszawa wrzesień 2018

In the future, the following measures (as indicated in the *Energy Policy of Poland until 2040 [PEP2040]*) should be implemented to improve supply stability[7]:

- the indicators of the quality of energy supply, i.e., the duration and frequency of interruptions in the NPS, should be constantly improved - in line with the targets set by the NRA,
- due to the age of the infrastructure (most of which is more than 25 years old), DSOs are obliged to reconstruct the network - the reconstruction rate should be at least 1.5% p.a. until the average age of the infrastructure falls below 25 years,
- the reconstruction of the LV lines should be done with the use of insulated cables or wires,
- the change of the overhead LV lines to underground (cabled) ones and increase in the number of medium voltage line switches equipped with remote control systems. For this purpose, a national plan for the MV cabling by 2040 was developed in 2021.

Ensuring security of electricity supply also requires readiness to act in emergency situations in the power system. For this purpose, it is envisaged to increase emergency response capabilities by, among others:

- increasing the use of control and automatic reconfiguration elements at the MV,
- expansion of IT systems and MV and LV line equipment with network operation diagnostics and analysis of grid operation,
- implementation of a digital grid communication system,
- construction of an intelligent energy infrastructure (smart grid) enabling the optimal use and integration of the distribution system, including the development of algorithms to create new optimal configurations.

The scale of challenges associated with distributed resources faced by grid operators

An important direction in the structure of distribution system users is the progressive replacement of stable and inflexible conventional generation with distributed generation - intermittent and unpredictable in production due to the existing technologies, mainly PV. On top of that, since consumers are looking for cost-effective ways to meet their own energy and transportation needs - the expansive development of *prosumerism* and ecological transport should be underlined as well. Both these directions lead to an increase in the number of micro-installations and electric vehicles requiring adequate charging infrastructure, both individual and public.

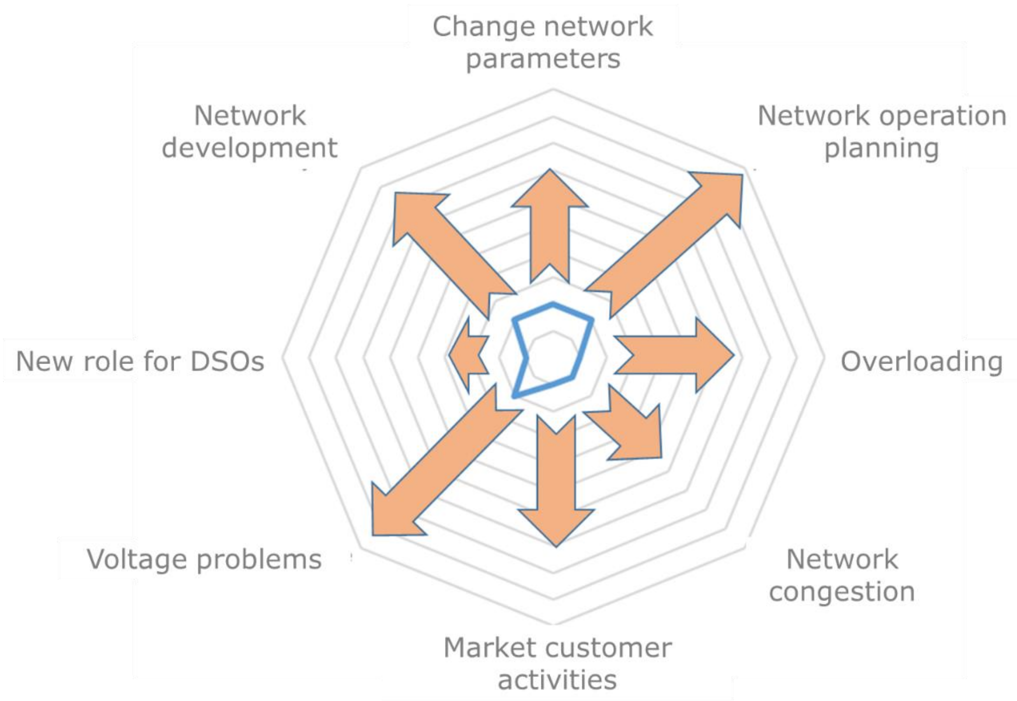
The forecasted increase of the installed capacity requires an appropriate operator approach, both in terms of technical feasibility of connection, which is realised on the grounds of development plan, and in terms of network flow management, which is realised by dispatching centers. It is of utmost importance to utilise the potential of the network users so that their energy resources could be appropriately used by the operator and support the elimination of congestion in the distribution system.

Every increase in the power of distributed generation is accompanied by a commensurate increase in network problems, whose elimination or reduction to acceptable levels should be

[7] Polityka energetyczna Polski do 2040 r.[PEP2040], Ministerstwo Klimatu i środowiska, 2021, access: 10.05.2022, https://www.gov.pl/web/klimat/polityka-energetyczna-polski

the essence of the model of operation and development of the distribution network comprising distributed energy resources.

Fig. 1. A conventional scale of DSOs challenges associated with distributed resources. The arrow reflects the strength of the impact on the category.



Own study

The expected increase in the number and capacity of distributed resources, territorial and grid dispersion, as well as customer market activity, means that the operator must be able to translate future events into anticipated problems that may arise as a result.

Operator challenges are expected to be materialised in the following areas:

- technical - in terms of changes in network parameters, voltage problems and overloads,
- network management - traffic planning, network congestion,
- network development in terms of connecting new generation capacities,
- customer market activities,
- the role of the TSO as regards the use of resources connected to the distribution network for the purpose of transmission network balancing.

Flexibility as an answer to challenges in DSOs network operation

Saturation of the distribution network with distributed energy resources means that DSOs must accept higher variability of energy generation, which in many cases is linked with weather conditions. This results in a shift from the *generation follows demand* principle to the *demand follows generation* principle. Most of the renewable generation is intermittent and not controllable. The more generation of this type will be connected to the grid, the harder it will be to keep balance with demand by dispatchable generation. The existing grids are designed to transport and distribute energy from central power plants to local customers. Changing this principle by adding local generation and storage systems will require a total review of their architecture[8]. On the other hand, grid users increasingly want to actively participate in the energy market by adapting their energy potential (generation, load, storage) to the current market situation. In other words, they respond to market signals, e.g., energy prices, by changing their typical behaviour - optimizing energy consumption, producing energy themselves, transforming themselves into active consumers[9]. This unique ability of the power system to respond to most of changes in demand and supply, caused by the dispersion of many types of generation resources and/or activating users on the energy market, is called *flexibility of energy system*.

Network flexibility should be considered in two dimensions[10]:

- technical (operational), allowing connected entities to exchange energy with the grid according to their needs and taking advantage of the natural ability of network elements to carry varying loads over time, and
- market-based, understood as the modification of production and consumption patterns at an individual or aggregated level, in response to an external signal (price signal / grid tariff / activation / congestion) to provide a service within the power system or to maintain stable network operation.

In view of the above, a fundamental distinction must be made between the market flexibility offered by market participants and the technical (operational) flexibility used by network operators. In the context of market participants, flexibility always refers to activities performed under the influence of external, mainly commercial, incentives. In the case of DSOs, it results from the obligation to ensure effective planning and efficient operation of the network. This type of flexibility is related to quality and security of supply. This flexibility can help system operators to maintain the expected level of network performance when the network is threatened by congestions.

For distribution system operators, changes in the energy market that directly affect network user activity pose several technical challenges. Handling all the behaviours of system users is a *sine qua non* of the grid flexibility issue and requires substantial investments by DSOs at various levels.

The occurrence of congestion in the distribution system depends on the confluence of many components: capacity and generation demand in individual nodes of the network area, topology of the network area and the topology of the superior network (TSO), conditions of dynamic network loading elements as derivatives of atmospheric conditions. Where technical flexibility is insufficient to achieve the intended results, i.e., to prevent congestion in the system, increase security of supply and improve the quality of distribution services provision in the most efficient way, the DSO may procure market flexibility from system users in the form of a service/product.

These services are referred to as *flexibility services*. Using flexibility services to maintain voltage and manage network congestion can provide benefits such as:

[8] Vison Paper - "The Journey to 'Green' Energy or 'a Quest for Flexibility'", tech.rep. Eandis 2015, https://www.edsoforsmartgrids.eu/a-journey-to-green-energy-2/, access: 10.05.2022

[9] Mataczyńska E. & Kucharska A., *Klastry Energii. Regulacje, teoria i praktyka*, IPE, 2020, pp.46-85, SBN: 978-83-946727-7-5

[10] Kara G, Tomasgard A., Farahmand H., Characterizing flexibility in power markets and systems, Utilities Policy, Volume 75, April 2022,101349, ISSN 0957-1787, access: 15.05.2022 https://www.sciencedirect.com/science/article/pii/S0957178722000145

- optimised investment in the distribution network,
- reduced technical losses,
- increased connectivity of unstable sources.

Perceptions of flexibility solely in economic terms (among others, through terminology such as service, service pricing, service provider, product) somewhat misses the point of the energy power system as a frequency-synchronised and balanced mechanism subject to *de facto* regulatory actions, which are called services more for the sake of better understanding. They should only be embedded in the process of day-to-day management and planning of network development.

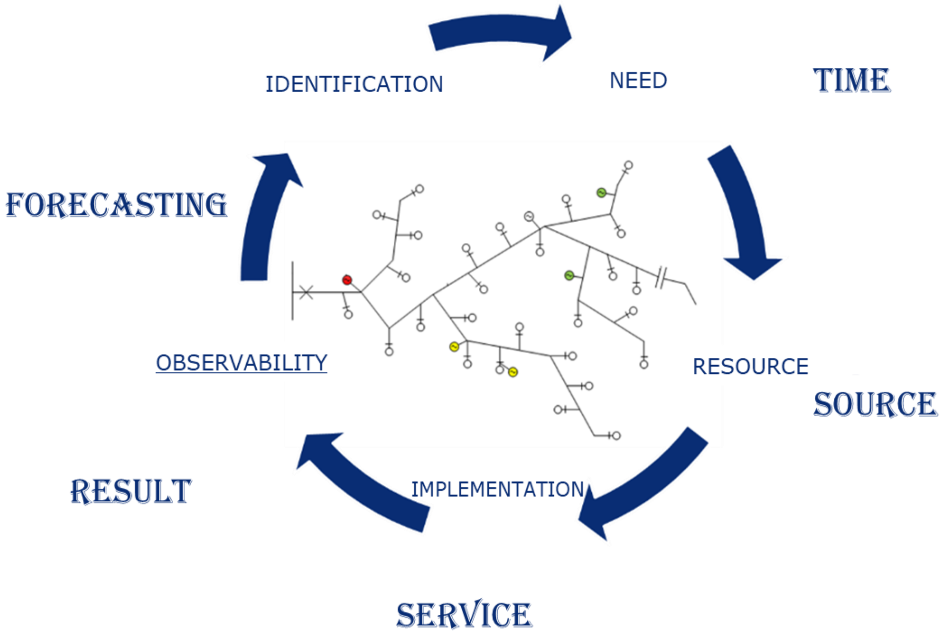
Apart from the availability of flexibility resources (networks and services), procedures for the connection planning of flexibility resources as well as IT procedures and tools that enable network observability and allow flexibility management constitute a prerequisite for the improvement of system flexibility.

The above implies a general approach of DSOs to the issue of flexibility. Thus:

- the operator must know the flexibility framework of its own system, it is necessary to have a proper representation of the network both from the topology side and from the energy flows and available power in the system,
- flexibility can be a tool in network congestion management, such an approach being derived from the possibilities offered by system users' willingness to manage their energy potential, especially if an appropriate economic incentive exists,
- congestion management must be considered from the point of view of both the current operation of the network and its development plans,
- day-to-day congestion management implies the ability of the operator to predict, over fixed time horizons, the behaviour of system users. This requires basic data on the state of network operation as well as information on user activity in the market - either directly or through third parties,
- in network development planning, it should be assumed that appropriate motivation and cooperation with system users may be an alternative to small range of network development. An expected level of energy consumption can be achieved through appropriate power differentiation over time,
- in the operational planning for day-to-day congestion management, existing contracts with other entities, e.g., aggregators, should be taken into account,
- all entities interested in using system users' energy potential may be the source of signals (incentives) addressed to the users ,
- the role of DSOs is also the proper grading (queuing) of access to the energy potential of users connected to their network (the rules of cooperation with the TSO with respect to access to flexibility sources should be viewed as important),
- the whole issue must be managed by a specialised IT system.

In summary, the use of flexibility in the operation and management of the distribution network and system can be captured in the form of the following diagram and the author's *flow-circle concept*:

Fig. 2. The flow-circle concept of network management using flexibility.



The concept of *flow-circle* type runs in the closed system shown in the diagram above and should be applied when using non-technical network management tools[11]. The idea is to use continuous observation tools (captured in the observability of the network), making predictions over different time horizons, across different areas, with varying observation granularity. Modern prediction tools are included in system state estimators. The result of the calculations allows to identify constraints in the system, e.g., overloads, risk of failure or shortage of power or energy, and to select countermeasures commensurate with the threat and available at the selected time horizon[12]. Each use of the available resource can be treated as the performance of a service (own or external) and be monitored and evaluated accordingly.

A grid development perspective that considers the increase in the number of DER and their capacity

According to the latest data, the number of micro-installations connected to DSOs network in Poland has increased 5 times in the last two years, with the number of such installations exceeding 1,006 thousand units and 7,336 MW of installed capacity[13]. Such a large number of installations is a challenge for DSOs, both on the technical and organisational side. Therefore, the impact of distributed resources on the distribution grid should be considered in terms of opportunities as well as threats to the grid.

[11] Miletić M., *Energy Flows and Energy Cycle From Resources to End Users*, In book: *Energy – Resources and Building performance*, Publisher: NL: TU Delft Open, March 2021, (pp.20-42)
[12] Mukherjee, D., Chakraborty, S. & Ghosh, S. *Power system state forecasting using machine learning techniques*. Electr Eng 104, 283–305 (2022).
[13] PTPIREE, Mikroinstalacje w Polsce, stan na dzień 31 marca 2022r, access: 13.04.2022 http://www.ptpiree.pl/energetyka-w-polsce/energetyka-w-liczbach/mikroinstalacje-w-polsce

The undeniable advantage of distributed generation is that it produces energy close to where it is consumed, which significantly reduces the need for long-distance energy transmission (typical transmission involves transporting energy mainly from conventional sources), reducing energy losses in the grid and the load on grid components. Proper stabilisation of source operation with energy storage or a mix of generation technologies strengthens the positive impact of distributed sources on the DSO grid. In small grid areas, sources are generally expected to meet the energy demand of customers in that area, contributing to the creation of *energy balanced areas*, usually in the long term. Based on the scenario of national energy system development and changes in the market environment presented in PEP 2040, three main groups of changes that may significantly affect the distribution network can be identified[14]:

(G1) Renewable Energy Sources (RES)

- Photovoltaics - in 2030 the installed capacity may reach about 5-7 GW in total in micro and large installations, and by 2040 between 10 and 16 GW.
- Onshore wind farms - expected to develop much less dynamically than in recent years (in 2021 installed capacity of about 7.06 GW).
- Energy from biogas and biomass - electricity production in co-generation is expected. One of the advantages of the sources is defined as the possibility to use the sources for regulation purposes, which will contribute to increased flexibility of operation.
- Hydropower plants - activities aimed at the use of hydropower plants potential are envisaged through the development of water resources management, enhancing the role of retention or revitalisation of water dams which will contribute to increasing the number of water thresholds. The regulatory potential of hydropower was indicated as an additional asset.

In the longer term, the connection of an energy source with high variability and low predictability of power supplied to the grid should be associated with the obligation to ensure balancing in periods when the RES does not supply electricity to the grid (through energy storage)[15].

(G2) Development of combined heat and power[16]:

- Systemic - to improve energy efficiency, development of co-generation and trigeneration;
- Individual - anticipated low-carbon direction of transformation of individual sources (heat pumps, electric heating). Increase in the use of heat pumps is considered in government documents, PSE SA (Polish Transmission System Operator – TSO) and expert analyses. Forecasts of the Polish Organisation for Heat Pump Technology Development (PORT PC) indicate a significant increase in installed capacity in single-family buildings by 2030. Depending on the scenario, peak electric power may reach 2.5 to 5.4 GW.

[14] Polityka energetyczna Polski do 2040 r.[PEP2040], Ministerstwo Klimatu i środowiska, 2021, access: 13.04.2022, https://www.gov.pl/web/klimat/polityka-energetyczna-polski

[15] Pooja Y., Raghuraj S.,Divakar D., *Distributed systems, Formal methods, Load balancing, Proof obligations, Rodin, Verification*, Journal of Scientific & Industrial Research, Vol 80, No 12, December 2021, pp. 1078-1090

[16] Polityka energetyczna Polski do 2040 r.[PEP2040], Ministerstwo Klimatu i środowiska, 2021, access: 13.04.2022, https://www.gov.pl/web/klimat/polityka-energetyczna-polski

(G3) Energy communities and prosumers[17]

Enabling consumers to take an active role - using the possibilities of energy communities: prosumers of energy, energy clusters, cooperatives. Two groups are expected to develop:[18]

- Active consumers - individual entities, including prosumers, who, in addition to generating energy for their own needs, supply excess power to the grid and, if necessary, reduce electricity consumption by offering services to the system operator. It is estimated that the number of prosumers in Poland will have exceeded 1 million by 2030.
- Energy communities - collective entities (e.g., energy clusters, energy cooperatives, or other entities) that organize themselves to generate electricity for their own needs and other needs (e.g., storage, resale, etc.). By 2030, 300 energy communities were indicated as a target.

With the increase in the number of DER in the distribution network, the following phenomena are more frequently observed[19] :

- problems with maintaining power quality indicators in the network, mainly voltage level,
- overloading of selected network sections and elements (e.g., secondary substation transformers) due to excessive local generation,
- export of energy surplus to other network areas or voltage levels because of mismatched production and consumption or excessive concentration of sources in each area,
- the need to maintain power reserves in the system for sources whose operation profile is dependent on weather conditions (unstable sources, i.e. solar or wind).

Consequently, without the development of new rules for the operation of distribution systems, the scale of the predominantly negative phenomena will increase, posing a threat to the continuity of supply and security of the distribution system[20].

Summary

DER, being connected to DSO grid, have a significant energy potential, which in turn has an impact on the operation of the distribution grid - it can either improve or disrupt its operation. This potential, if properly exploited by the operator, can support the operation of the power system, i.e., directly the distribution grid and indirectly the National Power System.

It is important for the DSO to carry out analyses of the possibility of connecting the DER to the DSO network, the potential held and the possible interactions supporting the operation of the power system. Such analyses should be conducted at least with regard to considering the needs of the grid when selecting a location for new sources, in order to support the grid and the power system in the most effective way. This approach will unlock DER resources as providers of market-based flexibility services. The operator should also develop rules and procedures related to TSO/DSO/market cooperation based on non-discriminatory principles to reduce all

[17] *Ibidem.*
[18] *Ibidem*
[19] Pijarski P. Analysis of Voltage Conditions in Low Voltage Networks Highly Saturated with Photovoltaic Micro Installations, Acta Energetica 3/36 (2018), pp. 4–9
[20] Khezri R., Mahmoudi A., Aki H., *Optimal planning of solar photovoltaic and battery storage systems for grid-connected residential sector: Review, challenges and new perspectives*, Renewable and Sustainable Energy Reviews, Volume 153, January 2022, 111763, ISSN 1364-0321, access: 15.05.2022, https://www.sciencedirect.com/science/article/pii/S1364032121010339

barriers. Ultimately, the operator should design an appropriate local flexibility market to solve congestion problems in the distribution grid as well as to provide non-frequency ancillary services to the power system.

These recommendations are part of the new energy market model, shaped as part of the ongoing energy transition towards distributed generation.

Bibliography

1. Kara G, Tomasgard A., Farahmand H., *Characterizing flexibility in power markets and systems*, Utilities Policy, Volume 75, April 2022,101349, ISSN 0957-1787, dostęp: 15.05.2022, https://www.sciencedirect.com/science/article/pii/S0957178722000145.
2. Khezri R., Mahmoudi A., Aki H., *Optimal planning of solar photovoltaic and battery storage systems for grid-connected residential sector: Review, challenges and new perspectives*, Renewable and Sustainable Energy Reviews, Volume 153, January 2022, 111763, ISSN 1364-0321, access: 15.05.2022.
3. https://www.sciencedirect.com/science/article/pii/S1364032121010339.
4. Mataczyńska, E., & Kucharska, A. (2020). *Klastry energii. Regulacje, teoria i praktyka* (Energy Clusters. Regulation, theory and practice). Intytut Polityki Energetycznej im. I. Łukasiewicza (I. Łukasiewicz Institute for Energy Policy), p.46-85.
5. Miletić M., *Energy Flows and Energy Cycle From Resources to End Users*, In book: *Energy – Resources and Building performance*, Publisher: NL: TU Delft Open, March 2021, (pp.20-42).
6. Mukherjee, D., Chakraborty, S. & Ghosh, S. *Power system state forecasting using machine learning techniques*. Electr Eng 104, 283–305 (2022).
7. Pooja Y., Raghuraj S.,Divakar D., *Distributed systems, Formal methods, Load balancing, Proof obligations, Rodin, Verification, Journal of Scientific & Industrial Research*, Vol 80, No 12, December 2021, pp. 1078-1090.
8. *PEP 2040 – Polityka Energetyczna Polski do 2040*. Obwieszczenie Ministra Klimatu i Środowiska z dnia 2 marca 2021 r. w sprawie polityki energetycznej państwa do 2040 r. Monitor Polski 2021 r. poz. 264.
9. Pijarski P. *Analysis of Voltage Conditions in Low Voltage Networks Highly Saturated with Photovoltaic Micro Installations*, Acta Energetica 3/36 (2018) | 4–9.
10. PTPIREE, *Mikroinstalacje w Polsce*, stan na dzień 31 marca 2022r. http://www.ptpiree.pl/energetyka-w-polsce/energetyka-w-liczbach/mikroinstalacje-w-polsce.
11. Sikora M., *Outline of using the Energy Cluster potential for the Distribution System Operator*, ENERGY POLICY STUDIES, No. 2 (8) 2021.
12. Vison Paper - *The Journey to 'Green' Energy or 'a Quest for Flexibility*, tech.rep. Eandis 2015, https://www.edsoforsmartgrids.eu/a-journey-to-green-energy-2/.

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The Impact of the Russian-Ukrainian War on the European Union's Energy Security

Ewelina Sadowska

Abstract: The conflict between Ukraine and the Russian Federation has far-reaching consequences on international relations in general and the economies of neighbouring countries. This includes also a significant impact on the energy sector. The Russian invasion of Ukraine has disrupted global markets. The aim of the article is to analyse the impact of the Russian-Ukrainian war on the European Union's energy security, examine the measures taken by the EU to secure its gas supply, and suggest actions to be taken to enhance the security of supplies.
Key words: energy security, security of supply, European Union's energy policy, Russian-Ukrainian war

1. Introduction

Energy is essential to the proper functioning of today's countries, in every aspect of this functioning — from the individual dimension to the economic and political dimensions. In the event of an energy supply disruption, the entire economy is at the risk of being paralysed and citizens are deprived of access to basic amenities such as heating and electricity. Given the above, the energy sector has been named one of strategic importance to the functioning of a country. The goal of any country's energy policy is to make sure it has access to supplies of energy — referred to as energy security. It is quite difficult to adopting one general definition of energy security due to the interdisciplinary nature of the concept [Ruszel and Podmiotko, 2019]. In addition, the concept of security — including energy security — is also subjective, which further complicates the establishment a universal definition thereof. It also makes it hard for all entities concerned to view it according to the same criteria because the perception and understanding of energy security depends on the view and perception of reality, and no objective factors can fully determine it [Przybojewska, 2017]. Nevertheless, it may be reasonable to quote the most common definitions of energy security. The International Energy Agency (IEA) defines energy security as uninterrupted access to energy, but also securing energy supplies at an affordable price [IEA, 2022]. On the other hand, in the European Union, energy security is considered as a state's ability to guarantee a steady, uninterrupted supply of energy at a price that can be paid while preserving the natural environment [Trubalska, 2017].

Kamila Pronińska argues that energy security threats can be divided according to the origin of the source of the threat. This includes external threats — i.e. all threats that lead to the disruption of supplies to a state or to world markets — and internal threats — i.e. for example, faulty energy infrastructure of a given state [Pronińska, 2012]. One of the biggest external threats to the energy security of countries that are importers of energy is the withholding of supplies of resources. Such a situation can be triggered by political or technical factors. Given that the Russian Federation is a major supplier of resources to the European Union, the current circumstances regarding the Russian-Ukrainian war are a significant threat to EU energy security. Tensions between the Russian Federation and Ukraine have been a fact for many years, as proven by the numerous gas crises of 2006, 2009, and 2014, when Russia suspended its gas supplies, using energy resources as a means to achieve its own political goals, i.e. resorting to so-called energy blackmail [Lis, 2011]. Early 2022 marked the climax of the conflict. On 21 February 2022, after weeks of tensions, the President of the Russian Federation recognised the Donetsk and Luhansk regions as independent states and sent Russian troops to be stationed there. This was followed by an invasion of Ukraine, which began on 24 February [*EU response*…, 2022]. It was met with a harsh response from many countries and international organizations. It was also condemned by the European Union. The conflict between Ukraine and the Russian Federation has far-reaching consequences on international relations in general and the economies of neighbouring countries. This includes also a significant impact on the energy sector. The Russian invasion of Ukraine has disrupted global markets. Global fuel prices have risen sharply since the official outbreak of the conflict. This is of particular importance for the economies of EU countries. The fact that the European Union imported about 155 billion cubic metres of gas from the Russian Federation in 2021 (which is about 40% of its total imports) makes the latter number one third-country gas supplier [van Halm, 2022].

The Russian Federation has never been a reliable supplier of resources to the EU, which the aforementioned gas crises certainly prove. Reducing natural gas supplies is a kind of display of strength, aiming to emphasise Russia's dominance in the energy sector, which fits in with the underlying ideas of the school of realism [Ruszel, 2015]. Yet, the effect was quite different. After the outbreak of war with Ukraine, the Russian Federation lost the remnants of its credibility in the eyes of EU member states. The sanctions imposed by the EU made the Russian Federation suspend its supplies to some member states. This is a significant problem for them in light of the upcoming winter of 2022/2023. Therefore, at the moment, the European Union spares no effort to secure the supply of gas resources and increase the sourcing of gas from other suppliers.

The purpose of this article is to analyse the impact of the Russian-Ukrainian war on the European Union's energy security, examine the measures taken by the EU to secure its gas supply, and suggest actions to be taken to enhance the security of supplies.

The thesis of the article is that the Russian-Ukrainian war has had both a negative and a positive impact on the energy sector in the EU. Despite triggering a massive energy crisis, it has helped accelerate some of the processes and decisions relevant to strengthening the union's energy security.

This article has made use of the following research methods: source analysis method, content analysis, and normative method.

2. Energy sanctions imposed by the EU on the Russian Federation and their implications

The European Union and other countries have strongly condemned the Russian Federation's invasion of Ukraine [Hosoi and Johnson, 2022]. European Union has repeatedly demanded that it withdraw troops from Ukrainian territory and respect the latter's integrity and sovereignty. The EU has imposed 6 packages of sanctions on the Russian Federation since the beginning of the war. The article examines only those sanctions that apply to the energy sector.

The first sanctions that affected the energy sector were imposed in the second package of sanctions, which was announced on 25 February 2022. The European Union imposed an export ban on the sale, supply, transfer, and export of certain goods and technology for oil refining to

Russia and intends to impose restrictions on the provision of services related thereto. This export ban is set to hit the Russian oil sector and prevent Russia from modernising its refineries [*Russian military aggression*…, 2022].

The fourth package of sanctions, which the EU Council announced on 15 March 2022, banned new investments in Russia's energy sector, and imposed extensive export restrictions on equipment, technology, and services for the energy industry.

The fifth package of sanctions, announced on 8 April, banned the purchase, import, and transfer of coal and other solid fossil fuels from Russia. The ban has been in effect since August 2022. An interesting fact to mention here is that the value of coal imported from Russia annually amounted to €8 billion [*EU adopts fifth round*…, 2022].

The sixth package of sanctions, announced on 3 June 2022, includes a ban on imports of crude oil and refined petroleum products from Russia. As a result, EU member states have 6 months to become independent of oil supplies from Russia. In the case of other petroleum-based products, this period is 8 months. However, there are some temporary exceptions to the ban. One such exception applies to oil transported by pipeline to EU countries which are at a particular disadvantage due to their geographic location, and the only option for them is to import oil by pipeline from the Russian Federation for example Hungary [Harrison, 2022]. Such countries depend heavily on supplies from Russia. In addition, Bulgaria was granted a temporary derogation to be able to the import Russian oil transported by sea, and Croatia has been allowed to continue to import vacuum gas oil [*Russian's aggressions*…, 2022].

In addition, the sixth package includes a ban on insuring Russian ships — which will also be implemented within six months. The ban affects oil shipments by sea because uninsured or insufficiently insured ships will not be able to enter any major port or pass through important maritime traffic bottlenecks such as the Bosporus or the Suez Canal. An important thing to add here is that the marine insurance market is dominated by European and American companies [Vakulenko, 2022].

The aforementioned sanctions were intended to significantly hit the Russian Federation and reduce its revenues — which the country uses to finance the war in Ukraine. However, the announcement of an oil import embargo with a postponement of up to six months without immediate action caused oil prices to increase, which in turn resulted in high costs for member states and even higher revenues for the Russian Federation on account of the change [Martin and Mauro, 2022]. Moreover, new regulations that allow free purchases for another six months made Russian oil producers feel confident about the necessary investments. The EU removed a certain degree of uncertainty regarding a possible sudden ban that would leave cargoes stranded halfway [Vakulenko 2022].

As for the gas sector, following the Russian Federation's invasion of Ukraine, the Federal Republic of Germany halted the process of certification of the Nord Stream 2 gas pipeline [Rogozinskaya, 2022]. The decision was prompted by the events in the Donbas region — i.e. Russia's recognition of two independent republics in eastern Ukraine. This means that the decision to launch Nord Stream 2 is purely political at this point. The pipeline is now complete and ready to operate. The only thing necessary to set it in motion, so to speak, and start the transmission of gas from Russia is an official approval from the German administration. From the point of view of the raw materials policy, the halt is a fateful decision. This investment project, whose cost amounts to several billion zlotys at the moment, is currently blocked and does not generate any profit whatsoever. In addition, Nord Stream 2 was to make Russia independent of transit countries and guarantee gas supplies under long-term contracts to Western European countries. At this point, Russia depends on gas supplies through Ukraine under a transit contract that remains valid until 2024. From the EU's point of view, the Nord Stream 2 pipeline would make European countries more dependent on gas supplies from Russia — which goes against the idea of an energy union. Now, the suspension of certification is one of the most painful sanctions of those imposed on the Russian Federation.

In order to make the sanctions more severe, the EU should also extend them to encompass the entire gas and nuclear sectors. The profits made from exporting uranium and fuel elements for nuclear power plants amount to hundreds of millions of euros per year. But it's hard to say whether such sanctions will be implemented because the EU is heavily dependent on both gas and uranium imports. For now, there is no agreement on how to deal with those two sectors. We should notice, though, that the sanctions imposed imply that there is a long-term plan to maintain these measures. The plan is to make the EU, seeking to decarbonise its economy, completely independent of Russian oil and gas, which is in line with its energy and climate policy.

In response to the imposed sanctions, the Russian Federation halted gas supplies to Poland and Bulgaria in April. The reason given was Poland's and Bulgaria's decision not to pay in roubles. Russia wanted to be paid in its national currency due to the adoption of new billing methods imposed on importers by Vladimir Putin's decree of 31 March. The decree imposed an obligation on buyers of Russian gas to set up foreign currency and rouble accounts with Gazprombank and to make payments following a two-step system: first, the due amounts were to be transferred in a given foreign currency, and then converted into roubles [Kardaś, 2022]. Most member states disapproved of the new rules set by the Kremlin. Russia hopes that the suspension of gas supplies will make at least some countries accept the new terms. This strategy aims also to drive a wedge between the member states and destabilise the EU as a whole — with the objective to hamper its decision-making processes.

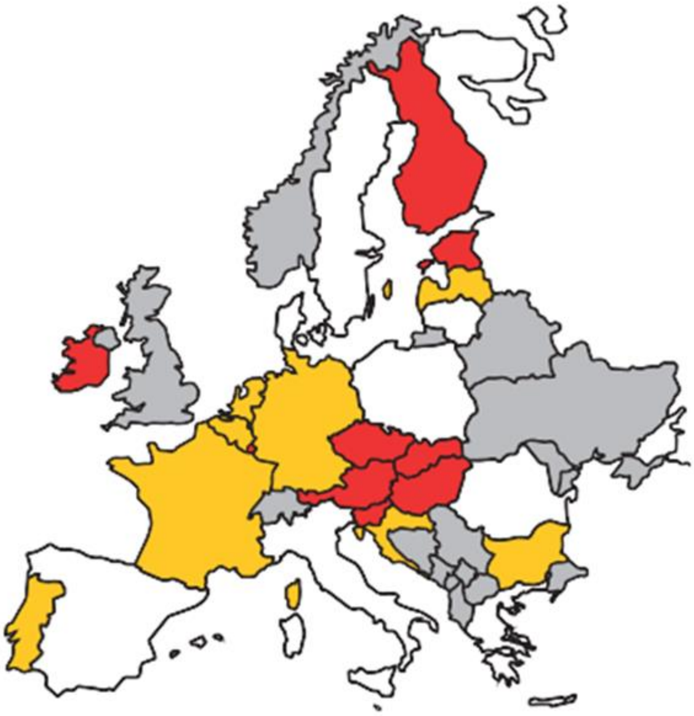
Hungary was particularly ready and willing to pay Russia in roubles. On 31 August, Gazprom announced that it reached an agreement with Hungary to increase the volume of gas supplies by an additional 700 million cubic metres per year. The gas will be supplied via the TurkStream pipeline and received at Hungary's border with Serbia [Sadecki, 2022]. Hungary claims it has no other way to diversify its gas supplies. Yet, it seems that not enough has been done to address the issue. Hungary has an extensive and dense network of gas facilities connected to other countries. It also has access to the Croatian gas terminal (it makes use of only part of its reserved capacity). Moreover, after the opening of the Polish-Slovak interconnector, it has access to the so-called Northern Gate. But Hungary's policy is clearly pro-Russian and aimed at securing supplies from the Russian Federation — unlike in the case of the other member states. Some countries — including Bulgaria, Poland, Denmark, and Finland — rejected the new terms, but there were also countries that agreed to work with Russia on the terms in question. This leads to a serious debate and reveals the lack of unanimity in the approach to the foreign policy pursued by the EU.

Russian Federation regularly reduced gas supplies exported to EU countries in June 2022. The reductions affected mainly the Federal Republic of Germany, Italy, and France, and the supplies were limited on the day before the visit of President Emmanuel Macron, Chancellor

Olaf Scholz, and Prime Minister Mario Draghi to Kyiv [Kardaś, 2022]. Taking the above into account, it is fair to argue that the supply restrictions come in the form of energy blackmail and their aim is limit the support provided by Western countries to Ukraine. Russian hinted already in June that supplies through the Nord Stream 1 pipeline could be even completely halted. Further cuts occurred in the period of 11-21 July due to a technical inspection and from 31 August to 3 September due to repairs taking place at the Portovaya compression station. However, as early as September 2, Gazprom gave notice of a complete halt of supplies via the Nord Stream 1 pipeline. The official reason was that there were some irregularities at the Portovaya compression station. No expected date for the restoration of supply was given. But the storage capacity of Russia's gas storage infrastructure was at 92% [WNP, 2022]. The complete stoppage of gas supplies via a major pipeline dealt a significant blow to the gas market again. The prices soared by about 30% [Twidale and Buli, 2022]. Gas supplies from Russia have also been curtailed in pipelines running through Ukraine.

The map below, drawn up by the Polish Economic Institute, shows which countries are exposed and most vulnerable to the effects of a complete suspension of supplies from the Russian Federation. Red indicates high-risk countries with insufficient storage capacity, limited opportunities for supply diversification, and low storage fill (below 30 percent). Yellow, in turn, indicates medium-risk countries, affected by two of the three risk factors indicated. The map shows that at this point, the EU is not ready to stop the gas supplies from Russia completely. According to a report by the Polish Economic Institute [Lipiński, Maj Miniszewski, 2022], only seven countries in 2019 did not import gas directly from Russia. Yet, the share of Russian gas re-exported by other member states was significant; in the case of e.g. Austria, it was as high as over 60%. This only proves the importance of the Russian Federation in the ecosystem of gas supplies.

Fig. 1. Winter 2022/2023 - Mid-term risk in case of appearance with Russian gas supply.



Lipiński, K., Maj, M., Miniszewski, M. A European Union independent of Russia? Alternative Sources supplies of energy resources, Polish Economic Institute, Warszawa 2022

The sanctions imposed by the EU caused a quick response from the Russian side in the form of multiple interruptions of gas supplies, leading eventually to the suspension of gas supplies to key EU customers. This shows clearly that the Russian Federation is not a reliable supplier of energy resources and does not honour contracts. It treats energy resources as a tool to achieve political goals by resorting to so-called energy blackmail. Due to the fact that the Russian Federation is a key supplier of both gas and oil to the EU, supply disruptions have had a huge impact on energy markets in EU countries. The prices of raw materials and other resources and commodities have skyrocketed, triggering an energy crisis and concern over the security of gas supplies during the coming winter. The European Union has been working for years to guarantee energy security, defining it as uninterrupted availability of energy sources at affordable prices. Taking into account that gas prices in the past amounted to €30/MWh and to around €100/MWh in the first half of 2022, sometimes peaking above €200/MWh [*Short-Term Energy Market*..., 2022], the condition of "affordability" is not fulfilled and therefore it's hard to speak of energy security. The increase in energy prices also impacts the overall economy because energy is a price-affecting factor. Growing energy prices are a major contributor to the widespread inflation and the slowdown in the economic growth in the EU. On the other hand, considering the second aspect of the definition of energy security, i.e. "uninterrupted availability of energy sources", we should realise that this criterion, too, is currently unmet due to interruptions in gas supplies from the Russian Federation. However, if the EU enters into new contracts to supply LNG from the US, Azerbaijan, Australia, Libya or Egypt, and increases pipeline supplies from Norway and Algeria, it will be able to make up the shortfall in gas supplies [Lipiński, Maj, Miniszewski, 2022].

3. Measures taken by the EU to enhance the security of supplies

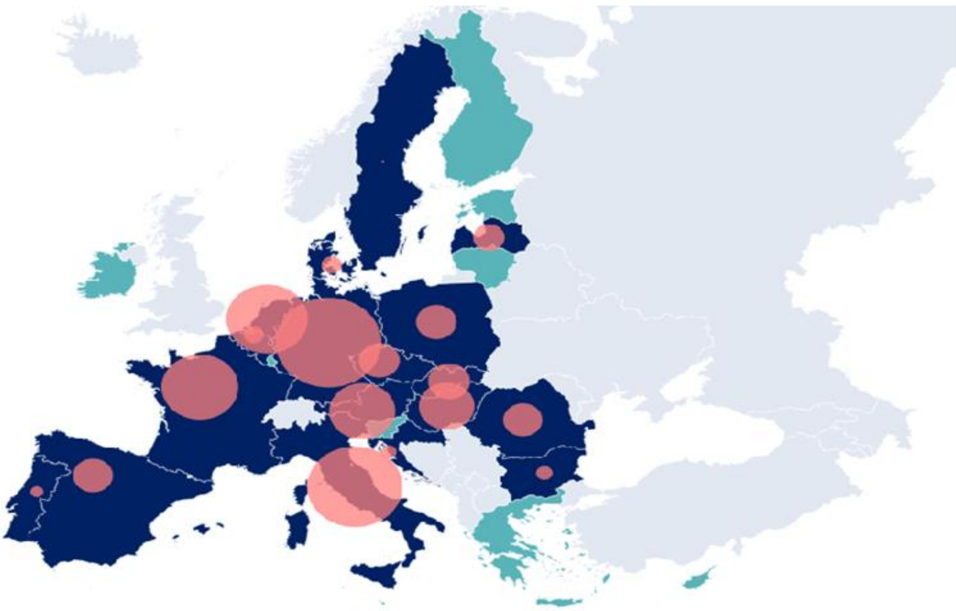
Heads of states and governments held an informal meeting in Versailles on 11 March 2022, which resulted in the adoption of the so-called Versailles Declaration — a commitment that included provisions aiming to enhance the security of the EU's energy supplies. One of the most important matters raised therein was the reduction of the import dependence on supplies from the Russian Federation. To this end, member states should diversify their energy sources, suppliers, and supply routes, including through the use of LNG and the development of biogas applications, and should continue to develop the hydrogen market. To increase energy independence, it is also necessary to invest in renewable energy sources, accelerate the procedures of granting permits to build and extend energy infrastructures, increase energy efficiency, and improve energy consumption management. On the other hand, in order to increase the security of energy supplies, it is important to finalise and streamline the interconnection of European gas and electricity networks, fully synchronise the different energy networks across the EU, and strengthen EU contingency planning. On account of the coming winter, it is necessary to make sure that there is sufficient gas in storage and to implement coordinated replenishment operations.

In May 2022, the European Commission announced the REPowerEU Plan [Communication from the Commission…, 2022]. The plan implements the provisions adopted in the Versailles Declaration and aims to accelerate the process of going towards independence from Russian resources, including speeding up the process of energy transition. First, the main objective is to save energy. The binding energy efficiency target would be increased from 9 to 13% compared to the 2020 Reference Scenario. Second, the idea is to diversify energy supplies and support international partners. The plan is to increase the extent of cooperation with international partners to diversify the portfolio of LNG and pipeline gas suppliers. The Commission also mentions joint gas purchases. It is also important to establish hydrogen corridors in the North Sea and the Mediterranean Sea. In the face of Russian aggression, the EU will provide support to Ukraine, Moldova, the countries of the Western Balkans, and the Eastern Partnership countries, as well as its most vulnerable partners [*Energy prices*, 2022]. To help the Ukrainian energy sector and secure energy supplies for the country, the EU will work with Ukraine under the REPowerUkraine initiative. Another objective is to spare no effort to increase and accelerate the use of renewable energy. The Commission proposes that the 2030 target for renewables be increased from 40 to 45%. The REPowerEU Plan also involves reducing fossil fuel consumption in industry and transportation and making smart investments. The efforts necessary to achieve the REPowerEU goals require an additional investment of €210 billion by 2027. The Recovery and Resilience Facility (RRF), modified and adapted to REPowerEU's demands, is to play a central role as the financing and planning instrument for the abovementioned activities.

In line with the above, at an extraordinary summit taking place on 30-31 May 2022, the European Council determined that by the end of 2022, the EU will stop importing almost 90% of its oil from Russia [*Energy Prices*, 2022]. The important thing is that this goal is achievable. Oil imports to EU countries have been steadily declining since 2010. In 2010, oil imports from Russia accounted for 34% of EU supplies. To compare, in the period of 2019-2020, this value was 25%. The EU's demand for oil could be satisfied with oil from Norway, Kazakhstan, the US or Iran [Polish Economics Institute, 2022].

To secure gas supplies, the EU Council adopted a new gas storage regulation in June [Regulation (EU) 2022/1032, 2022]. It obliges member states to fill their underground storage facilities before the winter of 2022/2023 to a level of 80% (and a minimum of 90% in subsequent years) and to share their gas stock with each other in the event of supply shortages or disruptions. At the community level, the EU will try to fill its storage facilities up to 85%. The regulation takes into account the fact that member states have different gas storage capacities. Therefore, member states will only be able to meet the storage target by including their stocks of LNG and alternative fuels, depending on conditions [*Council adopts regulation on gas…*, 2022]. Those countries that have significant storage capacity for domestic gas consumption will have to fill their underground storage facilities up to 35% of the average annual gas consumption over the past five years. Meanwhile, those countries that do not have their own underground storage facilities will be required to store 15% of their annual domestic gas consumption in storage facilities located in other member states. This way, they will have access to gas reserves stored in other countries. The regulation provides for derogations for Cyprus, Malta, and Ireland on account of the fact that they are not connected to the gas systems of other member states. The map below shows gas storage capacities in EU countries.

Fig. 2. Gas storage capacity in EU Member States.



https://www.consilium.europa.eu/pl/infographics/gas-storage-capacity/

An important thing to mention is that the EU has managed to reach an agreement on voluntary gas purchases. There is a plan to create a common European platform to enable companies to make gas purchases within the EU. This will help limit the increase in gas prices. Instead of outbidding each other, member states would make gas purchases together, which would increase their joint bargaining power.

One of the latest measures the EU has taken to secure gas supplies to consumers is the adoption of a regulation under which member states will voluntarily reduce gas demand by 15% in the period from 1 August 2022 to 31 March 2023 compared to the average consumption over the last five years [Council Regulation (EU) 2022/1369, 2022]. The regulation, however, enables the Council to declare — at the Commission's request — a state of emergency, in the case of which this reduction will be mandatory. The Commission may come forward with such a request in a situation where there is a significant risk of a serious shortage of gas supply, where there is an unusually high demand for gas, or where there is a request from at least five competent authorities that have declared a state of emergency at the national level.

The Council provided for exceptions in this regulation as well. Countries that are not connected to the gas networks of other countries are exempt from the obligation to reduce the demand for gas because they would not be able to release sufficient quantities of gas to be provided to other member states. Moreover, those countries that are not synchronised with the European electricity system and are more dependent on gas for electricity production are also exempted — as long as they are desynchronised from the networks of a third country [*Council adopts regulation on reducing*…, 2022]. Member states can reduce the 15% target obligation if:

- they have limited interconnections with other member states and are able to prove that their export capacity and their domestic LNG infrastructure are being used to transfer gas to other member states to the maximum extent possible
- they have exceeded their targets for filling their storage facilities
- they are heavily dependent on gas as a feedstock for their key sectors

4. Proposed measures to enhance EU energy security

In order to secure supplies of energy for the winter of 2022/2023, the European Union must act quickly. First of all, it is important for the portfolio of gas suppliers to be diversified. It should include new reliable suppliers. Stability of supply is key to ensuring energy security. Further investments in transmission infrastructure and interconnectors between member states are also required to make sure that all member states have access to gas. Investments aiming to increase efficiency will translate into significant energy savings, which will then result in lower demand. Most importantly, however, it is crucial to invest in renewable energy sources, which can partially satisfy member states' energy demands. Green hydrogen — i.e. hydrogen produced without emissions — will be instrumental in replacing gas. Electrolysers, used to obtain hydrogen, are to be powered by RES. This way, green hydrogen fits into the EU's long-term energy and climate policy. Hydrogen can also be transported through gas pipelines, which means that the existing gas infrastructure can be used to transport hydrogen in the future. The decrease in the costs of producing energy from RES will make it possible, in turn, to lower the costs of production of green hydrogen. It is estimated that the price of green hydrogen over a 30-year horizon could reach $1 per tonne [Kozdra, 2021].

Measures aimed at lowering energy prices are also necessary. To achieve this goal, it is important to intensify negotiations with reliable third-country gas suppliers and introduce appropriate instruments in the EU internal energy market. High gas prices lead to high electricity prices. Therefore, EU member states will be soon discussing the idea of setting a temporary cap on the price of gas used to produce electricity.

5. Conclusion

Russia's aggression against Ukraine has had a significant impact on the energy sectors of EU member states. The event has dramatically changed the direction of the energy policy of some member states, which until recently have relied on relatively cheap gas from Russia and believed that these supplies would last — example being the Federal Republic of Germany. Germany, which until now has not expressed interest in joint gas purchases — which Poland has been advocating for since 2014, is inclined to consider such an idea at this point. The war in Ukraine has caused big changes as to the sourcing of supplies. First of all, there has been a significant shift away from importing energy resources from Russia in favour of importing resources from reliable third-country suppliers. It is expected that more gas and LNG will be imported from Norway, but also from Qatar or Iran. The EU is also seeking to increase imports of LNG from e.g. the United States, Australia, and Japan, and intends to sign trilateral agreements with Egypt and Israel [*In focus*…, 2022]. There is therefore no denying that the war has radically transformed the landscape of gas supply in the EU.

Initially, the war and the ensuing energy crisis in the EU were expected to slow down the implementation of energy and climate policies — including the pursuit of the objectives of the European Green Deal. It has turned out, however, to be a catalyst that drives the transformation of the energy sector. By increasing energy efficiency, significant energy savings are possible, which translates into lower energy consumption. At the same time, increasing the share of RES in energy production will make it possible to become independent from Russian resources.

To conclude, the impact of the Russian-Ukrainian war has caused a massive energy crisis in the EU, which, on the one hand, has undermined its energy security and posed a threat of gas shortage for the upcoming heating season, while, on the other hand, it has become a powerful for a range of new initiatives that should have been implemented long ago. This means first and foremost becoming independent from Russian supplies, which has been long discussed since 2014. In practice, however, countries like Germany have continually increased their energy dependence on Russia through projects such as Nord Stream 2. The apparent disparity between the official EU energy policy and the actions taken by particular countries has brought the EU energy sector to where — and what — it is today. Therefore, the most important issue at this point is to actually pursue a truly common EU energy policy towards third countries and — in particular — towards the Russian Federation.

Bibliography

1. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee of the Regions, *RePowerEU Plan,* COM/2022/230 final, Brussels 18.5.2022.
2. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee of the Regions, *Short-Term Energy Market Interventions and Long Term Improvements to the Electricity Market Design – a course for action*, COM(2022) 236 final, Brussels, 18.5.2022.
3. Council of the EU, *Council adopts regulation on gas storage*, https://www.consilium.europa.eu/pl/press/press-releases/2022/06/27/council-adopts-regulation-gas-storage/.
4. Council of the EU, *Council adopts regulation on reducing gas demand by 15% this winter,* https://www.consilium.europa.eu/pl/press/press-releases/2022/08/05/council-adopts-regulation-on-reducing-gas-demand-by-15-this-winter/.
5. Council of the EU, *EU adopts fifth round of sanctions against Russia over its military aggression against Ukraine*, https://www.consilium.europa.eu/pl/press/press-releases/2022/04/08/eu-adopts-fifth-round-of-sanctions-against-russia-over-its-military-aggression-against-ukraine/.

6. Council of the EU, *Russia's aggression against Ukraine: EU adopts sixth package of sanctions,* https://www.consilium.europa.eu/pl/press/press-releases/2022/06/03/russia-s-aggression-against-ukraine-eu-adopts-sixth-package-of-sanctions/.
7. Council of the EU, *Russia's military aggression against Ukraine: EU imposes sanctions against President Putin and Foreign Minister Lavrov and adopts wide ranging individual and economic sanctions,* https://www.consilium.europa.eu/pl/press/press-releases/2022/02/25/russia-s-military-aggression-against-ukraine-eu-imposes-sanctions-against-president-putin-and-foreign-minister-lavrov-and-adopts-wide-ranging-individual-and-economic-sanctions/.
8. Council Regulation (EU) 2022/1369 of 5 August 2022 on coordinated demand-reduction measures for gas, (OJ L 206, 8.8.2022).
9. European Commission, *In focus: Engaging with energy partners in a changing world,* https://ec.europa.eu/info/news/focus-global-energy-partners-and-eu-2022-jun-14_pl.
10. European Commission, *REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition,* https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131.
11. European Council, *Energy prices and security of supply*.
12. European Council, *EU response to Russia's invasion of Ukraine*, https://www.consilium.europa.eu/pl/policies/eu-response-ukraine-invasion/.
13. *Gazprom has a pressing problem,* https://www.wnp.pl/gazownictwo/gazprom-ma-palacy-problem,617294.html.
14. Harrison M., *Western sanctions on Russia are working, an energy embargo now is a costly distraction,* [w:] Garicano L., Rohner D., Weder di Mauro B., *Global Economic Consequences of the War in Ukraine Sanctions, Supply Chains and Sustainability,* Centre of Economic Policy Research, CEPR Press, London 2022.
15. Hosoi A., Johnson S., *How to implement an EU embargo on Russian oil*, [w:], Garicano L., Rohner D., Weder di Mauro B., *Global Economic Consequences of the War in Ukraine Sanctions, Supply Chains and Sustainability*, Centre of Economic Policy Research, CEPR Press, London 2022.
16. International Energy Agency, *Energy security. Reliable, affordable access to all fuels and energy sources*, https://www.iea.org/topics/energy-security.
17. Kardaś S., *Russia suspends gas supplies to Poland and Bulgaria*, https://www.osw.waw.pl/pl/publikacje/analizy/2022-04-27/rosja-wstrzymuje-dostawy-gazu-do-polski-i-bulgarii.
18. Kardaś S., *Russia: another reduction in gas supplies to Europe,* https://www.osw.waw.pl/pl/publikacje/analizy/2022-06-17/rosja-kolejne-ograniczenie-dostaw-gazu-do-europy.
19. Kozdra D., *Does Poland have a hydrogen potential?,* https://ptsp.pl/czy-polska-ma-potencjal-wodorowy/.
20. Lipiński, K., Maj, M., Miniszewski, M. *A European Union independent of Russia? Alternative Sources supplies of energy resources,* Polish Economic Institute, Warszawa 2022 (in polish).
21. Lis W., *Energy blackmail as a means of shaping Russia's foreign policy, and the energy security of the former USSR countries,* [in:] Miłek M., Wilk-Jakubowski G., *Political, economic and cultural aspects of Poland's relations with the world of the former USSR,* Kielce 2011 (in polish).
22. Martin P., Mauro B. W., *Winter is coming: Energy policy towards Russia,* [in:] Gericano L., Rohner D., Mauro B. W., *Global Economic Consequences of the War in Ukraine Sanctions, Supply Chains and Sustainability,* Centre for Economic Policy Research, London 2022.

23. Polish Economics Institute, *The restriction of Russian oil imports to the EU is real,* https://pie.net.pl/ograniczenie-importu-rosyjskiej-ropy-do-ue-jest-realne/.
24. Pronińska K. M., *Energy security in EU-Russia relations. Geopolitics and economics of energy resources,* ELIPSA, Warszawa 2012 (in polish).
25. Przybojewska I., *The importance of trans-European energy networks for ensuring energy security,* C. H. Beck, Warszawa 2017 (in polish).
26. Regulation (EU) 2022/1032 of the European Parliament and of the Council of 29 June 2022 amending Regulations (EU) 2017/1938 and (EC) No 715/2009 with regard to gas storage (OJ L 173, 30.6.2022).
27. Rogozińska A., *Determinants of the Russian-Ukrainian Conflict in the International Security Environment,* Central European Political Studies No. 1, 2022 r.
28. Ruszel M., Podmiotko S., *Energy security Poland and Europe. Conditions, challenges, innovations,* Energy Policy Institute, Rzeszów 2019 (in polish).
29. Ruszel M., *The impact of Russian-Ukrainian gas crises on the EU's energy policy - theoretical approach*, Political Review Nr 2 (2015), (in polish).
30. Sadecki A., *Hungary: new agreement with Gazprom for additional gas supplies in autumn,* https://www.osw.waw.pl/pl/publikacje/analizy/2022-09-01/wegry-nowa-umowa-z-gazpromem-na-dodatkowe-dostawy-gazu-jesienia.
31. Trubalska J., *Towards energy union. The new concept of energy security in the European Union,* The Bulletin of The Mineral and Energy Economy Research Institute of the Polish Academy of Sciences 2017, No. 97 (in polish).
32. Twidale S., Buli N., *EU gas price rockets higher after Russia halts Nord Stream flows,* https://www.reuters.com/business/energy/no-stream-eu-gas-markets-brace-price-surge-after-latest-russia-gas-cut-2022-09-04/.
33. Van Halm I., *How can the EU end its dependence on Russian gas?,* https://www.energymonitor.ai/policy/how-can-the-eu-end-its-dependence-on-russian-gas.
34. Wakulenko S., *A Big Bang? Anticipating the Impact of Europe's Sanctions on Russian Energy,* https://carnegieendowment.org/politika/87318.

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